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2012

Year in review

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AEROSPACE AMERICA

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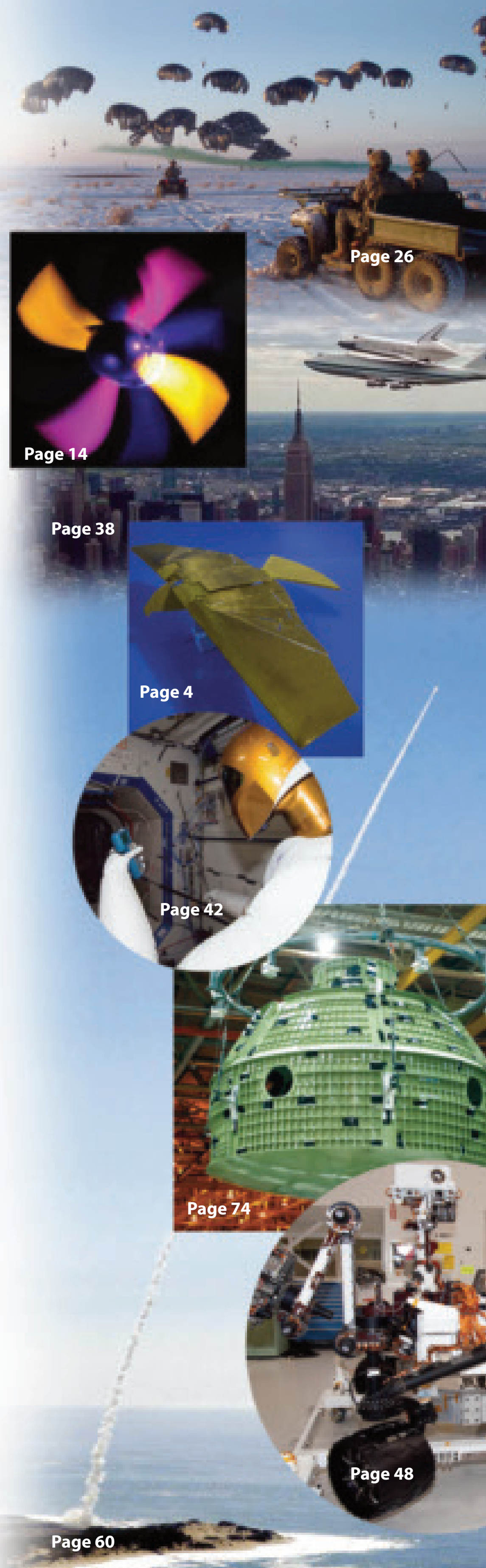
THE YEAR IN REVIEW

BULLETIN



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AIAA
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Editorial

The very best of old and new

As we look back over significant events of the year, two remarkable accomplishments immediately come to mind, and remind us of the possibilities for greatness that can be found in both the public and private sectors of the aerospace industry.

In May, even as many of us were still watching the fleet of space shuttles being ferried to their final destinations, SpaceX made history when its Dragon spacecraft, on its first demonstration flight, became the first commercial vehicle in history to successfully berth with the international space station. After an exchange of cargo, the capsule returned to Earth and was successfully retrieved. This was followed in October by a commercial delivery flight to the station and then a safe splashdown with return cargo. The resumption of U.S. deliveries to and from the ISS is an exciting first step toward the return of domestic crew transportation.

Excitement of another kind came for many in the early morning hours, as people around the world watched the celebration at the Jet Propulsion Laboratory as the Mars Science Laboratory landed its automobile-sized rover with pinpoint accuracy on the surface of that planet. This astounding feat was documented not just by signals transmitted from the surface but by an image captured by the Mars Reconnaissance Orbiter as it passed overhead. Just hours later, after a 36-week, 350-million-mile journey, Curiosity started beaming back images of its new home.

Either of these accomplishments alone would have made 2012 a red letter year. Together, they resulted in an outstanding one.

But there is one more event to be considered as we examine the year and the significant role aerospace can play. An enormous storm hit the East Coast of the United States in October, with a force most of the nation, or the world, had not witnessed before. Sandy leveled homes, buildings, beaches, and whole towns, leaving populations struggling to find food, shelter, and loved ones, and to grapple with the enormity of its devastation.

Sadly, lives were lost—but not the untold thousands that might have been. To a great degree, possessions were destroyed, but families were not. Businesses were wiped out, but possibilities remained. It may take months or even years to recover, but the opportunity for recovery was preserved.

That the horror that might have been did not happen was thanks to some old, but dependable, resources. NOAA satellites, along with Europe's newly launched Metop-B, provided the detailed data that enabled remarkably accurate computer models to forecast the path of the storm days ahead of landfall, allowing the majority of the population in its path to escape from harm's way.

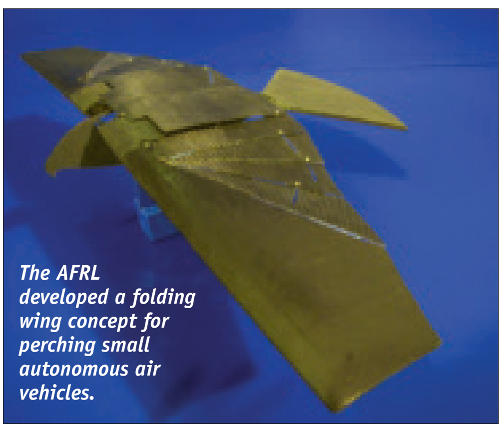
As happy an ending as this story has, it also comes with a warning. The polar orbiting satellites that provided most of the data showing us Sandy's path and power are aging, and by one estimate many of the instruments have just a few years of useful life left. Their replacements, however, are far from ready, delayed by a combination of funding and technology woes.

We were not lucky—we were informed. It is up to us to make sure we stay that way.

Elaine Camhi
Editor-in-Chief

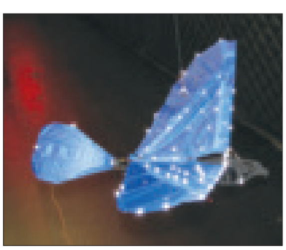
Adaptive structures

Motivated by the idea of 'hiding in plain sight,' the adaptive structures team in the Aerospace Systems Directorate at the Air Force Research Laboratory developed a folding-wing concept for perching of small autonomous vehicles. The vehicle folds its wings while perched to reduce visibility and decrease the likelihood of being dislodged. The team, with the University of Dayton Research Institute, generated control concepts for successful perching landings and demonstrated perching maneuvers in an indoor flight facility. AFRL is also working on reconfigurable skin concepts for morphing applications based on cellular structures consisting of individually addressable regions of variable-stiffness material.



The AFRL developed a folding wing concept for perching small autonomous air vehicles.

University of Maryland graduate students, in collaboration with Penn State University, conducted an unprecedented flight test of a custom-built avian-scale flapping wing UAV. The test, conducted at the AFRL Micro Air Vehicle Laboratory (the largest Vicon motion capture system lab in the U.S.), evaluated the performance of the ornithopter, whose compliant wing structure mimics the function of an avian wrist.



The University of Maryland conducted a flight test of a custom-built avian-scale flapping wing.

Penn State conducted research in several other areas as well. Researchers experimentally validated a method for reducing high cycle fatigue in turbomachinery blades, with emphasis on monolithic blisks having low intrinsic damping. The method reduces the resonant structural dynamic response associated with changes in engine speed. Blade stiffness properties are modified by switching the electrical boundary conditions on integral piezoelectric elements. In addition, the university is investigating a variable-thermal-conductivity baseplate for spacecraft to passively prevent unacceptable temperature excursions of electronics modules. Success requires shape and materials optimization to increase thermally driven displacements, reduce thermal contact resistance, and decrease the need for high-precision manufacturing.

The Army Aviation Missile Research, Development, and Engineering Center, teamed with Boeing and Sikorsky, kicked off the Multi-Role Rotor program. MRR will mature and demonstrate integrated active rotor technologies that improve both hover and cruise efficiencies and reduce the vibration and acoustic levels of the Army's next-generation rotorcraft fleet.

Structural health monitoring (SHM) is another area of development. Arizona State University is creating hybrid methodologies for real-time SHM of metallic and composite aerospace components. The probabilistic approach to damage localization in complex geometry is comprised of a Bayesian framework and sensor fusion to account for uncertainty. Recent accomplishments include an efficient physics-based multiscale model using statistical volume elements, a fully coupled electromechanical elastodynamic model for wave propagation, and a stochastic signal processing and feature extraction algorithm.

The University of Michigan, through the support of NASA, has been characterizing guided waves (GW) for SHM of composite sandwich structures. An innovative local interaction simulation approach, based on iterative equations where the coefficients depend only on the local physical properties, was successful in capturing GW propagation characteristics accurately in composite laminates. Current effort focuses on extending the method for complex composite sandwich structures and damage interaction of GW.

In other research, the University of Michigan experimentally demonstrated a novel shape memory alloy knitted rib skin for active flow control of aircraft. The pattern actuates normal to the surface, producing spanwise discrete periodic arrays that can withstand aerodynamic forces while simultaneously supplying displacement.

Decades of progress in engine noise reduction have made airframe aeroacoustic noise an equal contributor to overall noise during approach and landing. Earlier work identified mechanisms and notional solutions for aeroacoustic noise in the flow field around high-lift systems of typical commercial transport aircraft. Recent work at NASA Langley focused on adaptive structural concepts to make such notional solutions physically attainable. The most promising solutions involve highly deformable structures integrating superelastic shape memory alloy and elastomeric materials to adapt between very disparate configurations.

by **Louis R. Centolanza**

Design engineering

Exploration of Mars continues following the successful launch of the Mars Science Laboratory (MSL) spacecraft from Cape Canaveral AFS on November 26, 2011, and the Curiosity rover's subsequent landing.

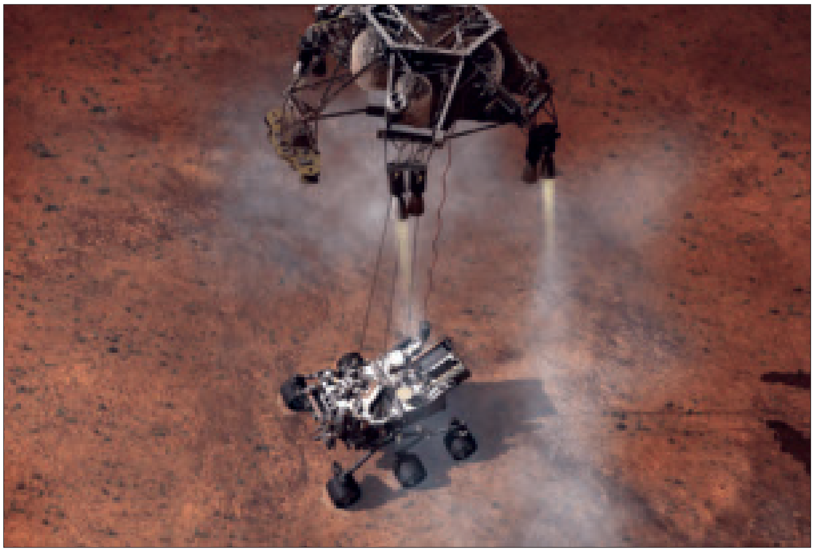
One of the major trends in aviation design is greater autonomy for vehicles, from remotely piloted aircraft to vehicles with entirely autonomous operations. The MSL spacecraft demonstrated this with its completely autonomous entry, descent, and rover landing. Entry of the MSL began with separation of the cruise stage from the descent stage. The descent stage then steered itself through the Martian atmosphere with a series of S-curve maneuvers, followed by the use of a parachute, jettisoning of the heat shield, jettisoning of the parachute and back shell, retrorocket firing, and finally, while hovering over the Martian surface, the unfolding of Curiosity, which the descent stage lowered to the surface by a tether, afterward flying away and landing in a separate location.

For the rover landing, use of the Sky Crane and tether maneuver rather than the previous airbag landing system was necessary because Curiosity weighed over 1 ton (much more than previous rovers) and because of the desire to be much more precise in where it landed. If not for this improved precision—about five times better than that of previous missions—the Gale Crater landing site would have been considered unsafe because of its close proximity to the crater wall.

The descent stage's structure is a lightweight space-efficient truss and stiffened panel design. The MSL faced severe design challenges from mass limits, launch vehicle payload dimensional constraints, and launch site integration of the cruise stage, back shell, descent stage, rover, and heat shield.

Curiosity did inherit many design elements from previous rovers, such as a six-wheel drive, a rocker-bogie suspension system, and mast mounted cameras. The rover can roll over obstacles up to 65 cm (25 in.) high, and can travel up to about 200 m (660 ft) per day on Mars.

The U.S. government's shift toward using commercial space companies for space access reached a major milestone in May when a SpaceX Falcon 9 rocket boosted a SpaceX Dragon supply capsule into orbit, where it successfully berthed with the ISS. The capsule later returned to Earth and was recovered after performing a parachute landing into the Pacific Ocean. With the new generation of commercial space capsules, the design philosophy for safety is changing from redundancy to quick-acting escape mechanisms to achieve fail-safe reliability. The new commercial capsules are also attempting to achieve cost efficiencies through dual-use propulsion systems that can be used for both launch escape and on-orbit maneuvers.



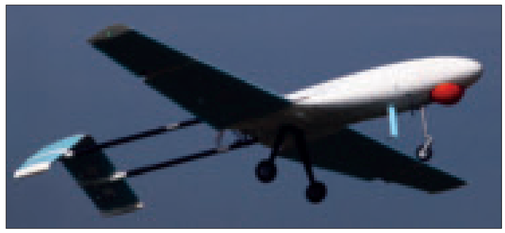
An artist's rendering depicts the Sky Crane lowering Curiosity to the Martian surface. Image credit: NASA.

The X-47B is an example of the trend toward autonomous vehicles. Courtesy: Northrop Grumman.

Another example of the trend toward autonomous vehicles is the X-47B. This tailless strike fighter-class unmanned aircraft was developed by Northrop Grumman as part of the Navy's Unmanned Combat Air System Carrier Demonstration program. The company, which was awarded the development contract in 2007, has designed, produced, and is currently flight testing two X-47B aircraft. The plane made its first flight from Naval Air Station Patuxent River in July, and these aircraft will be used in 2013 to demonstrate the first carrier-based launches and recoveries by an autonomous unmanned aircraft. In 2014, the X-47B is scheduled to demonstrate autonomous aerial refueling.

by **Jerry Brown**

Multidisciplinary design optimization



The DECODE software system created by the University of Southampton was used to carry out MDO and then detailed design, build, and test for this prototype aircraft, which uses laser sintered nylon structures with carbon spars. It also carries an inertially stabilized camera system with full onboard autonomy allowing for automated takeoff, mission segments, and landing. Credit: University of Southampton.

New MDO methods are enabling incorporation of higher fidelity analyses and consideration of more complex systems. The University of Michigan achieved optimal aeroelastic tailoring by integrating CFD with finite-element structural models and optimizing hundreds of aerodynamic shape and structural sizing variables simultaneously. These tools are being used to optimize high-aspect-ratio wings in collaboration with NASA. The University of Arizona developed an optimization algorithm that combines Kriging and support vector machines. It is well suited for problems that have many constraints and response discontinuities. MIT adapted information entropy concepts to create a metric for system complexity, and developed Bayesian estimation methods to characterize and manage uncertainty in complex system design.

Wright State University developed topology optimization methods for thermal-structural disciplines that are unique to aircraft engine exhaust wash structures and thermal protection systems. The University of Bath developed practical robust topology optimization methods, addressing challenges of buckling constraints, and optimized bistable piezocomposites geometry for morphing applications. This concept is being investigated for broadband vibration-based energy harvesting in collaboration with the University of Michigan.

MDO frameworks continue to evolve. NASA Glenn is developing OpenMDAO, an open source framework. A joint development by Genworks, Noesis Solutions, and TU Delft coupled Optimus (an industry-standard workflow and MDO framework) with Genworks GenDL (a language for representing engineering 'knowledge' through easily authored object definitions).

Iowa State's Virtual Reality Applications Center is providing intuitive tools for visually exploring optimal design spaces. These include a virtual reality CAVE environment for visualizing Pareto frontiers and a desktop application using self-organizing maps to visualize the characteristics of high-dimensional design spaces. Researchers at Penn State and the Applied Research Lab are developing multidimensional data visualization tools to enable manufacturing tradeoff analysis and feedback in support of DARPA's upcoming Adaptive Vehicle Make design challenges.

MDO contributed to the design, build, and test of prototype vehicles. The University of Southampton developed an optimization environment to design UAVs for air-sea rescue, and conducted optimization followed by detailed design, build, and test for a prototype aircraft. EADS Innovation Works presented a prototype of a portable UAV produced by additive layer manufacturing technology and designed by students from the University of Leeds, using Altair's HyperWorks software. The University of Oklahoma is developing trajectory optimization for glide and climb of a supersonic interceptor, using the Chebyshev pseudospectral method.

The AFRL/Virginia Tech/Wright State University Collaborative Center for Multidisciplinary Sciences achieved developments in efficient supersonic air vehicles, micro air vehicles (with University of Maryland), SensorCraft (with Quaternion Engineering), flight testing to understand nonlinear aeroelastic behavior of scaled models, and an extended markup language that improves technical information exchange at the conceptual and preliminary design stages.

The University of Michigan optimized vehicles for occupant safety and fuel efficiency, and implemented analytical target cascading for commercial systems at Hyundai Motor with the support of Altair. Boeing used its MDO capabilities in the energy domain, applying its energy security assessment tool at several Air Force bases. This tool optimizes investment portfolios for candidate projects with respect to value of savings, CO_2 emissions, and energy security/assurance concerns.

The University of Illinois developed techniques for integrated physical and control system design and for optimal redesign of mechatronic systems with application to robotic manipulators. N.C. State explored reconfigurability and adaptability to achieve resiliency in complex engineered systems, and collaborated with General Motors to tailor designs using respondent-level utilities from the marketing domain.

by **Karen Willcox**

Nondeterministic approaches

Diagnosis and prognosis have become essential elements of safe, intelligent, efficient, and cost-effective systems. Structural health methodologies have enabled use of existing information to understand interactions among subsystems, components, and uncertainties that help develop procedures for system-level diagnosis and prognosis. A comprehensive reliability-based damage prognosis consists of monitoring critical components, assessing their structural integrity, and predicting the remaining life of the component and systems.

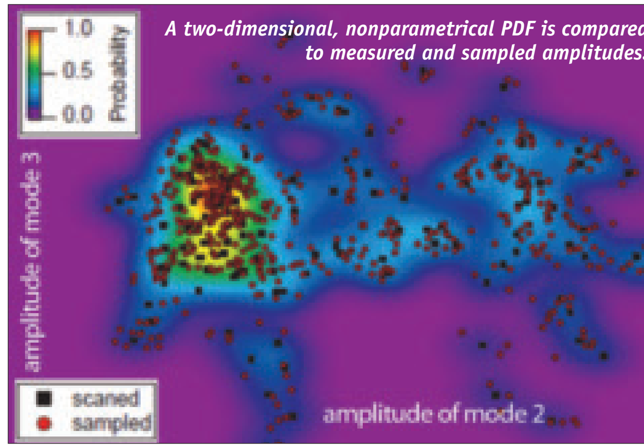
There is an increasing need for reliability-based uncertainty assessment of a system that can be validated with a limited number of hardware and component tests. Assessment models that are built from fundamental principles and calibrated to match experimental results must also provide predictive accuracy under changes in external load parameter and environment. One example of real-time health and integrity assessment using real-time inspection results is crack growth in airframe bolts/joints and aircraft engine components.

New approaches and standards are established through probabilistic and sensitivity analysis for the assessment of risk due to manufacturing and mission variability.

The R&D of complex engineering design emphasizes system optimization for high reliability, ease of maintainability, and lower cost. OUU (optimization under uncertainty) and RBO (reliability-based optimization), along with modeling and analysis that are complementary to probabilistic approaches, hold promise for facilitating these types of system optimizations.

For sensing and communication systems performance depends strongly on their terrestrial operating environments. Even when high-fidelity physics models are available and the properties of disturbances are well known, these environments typically cannot be characterized with sufficient detail to permit precise predictions of detection performance. Multifaceted uncertainties in the properties of these environments, probabilistic models of their constitutive properties, and the resulting signal propagation characteristics are essential.

High-fidelity analysis and simulation capabilities have been developed to deliver analysis and design tools for thermal protection systems for objects traveling at hypersonic velocities. The tools enable performance safety and reliability assessments. Despite these efforts, significant errors and uncertainties persist, which limit the accuracy and utility of this predictive capability.



A two-dimensional, nonparametrical PDF is compared to measured and sampled amplitudes.

Furthermore, gaps exist in the current body of work, particularly regarding the characterization of the input probability density functions used to represent uncertain parameters. This is largely due to a lack of sufficient experimental datasets. Thus input distributions for the cited analyses have usually been generated using ad hoc approaches, with assumptions of PDF functional forms, statistical moments, and parameter independences. And there has been little emphasis placed on determining the effect these assumptions have on output statistics and reliability metrics.

It is possible to construct an experimentally based set of probability density functions, interval or ellipsoid bounds, or other uncertainty representations for ablator material properties, performing a standard uncertainty propagation, contributor breakdown, and sensitivity analysis for a problem of relevance to the ablation modeling community. Such a construction, by error characterization of PDFs as functions of the quality of the input distributions, enables intelligent design of experiments to efficiently capture the most important contributors to overall uncertainty and establish the relationship between input quality and output error. It also establishes the expected variation in the quantities of interest, highlighting potential sources of epistemic uncertainties in the model. As more data become available, this can help construct a seamless process by which experimental test results can be incorporated directly into the analysis.

by **Shyama Kumari, Ben Thacker,** and **Isaac Elishakoff**

Structural dynamics

Gulfstream Aerospace executed the first phase of an unsteady aerodynamics and flutter research campaign to advance the state of the art in production flutter and dynamic gust analyses.

The Air Force Institute of Technology has been evaluating the flight characteristics of the wing of *Manduca sexta*, the hawk moth, for micro air vehicle applications. The wing structure has been studied in air as well as in vacuum conditions, both experimentally and using finite-element analysis, as it goes through its flapping motion. A great deal of effort has gone into the evaluation of the vein properties and dimensions as well as the material properties of both the veins and the membrane. An attempt to duplicate the wing camber was also carried out. The wing has a longitudinal length of 50 mm and a chord length of about 27 mm; this should give one a better appreciation of the dimensionality leading to dynamics that are very different from the normal aircraft wing structure.

The image on the left is the real wing of the hawk moth; at right is the finite-element model.

Gulfstream Aerospace executed the first phase of an unsteady aerodynamics and flutter research campaign to advance the state of the art in production flutter and dynamic gust analyses. The first phase consisted of testing a rigid horizontal tail model, oscillating in pitch, at high transonic speeds, in the Transonic Dynamics Tunnel (TDT) at NASA Langley.

The test conditions included both air and heavy gas, as well as the effects of ice accumulation on the leading edge of the tail. Extensive instrumentation was carried onboard the model, including Kulite unsteady pressure transducers at four spanwise stations on both the upper and lower surfaces. The test conditions ranged from low subsonic Mach numbers up to a maximum Mach number of 1.05.

The maximum oscillating frequency achieved was 27 Hz (limited by model structural dynamics), and the corresponding reduced frequency was 0.5 Hz. The data will be used to calibrate production unsteady aerodynamic codes, which are of lower order than state-of-the-art unsteady CFD capability. The use of these codes is necessitated by the sheer number of cases to be run in a finite amount of time during an aircraft design cycle. Phase 2 of the test will be a dynamic flutter model, scaled to flutter in the TDT boundary. This will provide the test correlation of the corrected production methodologies.

Polytec's new remote sensing vibrometer (RSV) was used for the first time in a continuous-scan mode by Matt Allen and his research group at the University of Wisconsin-Madison to measure the mode shapes of a wind turbine blade under ambient excitation. The new RSV laser was able to measure the mode shapes of the blade from over 70 m away without the need to apply any retroreflective tape. The measurements also showed remarkably low speckle noise, even as the laser swept along the surface at more than 400 m/sec.

by **D. Todd Griffith**

Structures

Mississippi State University is investigating key elements in the development of a damage tolerance plan for multifunctional composites that accounts for loss of structural integrity as well as degradations in multifunctionality. While the effect of in-service or discrete source damage on composite structural integrity is relatively well understood, the effect of damage on safety-of-flight aspects of multifunctionality remains to be explored. A crucial consideration is for cases where loss of mission-critical composite functionality occurs while structural integrity is preserved. Such issues must be addressed if the full weight-saving potential of multifunctional structural composites is to be realized.

The Air Force Institute of Technology continues to work on the biological characteristics of a *Manduca sexta* for application to a flapping-wing micro air vehicle. The team has dissected the species and studied the thorax to evaluate the dorsal ventral muscle and determine its lifting power. This tiny creature, appropriately 1.5 g in mass, can produce a lifting power of 73 W/kg. Its thorax/wing structure can be modeled as a mechanical spring system. Loads applied to the thorax by the flight muscles cause compression, which in turn moves the wings through hinges on either side of the thorax.

Carbon nanotube, graphene, oxide nanoparticle, and nanoclay-reinforced polymer nanocomposites research continues at Michigan Technological University (MTU) and MIT, which are collaborating on model-experiment comparison and correlation across length scales for next-generation composites for NASA applications. MIT is working on large-scale bulk structured materials that have nanoscale reinforcement and take advantage of nanoscale physics. MIT and Metis Design (MDC) have collaborated on Air Force and Navy programs to leverage multifunctional nanoengineered laminate properties for ice protection systems and structural health monitoring. Nanomaterials are literally getting bigger as evidenced by the recent MIT-MDC full-scale test of a nanoengineered composite.

Arizona State researchers are synthesizing novel multifunctional core-shell composite particles, composed of a polymeric core and an inorganic shell, which are responsive to environmental damages. The new matrix system that uses poly (ionic liquids) will replace the traditional epoxy, bringing additional sensing and healing benefits to composite structures under service conditions.

At NASA Glenn, 'smart materials' are being used to achieve performance improvements. Studies have shown that substantial gains in engine noise, fuel efficiency, and emissions can be achieved not just by increasing material properties but also by individually optimizing different components for different portions of a flight's mission cycle. Thus the main structural components could remain as those of today, but could then be used in configurations that take advantage of properties optimized to specific environments. Analytical and experimental methods on piezoelectric blade vibration damping have produced the first successful demonstration of vibration damping on GE's GEnx engine composite fan blades. The damping levels achieved lead to reduced dynamic stresses. New compositions have been developed to extend the temperature capability of high-performance piezoelectrics to near 400 C.

The Structures and Materials Division at Glenn has established the NASA Multiscale Analysis Center of Excellence, to develop, integrate, and validate physics-based models and the associated multiscale computational design, analysis, and optimization tools required to make these models accessible to the engineering and materials science communities. Working with industry (GE Aircraft Engines, HyperSizer, Firehole Composites) and academia (University of Michigan, Mississippi State, University of Alabama, Miami University, Clarkson), NASA is developing methods and tools for advanced composites (PMCs, CMCs), high-temperature metallic alloys, and smart (piezoelectric, shape memory alloy) materials that link microstructure-scale mechanisms to structural performance. Projects include modeling of lightning damage on PMCs, deformation and fatigue life prediction for hot engine component CMCs, efficient multiscale microstructural modeling of nickel-based superalloys, and development of nano-informed damage models for polymer matrix materials.

Antiicing was demonstrated on unmanned air system aerosurface. Left: Aeosurface (white) with CNT-modified regions. Right: Deicing during ice tunnel testing. Courtesy: MIT and MDC.

by **Harry H. Hilton**

Survivability

There is a newly recognized threat facing civilian commercial aviation: engine flameout due to crystal ice at 20,000-30,000 ft, a medium altitude range routinely traveled by commercial airliners. The physical phenomenon is under investigation but is still not fully understood; the possibility that ice can accumulate in a hot running engine is not always believed. As in the case of the volcanic ash that stopped most civil aviation from Iceland over Europe in April 2010, the damage is not mainly due to the ice crystals impacting an engine's fans or compressor blades, but rather due to entering, accumulating, and then breaking out and cooling the combustion chamber, causing either power loss or complete flameout to both engines, if one is fortunate enough to have more than one engine.

The USAF kicked off its live fire test and evaluation program for the KC-46A fuel tanker.

NASA Glenn in Cleveland has begun a program to study the phenomenon and is preparing one of its wind tunnels with engine ice crystal equipment for a full-scale engine at simulated low-temperature, low-pressure altitude. The ice crystals are so fine that they are not detected on radar (unlike the volcanic ash); therefore, pilots are not warned of flying areas to avoid. Canada is joining the U.S. in the study and has performed preliminary tests in Ottawa. The FAA and the European aviation safety agency have informed the aviation industry that new certification requirements for engine icing are being prepared.

For military aircraft, the USAF has kicked off its live fire test and evaluation (LFT&E) program for the in-flight KC-46A fuel tanker. The LFT&E strategy for this tanker is to conduct a comprehensive evaluation of KC-46A system-level vulnerabilities against the ballistic and advanced threats expected in combat. The program includes live fire tests (LFT), modeling, simulation, and analysis, and the evaluation of existing data (experimental and otherwise) for vulnerability assessments. LFT and other experiments include evaluations of hydrodynamic ram on the wings; fire extinguishing capabilities in engine nacelles; vulnerabilities on engine pylons and air refueling pods; threat-induced fires on wing and landing gear dry bays, fuselage, and refueling components; and crew/passenger armor.

The results of the LFT&E program are used by the Air Force and the director of operational test and evaluation in the Office of the Secretary of Defense to make independent assessments on the overall combat survivability of the aircraft.

For space systems, two survivability events had happy endings following years of study and designs. First was the survival of the SpaceX Dragon crew capsule, which reentered the atmosphere and parachuted into the Pacific on May 25 after berthing with the ISS and surviving 3,000 F at reentry. The reentry was with no crew, as a test, before regular cargo flights began. NASA partially funded the private company for support of the ISS after the shuttle program ended. Also, NASA's crew capsule Orion (developed by Lockheed Martin under NASA funding) successfully tested its parachutes on July 18 and was dropped for low-speed water impact testing in an artificial pond on August 23.

The second survivability success was the August 6 landing of the Mars Curiosity rover, which survived Mars reentry heat through a successful thermal shield. Curiosity is expected to send information about the Martian surface for two years.

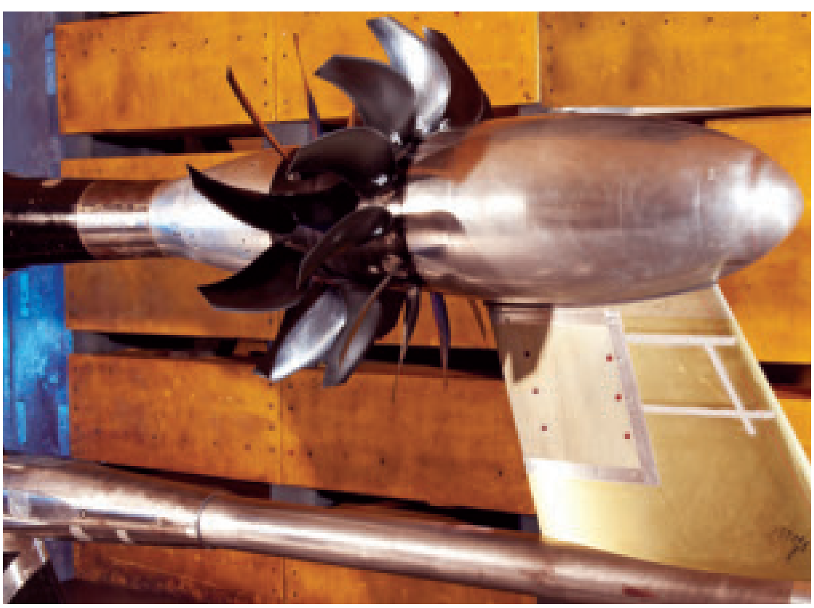
On other survivability topics, the USAF made efforts to test and evaluate the effect of high-energy lasers on aircraft survivability by testing different materials and energy levels. The Air Force also continued concentrated modeling and simulation efforts on threat-induced fires through continued enhancements in the fire prediction models.

by **Ameer G. Mikhail, Jaime J. Bestard,** and **John J. Murphy Jr.**

Aeroacoustics

Noise reduction continues to be a major driver in aerospace R&D amid growing concern for community noise reduction and for protection from hearing loss in military applications, with more stringent requirements on the horizon for civil aviation.

The jet noise reduction component of the Office of Naval Research Noise Induced Hearing Loss Program is supporting eight research projects that address noise generated by tactical fighter aircraft. These projects focus on gaining a better understanding of the noise source mechanisms, characterization of the noise in the near and far fields, nonlinear propagation effects, adverse health effects of exposure to high levels of very-low-frequency noise, and the development of active and passive noise reduction technologies.



Detailed flow field measurements for an open rotor with pylon installed were made in the 9x15-ft Low Speed Wind Tunnel at NASA Glenn.

The investigations are split among computational aeroacoustics, development of new jet noise measurement techniques, and bench testing novel noise suppression methods. Promising results have been reported by Penn State researchers who have developed a technique that uses distributed blowing inside the divergent section of converging-diverging nozzles to create ‘fluidic inserts’ that mimic hard-walled inserts being developed at the University of Mississippi. Actively controlled levels of blowing in small-scale experiments significantly decrease large-scale structure noise as well as broadband shock-associated noise.

The second Workshop on Benchmark Problems for Airframe Noise Computations, organized by AIAA and NASA, was held in conjunction with this year’s aeroacoustics conference. Noise sources studied included a trailing edge, tandem cylinders, three landing gear, and two slats. Research groups around the world provided experimental data and numerical predictions, and some tests were blind. Turbulence-resolving simulations have reached good consensus between teams and with experiments. Calculation of radiated noise from these simulations is not as mature.

NASA successfully conducted a sonic boom community response study directed toward understanding the potential impact of overland supersonic flight of low-boom aircraft. The Edwards AFB housing area was exposed to low-amplitude sonic booms; 100 volunteer residents responded to questions for each boom event experienced at home and at the end of the day to the multiple booms heard that day. To quantify boom variation over the test area, 13 networked sonic boom monitors were placed throughout the community to record the individual sonic boom events.

The GE/NASA/FAA open-rotor test campaign completed both high- and low-speed wind tunnel entries for the second generation of modern blade designs. The team characterized the aero and acoustic performance of several advanced designs for isolated rotor systems and pylon-installed configurations. Technologies to mitigate the pylon installation influence were validated. These blade designs demonstrated substantial noise reduction relative to both legacy designs and Stage 4 regulations while maintaining the efficiency of open rotor systems.

NASA and Honeywell are partnering on a research effort to measure the unsteady temperature and pressure fluctuations generated inside the core of a gas turbine engine. Efforts have focused on bench testing of a dual wire thermocouple probe measurement system previously developed by NASA and Pratt & Whitney.

Honeywell completed installed acoustics compatibility testing on its newest auxiliary power unit (APU), the HGT1700, within the A350XWB aircraft tail cone. During the test, Optinav demonstrated its 24-microphone phased array system to identify the positions of known and contaminating noise sources. This new application of phased array technology within Honeywell provided unprecedented understanding of installed APU source locations and magnitudes.

by **Walter Eversman**

Atmospheric flight mechanics

The remotely piloted X-48C aircraft made its maiden flight on August 7 at NASA Dryden. The vehicle is a modified version of the X-48B predecessor with configuration modifications to enhance the fan and jet noise shielding provided by the blended-wing-body concept. The modifications involved extending the aft centerbody section and moving the wing tip rudders to the new extended aft centerbody. The propulsion system was reconfigured from a trijet to a twin-jet design. Ongoing flight tests will explore low-speed flight dynamics and control. The Air Force Research Laboratory, Boeing, Cranfield Aerospace, and NASA jointly sponsored the research.

The Northrop Grumman X-47B Navy unmanned combat air system has continued flight tests at Patuxent River, Maryland, and is scheduled to begin precision landing tests on an aircraft carrier in 2013. A flight on July 30 included an evaluation of the command interface, aerodynamic performance, and flight control system. The 36-min flight included two precision patterns in which the aircraft achieved an altitude of 7,500 ft and an airspeed of 180 kt.

Northrop Grumman's optionally manned Firebird continued flight tests in 2012 with a variety of sensor payloads designed to provide high-resolution aerial intelligence. Firebird is designed to be flown either with an onboard pilot or remotely, which requires it to satisfy requirements for both piloted handling qualities and autonomous capability.

Flight tests of the Firebird continued this year.

The Long Endurance Multi-Intelligent Vehicle, developed by Northrop Grumman and Hybrid Air Vehicles, made an initial 90-min flight on August 10 in a demonstration of the optionally piloted lighter-than-air configuration. The operational vehicle is expected to fly for more than 3 weeks in a reconnaissance role. The aircraft is designed to incur less drag than typical airships and will have improved speed, range, and efficiency while carrying large payloads to altitudes above 22,000 ft.

Flight testing of the X-47B continues at Patuxent River.

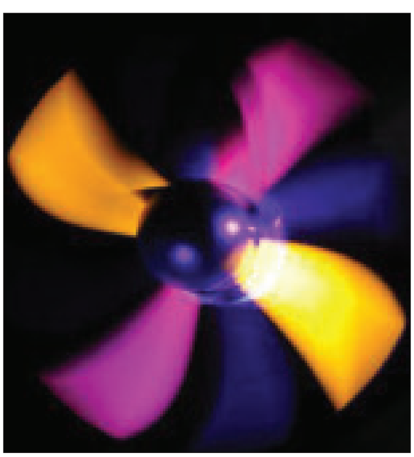
The X-48C technology demonstrator awaits its first flight on August 7 at Edwards AFB.

by **Mujahid Abdulrahim, Dan D. Vicroy, Kamal Shweyk,** and **Steve Komadina**

Aerodynamic measurement technology

Researchers at Auburn University have developed a novel 3D three-component (3C) particle image velocimetry (PIV) technique based on the light-field-capturing capability of a plenoptic camera. This type of camera uses a microlens array and CCD sensor to record both the position and angle of light rays entering the camera. The technique allows images to be computationally refocused, or new views to be generated from a single snapshot. Tomographic reconstructions of a pair of time-correlated particle volumes produced a 3D 3C volumetric velocity field in a turbulent boundary layer using PIV.

At NASA Langley, the first quantitative freestream density measurements in a Mach 10 freestream were made using laser Rayleigh scattering. The same team also performed the first quantitative off-body air density measurements along a line in a Mach 10 wake using iodine Cordes-bands laser-induced fluorescence. Air densities behind a multipurpose crew vehicle model were measured to be 14.5% of the freestream density. In addition, a three-laser, quantitative NO_2 photodissociation tagging velocimetry method was applied to study hypersonic boundary layers in the 31-in. Mach 10 wind tunnel.



A rotating propeller is coated with pressure (magenta) and temperature (yellow) paints. Obtained by DLR and the University of Hohenheim.

Researchers at the Air Force Research Lab, aided by Spectral Energies and Innovative Scientific Solutions, have used femtosecond two-photon laser-induced fluorescence (fs-TPLIF) to demonstrate kilohertz-rate imaging of hydrogen and oxygen atoms in hydrocarbon flames. The group obtained an excellent match between the shapes of the experimental fs-TPLIF line profiles and numerical flame calculations.

The method enables efficient nonlinear excitation, while the low energy nearly eliminates interfering single-photon photodissociation processes, which can generate the same species being probed. They also performed hydrogen and oxygen atom TPLIF line images as well as 2D planar imaging in a series of laminar and turbulent diffusion flames. Such measurements are providing unprecedented critical experimental data for validating complex turbulent combustion models.

The Laboratory for Turbulence Research in Aerospace and Combustion at Monash University in Melbourne, has combined ultra-high-speed magnified digital holography and coherent imaging to investigate particle/shock interactions in a supersonic jet flow. Ultra-high-speed recording a1 million Hz enables simultaneous tracking of 3D particle motion and shock wave interaction. Results have provided some of the first time-resolved visualizations of the interaction between micron-sized particles and the complex shock structure, including bow shocks in the wake of the particles as they are entrained into the gas phase and accelerate toward supersonic speeds.

To date, it has proved challenging to measure temperatures and pressures on the surface of a rotating propeller blade. Spatially resolved 2D techniques are highly desirable to enable certain flow structures to be resolved on the surface, such as separation bubbles and boundary layer transitions. The DLR, in cooperation with the University of Hohenheim, has synthesized special fast paint formulations for unsteady temperature-sensitive paint and pressure-sensitive paint, and tested them in measurements on a propeller rotating at 15,000 rpm in a Mach 0.2 flow to obtain pressure and temperature distributions. The technique enabled visualization of laminar-to-turbulent transition regions of the boundary layer on a propeller blade.

JAXA applied time-resolved PIV to an unsteady transonic flow field around a rocket fairing model in their 2x2-m transonic wind tunnel. Images were acquired at 20 kHz using a high-speed CMOS (complementary metal oxide semiconductor) camera. Measurements in the transonic flow field provided mean velocity and power spectral densities of velocity fluctuation with high temporal resolution. Also in the same wind tunnel, velocity distributions of the supersonic boundary layer on a flared cone model were measured using a long-range micro-PIV system. The result was found to agree qualitatively with the CFD prediction, and explained a characteristic transition pattern of the supersonic boundary layer on the model.

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

Applied aerodynamics

The AIAA Aeroelastic Prediction Workshop took place in April, with 23 analysis teams from 11 countries submitting computational results for three configurations. Existing experimental data sets were selected for benchmarking and were made available to the participants. The workshop yielded code-to-code and analysis-to-experiment comparisons.

Key conclusions on the aeroelastic predictive capabilities showcased include:

- Reynolds-averaged Navier-Stokes appears to be the state of the art, based on participants' code selection.
- Seemingly simple cases captured complex and important flow phenomena.
- Substantial variations were observed among the CFD analyses and between the CFD analyses and experiments.

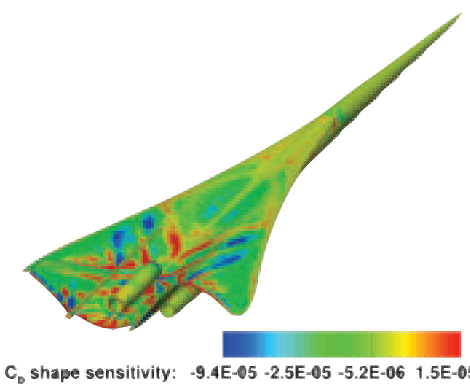
Key phenomenological challenges to improved predictive capabilities included oscillatory shock behavior, shock-induced flow separation, and tunnel wall boundary-layer influences.

NASA's Fundamental Aerodynamics N+2 program worked with a Lockheed/GE/Rolls-Royce/Stanford team and with Boeing on next-generation supersonic transport concepts, validating low sonic boom configurations and low airport noise propulsion for supersonic commercial transports beyond 2020. The low boom design was enabled through application of advanced computational methodologies, including structured Mach aligned swept cells, unstructured grids, and adjoint CFD-based design refinement. These efforts resulted in a breakthrough for a critical supersonic enabler—complete cruise low boom without performance degradation.

In the airport noise arena, new three-stream nozzle concepts from GE and Rolls-Royce were tested at NASA Glenn acoustics labs and demonstrated potential for achieving noise levels below FAR-36 stage 4.

The DOD 12-year Computational Research and Engineering Acquisition Tools and Environments (CREATE) program was established in 2008 to enable major improvements in engineering design and analysis processes. It seeks to develop and deploy scalable multidisciplinary physics-based computational engineering products for the design and analysis of ships, air vehicles, and RF antennas. The Air Vehicles program, CREATE-AV, released three products this year: the fixed-wing analysis tool KESTRELv3.0, the rotorcraft analysis tool HELIOSv3.0, and the grid generation tool CAPSTONEv3.0. KESTRELv3 adds automated overset capabilities for moving aircraft/body simulations. HELIOSv3 enables off-body adaptive mesh refinement and provides the ability to handle multirotor configurations. CAPSTONEv3 allows for dirty geometry cleanup, surface mesh generation, and volume mesh generation for CFD/ CSD applications.

NASA 2020 N+2 worked on low-noise supersonic transport studies, such as the Low Boom Adjoint Design Computation of Drag.



The NASA Subsonic Fixed Wing project worked with Northrop Grumman to develop 'N+3' advanced high-lift leading-edge technology for laminar flow wings. Two configurations were successfully tested to TRL 4, exceeding target lift improvement goals by about 30%. The first configuration was a Northrop-developed blown leading-edge concept that achieved a maximum section lift coefficient of 4.6. The second configuration, a drooped leading edge with a blown shoulder, achieved a maximum lift coefficient of 5.0. Both configurations assumed the use of an integrated slot design that enables laminar flows during cruise; they also shared a common 45-deg, blown trailing-edge flap.

The Fifth Drag Prediction Workshop was held in conjunction with the 29th Applied Aerodynamics Conference. The workshop centered on a common grid and buffet study for the NASA Common Research Model. An additional case for turbulence model verification was also included. A special session showcasing results from several contributors will be held in January.

Applied CFD work at NAVAIR made further inroads in predictive modeling of naval air vehicles, focusing on complex unsteady aerodynamics effects. One example is the simulation of the unmanned combat air vehicle 1303 configuration, to leverage DOD interest in weaponized UAVs. CREATE-AV Kestrel delayed detached eddy simulation tools were used to predict bay-cavity sound pressure levels and tonal content within 10% of wind tunnel measurements.

by **Nathan Hariharan**

Atmospheric and space environments

This year brought a variety of developments in the fields of atmospheric and space environments. Testing capabilities were upgraded, weather forecasting tools developed, flight experiments conducted, and new guidelines produced.

NASA engineers measure ice accretion thickness on a cloud uniformity grid during a PSL-3 system checkout.

Construction is complete on the ice crystal upgrade to Propulsion Systems Laboratory test cell three (PSL-3) at NASA Glenn in Cleveland, Ohio. PSL-3 is a direct-connect, altitude simulation engine test facility that was retrofitted with water injection spray bars to enable production of an ice crystal cloud throughout a typical commercial turbofan engine mission profile.

PSL-3 is undergoing integrated systems testing, with cloud calibration testing scheduled to take place by year's end. The first tunnel validation testing with a fully functional and operating turbofan engine is scheduled for January-February 2013. The test cell is designed to operate at pressure altitudes of 4,000-40,000 ft and at temperatures ranging between -50 F and 15 F. Ice water content ranges from 0.5 to 9 g/m^3.

Beginning this year, anyone in the eastern two-thirds of the continental U.S. who is worried about a warm weather event being rained out can get up-to-date nowcasts of 'pop-up' storms from a new website created at the Earth System Science Center at the University of Alabama in Huntsville. The algorithm on which the site is based uses data from geostationary satellites to track cumulus clouds as they develop and, as much as an hour before they show up on Doppler radar, provides a color-coded forecast of which clouds are likely to produce rain or lightning. The website can be viewed at http://nsstc.uah.edu/SATCAST/.

Six samples of pristine and dust-abraded outer layer spacesuit fabrics were included in the Materials International Space Station Experiment-7, or MISSE-7, which was returned in May 2011. The fabrics had been exposed to the wakeside LEO environment on the ISS for 18 months to determine whether abrasion by lunar dust increases radiation degradation. Comparison of pre- and postflight characterizations carried out at NASA Glenn showed that the environment darkened and reddened all six fabrics, increasing their integrated solar absorptance by 7-38%. There was a de- crease in the ultimate tensile strength and elongation to failure of lunar dust-abraded Apollo spacesuit fibers by a factor of four, and an increase in the elastic modulus by a factor of two. Clearly spacesuits will need to be protected from this degradation if they are eventually to be used for long-term space exploration.

A new AIAA standard entitled *Low Earth Orbit Spacecraft Charging Design Standard Requirement and Associated Handbook* (BSR/ANSI/AIAA S-115-2013) has been developed and is set for release in early 2013. This standard presents an overview of current understanding of the various plasma interactions that can result when a high-voltage system is operated in the Earth's ionosphere. In addition, common design practices that have exacerbated plasma interactions in the past are referenced, and standard practices for eliminating or mitigating such reactions are recommended. (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**

Astrodynamics

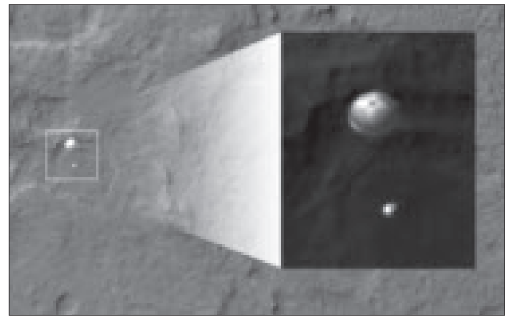
This year began with the arrival of NASA's GRAIL (gravity recovery and interior laboratory) orbiters at the Moon. Launched on a Delta II rocket on September 10, 2011, the twin orbiters Ebb and Flow embarked on a four-month low-energy transfer and performed lunar orbit insertion maneuvers on New Year's Eve and Day. Followed by two months of circularization, the probes were placed in tandem orbits around the Moon and initiated the prime science data collection on March 1, making this the first interplanetary formation-flight mission.

During the three-month prime science phase, the orbiters mapped lunar gravity in unprecedented detail using a technique similar to that of the gravity recovery and climate experiment mission, which on March 17 celebrated the 10th anniversary of mapping Earth's gravity field. The GRAIL orbits were raised in late May to avoid a lunar eclipse and were reconfigured to initiate the extended mission data collection on August 30. GRAIL will be decommissioned this month by impacting the lunar surface.

NASA launched another set of twins, the Radiation Belt Storm Probes, on August 30. They will be studying the Van Allen radiation belt.

On November 6, 2011, the Phobos-Grunt spacecraft was successfully launched aboard a Zenit launcher. However, the spacecraft failed to respond to ground command and was trapped in an undesirable low Earth orbit. The 13-ton spacecraft eventually disintegrated and on January 15 fell back to Earth over the Pacific Ocean. In between its launch and reentry, observers around the world tracked Phobos-Grunt and shared estimates and trending of orbital properties.

On August 6, the Mars Science Laboratory spacecraft, launched in November 2011, successfully landed the 1-ton rover Curiosity on Mars, inside Gale Crater. After successfully navigating to a very tight flight path angle requirement, the interplanetary navigation function performed the first handover to an active guidance system, which adjusted errors during the craft's descent through the atmosphere on its way to the surface. Two other spacecraft, Odyssey and the Mars Reconnaissance Orbiter, were precisely positioned at the time of the landing to receive transmissions and to take descent images of the rover.

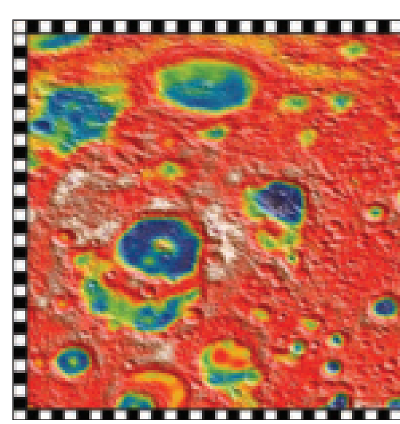


NASA's Curiosity rover and its parachute were spotted by NASA's Mars Reconnaissance Orbiter as Curiosity descended to the surface on August 6. The high-resolution imaging science experiment camera captured this picture while the orbiter listened to transmissions from the rover. Courtesy NASA/JPL-Caltech/University of Arizona.

The Dawn spacecraft, which began orbiting the protoplanet Vesta in July 2011, has explored that uncharted world for more than a year. Using its solar electric propulsion system, the probe maneuvered to different orbits to optimize its investigation. The lowest altitude orbit was achieved in December 2011 and mapped Vesta at an average altitude of 210 km for five months. Dawn then gradually spiraled away from Vesta and escaped its gravity well on September 5. The probe is currently enroute to its second target, Ceres, and is expected to arrive in February 2015.

On December 5, 2011, NASA announced that Voyager 1 had entered the stagnation region between interstellar space and our solar system. On March 17, 2012, NASA's MESSENGER (Mercury surface, space environment, geochemistry, and ranging) spacecraft successfully wrapped up a year-long primary campaign for the first complete reconnaissance of the solar system's innermost planet. An extended mission phase started on the following day where the orbit period is reduced from 12 hr to 8 hr.

In April, China's second lunar orbiter, Chang'e 2, departed the Sun-Earth L2 point and headed to the asteroid 4179 Toutatis for a flyby expected in January 2013. On June 18, three astronauts on Shenzhou-9 successfully completed China's first crewed docking with the Tiangong-1 module.



Free-air gravity from GRAIL depicts a region of the Moon's farside highlands. Red corresponds to mass excesses and blues and purples correspond to mass deficiencies. The crater at center left is about 150 km in diameter. The figure illustrates how GRAIL resolves details of the Moon's highland crust as well as crater structures. Courtesy NASA/JPL Caltech/MIT.

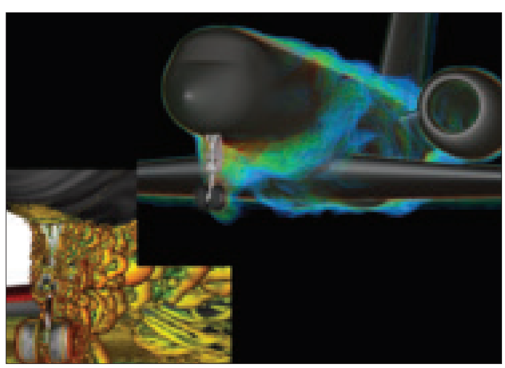
A fifth satellite of Pluto was discovered from a Hubble Space Telescope optical survey. NASA's New Horizon spacecraft is scheduled to conduct the first-ever reconnaissance of the Pluto system in 2015; this new finding adds invaluable information for designing robust flyby sequences.

by **Ryan S. Park**

Fluid dynamics

Highlights in fluid dynamics research this year include advances in flow control, laminar-turbulent transition, unsteady flows, CFD, and flow data from the atmospheric entry of the Mars Science Laboratory.

NASA Ames is exploring novel approaches to controlling free shear layers, which are found in a host of applications including combustion chambers, airfoils (fixed wing, rotary wing), cavity flows, and many environmental flows. The approach involves appropriately perturbing the spatially growing mixing layer (close to its origin) and then allowing the mixing layer to evolve downstream. Depending on the imposed perturbations, mixing layer growth can be enhanced or suppressed, as desired. The perturbations can be imposed via temperature or velocity or both. A simple linear control has been demonstrated to control the mixing layer in a feedback loop.



Simulations by Gulfstream and EXA indicate that the details of unsteady flow over the complex landing gear configuration can be captured with sufficient fidelity to permit physics-based prediction of landing gear noise in flyover configuration. On the left, instantaneous turbulent structures, in color, are superimposed with wall pressure fluctuations in grey; at right is a volume rendering of the time-average flow vorticity.

Work at the University of Arizona has brought advancements in understanding the thermal mechanisms behind high-amplitude actuation for aerodynamic flow control. The objective is to understand the basic physics underlying flow control with localized thermal perturbations and their relatives to reveal new strategies for tailoring active flow control to encompass more extensive Reynolds and Mach numbers, which remain limiting factors in the transition of this technology from the laboratory to the field. The response of mixing layers to both spatially and temporally varying energy deposition from pulsed plasmas and lasers is being studied experimentally within a strong theoretical framework.

Researchers at the University of Texas are examining the mechanisms of lateral spreading of turbulence into an otherwise laminar but transitional boundary layer. Direct numerical simulation, using immersed boundaries, is used to model turbulent spots and wedges over smooth and textured surfaces such as straight or inclined riblets. By varying the surface boundary condition (for example, by allowing slip in the spanwise direction or damping crossflow fluctuations just above the surface), it is possible to show that spreading occurs via a destabilization of the surrounding laminar flow and a turning of the spanwise vorticity into the streamwise and wall-normal directions only at the boundary between the turbulence and the bordering laminar flow.

Recent advances in the application of high-fidelity unsteady flow simulations involving high-lift devices and aircraft undercarriage have led to an ambitious attempt to use numerical simulations for the prediction of airframe noise associated with a full-scale aircraft in flyover configuration. The promising results obtained by Gulfstream Aerospace and EXA are a harbinger of the eventual application of CFD as part of certification-related activities.

At NASA Langley, a discretely consistent time-dependent adjoint methodology has been implemented in the unstructured-grid RANS (Reynolds-averaged Navier-Stokes) solver FUN3D. This capability enables design optimization of unsteady flows using dynamic overset grids in massively parallel computing environments, and has been demonstrated on aerospace, wind energy, and micro air vehicle configurations. The implementation also enables mathematically rigorous error estimation and mesh adaptation strategies for such applications.

The Mars Science Laboratory (MSL) entry, descent, and landing instrumentation (MEDLI) suite measured the temperature and pressure on NASA's MSL heat shield as the spacecraft entered the Martian atmosphere on August 6. MEDLI included seven transducers mounted to the 4.5-m aeroshell's interior to measure pressure in the phenolic impregnated carbon ablator (PICA) heat shield material. In addition, seven thermal plugs were embedded in the heat shield to measure the PICA temperature profile and recession. MEDLI data and postflight Navier-Stokes CFD computations are now being used to reconstruct the heat shield's aerothermal environment, aerodynamic parameters (dynamic pressure, angle of attack), and PICA performance. MEDLI is a major advance that engineers hope will be included on every future EDL mission.

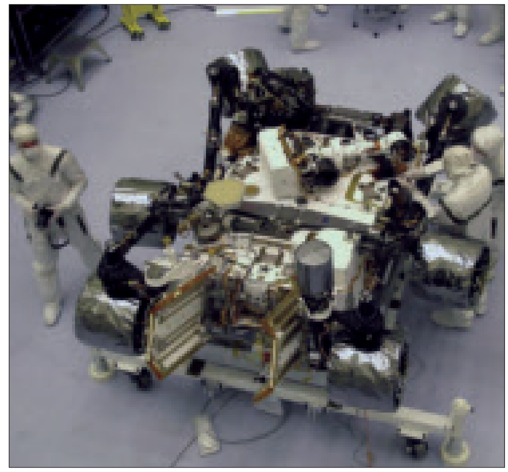
by **Michael W. Plesniak**

Guidance, navigation, and control

In November 2011 the Army successfully tested the Advanced Hypersonic Weapon (AHW), developed by Sandia National Labs. The test's objectives included demonstration and data collection of the vehicle's aerodynamic stability, aerothermodynamic heating, and guidance, navigation, and control (GN&C) of the missile and glide vehicle in the hypersonic regime. The flight involved new maneuvers that keep the weapon on a highly depressed trajectory during ascent; postapogee, the vehicle pulled up after an initial descent through the atmosphere to capture its glide altitude, from which it glided to its target, skimming the atmosphere over its long-range atmospheric approach. AHW's eight tail grid fins were used to improve the missile's aerodynamic stability and to control the glide path during its long in-atmosphere flight. This was the first demonstration of a hypersonic gliding vehicle at such altitudes and ranges.

Less successful was the X-51A Waverider test conducted by the Air Force in August to evaluate hypersonic flight at speeds of Mach 6+. The X-51 is an unmanned, scramjet-powered hypersonic demonstration aircraft. The plan was to release it from a B-52 at 50,000 ft; after release, a solid rocket booster (SRB) would propel the plane to Mach 4.5; the booster would then jettison and the scramjet engines fire to accelerate the aircraft to its top flight speed of Mach 6+. While separation from the B-52 went as planned, and the SRB fired as expected, a faulty tail control fin resulted in loss of control authority once the rocket motor jettisoned, and the vehicle was unable to stabilize itself; thus it was terminated 16 sec after separation from the SRB and before the scramjet engine could be lit.

In June, DARPA concluded UAVForge, a crowd-sourced competition program designed to solicit the do-it-yourself UAV enthusiast community for innovative concepts to design and build autonomous backpack-scale UAVs with specific militarily relevant capabilities. DARPA downselected nine teams from 140 who had submitted videos demonstrating 'early flight behavior' capabilities of their drones. The flyoff required each system to perform a vertical takeoff, navigate beyond line of sight, land on a structure, and capture surveillance footage before returning to the start. However, although all the drones managed to take off and navigate fairly well, not a single one successfully landed on a structure to collect video, according to DARPA.



Curiosity is prepared for final integration into the complete NASA spacecraft in the Payload Hazardous Servicing Facility at NASA Kennedy.

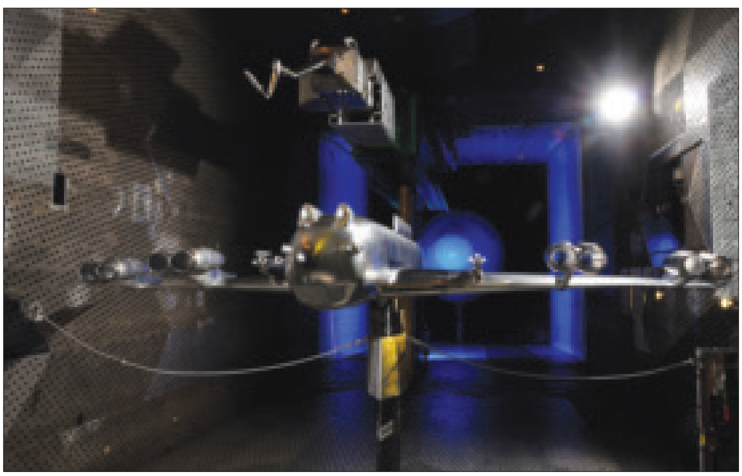
After nearly nine months of travel, NASA's Mars Science Laboratory (MSL) arrived at the red planet, carrying Curiosity, a rover set to explore Mars for at least one Martian year. The spacecraft's entry, descent, and landing sequence successfully brought the rover from a velocity of 5,900 m/sec down to an altitude hold-hover within 7 min and safely landed it on the surface. The entry, descent, and landing concept is based on a guided system and supported by a Sky Crane. The MSL made a more accurate landing than any previous spacecraft to Mars, aiming for a small target landing ellipse only 7 km by 20 km and landing only 2.4 km from the center of the target.

While the worldwide launch rate remains flat, the launch vehicle world has seen much development. NASA awarded three contracts for development of commercial crewed vehicles. SpaceX successfully launched its demonstration Dragon capsule, making it the first commercial U.S. spacecraft to visit the ISS. It was followed by a commercial berthing. ESA lofted the first Vega launcher and conducted a flawless qualification flight from its spaceport in French Guiana. Orbital Sciences is closing in on the first flight of NASA's COTS system. While the commercial spacecraft market reduction that drove the formation of United Launch Alliance has not rebounded, Atlas V and Delta IV have launched successfully 52 times. NASA continues to make progress on the Space Launch System and Orion multipurpose crew vehicle, efforts that spur interest in new rendezvous, proximity, and avoidance GN&C approaches.

by **Leena Singh, Luisella Giulicchi, John Reed,** and **Lance Page**

Ground testing

This year several ground test facilities made concerted efforts to upgrade aging systems. Many of the systems are well beyond their designed life expectancy and are no longer flexible enough to meet future test requirements. These upgrades will provide state-of-the-art facilities that meet the demands of future test programs.



AEDC set a record with the largest aircraft model to conduct a B-52H store separation test.

At NASA Langley, a new facility automation system (FAS) and data acquisition system (DAS) are being installed in the National Transonic Facility. The upgrades will improve technical viability by providing continued high-quality, high Reynolds number testing and will include installing a new tunnel control system, new DAS, and modern simulation tools. The FAS upgrades will allow for a fivefold increase in Mach number measurement accuracy while reducing annual calibration costs. The DAS upgrades will improve data quality and provide continual support of advanced testing.

At NASA Glenn, upgrades to the Propulsion Systems Lab test cell three (PSL-3) have been completed. They included retrofitting the direct-connect, altitude simulation engine test facility with water injection spray bars to provide the ability to produce an ice crystal cloud throughout a typical commercial turbofan engine mission profile. The PSL-3 is currently undergoing integrated systems testing, with the first test of a fully functional and operating turbofan engine scheduled for early next year.

At the Arnold Engineering Development Complex, upgrades to the von Kármán Facility and the Propulsion Wind Tunnel Facility continue. The upgrades will allow the facilities to meet the demands of future test programs by improving reliability, decreasing operational and test customer costs, and providing commonality across facilities.

AEDC also set a record for fabricating the largest ground test model ever built at the complex. The B-52H Stratofortress store separation effort resulted in AEDC using all its capabilities, from planning, design, fabrication, testing, and computations to analysis and reporting. Combining the center's capabilities with ongoing external customer collaboration made the test effort a truly 'integrated test and evaluation' program.

Also, as news broke of the NASA Mars Science Laboratory Curiosity rover's successful landing on August 6, a number of people across AEDC's facilities were paying close attention. AEDC provided aerothermal characterization of the heat shield design at the Hypervelocity Wind Tunnel 9 in Silver Spring, Maryland, material characterization in AEDC's arc jet facilities in Tullahoma, Tennessee, and full-scale parachute testing in AEDC's National Full-Scale Aerodynamic Complex, located at NASA Ames.

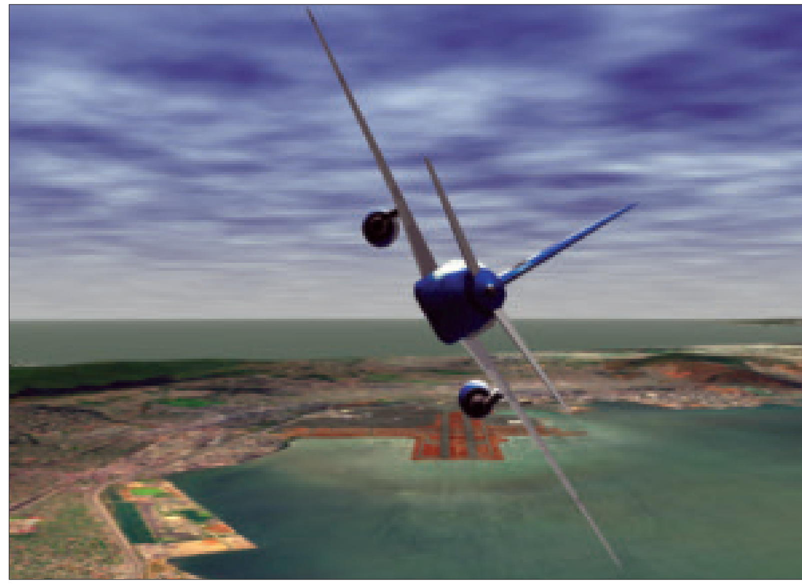
At NASA Ames, reactivation of the Unitary Plan Wind Tunnel's (UPWT) Mitsubishi compressor system was completed and is scheduled to replace the existing Clark compressor as the primary make-up air source. The Mitsubishi compressor will improve productivity and reliability of the UPWT by providing additional air and vacuum pumping capability. Also at the 11-Ft Transonic Wind Tunnel, installation and validation of a noncontact stress monitoring system for the three-stage compressor was completed. The new system allows for continuous monitoring and recording of compressor blade bending and torsion stresses during normal test operations.

A series of sonic boom tests were completed in the UPWT. Part of the Fundamental Aeronautics Program, the tests were a collaborative effort with Boeing and Lockheed Martin. One goal of the series was to develop test techniques and hardware capable of measuring sonic boom signatures in the transonic and supersonic regimes. Data on various model designs were also collected and will be used to validate CFD predictions.

Finally, an atypical test of the crew exploration vehicle parachute assembly system was completed in the 11-Ft Transonic Wind Tunnel. The goal of the test was to acquire aerodynamic and flow field data for use in validating CFD methods and tools.

by **Ben Mills**

Modeling and simulation



Simulating aircraft in an upset is assisting in understanding the causes and preventing the problem.

Upset prevention and recovery training for air carriers continues to be a fertile area of activity in the field of modeling and simulation. Evidence reveals that stalls are the leading cause of upsets. Prior to the introduction of a 2010 U.S. law, pilots practiced recovering from the first indication of a stall, such as a stick-shaker activation, in simulation. The 2010 law will soon require pilots to be trained at angles of attack beyond that first indication, and to recover from full aerodynamic stalls.

A challenge for the simulator community is how to reasonably model these higher angle-of-attack regimes completely, which is beyond what has been previous practice in most cases. For some of the more recent aircraft models, there are sufficient flight test data to create full-stall aerodynamic models. For some of the older aircraft models, data access and completeness create challenges.

However, if one considers the training objective, which is to teach the appropriate stall recovery technique under a variety of possible entry conditions, matching a simulator model to flight test data may not be necessary. Instead, it might be possible to create a model that has the typical dynamical features that occur during a typical stall, such as reduced stability, reduced control effectiveness, and a pronounced roll-off at the stall point. Such a model may be sufficient for training purposes.

This year Boeing created a poststall model using an extensive flight test database of stalls for the 737-800. Separately, a team comprised of Cherokee Research, Bihrle Applied Research, and Testpilot created a poststall model using computational analysis, wind tunnel similarity data, and expert pilot opinion—from a pilot with experience in stalling the actual aircraft in flight test—for the 737-800.

In 2013, both of these models will be evaluated in an experiment to determine whether a poststall model needs to match flight data for the purposes of stall training. If the latter model is feasible for such training, it could potentially be cost effective and allow for modification of simulators used for training on older aircraft types.

Another question often asked for upset training is whether the motion cues provided by the typical simulator help or hurt. Several research organizations, including the University of Toronto and both NLR and TNO in the Netherlands, have been investigating possible motion cueing improvements. Results of these studies were reported at the 2012 Modeling and Simulation Technologies Conference.

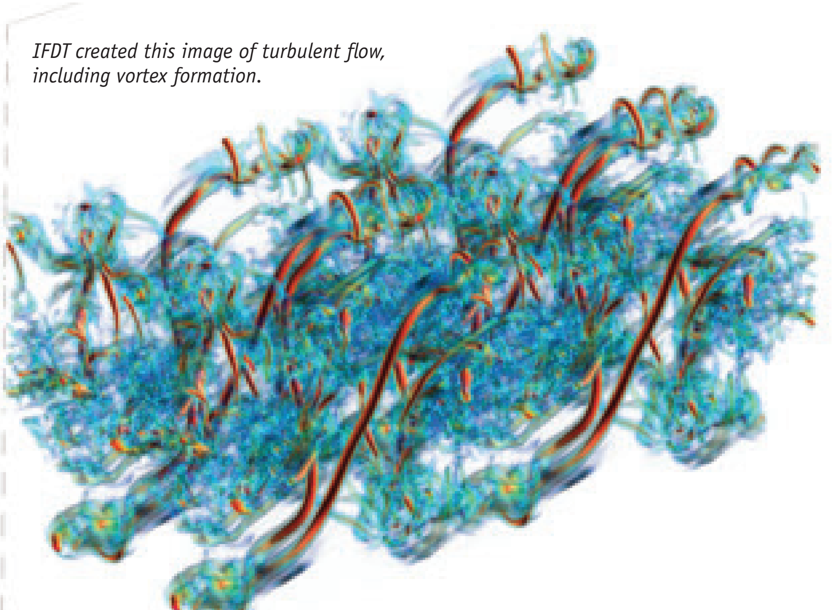
Sometimes a contributing factor to an accident is that a pilot inexplicably takes actions inconsistent with his or her simulator training. This is often attributed to some sort of cognitive breakdown that may have arisen from being surprised. Equaling in-flight surprise in simulation is difficult. This year a NASA simulator study found that pilots, on average, had three to four times more delay in their response to unexpected stalls than they did for expected stalls. While most everyone agrees that inserting unexpected events in simulator training offers benefit, the practice has not been implemented widely. Such research evidence showing the specific benefits may raise the priority for action.

Another area receiving considerable modeling and simulation attention is unmanned aircraft systems. Under a NASA-sponsored project, simulator facilities across the U.S. have been linked together in ways similar to distributed simulations performed for defense purposes. This linkage allows for expertise available at different locations—on subjects such as airspace, proprietary vehicle models, live aircraft, and classified programs—to be combined into one experiment. A demonstration of a distributed simulation took place this year with participation by NASA, the FAA Tech Center, NAVAIR, and Boeing.

by **Jeffery Schroeder**

Meshing, visualization, and computational environments

Although the adage "a picture is worth a thousand words" rings true in both the pedagogy and practice of science, it is displayed in perhaps its most elegant fashion in mesh generation, visualization, and computational environments (MVCE). Indeed, without the many advances in visualization techniques, debugging would be harder, sharing results would be nearly impossible, and much computational research would be merely huge strings of nearly indecipherable numbers to be combed through by graduate students.



IFDT created this image of turbulent flow, including vortex formation.

For instance, researchers at Intelligent Light have developed a new prototype visualization and CFD data analysis software system, Intelligent In-Situ Feature Detection, Tracking and Visualization for Turbulent Flow Simulations (IFDT), which enables the user to readily explore, detect, track, and analyze flow features predicted by large-scale unsteady CFD simulations. The system employs volume rendering that allows the user to automatically highlight flow features such as turbulent vortices. A feature extractor method then tracks and extracts the flow features and determines the statistics of features over time. The Air Force Research Laboratory funded this work in collaboration with the University of California–Davis.

Mesh generation and visualization have proven to be useful tools not only in speeding up CFD solutions and improving accuracy, but also in exploring the origins of some of the strange phenomena seen in experimentation. For instance, in a paper by scientists from the Royal Military College of Canada, the use of direct numerical simulation and visualization has shown very long streamwise vortices (also known as the 'colored-fingers phenomenon') in CFD results that mimic those reported in turbine heat transfer experiments. This may change the community's ideas about how these pressure-side vortices form in turbomachinery applications.

Also, scientists from the University of Alabama at Birmingham and the Japan Aerospace Exploration Agency have described their approach to further automating mesh generation. This includes novel ways of dealing with sharp corners and marching viscous layers off the surface.

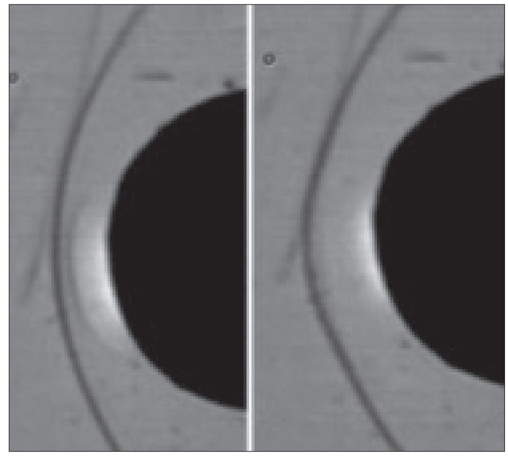
Overset mesh generation has seen a resurgence in popularity as a method for discretizing domains, thanks to more available storage, more robust mesh interpolation codes such as SUGGAR++, which was developed by researchers at Penn State, and fully capable overset mesh assembly software such as that developed at NASA Ames and Celeritas Simulation Technology.

Commercial software packages such as Pointwise have begun to work on streamlining the process of overset mesh generation in these products, enabling visualization of the assembly results, use of structured, unstructured, and hybrid meshes in creating the overset mesh, and mesh adaptation to improve results. Organizations such as the Air Force Materiel Command and Arnold Engineering Development Center have taken the lead in funding projects to streamline the use of overset methods for CFD analysis.

With processors becoming faster, accelerator technologies such as NVIDIA GPGPUs and Intel Xeon Phi cards becoming more widespread, and overall memory growing as latency shrinks, MVCE continues to evolve to take advantage of these groundbreaking technologies, with the end goal being truly dynamic, adaptive meshing. To this end, the AIAA/DOD-sponsored Mesh Quality Workshop was held at Wright-Patterson AFB, producing vigorous discussion. The community continues to converge on specific metrics and quality measures to amplify the power of current CFD solution methods by holding these important conversations.

by **Vincent Charles Betro, Earl Duque,** and **Nick Wyman**

Plasmadynamics and lasers



Schlieren images illustrate bow shock control at Mach 5 using nanosecond-pulse barrier discharge actuators (left image 2 μsec after the pulse; right image 4 μsec). Courtesy Ohio State University, Dept. of Mechanical and Aerospace Engineering.

Plasma aerodynamics continued to be a popular research area this year. Topics of particular interest include developments in plasma-based flow control and plasma-assisted combustion.

Industry seems to be receptive to the adoption of plasma-based technology, but has reservations about technical risk, performance, reliability, and integration. There is a need to identify applications where plasma devices are significantly better than competing technologies.

Plasma-enhanced combustion is a very promising area for both low- and high-speed regimes. Discharges are being used to break down fuels, enhance ignition, and promote combustion efficiency.

Laser scattering techniques are among the best options for making measurements of the detailed features of electrical discharges, and the field is progressing rapidly. For example, nonintrusive measurements of electric fields have recently been made via the USED-CARS (unstable resonator enhanced-coherent anti-Stokes Raman scattering) technique.

The main challenge for numerical simulations is the disparity in the time and length scales present for an electrical discharge in a large-scale gas flow. This challenge has motivated the use of reduced-order models, but there is a strong need to corroborate their accuracy with experiment and high-fidelity computations.

The accuracy of numerical modeling also depends to a great degree on the chemical kinetic model. The kinetics of plasmas in air and air-fuel mixtures is extremely complex, and care must be taken in calculations to stay within the bounds of validity of a plasma kinetic model. There is a lack of detailed experimental data to compare with new kinetic mechanisms. In general, there is a need for consistent effort to establish the accuracy of plasma aerodynamic modeling.

This year has seen considerable activity on many fronts in laser technology development. In the gas laser area, CU Aerospace performed a scaling demonstration of the electric oxygen-iodine laser technology, extracting 500 W of high beam quality light and meeting a critical milestone in the advancement of this technology. In a related development, researchers at the Russian Federal Nuclear Center demonstrated extraction of 1 kW of laser light from a flowing diode pumped alkali laser (DPAL) using cesium as the active lasing species.

This work complements recent successes at the Air Force Academy and the Air Force Research Laboratory in the development of flowing DPAL technology, indicating strong scaling potential for this technology. Elsewhere within the Defense Dept., the Missile Defense Agency's Airborne Laser Testbed program concluded, marking the end of a program that successfully demonstrated the ability to target, track, and shoot down missiles using a megawatt-class laser on an aircraft.

Airborne Aero-Optics Laboratory at the University of Notre Dame, an in-situ facility for measurement of aerooptical aberrations and assessment of laser turret configurations, was active this year characterizing hemisphere-on-cylinder and hemisphere-only turret configurations. The hemisphere-only configuration demonstrated an advantage with regard to measured optical path difference for wake optical propagation, and the hemisphere-on-cylinder had some advantage for high elevation pointing angle propagation.

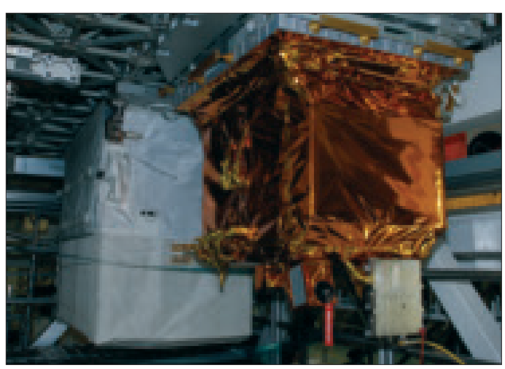
In other work, the University of Notre Dame validated application of a phase-lock loop controller to phase-lock to a low order optical field measurement, providing a path toward synchronization of a feed-forward aerooptic correction of shear layer aberrations. Notre Dame also developed a useful analytical model based on an empirical fit of experiment optical path difference data from turbulent boundary layers over varying size apertures in the Mach 0.4-0.6 range with varying laser beam deflection angles, good for aperture diameters up through 10 boundary layer thicknesses.

by **Timothy J. Madden** and **Jonathan Poggie**

Thermophysics

by **Eric Silk, David Kuntz, Heather Clark, Andrew Williams, Egidio Marotta,** and **Michael Yovanovich**

As part of an effort to identify cost-efficient fabrication techniques for loop heat pipe (LHP) construction, NASA Goddard's Cryogenics and Fluids Branch collaborated with the U.S. Naval Academy's Aerospace Engineering Dept. this spring to investigate the viability of carbon foam as a wick material within LHPs. The carbon foam was manufactured by ERG Aerospace and machined to geometric specifications at the academy's Materials, Mechanics and Structures Machine Shop. Goddard's fractal loop heat pipe (FLHP), developed under small business innovation research contract NAS5-02112, was used as the validation LHP platform. In a horizontal orientation, the FLHP system demonstrated a heat flux of 75 W/cm² with deionized water as the working fluid. No failed startups occurred during the six-week performance testing period.



Wrapped in red, the MHTEX experiment was sent to the ISS on April 29. The box below and to the right of the wrapping is the VADER experiment. Image courtesy USAF.

The success of this study validated that foam can be used as a wick structure. Furthermore, given the commercial off-the-shelf status of foam materials, this study is one more step toward development of a 'low-cost LHP.'

In the early morning hours of November 17, 2011, the Army and Sandia National Laboratories successfully flew the Advanced Hypersonic Weapon flight test vehicle. AHW was launched on a three-stage booster system from the Kauai Test Facility in Hawaii and flew 4,000 km to the Army's Reagan Test Site on the Kwajalein Atoll.

The flight included numerous firsts, including the first time a Sandia-developed booster had flown a low-altitude, intermediate-range horizontal flight path at the edge of Earth's atmosphere; the first time eight grid fins were used to stabilize a U.S. missile system; and the first time a glide vehicle flew at hypersonic speeds at such altitude and range. The Army Aviation and Missile Research Development and Engineering Center in Huntsville, Alabama, conducted the thermal protection system development for the glide body, while Sandia led the design and development of the booster and glide vehicle, including improved navigation, guidance, and control technologies. The test's objective was to collect data on the technologies and test range performance for intermediate-range atmospheric flight.

This year marked the reemergence of capillary pumped loop (CPL) technology as a viable solution for spacecraft thermal control systems. Launched on May 16, 2011, on Endeavour's final mission, the Massive Heat Transfer Experiment (MHTEX) completed 12 months of successful operations aboard the ISS. During that time, MHTEX demonstrated the ability to start up from a variety of initial conditions and passively control temperatures from multiple heat loads under various environmental conditions.

Developed by the Air Force Research Lab/Space Vehicles Directorate in conjunction with Goddard, DOD Space Test Program, and Northrop Grumman Aerospace Systems, MHTEX is a multievaporator, multicondenser capillary pumped loop with four traditional porous wick evaporators, one advanced hybrid wick evaporator, two condensers, and one reservoir.

The key technology demonstrated on MHTEX was the advanced hybrid evaporator, which enables startup under all initial operating conditions, thereby eliminating the need for a dedicated starter pump to purge the system of bubbles before initiating the CPL. While on orbit, MHTEX demonstrated the ability to start the system with the hybrid evaporator, balance loads between the five evaporators, and provide tight temperature control.

In general, CPLs are ideal for spacecraft thermal control systems because they use capillary pumping and two-phase flow to provide passive high-performance heat transfer in a reliable, vibrationless package. In addition, they offer tight temperature control and thermal diode operation, allowing the system to throttle heat transfer during cold orbital periods to eliminate the need for survival heater power. The addition of multiple evaporators and multiple condensers enhances the flexibility and scalability of CPLs by providing the ability to deal with the multiple heat sources typically found on high-performance spacecraft.

Aerodynamic decelerator systems

The year 2012 has seen exciting advancements and historic events in our field.

On August 5, the Mars Science Laboratory rover Curiosity landed safely on the surface of Mars. NASA's entry, descent, and landing system was the most advanced yet. Among the biggest challenges was the supersonic parachute, a mortar-deployed disk-gap-band canopy with a 21.4-m diameter. Built by Pioneer Aerospace, it is the largest parachute used on Mars and also has the highest deployment Mach number. It underwent more than 70 full-scale wind tunnel tests at NASA Ames, as well as subscale supersonic wind tunnel testing at NASA Glenn. The parachute used 3.9 km of suspension cord and was designed to withstand a 356-kN inflation force, yet weighed just 58 kg. Telemetry confirms that the parachute deployed and performed nominally, contributing to the most precise Mars landing to date.

DOD airdrop programs continued to provide critical support to warfighters and to make important advances in the development of accurate ballistic and autonomous airdrop systems. Airdrops in Afghanistan—where aerial delivery continues to demonstrate the fastest and safest resupply method—provided more than 90 million lb of supplies this year. The High Speed Container Delivery System program demonstrated the ability to accurately airdrop up to 16,000 lb from altitudes as low as 250 ft at speeds as fast as 250 kt. The Air Force Research Lab has initiated a capability concept program to address high-altitude cargo and humanitarian airdrop capability.

The Low Cost Aerial Delivery System is dropped in Afghanistan.

NASA's Orion capsule parachute assembly system has begun system-level airdrop flight testing. All six system-level tests, ranging from high dynamic pressure drogue deployment tests to complete system tests using a representative capsule, have successfully accomplished their primary objectives. While minor improvements have been identified and implemented as a result of the testing, the basic design remains unchanged. A flight hardware version will be manufactured and integrated with the Entry Flight Test 1 spacecraft for a 2014 launch and landing.

In June, a successful system test of ESA's Intermediate eXperimental Vehicle (IXV) descent system was conducted at the Army's Yuma Proving Ground. The IXV reentry system is a technology platform for verifying in-flight performance of critical reentry technologies. The Pioneer Aerospace IXV descent system consists of a mortar-deployed disk-gap-band supersonic pilot chute, a ribbon subsonic drogue chute, and a 33.5-m-diam. Ringsail main parachute.

In July, the inflatable reentry vehicle experiment-3 (IRVE-3) launched from NASA's Wallops Flight Facility. This was the third in a series of suborbital flight tests to provide fundamental data for NASA efforts to develop and integrate hypersonic inflatable aerodynamic decelerator technology into future missions. IRVE-3 successfully inflated, reconfigured to generate lift prior to atmospheric entry, and demonstrated reentry steering capability. IRVE-3 traveled at Mach 10 and experienced peak deceleration of 20 *g*s, with heat shield temperature reaching 400 C.

The low-density supersonic decelerator project, also part of NASA's Space Technology Program, is developing a new family of supersonic decelerators, to include two supersonic inflatable aerodynamic decelerators and a 33.5-m-diam. supersonic parachute. These technologies will enable future Mars missions to land greater mass to higher elevations more accurately than ever before. This year brought completion of a number of ground-based rocket sled tests.

Precision autonomous systems saw the first tests of an enhanced avionics suite, including vision-aided navigation and state-of-the-art sensors to operate in GPS-denied environments. Longitudinal control using advanced guidance algorithms for angle of incidence or bleed air actuators has led to accuracy improvements when gliding parachute systems encounter thermals and updrafts. DOD collaborative research programs with Georgia Institute of Technology and California State University, Northridge, have provided unique insights from coupling CFD results, wind tunnel experiments, and airdrop tests.

by **Lauren S. Shook** and **John W. Watkins**

Air transportation systems

Integration and implementation of concepts, technologies, and procedures for the Next Generation Air Transportation System (NextGen) continued this year, spurred on by an FAA reauthorization bill that required the agency to indicate how it plans to incentivize air carriers to incorporate the new equipment.

Use of NextGen concepts and technologies by carriers is still uneven, with FedEx and Alaska making significant use of GPS required navigation performance and continuous descent procedures to save flight time and fuel. The FAA has deployed more than 1,000 performance-based navigation procedures and is accelerating their review and implementation. However, concerns over their effectiveness and the speed with which they can be implemented have been expressed by the House Committee on Transportation and Infrastructure and the subcommittee on aviation.

The pressure and pace of integrating UAVs into domestic airspace increased this year. The desire of UAV manufacturers to offer a myriad of remote monitoring applications, along with the interest of law enforcement and other government agencies in operating them, has been at odds with privacy concerns and with the concerns of pilots and air traffic controllers over a UAV's ability to 'sense and avoid' and remain safely separated from other aircraft.

NASA's Ikhana UAV conducts an imaging mission in southern California.

The FAA has approved approximately 60 agencies to operate UAVs in domestic airspace for a variety of purposes, including hurricane tracking, wildfire monitoring, drug raids, and border protection. It has also begun planning the competitive process to designate a number of UAV test sites.

To assist with separation assurance, many vendors continue to develop and advance sense-and-avoid radar capabilities. Both the FAA Modernization and Reform Act of 2012 and the National Defense Authorization Act had specific language concerning FAA integration of UAS into the U.S. national airspace system (NAS) by 2015. The RTCA Special Committee 203–Unmanned Aircraft Systems is on schedule to complete work on a Minimum Aviation System Performance Standard for UAS this month. The NASA UAS integration into the NAS project continued in FY12. It focuses on providing the FAA with recommended approaches and necessary data.

With the number of general aviation accidents increasing in recent years and the number of controller errors remaining about the same but expected to rise in the next few years because of better reporting, the FAA has continued its implementation of a proactive safety management system (SMS). The agency is moving to require that Part 121 airlines participate in SMS, already an ICAO requirement. SMS systematically tracks recorded data in order to spot potential problems before they manifest themselves in incidents or accidents.

As part of this effort, some smaller or Part 121 airlines and Part 135 operators have begun participating in the Flight Operational Quality Assurance program, under which airlines record numerous aircraft state parameters, including position, speed, and switch position, every few seconds, and voluntarily report this information to the FAA. (Such flight data monitoring is required under ICAO rules.) More nonpunitive employee reporting programs are being implemented to document safety issues as well as employee errors. To encourage the practice, the FAA has promised to avoid punishing employees who report their mistakes in a timely manner.

A flurry of airline consolidations over the past 10 years was punctuated this year by the completion of the United/Continental merger. However, several other types of business moves involving carriers also occurred. Delta Air Lines purchased an oil refinery from Conoco-Phillips in May in a move some felt might presage a trend for the industry. Airlines have also been increasing their use of 'capacity purchase agreements.' Under these agreements, work such as piloting can be outsourced to other companies, so that a pilot of one company can operate the equipment of another. This allows airlines to pay less for the same service, but the practice is controversial because it leaves the airline with less control over such elements as training.

by **Steven J. Landry, Chris Nutter,** and **David Thipphavong**

Aircraft design

This year has seen various interesting developments for next-generation aircraft.

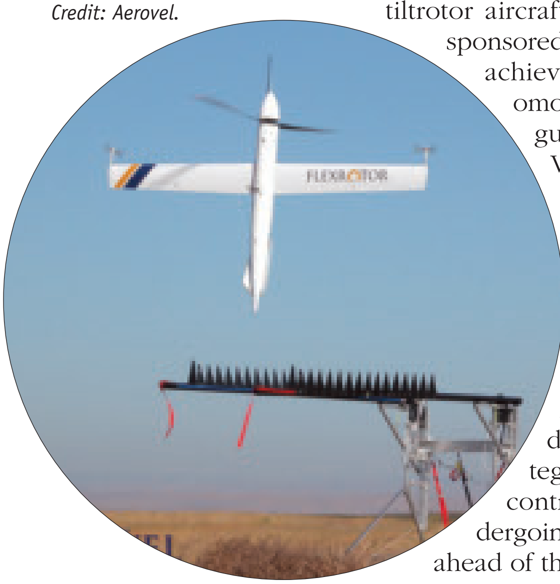
The Army's Long Endurance Multi-Intelligence Vehicle flew for the first time over Naval Air Station Lakehurst, birthplace of the Navy's lighter-than-air programs. This initiated the flight test program and demonstrates successful design and development of the world's largest, most persistent lighter-than-air optionally piloted aircraft.

Northrop Grumman rolled out the Navy MQ-4C Triton Broad Area Maritime Surveillance UAV, with maiden flight expected shortly. The multifunction active sensor radar equipped Triton will be operated as a fleet of 68 jointly with the Navy's P-8 Poseidon, providing persistent intelligence, surveillance, and reconnaissance.

Boeing's Phantom Eye liquid-hydrogen-powered UAV completed its first autonomous flight. The aircraft is designed to remain on station for four days at a time, providing critical information and services.

In conjunction with the Army's Joint Multi-Role Technology Demonstrator Program, the Office of Naval Research-sponsored Navy design team has developed initial design variants for small-ship-compatible single-rotor, compound, and tiltrotor aircraft. The ONR and NAVAIR sponsored Aerovel Flexrotor project achieved its first fully autonomous vertical retrieval in August. The Flexrotor is a VTOL long-endurance surveillance UAV.

Flexrotor prepares for a vertical recovery in its retrieval rig. Credit: Aerovel.



Two other military aircraft made headlines. The Navy's X-47B unmanned combat aircraft system demonstrator completed its first flight from a naval air station, demonstrating airspace integration and command-and-control functionality; it is undergoing carrier suitability testing ahead of the first aircraft carrier landing in 2013.

The F-35 Lightning II flight test program continued to make progress, including flight envelope expansion, night refueling, and external weapons testing. The Air Force began F-35A Operational Utility Evaluation in September, in preparation for pilot and maintenance training.

In commercial aviation, Bombardier's CSeries completed systems integration testing and virtual flights, in preparation for first flight. Boeing unveiled its B737 MAX winglet, which provides a 1.5% fuel-burn improvement, and Airbus continues design and development of its A320neo. In business jet aviation, Gulfstream's G650 received type certification; Dassault's Falcon 2000S and Cessna's Citation Ten and Citation M2 are in flight test.

The electric aircraft sector reported various accomplishments. Chip Yates made history by flying his 'electric' Long-EZ at 200 mph. Next steps are to cross the Atlantic and attempt higher speeds. Bertrand Piccard's Solar Impulse completed the world's first solar-powered roundtrip intercontinental flight (4,000 miles). Fitted with 12,000 solar cells feeding four electric engines, the aircraft demonstrated day and night flight without fuel. Pipistrel's 4-seat all-composite Panthera, with a choice of three powerplants (electric/hybrid/conventional), has begun flight testing.

NASA's Environmentally Responsible Aviation project continues to support advanced concept studies and propulsion technologies development to enable 2020-era aircraft with aggressive goals for fuel consumption, NO_x emissions, and noise. Results indicate that engine fuel burn can be reduced by over 40% relative to 2005 best-in-class aircraft, a 75% reduction in NO_x from current standards is feasible, and a blended wing body (BWB) configuration can meet the goal of 42-dB noise reduction below current limits.

Other research developments occurred in NASA's Subsonic Fixed Wing project. A study for 2030-era aircraft demonstrated enabling high-lift technology for laminar flow wings, exceeding lift improvement targets by 30%. Another study included the development of a mission adaptive variable camber flap control system to optimize high lift and cruise lift-to-drag ratios for transports. NASA's Subsonic Ultra Green Aircraft Research study identified 2040-era technologies, including liquefied natural gas, hydrogen, fuel cell hybrids, battery electric hybrids, boundary layer ingestion propulsion, unducted fans, and advanced propellers.

Boeing's X-48C BWB had first flight; this aircraft will help validate the BWB aerodynamic characteristics and evaluate the impact of noise shielding concepts on low-speed flight characteristics.

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

Balloon systems

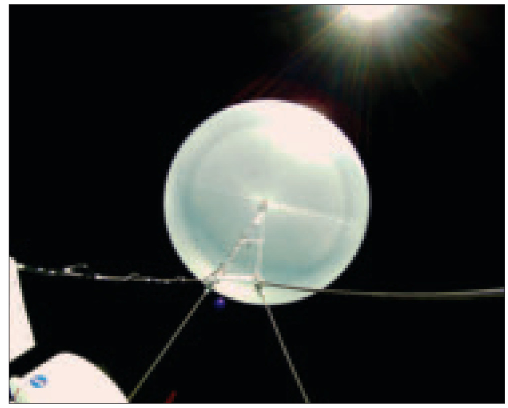
Balloon research spanned the globe from the Arctic to Antarctica this year. Balloons ranging from 0.5 to over 1 million m^3 in volume accomplished diverse missions, from probing surface winds to floating in the stratosphere. Researchers continued developing technology for future balloon missions to Titan and Venus. In addition, construction began on a substantial new flight facility in Oregon.

The NASA Balloon Program continued to support science users by providing stratospheric platforms. Personnel from NASA's Columbia Scientific Balloon Facility conducted flights from Antarctica, Sweden, and New Mexico with mission and safety oversight from NASA's Wallops Flight Facility. The Wallops arc-second pointer was flown with an integrated star camera to demonstrate nighttime pointing with arc-second accuracy. In addition, a new launch process is being developed to support the low-density supersonic decelerators project.

In August, NASA's Balloon Program launched its 532,200-m^3 pumpkin-shaped superpressure balloon on a short test flight from Kiruna, Sweden. It was the first flight of a vehicle this size and carried a gondola specifically configured for a deployment verification test. The mission was a success, with excellent flight performance and full deployment at a very low differential pressure. The balloon was pressurized to near the design limit via ballast drop before being terminated on command at a float altitude of more than 34 km. Both altitude and pressure remained stable throughout the flight. The mission was another successful step in the development of this class of vehicle for use by the science community.

Jet Propulsion Lab and its collaborators at Caltech, CNES, Near Space (NSC), and Lamart continued the development of planetary balloon technology for future missions to Titan and Venus. Accomplishments included buoyancy and permeation measurements on a 1.5-m prototype Titan helium superpressure balloon at 90 K, validation of CFD models for Titan hot air (Montgolfiere) balloons, and the development of superpressure balloon material with improved strength and acid resistance for eventual use on Venus.

Researchers from Smith College and the Norwegian Meteorological Institute conducted a month-long study at the Troll Research Station in East Antarctica using small altitude-controlled CMET (controlled meteorological) balloons. In a unique experiment, the balloons were flown into the katabatic winds (a shallow layer of frigid air draining from the Antarctic pla-teau), where they performed multiple soundings to probe this important component of the large-scale circulation in Antarctica. In the field, the team also successfully flight tested a new 220-g electric plane that it is developing for meteorological studies; however, this project is currently inactive because of FAA restrictions on aeronautical research in the United States.



NASA's 532,200-m^3 superpressure balloon made its first test flight, reaching approximately 34 km altitude.

NASA's Flight Opportunities Program selected NSC as one of seven commercial suborbital flight providers that will offer flight tests of promising new space technologies. Under this two-year contract, the Flight Opportunities Office is funding balloon test flights for competitively selected technology payloads. NSC provides a range of standard and nonstandard flight services to match a wide variety of payload requirements, including flights using its High Altitude Shuttle System. Information on this unique program and participation can be found at flightopportunities.nasa.gov.

In May, NSC began construction on a new \$7-million flight facility in Tillamook, Oregon. This unique West Coast facility, scheduled to become operational in February 2013, will serve as NSC's new corporate headquarters and will house engineering, production, and flight operations. The 30,000-ft^2 facility, including a payload integration hangar and three-story control center adjacent to the launch area, has been designed to support a wide range of unmanned platforms including high-altitude balloons and UAVs. The center will also be used for coordinating flight operations at NSC's Hawaii and Madras launch sites and in other remote operations.

by **Paul Voss**

Flight testing


In June, Boeing's Phantom Eye was flown for the first time.

This year saw continued emphasis on the use and integration of remotely piloted, unmanned, or autonomous flight vehicles. The Phantom Eye, a liquid-hydrogen-powered, long-endurance UAS, was successfully flown for the first time in June at Edwards AFB. The X-47B, a carrier-based unmanned combat air system developed by Northrop Grumman, completed its first flight at NAS Patuxent River (PAX) on July 29—the first time an autonomous tactical aircraft has operated at PAX. At NASA Dryden, the blended-wing-body X-48B completed its noise-reduction modifications, resulting in the X-48C configuration, and successfully returned to flight on August 7. NASA Dryden also tested an autonomous ground collision avoidance system using a small UAV, and several flight science projects involving three Global Hawk high-altitude science aircraft continued.

Bearing out lessons learned in previous years, flight tests of hypersonic vehicles remain a challenge, with the X-51 scramjet testbed having failed during its third test flight before lighting the scramjet engine.

In space vehicle testing, the first commercial reusable spacecraft berthed successfully with the ISS, and SpaceX successfully returned its Dragon capsule to Earth. The second X-37B Orbital Test Vehicle landed at Vandenberg AFB on June 16. This concluded a 469-day experimental test mission for the USAF Rapid Capabilities Office to demonstrate an affordable space vehicle that can be repeatedly reused. The Sierra Nevada Dream Chaser continued in development and completed testing slung under a helicopter to prepare for an unmanned flight test of a full-scaled vehicle's approach and landing.

Development of NASA's Orion exploration vehicle continued, with flight tests aimed at characterizing dynamics during return to Earth under parachutes. SpaceShipTwo continued developmental flight tests, completing a glide test from 51,000 ft after release from the WhiteKnightTwo on June 26. From the NASA Wallops Flight Facility, a Black Brant XI sounding rocket boosted IRVE-3, an inflatable reentry vehicle. It showed the capability of such a craft to withstand the heat of reentry and evaluated potentials for control during a successful test in June.

In commercial and general aviation, business jet manufacturers have been busy this year with development and testing of new variants. This included certification testing of the Gulfstream G650 and the first flight of the Cessna Citation M2. The Terrafugia roadable airplane continued development, completing phase-I flight tests to evaluate flying qualities. Boeing completed flight tests in March for certification of the B-787 Dreamliner with GE engines.

In rotorcraft flight test work, the Boeing Chinook CH-147F made its first flight on June 24 with a digital automatic flight control system and many other upgrades. In March, Boeing and the Army tested the adaptive vehicle management system, an advanced rotorcraft flight control system that provides tactile cues through the control sticks for greater stability and improved safety in reduced visibility situations. A specially modified Boeing H-6 helicopter was used for the tests.

The final F-22 aircraft had its first flight on March 15 and was delivered to the Air Force on May 2. This concludes the production run of F-22s. A total of 195 were built; 187 of these are operational jets. The JSF F-35 has continued testing at a rapid pace. As of June 30, 595 test flights had been flown this year, including as many as 12 flights in a single day. Some specific flight test accomplishments were the first night flights of the carrier variant, and test flights of asymmetric weapons loading with the STOVL variant.

by **Jay Brandon**

General aviation

The slump in general aviation sales seems to have bottomed out; last year's figures were only a few percentage points lower than those of 2010, and in the first half of this year, they showed an increase from those of the same period last year. Overall, shipments were up 6% at 918 units and billings of $8.2 billion were up 13%. The largest increase in deliveries was in business jets, up 13% from last year, followed by turboprops, up 10%.

Piston aircraft figures were essentially unchanged, although Piper reported a significant increase. Its 70 piston deliveries were up over 50%, and billings rose over 20%. The surge was attributed largely to international sales, particularly in Europe.

In March, Cessna entered into an agreement with AVIC, a Chinese firm, and the two will jointly establish a line of general aviation aircraft to be manufactured in both China and the U.S. The Chinese firm will also provide two-thirds of future research funds for Cessna, putting the company in a good position to develop new aircraft, particularly business jets. Hawker Beechcraft had also sought such help, but the attempt initially failed, and the company filed for bankruptcy in May. In July, however, a new Chinese firm, Superior, expressed interest in purchasing the entire general aviation line, and negotiations are proceeding. The Beech military line would remain under U.S. ownership as a separate organization.

Following similar negotiations last year, Cirrus is now under Chinese ownership. In April, the company revealed that the Vision SF50 personal jet is now fully funded through certification and initial production, and will proceed toward delivery in 2015. Eclipse, meanwhile, has received a production certificate for the new Model 550. Following an agreement with PZL in Poland to produce major components, production is proceeding, and deliveries are forecast for 2013. With the Diamond Jet and the Honda Jet still in active development, the very light jet class may yet prove significant.

In February, Icon announced the completion of its flight test program to prove the A5 amphibian meets the spin resistance standards of FAA Part 23 certification, even though it will be marketed as a light sport aircraft (LSA). Icon has since teamed with Lotus Engineering of sportscar fame to design a lightweight, attractive interior; another agreement was made with Cirrus to produce the major composite structural components. They expect to complete the first production version next summer.

In the spring, Pipistrel unveiled its sleek four-place Panthera.

Pipistrel in Slovenia was a little-known aircraft company until last year, when its Taurus G4 won the $1.35-million prize in the NASA-CAFE (Comparative Aircraft Flight Efficiency) Foundation Green Flight Challenge. The four-place G4 was specially designed from two G2 motorgliders and a 194-hp electric motor in between that flew over 200 mi. This spring, the company revealed its Panthera, a striking lightweight, highly aerodynamically refined four-place that is predicted to cruise over 200 kt on its 210-hp Lycoming IO-390 engine. Pipistrel also produces a number of notable LSA-class airplanes and motorgliders.

Now fully funded, the Cirrus Vision jet is actively proceeding in development.

Terrafugia has completed Phase-1 flight testing of the roadable Transition and is proceeding with more advanced tests. The first flight of the production prototype outside of the airport environment occurred in June. If all goes well in the remaining tests, it could be in production next year.

The Sling from South Africa became the 125th model to be certified as an LSA. There are now over 2,200 LSAs in the U.S., but only about 10 companies have significant market shares, with 340 of these from Flight Design alone. Analysts predict that in the coming 10-year period, the growth in general aviation will be primarily in LSA and, at the other end of the spectrum, business jets.

by **Hubert C. 'Skip' Smith**

Lighter-than-air systems

The Air Force, monitor for the Blue Devil 2 project, notified the contractor, Mav6, on May 23 to deflate the partially assembled 370-ft M1400 host airship and discontinue further work. No funds are listed for further development.

The LEMV hovers above Joint Base McGuire-Dix-Lakehurst during its first flight on August 7.

The LEMV (long-endurance multiintelligence vehicle) hybrid airship, under Army contract, made its first flight on August 7. It will make one or more flight tests at the Joint Base McGuire-Dix-Lakehurst, New Jersey, before being flown to the Melbourne, Florida, airport. Northrop Grumman has leased eight acres for six months to test the hybrid 300-ft airship and install its payload of surveillance and communication gear. Further plans include developing an unmanned flight control and making the airship's delivery flight to Afghanistan, where it would be tested under front-line conditions. The original contract requires construction of three airships.

The TCOM LP 22M tactical aerostat has performed well in Afghanistan as part of the Persistent Ground Surveillance System. A 28M system has been developed with increased payload weight, more airborne power, and greater altitude. TCOM is conducting field tests on 74M systems, the largest in the world for U.S. government use. These craft use transportable mooring systems. TCOM has received orders for more than 70 tactical aerostat systems for use in the military theater.

Van Wagner Communications has acquired American Blimp (ABC) and its Lightship Group division to add to its other modes of advertising. James Thiele, the founder of ABC, will continue to be involved primarily in a technological role. Eight Lightship blimps operated in the U.S. and one in Europe during 2012.

The Navy airship MZ-3A, an ABC-built nonrigid, will continue to conduct various experiments for government agencies this year and perhaps later. It will be maintained at Joint Base McGuire-Dix-Lakehurst.

The Office of the Secretary of Defense has awarded Worldwide Aeros a $50-million contract for a five-year effort that includes building Pelican, a small rigid hybrid incorporating compression of helium to control lift. Some of the innovation was investigated under earlier DARPA contracts, which indicated it is feasible and may lead to full-scale craft. The company recently acquired a 45,000 ft^2 engineering facility.

World Surveillance Group has successfully completed tethered flights with payload by Argus One, the segmented UAV nonrigid developed by the company. The tests were conducted by DOD at a Dept. of Energy test site in Nevada. Further tests will be continued in Easton, Maryland.

Airship Ventures and FLIR Systems have a partnership to utilize infrared technology aboard the Eureka, Airship Ventures' Zeppelin airship. Special equipment such as FLIR's 230-HD will be mounted on the Zeppelin car. It will be used for various search missions over both sea and land. The Eureka is equipped with a radar to augment its navigation capabilities. The airship was also used to search for fragments of a recent meteorite impact in northern California. Another science-related use of Zeppelin Luftschifftechnik's NT-07 airship is the study of climate change across Europe in EU's Project PEGASOS.

Zeppelin has also completed arrangements for the erection of the three NT-07 airships ordered by Goodyear Tire. Construction will begin in the first quarter of 2013 in the U.S. Zeppelin is training a Goodyear team who will share responsibility for the work. The airships will have a new cockpit display system and some inner structure reinforcement. They will also use a special mooring system.

Digital Design & Imaging Service flew its surveillance aerostat above the proposed site for the planned Transbay Terminal, to be the tallest building west of the Mississippi River. The balloon-borne camera, flown up to 950 ft, took floor-specific views for the architect's use.

by **Norman Mayer**

Legal aspects

The LightSquared saga moved to an endgame when the FCC indefinitely suspended the company's authority to carry terrestrial broadband signals on frequencies close to GPS frequencies. In February the FCC received a report from the National Telecommunications and Information Administration, which concluded the two systems cannot currently coexist. Based on its review of federal agency testing and analysis, it concluded there is no practical way to mitigate the potential interference at this time. Although new technology might be able to mitigate these issues at some time in the future, said the report, the time and money required for users to replace current technology cannot support deployment of the terrestrial system proposed by LightSquared. The company then filed for bankruptcy in May, but said it still wanted to resolve the concerns of U.S. regulators.

Export control headaches continue, and the AIAA conducted a well-received workshop on the subject in May on Capitol Hill. In April, DOD and the State Dept. released a joint final report to Congress on the national security imperatives for revising U.S. export controls on satellites and related items. These items are strictly controlled as part of the U.S. Munitions List (USML). The report, prepared with support from the intelligence community and NASA, is part of the administration's broader review of the nation's space policy and export controls.

"A code of conduct will help maintain the long-term sustainability, safety, stability, and security of space by establishing guidelines for the responsible use of space…." Secretary of State Hillary Clinton

Noting that other nations have fewer export controls than the U.S. on commercial space and space-related items, the report concluded that the following items would be more appropriately controlled on the Commerce Control List administered by the Dept. of Commerce: communications satellites that do not contain classified components; remote sensing satellites with performance parameters below certain thresholds; and parts and components associated with these satellites and with performance parameters below thresholds specified for items remaining on the USML. The hope is that these changes will improve the long-term health and competitiveness of the U.S. satellite industrial base. The report's authors believe the changes would also modernize satellite-related export controls essential to meeting the challenges of this century.

The Obama administration continued its moves to address on-orbit space debris and electromagnetic interference challenges. In January, Secretary of State Hillary Clinton said the U.S. would join Europe and other nations in developing an international 'code of conduct' for space operations, an idea proposed by the EU. Clinton endorsed the idea, with the proviso that such a code would not restrict U.S. "national security-related activities in space."

Clinton said, "A code of conduct will help maintain the long-term sustainability, safety, stability, and security of space by establishing guidelines for the responsible use of space….Unless the international community addresses these challenges, the environment around our planet will become increasingly hazardous to human spaceflight and satellite systems, which would create damaging consequences for all of us."

The challenge faced by U.S. policymakers is that although the European code proposal has many attractive attributes, it will need some modification to ensure that it does not, intentionally or otherwise, restrict U.S. freedom of action in space by national security systems.

Several members of Congress have expressed concerns about the administration's moves, however, especially if the 'code' is negotiated without consultation with or approval of Congress. Under the U.S. Constitution the president has the power to make treaties, subject to the Senate's power to advise and consent to it. A two-thirds vote of the Senate is required for passage. Critics note that policies derived from signing onto a 'nonbinding' code would inevitably require DOD and the intelligence community to implement regulations that would be legally binding, and that these in turn could influence both the national and economic security of the U.S. They also note that the regulations created to implement the code would inevitably affect the commercial sector. They add that this could implicate interstate commerce; as a result, the regulations would fall under the purview of the Congress's constitutionally enumerated power to regulate interstate commerce.

by **James D. Rendleman**

Management

Aerospace is a cyclical industry. Commercially, demand is up from the recession levels of 2008. After the Farnborough Air Show, discussions of an 'order bubble' quickly followed; Boeing and Airbus are set to deliver close to 1,000 narrowbody passenger aircraft in 2014, up from 754 in 2010.

Offsetting this optimism is that serious fiscal challenges are facing the governments of Europe, the U.S., and Asia. The result is that military aerospace markets and government-funded aerospace science programs are declining. U.S. federal government indecision on how spending cuts will be implemented has put many U.S. aerospace industry leaders on edge.

Though many military and government space programs face fiscal uncertainty, the industry has demonstrated several stunning triumphs. SpaceX successfully berthed Dragon with the international space station in May. In August, JPL's Curiosity safely landed on Mars and began sending images back to Earth.

Amidst these industry market forces, U.S. aerospace leaders worry about maintaining a skilled, robust workforce. With almost 60% of the U.S. aerospace workforce 45 or older, numerous public and private initiatives continue working to inspire and motivate the next generation of aerospace professionals to enter the field.

Only through an expansion of science, technology, engineering, and mathematics (STEM) programs, ranging from K-12 to postgraduate education, will the U.S. produce the number and quality of engineers, designers, and technicians needed to replace those who have served so well. Programs such as the Team America Rocketry Challenge, Project Lead the Way, MATHCOUNTS, and FIRST (For Inspiration and Recognition of Science and Technology) Robotics are examples of industry initiatives to address the national STEM need.

Government, industry, and academic leaders are also keenly aware of millennial workers' desire for mentoring, collaborative leadership, and challenging and meaningful work. Leadership's impact within the aerospace industry is growing in importance as program managers position their teams to remain on schedule, make their programs more affordable, and remain responsive to changing future programmatic conditions.

With almost 60% of the U.S. aerospace workforce 45 or older, numerous public and private initiatives continue working to inspire and motivate the next generation of aerospace professionals to enter the field.

Adding to the excitement, aerospace technology advances are positioning the profession to solve emerging needs and offer new approaches. UAVs are a growing, persistent part of the aerospace landscape. Laser inertial navigation systems offer the promise of GPS accuracy when GPS may not be available. Space weather advances are helping to focus risk mitigation efforts to secure key infrastructure and social services from solar disruption. Cubesats offer expanded, lower cost access to space for governments, entrepreneurs, companies, scientists, and students. New flight control systems will increase airspace capacity without compromising safety.

The aerospace community can be proud of over a century of technological and organizational accomplishments.

The aerospace community can be proud of over a century of technological and organizational accomplishments. Aerospace passenger and cargo systems provide our economy with access to markets around the globe. Military aerospace solutions are critical to our nation's efforts to provide peace through strength. Satellite services are critical to communications, weather, navigation, and environmental sciences. Space exploration continues to open doors to new questions about the universe and our place in it.

The future offers both challenges and opportunities for today's leadership and workforce to face with its enduring optimism and creativity.

by **Tom Goudreau**

Society and aerospace technology

by **Soumyo Dutta**

Hundreds gathered in New York City's Times Square on the night of August 12 to watch the televised landing of the Curiosity rover on Mars. Credit: MSNBC.

Late on a Sunday night in August, hundreds gathered to watch a historic event unfold on the giant screen in Times Square. The occasion was not a concert by a famous band or the finale of a hit show, but was instead the next step in human exploration of other planets. Like the Times Square viewers that night, millions of others also tuned in to NASA TV and webcasts to see the Mars Science Laboratory spacecraft land Curiosity, a 900-kg, nuclear-powered, laser-equipped rover, on the Martian surface.

Although this was the seventh successful Mars landing mission for the U.S., the technology needed to safely land the huge rover represents a gigantic leap toward sending humans to Mars someday. More important, the event garnered massive public support for science and technology development and may have inspired the next generation of scientists and engineers who could make humans a multiplanet species.

The space shuttle Enterprise flies over New York City in April. Credit: NASA/Robert Markowitz.

The future of space development was frequently in the news this year, especially with the retirement of the space shuttles and their subsequent delivery to various museums across the country. The shuttles will be housed in Washington, D.C., New York, Los Angeles, and the Kennedy Space Center in Florida, where they will educate and encourage future generations. Pictures of the Enterprise soaring over the Manhattan skyline provided an image of inspiration and stirred reminiscence of a program that embodied the ingenuity of a nation.

As Americans were fondly remembering their country's past, commercial space companies were pushing into the next frontier. SpaceX's Dragon capsule berthed successfully with the ISS in May and then returned safely to Earth, a feat previously achieved by only a handful of nations. Like SpaceX, other commercial aerospace companies have also started showing that for-profit businesses can be successful in the space sector and have opened job opportunities for many while broadening the economic impact of the aerospace industry.

As the effects of aerospace technologies are felt more broadly by society, there are some pitfalls associated with them as well. Several U.S. government agencies recently came under fire from civil liberties groups for using unmanned aerial vehicles to surveil the public. The Environmental Protection Agency, for example, was found using drones to monitor ranchers in the Midwest. Although the agency stated that its purpose was to monitor livestock contamination in protected watersheds, this information underscores the potential for abuses in the application of such technology.

Overall, aerospace technology continues to have a positive effect on society. Satellite-based systems have been used for humanitarian purposes, having helped to track abuse of individuals in Syria while also allowing eyewitnesses to broadcast their stories around the world. Weather satellites and reconnaissance planes (nicknamed 'hurricane hunters') provide real-time measurements of storms for improved predictions of hurricane paths. Carbon fiber—a spinoff of an aerospace technology originally designed for aircraft engine rotors—has enabled the development of lightweight prostheses such as the one used by sprinter Oscar Pistorius, who became the first double-leg amputee to participate in the Olympics. These are just a few examples of the many broader societal benefits of aerospace-related technologies.

Systems engineering

Throughout history, governments and societies have experienced cyclical budgets whose ebb and flow depend on a variety of influences. The cycle time of these swings has increased greatly over the past 50 years, with the most recent upswing lasting from roughly 1981 through 2010. This upswing culminated in the 'if you build it they will come' paradigm, which drove significant technology development and associated costs into many programs. Governments today, from the federal down through the municipal level, are planning for or already implementing budget cuts that could severely impact the viability of future programs and the sustainment of existing systems. Future modernization efforts will look very different from those undertaken over the past 30 years, and this could lead to a renaissance in systems engineering thinking and practice.

Decreased budgets, after the initial shock, can provide an opportunity for improved program performance. Fiscal constraints will force customers and engineers to think much more deeply about how to define system effectiveness and related measurements. Whereas many systems have measures of performance (MOP)—often related to easily measurable items such as software lines of code, thrust, bandwidth, and so on—accurate measures of effectiveness (MOE) require a thoroughly developed concept of operations, to explain what the system is meant to accomplish and thereby inform the MOE development.

MOEs must be developed in a manner to balance the evaluation of systems across key areas. Whereas programs have been judged by cost, schedule, and performance for many years, performance was often pursued via spending increases and delays in delivery of the system. During times of fiscal constraints, costs can become the overriding focus, leading to similar imbalances. MOEs that balance key factors—initial cost, system performance, time to deliver a usable product to the customers, and costs for sustainment and upgrades—will enable future program managers to provide continuously valuable products in this new age. A well-developed concept of operations that leads to a balanced set of accurate MOEs will enable systems engineers and program managers to then develop meaningful MOPs that lead to a product's successful design, fielding, and operation.

Fiscal constraints will also likely impact the requirements development process. Previously, users often were asked what they wanted a system to do; operational and technical requirements documents were then drafted to meet those needs. Future requirements, by contrast, will likely focus more stringently on maximizing total system capability within the initial funding levels, with no funding plus-ups available in future years. These types of fiscal constraints could lead to pursuit of more mature technologies, instead of programs pursuing technology development efforts.

Future modernization efforts will look very different from those undertaken over the past 30 years, and this could lead to a renaissance in systems engineering thinking and practice.

Optimally, the user mission to be served by the system would be modeled, and simulations then would show the impact that a new/replacement system meeting certain requirements and performance measures would have on mission effectiveness. Iterations of system requirements followed by the associated straw-man designs will facilitate more accurate cost estimates based on designs and not merely on requirements.

The resultant cost analysis should lead to a requirements development process that thoroughly describes and optimizes benefits by costs. This process could result in some modernization efforts not being pursued because their missions lack sufficient benefit.

Dovetailing well-developed MOEs with the use of models and simulations to support requirements development, plus iterating the process to include amended system designs and cost analysis, offers the chance to avoid some of the significant cost and schedule overruns that plague modern programs. The potential improvements in metrics development, in requirements development and management, and in cost benefit analysis could greatly impact the affordability, efficiency, and effectiveness of both commercial and government programs for decades, giving practicing organizations a significant competitive advantage.

by **John W. Dahlgren**

Computer systems

IBM's Sequoia has 1,572,864 PowerPC A2 cores.

"The purpose of computation is insight, not numbers." So wrote Richard Hamming in his book on numerical analysis. Insight enables design. Design is refined through simulation. Computing with sensors provides real-world insight. And adding controls enables autonomy.

The most stunning display of design, simulation, and autonomy came in early August with the entry, descent, and landing (EDL) portion of the Mars Science Laboratory (MSL) mission. At 14 light-minutes from Earth, MSL was on its own to land the Curiosity rover on the surface of Mars. Within minutes of touchdown, the first crude thumbnail images were communicated up to the Mars Reconnaissance Orbiter, which relayed the pictures back to Earth to a jubilant mission team and waiting public.

The brains of Curiosity are a pair of BAE Systems RAD750 3U CompactPCI cards. At 0.55 kg each, they are derived from the IBM PowerPC 750 and designed for the space environment. They can run 290 million instructions per second. On MSL, they handled the navigation algorithms, including the EDL, and have now been reprogrammed for the science mission.

LEO is becoming the proving ground for universities, small startups, and even do-it-yourself hobbyists. The open source Arduino prototyping platform is the basis for several CubeSat projects that have raised funds through the crowd-funding site KickStarter.com.

A laboratory technician does some very precise measurements on the tiny TechEdSat.

by **Rick Kwan**

CubeSats trade short lifespan (months to a few years) for dramatically reduced project costs by using commercial electronics, which increase significantly in computing power (now greater than 1 GHz clock) or sensor capability each year. This year's CubeSat will definitely be obsolete next year. If the CubeSat launch is delayed by a year, then it is probably time to upgrade the design.

The ISS has become a proving ground for computing and data collection. The MIT-built SPHERES (synchronized position hold, engage, reorient, experimental satellites) roaming inside the ISS have been enhanced with Android smartphones. NanoRacks has a USB-enabled experiment rack aboard the station, allowing commercial and educational customers to conduct small microgravity experiments for a month; the company arranges paperwork and reviews, launch, and uplink/downlink of commands and data.

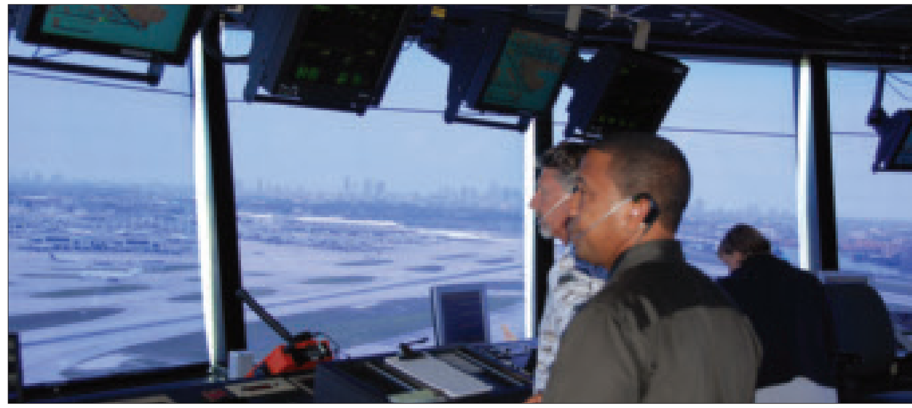
The ISS has also become a platform for launching CubeSats. One of these is TechEdSat, a collaboration between NASA Ames and San Jose State University. It uses Space Plug-n-Play Avionics (SPA) from Swedish ÅAC Microtec, and will do communication experiments using the Iridium and Orbcomm satellite phone networks. A number of other CubeSats were brought to the ISS via NanoRacks.

Computing and sensors are also providing insight through UAVs. Civilian applications abound. As a result, the FAA and NASA are working on rules to integrate UAVs into the National Airspace System.

Increased computing power can enable increased insight, which in turn can enable increased national competitiveness. This year the U.S. once again had the fastest supercomputer. IBM built a Blue Gene/Q supercomputer named Sequoia at Lawrence Livermore National Laboratory. At 16.32 petaflops on the Linpack benchmark, it packs 1,572,864 PowerPC A2 cores.

The omnipresence of computing in civil society and the military has now raised cybersecurity concerns. Furthermore, recent intrusions have been ascribed to government actors, raising concerns about preparedness for cyberwarfare. In situations where lives and critical systems are at stake, add concerns about counterfeit electronic parts creeping into the supply chain.

Digital avionics



Integrating UAVs into the national airspace will take the combined efforts of many groups.

Since the start of the millennium, the development and production of UAVs has been the central focus of aviation engineering. Concurrent with this trend has been the ongoing modernization of the systems for managing air traffic—to accommodate the ever-increasing demand for a finite airspace. The operational objectives of these systems are complementary and require similar technologies for distributed control and automation. The federal roadmap for the Next-Generation Air Transportation System (NextGen ATS) underscores the need to mix the operations of manned and unmanned vehicles.

Given this emphasis, and public concern over computer-controlled airplanes with no pilot onboard, there apparently has been no market force for risking private investment on innovation of unmanned systems—instead companies depend on government programs to develop and mature the technology as part of the NextGen ATS.

Recognizing this and the value of UAVs to commerce in the U.S., Congress decided civilian UAVs shall have routine access to the National Airspace System by September 2015. This mandate has changed the private sector's focus—especially in the avionics segment, which is, arguably, the enabling factor. One key capability that avionics must support to comply with the mandate is radio data communication.

For both autonomous and remotely piloted UAVs that will be certified to operate in controlled airspace, an RF data link is the means by which the vehicle's guidance and control system is connected to the air traffic control authority and the operator's command and control (C^2) center. One theme that has emerged from the working groups developing the performance standards for data link services is that the control of a UAV must be transparent to human air traffic controllers. This means a human controller must be able to communicate with a UAV in the same discretionary manner as a manned vehicle, using voice or data link.

Therefore, except for locally controlled UAVs with limited range, verbal traffic control directives must be uplinked to the vehicle via standard line-of-sight (LOS) communication radios, then relayed to a remote human operator who can verbally acknowledge the directive and change the vehicle guidance accordingly. The verbal reply and guidance command must be uplinked from the center to the vehicle, and the verbal reply must be sent on to the traffic controller. This must happen within a prescribed delay, and the type of radios used to exchange the data between the vehicle and the center will depend on the distance between the transceivers—LOS VHF or SATCOM. Moreover, given the safety implications, the reliability demanded of the transmitting and receiving equipment is higher than that required of the systems in service today.

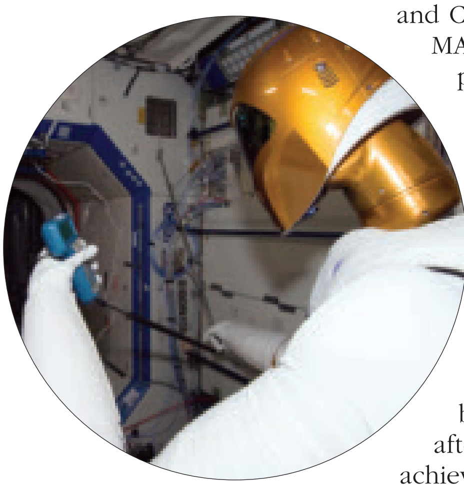
There are alternatives to this approach. For example, voice detection/synthesis and machine intelligence can be used to implement voice communication between a controller and UAV, independent of the C^2 center. However, it is unlikely the required robustness and airworthiness of a system built on current technologies can be demonstrated and certified before the 2015 deadline. The ground-based enterprise network that is the backbone of the NextGen ATS can also be used to transport sampled voice data between controller and operator; but the present development schedule also makes this alternative impractical.

Data link systems are but one enabling technology, and one that is readily available. Practical designs for the other required systems, such as traffic sense-and-avoidance, are still under development for civil applications.

One can appreciate the monumental challenge the FAA is facing. However, executive challenges have inspired phenomenal achievements in the past. If the government remains diligent in asserting the need for UAVs, and their importance is elevated to public consciousness, then perhaps the can-do spirit of the U.S. will be reborn, and seemingly unachievable goals can be attained again.

by **Mark Darnell** and the **AIAA Digital Avionics Technical Committee**

Intelligent systems



R2 can carry out many chores on the station, freeing up astronauts' time.

This year brought a boom in autonomy, particularly for micro air vehicles (MAVs) and other UAVs. The University of Illinois at Urbana-Champaign's Aerospace Robotics and Control Lab developed a bird-like MAV that can make a precise perched landing on a small target or human hand. This MAV lacks a vertical tail for lateral-directional control and stability, using wing morphing for flight control and steering. The flapping wings are inherently articulated, eliminating the need for traditional control actuators. Autonomous control algorithms were developed to bring the MAV close to the hand, after which a traditional pitch-up achieves the deceleration and perched landing. The use of wing articulation is significant in developing bird-like flapping-wing MAVs capable of effective, agile flight even while gliding (http://www.youtube.com/watch?v=2QqTcQ1BxIs).

The University of Cincinnati finesses the collaborative assignment of tasks to multiple UAVs by using intelligent systems to solve problems under realistic conditions, including limited communication, minimum turn radius, visibility constraints, and scenario uncertainty. A market-based solution exhibited versatility to various cost functions and adaptability to scenario changes, while being near-optimal, computationally efficient, and scalable. Another scalable, fast, and near-optimal solution, based on a 'cluster-first, route-second' heuristic, tackles the UAV routing problem with limited communication ranges. This work advances the state of the art in terms of optimality, computational cost, and scalability (http://most-aero.uc.edu/).

The Michigan Autonomous Aerial Vehicles (MAAV) team earned first place in the International Aerial Robotics Competition. The contest required teams to build an autonomous aerial vehicle that could enter and navigate an unknown building, follow Arabic signs to a particular room, find and retrieve a flash drive, deploy a decoy, and egress in under 10 minutes without being spotted by cameras or laser trip wires. MAAV deployed a custom quad-rotor equipped with two laser range scanners for navigation and obstacle avoidance. The vehicle autonomously entered the course, explored and mapped the entire interior, exited safely, and landed outside (http://maav.engin.umich.edu).

NASA Johnson's Robonaut 2 (R2) is a humanoid robot that can be teleoperated using partial self-contained autonomy or operate fully autonomously using techniques learned in advance via machine learning. On March 14, astronaut Dan Burbank handed R2 an airflow meter and a measurement wand while ground personnel controlled the robot as it steadily manipulated the wand to collect data. R2 uses tools without needing special interfaces to perform tasks such as reading data meters, acting as a sort of avatar for ground personnel. This experiment is the first step in the robot's relieving the crew and, eventually, giving them more time for science and exploration.

The autonomous systems (AS) project, led by NASA Ames, is developing software for system operation automation. AS technology will help astronauts make more decisions without the assistance of people on the ground, providing software for automatic diagnosis of failures in a spacecraft or other system, and software to automate the execution of sequences of actions at the discretion of human operators. In June, AS software increased coordination capability while decreasing workload under varying operational scenarios, time delays, and levels of crew autonomy during the autonomous mission operations experiment in the Deep Space Habitat at Johnson (http://www.nasa.gov/centers/ames/cct/technology/stp/gamechanging/autonomous_systems.html).

As increasingly capable autonomous systems pervade our lives, advances that enable more rigorous verification are vital. IKOS is a new generation of static analysis tools from the NASA Ames Intelligent Systems Division, Carnegie Mellon University, and SGT. IKOS achieved approximately 2% false positives on a suite of flight control systems written in C and C++. This represents a significant advance in the state of the art, in terms of both precision and analysis time (from hours or days for the most precise commercial analyzers to seconds or minutes for IKOS). Though it is particularly efficient on embedded code, IKOS also demonstrates broader applicability than previous analyzers for general C programs.

by **Kristin Yvonne Rozier**

Sensor systems

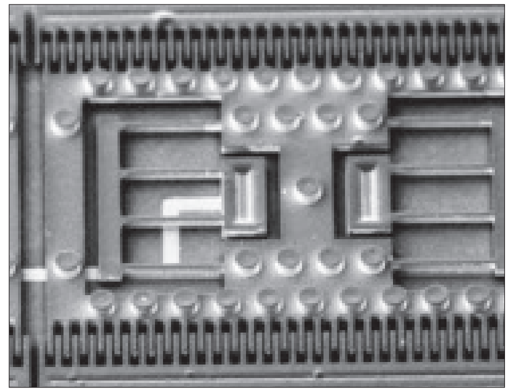
The past year saw developments in many sensor areas, including large-scale imaging sensors, data fusion, microsensors, and photonics technology.

Lockheed Martin is developing an infrared version of the combat-proven Argus-IS (autonomous real-time ground ubiquitous surveillance imaging system), called Argus-IR. Argus-IS provided at least 65 full-motion video feeds with a 1.8-gigapixel video system, while Argus-IR will have 130 full-motion video feeds. ITT Excelis is developing a similar system with a mix of five electrooptical and four infrared cameras with 12 different subviews.

Advanced heads-up displays now use computer-generated 3D views of the world generated by sensor fusion, providing daylight-equivalent views in low-visibility environments. The technology is already available for multiple aircraft types via integrated avionics suites such as the Pro Line Fusion system from Rockwell Collins. It is also being implemented for 3D depth perception in Boeing's KC-46A tanker to aid in refueling operations. In related efforts, the MFRF (multifunction radio frequency) and ViSAR (video synthetic aperture radar) programs, both funded by DARPA, will use advanced millimeter-wave or extremely high-frequency radar to aid aircrews in sensing through clouds and near-ground clutter. Future developments will combine radar and lidar data to produce a full 3D visualization system for helicopters.

Researchers at Tufts University and at Spirit Aerosystems are collaborating on the development of MEMS-based surface pressure and shear sensor array-on-a-chip devices for characterizing the pressure and shear spectrum under the turbulent boundary layer. These microscale systems incorporate multiple submillimeter-sized sensors on a single chip for high spatial and temporal resolution measurement of flow properties. In 2011, a 64-element MEMS microphone array-on-a-chip was deployed in a 6x6-in. flow duct at the Spirit acoustics lab in Wichita, and was used to measure both single- and multipoint wall pressure spectra at Mach numbers from 0.1 to 0.6. The microphone elements in the array are only 0.6 mm in diameter and spaced center to center on a pitch of 1.2 mm.

These are among the highest spatial resolution wall pressure measurements ever taken under the turbulent boundary layer. By better understanding the properties of the forcing from the boundary layer, researchers hope to reduce structural vibrations that lead to internal and external acoustic transmissions, while maintaining low weight and drag for fuel efficiency.



This MEMS array uses a floating element microstructure with 'hairs' for highly linear surface shear measurements.

MEMS surface shear sensor arrays also are under development and have been demonstrated under laboratory conditions. Current floating element shear sensors use digital interface circuitry, have a unique hair-covered microstructure to enhance sensitivity, and have demonstrated linearity out to surface shear stress levels of more than 23 Pa. Continuing efforts will characterize possible error sources such as sensitivity to surface pressure fluctuations, pressure gradients, and cross-flows. The hope is that surface shear sensors will be a valuable addition to the aerodynamicists' toolbox. The team plans to deploy the shear sensor arrays into the high-speed wind tunnel environment by year's end.

In late summer the National Research Council released a prepublication review, "Optics and Photonics: Essential Technologies for Our Nation," the first such detailed assessment in 14 years. The interdisciplinary study groups' authors identified several areas where "grand challenge" research questions can address important national technological needs. Two of particular benefit to the aerospace community are the seamless integration of photonics and electronics to provide for highly advanced system-on-a-chip devices, including sensors; and an explicit call for further development of key photonic technologies to assist the defense community, including wide-area surveillance, advanced imaging, and free-space optical communications. The report is available at the National Academies publications site, nap.edu.

by **Timothy L. Howard, Wei-Jen Su,** and **Robert D. White**

Software systems

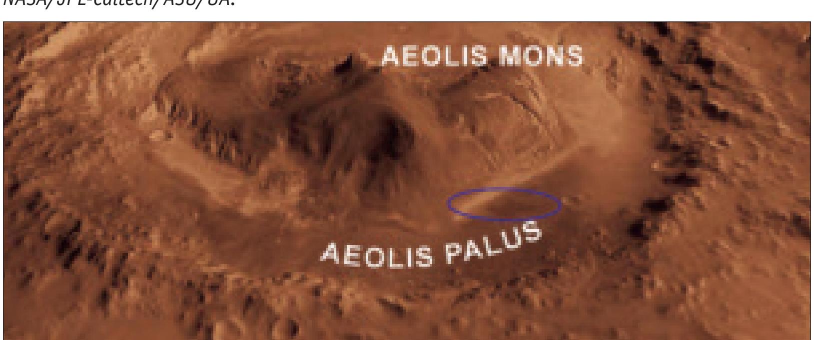
Software backbones continue to enable new aerospace capabilities. However, the aerospace industry is advancing the art of software at the cost of increased intricacy. For example, the newest transport aircraft have 4 million onboard source lines of code; this number has doubled every four years since 1970. In a related statistic, software now constitutes 70% of an aerospace system's development cost.

Fortunately, maturing software techniques continue to aid in managing system complexity. NASA's Curiosity successfully accomplished an elaborate and completely autonomous sequence for entry, descent, and landing (EDL) on Mars in August. To minimize mass by requiring less computer hardware, Curiosity engineers replaced the EDL flight software with the science flight software after landing. Lightweight static analysis (Coverity) automatically detected about 2,000 defects in Curiosity's 2 million lines of code. Engineers also used other automated tools, including formal methods tools, for verification and validation.

While Curiosity captured the biggest headlines, there are examples of many other software successes this year:

•The Dawn spacecraft, which is studying the asteroid belt, compensated for two different reaction wheel failures through software patches.

The perfect landing of Curiosity on Mars in August required 2 million lines of software. The science software package replaced the descent software after landing. Courtesy: NASA/JPL-Caltech/ASU/UA.



•SciBox, the science planning software for NASA's MESSENGER (Mercury surface, space environment, geochemistry, and ranging) spacecraft, enabled a more complete global survey of Mercury's surface by creating a coordinated schedule involving 12 payload elements plus the guidance, navigation, and control and RF systems.

•In July, Space Ground Amalgam won the Space Frontier Foundation's prize for inflatable antennas that can be deployed and hardened in space; software designed to compensate for defects in the antenna shape is key to their technology.

•A new flight control software algorithm for augmenting aircraft carrier landings requires less training time for pilots, and may prompt an aerodynamic redesign of future aircraft.

•Robotic aircraft received a boost for aircraft carrier landings; MIT researchers developed a system that lets drones identify hand gestures.

While there were advances this year, there were also more than a few challenges. SpaceX had to delay the ISS cargo demonstration mission schedule several times this year because of software concerns. On October 12, the SpaceX software safety review panel highlighted some of these concerns at a congressional hearing. But that same month, SpaceX successfully resupplied the ISS.

While SpaceX software woes received most of the news coverage, other aerospace software problems also surfaced. Because of limited budgets, the Air Force delayed to 2016 the SBIRS (Space-Based Infrared System) ground system software's capability to automate fast-time detection of missile launches. Pegasus launch vehicle flight software problems caused NASA's NuSTAR (nuclear spectroscopic telescope array) to miss its scheduled March launch window. In October 2011, the Telesat Anik F2 satellite went into safe mode after a software update caused an anomaly.

In civil aviation transport news, the FAA's En Route Air Modernization (ERAM) software is currently scheduled to be completed three years late (in 2014) and about $330 million over budget. ERAM suffered from early errors in which it reported erroneous flight information to controllers. As a result, airlines have delayed buying the equipment needed for compatibility with ERAM.

Aerospace system security had its own quandaries this year. A virus detected in Predator and Reaper drones in late 2011 logged pilots' keystrokes as they remotely flew missions in war zones. Eventually, the infected hard drives had to be wiped and rebuilt to remove the virus. Hackers used a different software worm, ACAD/Medre.A, to steal tens of thousands of AutoCAD designs. Collaboration among several organizations, including ESET, Autodesk, Tencent, and CVERC, blocked the hackers' access and stopped the industrial espionage.

by **Misty Davies**

Air-breathing propulsion systems integration

This year brought several key developments in propulsion integration.

A novel inlet concept that could lead to a new generation of simpler, lighter supersonic and hypersonic propulsion systems is under development. NASA Dryden completed flight tests of a unique experimental jet engine inlet design in the channeled centerbody inlet experiment (CCIE) and began detailed analysis of the test results. The eight test flights, which took place between August 2011 and January 2012, involved an F-15B testbed aircraft that flew the CCIE inlet to speeds up to Mach 1.74.

NASA research pilot Jim Less checks out the CCIE experimental jet engine inlet mounted underneath NASA's F-15B prior to a test flight. Photo courtesy NASA/Tony Landis.

The CCIE concept uses channels in the inlet centerbody that increase the amount of air flowing into the engine, improving its performance over a wide range of Mach numbers. A fully operational inlet would have movable channels that open and close to adjust throat area and vary mass flow into the engine, depending on flight conditions. This provides major benefits relative to mixed-compression inlet designs, which move the centerbody fore and aft using complex and heavy mechanisms.

As part of the research, airflow through the experimental jet engine inlet was defined and compared to the standard inlet airflow. The airflow was measured around two interchangeable centerbodies (channeled and smooth/conventional) installed inside an inlet tube. A series of three nozzles was used to vary the mass flow rate. Flight data from the smooth centerbody, such as inlet mass airflow, internal surface pressure distribution, and airflow distortions, were used to benchmark performance data for the channeled unit. The results are being compared with CFD predictions.

NASA's Environmentally Responsible Aviation program reported interesting progress this year. in the propulsion technology portfolio aiming to develop 2020-era technologies yielding 50% reduced fuel burn, 75% reduced NO_x, and 42-dB reduction in noise.

A new class of low-emissions lean combustors burn concepts (yielding 75% NO_x reduction) are being developed and will be tested at the NASA Glenn Advanced Subsonic Combustor Rig. Work is also being done to develop active control of combustion instability for this class of combustors.

In the propulsor research area, three milestones were attained.

The NASA Glenn/General Electric collaborative open rotor test campaign has concluded. Model scale tests of advanced low-noise open rotor propulsor concepts were conducted in the 9x15-ft Low Speed Wind Tunnel and the 8x6-ft Supersonic Wind Tunnel, from late 2009 through early 2012. Aerodynamic and acoustic data were acquired for takeoff, approach, and cruise conditions.

An integrated inlet/fan embedded system was designed, built, and verified using computational analysis. Results indicate that the drag-reducing propulsor design will incur less than 1% loss in fan performance. Wind tunnel testing is expected in 2013.

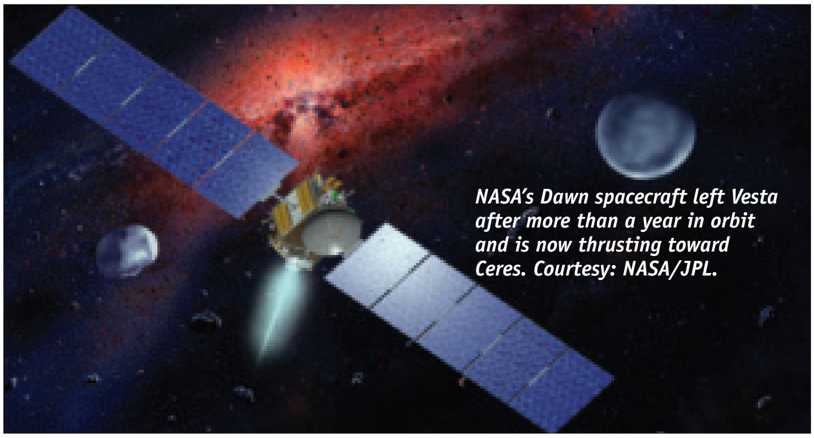
NASA completed integrated shape optimization of a single-aisle transport wing and ultra-high-bybass (UHB) fan nacelle. The design, optimized using the Cart3D-Adjoint Optimization Framework, was tested in the NASA Ames 11-ft Transonic Wind Tunnel to investigate the aerodynamic effects of the UHB nacelle on the wing. Pressure and force moment data were acquired on a 1/8 scale semispan transport configuration. A 10.75-in. turbine-powered simulator was used to simulate an engine with bypass ratio of 16.

The Air Force Research Laboratory continues development of its highly efficient adaptive versatile engine technology (ADVENT) engine. Core tests were completed, demonstrating key adaptive fan technology. In 2013 ADVENT will mature to a bigger adaptive engine technology development project, which will demonstrate critical technologies through full engine testing, including engine component risk reduction, engine core maturation, integration technologies, performance analysis, and full-scale ground testing. This will eventually lead to full-scale engine development.

The Advanced Research Projects Agency-Energy (ARPA-E) is researching liquid 'electrofuels' that are cost competitive with traditional aviation fuels and 10 times more efficient than existing biofuels.

by **Dyna Benchergui**

Electric propulsion



NASA's Dawn spacecraft left Vesta after more than a year in orbit and is now thrusting toward Ceres. Courtesy: NASA/JPL.

Electric propulsion (EP) continues to make enabling contributions to Earth and solar system science. NASA's Dawn spacecraft, powered by its ion propulsion system (IPS), has left the protoplanet Vesta and is now cruising toward a 2015 arrival at the dwarf planet Ceres. Through September of this year, IPS has operated over 25,000 hr, provided a delta-V of over 7 km/sec, and consumed 262 kg of xenon propellant. ESA's GOCE (gravity field and steady-state ocean circulation explorer) mission is mapping the Earth's gravitational field in conjunction with a QinetiQ T5 ion thruster system. The system, commissioned in March 2009, has accumulated 24,000 hr of operation.

A study by the Keck Institute for Space Studies at Caltech demonstrated that 40-kW-class EP can enable a mission to capture and return a small near-Earth asteroid to cislunar space. The retrieval of a 7-m-diam., 500-metric-ton asteroid could be completed by the mid-2020s. ESA's BepiColombo mission will deliver two spacecraft to Mercury orbit in 2021. The craft will rely on a QinetiQ T6 ion thruster system that is now undergoing qualification.

The use of EP on commercial spacecraft continues to expand rapidly worldwide, led by the announcement of the first 'all-electric' communications spacecraft, Boeing's 702SP. L-3 Communications now has 76 xenon ion propulsion system thrusters in orbit on 18 Boeing satellites. Space Systems/Loral has launched 12 spacecraft with Hall thrusters that have logged over 20,000 hr on orbit, with two single thrusters having fired for more than 2,500 hr each. The second Air Force AEHF spacecraft reached GEO on August 27. On board the satellite are four Aerojet/Lockheed Martin BPT-4000 Hall thrusters, bringing the total in orbit to eight. The launch of Yahsat 1B in April has raised the number of Snecma's Hall thruster systems in space to 14. By the end of this year, they will have accumulated 18,770 hr of operation.

Research activities continue worldwide in industry, academia, and government laboratories. Busek is investigating condensable propellants for Hall thrusters. Performance meeting or exceeding that on xenon was measured with iodine-fueled Hall thrusters at power levels up to 9 kW. At the Australian National University, work on the helicon double-layer thruster is proceeding. Construction will begin soon on a large Space Simulation Facility to be used for thermal/vacuum testing.

NASA's evolutionary xenon thruster, or NEXT, a 7-kW ion thruster developed by NASA Glenn and Aerojet, has processed 750 kg of propellant in life testing. An engineering model high-voltage Hall accelerator thruster, built by Glenn and Aerojet, has undergone characterization testing as part of a sequence that precedes a life test. Performance testing of 20- and 50-kW Hall thrusters has also been conducted.

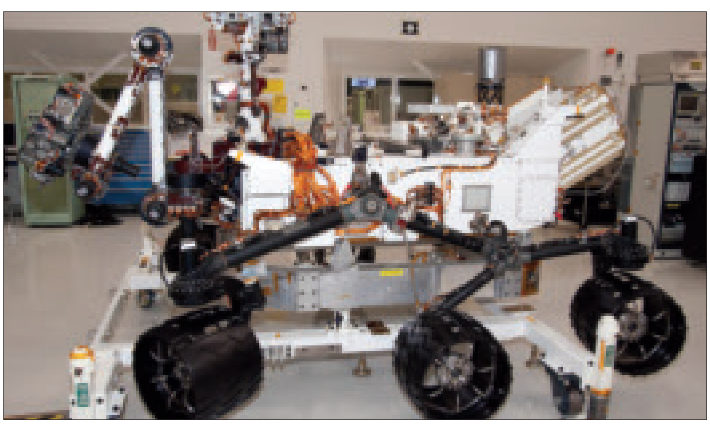
Inductive pulsed plasma thrusters are under development at NASA Marshall. Several conical theta-pinch thrusters with different cone angles, and a flat-plate thruster with pulsed gas injection and solid-state switching, were tested on a sensitive hanging-pendulum thrust balance.

Researchers at JPL have demonstrated magnetic shielding in Hall thrusters, a technique that protects the channel walls from ion sputtering. The first principles of magnetic shielding were derived through numerical simulations with the code Hall2De. Experiments with a magnetically shielded H6 Hall thruster showed that erosion rates were at least two orders of magnitude lower than those of unshielded thrusters, effectively eliminating channel erosion as a life-limiting mechanism. JPL also demonstrated a graphite-walled version of the H6 operating at high efficiency (over 60%) by exploiting the reduction in plasma-wall interactions provided by magnetic shielding, which is anticipated to yield significant reductions in the mass and cost of Hall thrusters. Finally, JPL installed a 12-kW solar array for direct-drive system development and successfully demonstrated single and dual Hall thruster configurations at over 10 kW.

by **Richard Hofer**

Energetic components and systems

Energetic components and systems (ECS) continue to address a wide variety of platform and applications-specific requirements. With ever-changing programmatic and budgetary constraints, the need for ECS designs and components to ensure reliable performance at the lowest possible cost has never been greater. Overall, the ECS technical community has remained relatively stable this year. One notable exception was United Technologies' acquisition of Goodrich. This action, completed on July 26, promises to strengthen both companies and will supplement the technical baseline of the ECS community as well.



The Curiosity Rover goes through its paces at JPL. Credit: NASA.

At 01:32 on August 6, the Mars Science Laboratory successfully completed the entry, descent, and landing (EDL) phase of its overall mission. Energetic components and systems directly contributed to this successful spaceflight and landing on Mars. The spacecraft itself used 86 pyromechanical energetic components consisting of 39 separation nuts, 22 cable cutters, 20 pyrovalves, three pin pullers, a thruster, and a parachute mortar. Seventy-five of these energetic components were activated during the 'seven minutes of terror' otherwise known as the EDL phase of the mission. Eleven energetic components were activated after touchdown on the Martian surface, accomplishing the release of various elements on the Curiosity Rover.

Specifically, the separation nuts were activated throughout the cruise stage, the descent phase, and on the rover to accomplish various mission objectives, including the release of the heat shield, positioning of the ballast to alter the vehicle center of gravity, and the release of the rover wheels. Cable cutters severed electrical lines and other connections to allow safe transfer to the surface during the Sky Crane maneuver, among other operations. The pyrovalves were also activated throughout the mission to ensure flow or cease flow as required. The total amount of energetic material included in all of these components, except for the large parachute mortar cartridge, was less than 50 g. And for redundancy, each energetic component was initiated by two NASA standard initiators. All in all, 172 were successfully activated throughout this mission.

Energetic components and systems continue to provide safe ejection for crewmembers on both aircraft and spacecraft. SpaceX has successfully implemented a new launch abort system for its Dragon spacecraft. The energetic material, utilized to provide the thrust for the abort escape engines, can be reused for multiple missions, as these engines are mounted into the sidewalls of the capsule and remain with the spacecraft throughout the mission. This integrated abort system provides for crew safety while minimizing the cost of capsule retrofit.

Obsolescence remains a major concern throughout the ECS community. Ensuring continuing availability of the needed raw chemicals, blended energetic materials, and integral electronic subcomponents has required specific actions. Teams have been established, involving both government and industry representatives, to evaluate the many factors associated with the obsolescence issue. The Naval Surface Warfare Center has established obsolescence teams whose charters include identifying at-risk materials or processes, developing joint approaches to maintaining the availability of these materials, and/or investigating new alternative energetic materials capable of meeting specific mission needs.

Education and mentoring remain primary objectives in the ECS community. The 9th Cartridge Actuated Device/Propellant Actuated Device (CAD/PAD) Technology Exchange Workshop, held May 22-24 in Waldorf, Maryland, hosted by the CAD/PAD Joint Program Office and sponsored by the Naval Air Systems Command, PMA-201, featured over 30 technical presentations and invited speakers. Topics ranged from an update by the Dept. of Commerce on its CAD/PAD Industry Report to a presentation on the 2011 CAD/PAD Technology Roadmap.

by **Tom Blachowski**

Gas turbine engines

This year brought significant advances in R&D, production, and educational outreach activities related to gas turbine engines. U.S. military R&D programs continue to emphasize increasing energy efficiency as a means of reducing operational costs and improving performance.

The adaptive versatile engine technology (ADVENT) program is seeking to improve efficiency through advancing the technology of engine components and through adaptive engine technology. Under this program, component rig testing was completed this year as a part of risk reduction activities. Significant progress was made in core build-up in preparation for full engine testing, which is expected to take place throughout 2013. The Air Force is looking at ways to bring ADVENT technologies to maturity and to transition them through the Adaptive Engine Technology Development program, which is anticipated to start in FY13.

The highly efficient embedded turbine engines (HEETE) program is an ongoing effort to develop fuel-efficient large fan/jet propulsion technologies supporting extreme endurance and range for multiple future platforms. The program has a target of 35% efficiency improvement. Technologies being considered for HEETE include ultra-high-pressure ratio compressors, adaptive core, and high-temperature metal and ceramic materials.

Gas turbine engine manufacturers hit several milestones this year. General Electric's newest commercial engine, the GEnx, entered service on the Boeing 787 Dreamliner and 747-8 aircraft. The new engine offers up to 15% better fuel efficiency than current engines of its class. CFM International, a 50/50 joint venture between GE and Snecma of France, has received over 3,500 orders/commitments for its new LEAP (leading edge aviation propulsion) engine, which will power the COMAC (Commercial Aircraft Corporation of China) C919, the Airbus A320neo, and the Boeing 737 MAX. The LEAP engines incorporate advanced aerodynamic design techniques as well as lighter, more durable materials and leading-edge environmental technologies.

The Rolls-Royce Trent XWB took to the skies for the first time, powering an Airbus A380 test aircraft in Toulouse, France. The Trent XWB will power the new Airbus A350 XWB widebody under development by Airbus. Trent 1000 engines, powering the Boeing 787 Dreamliner, completed 4,000 flying hours in just five months of revenue service with a record of 99.9% dispatch reliability.

GE's GEnx-2B engines have entered service powering the Boeing 747-8 Freighter and Intercontinental.

This year also saw significant educational and outreach activities. The first joint AIAA/ASME-IGTI (International Gas Turbine Institute) undergraduate engine design competition was introduced this year. Written proposals were evaluated by a panel of judges. Two teams from the University of Kansas and a team from the Istanbul Technical University were chosen to present their work at the 48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference. Teams from the University of Kansas took first and third place while the team from Istanbul Technical University took second.

The von Kármán Institute continues advancing education through research programs related to aerothermal investigation of gas turbine engines. Compression tube rigs are used to provide unique experimental data at engine-like conditions. The Embry-Riddle Aeronautical University student chapter of the AIAA hosted its annual dinner with keynote speaker John D. Anderson Jr, professor at the University of Maryland. Cairo University is embarking on an extensive research activity studying cooling effectiveness in turbine blades with emphasis on the various forward and lateral diffusion angles.

by the **AIAA Gas Turbine Engines Technical Committee**

High-speed air-breathing propulsion

by **Foluso Ladeinde** and **Jeff Dalton**

Important advances were reported this year in high-speed-vehicle propulsion that uses atmospheric air as the oxidant in the combustion process. Freestream airflows in such vehicles are hypersonic (Mach 5 or greater).

Researchers in the X-51 scramjet demonstration program conducted an extensive review of flight data and data from several ground tests to analyze an inlet/engine unstart event that occurred during the aircraft's second flight in June 2011. Modifications were made to the X-51A configuration, and flight 3 took place in August of this year. However, the flight was cut short because of the malfunction of a flight control actuator. Plans are under way for a fourth flight, to be conducted mid-2013.

The SABRE engine air precooler, here installed in the testbed, was tested successfully this year.

The Hypersonic International Flight Research Experimentation (HIFiRE) program, a joint U.S./Australia initiative, reported a successful launch of its HIFiRE 2 scramjet experiment in May. This flight test yielded a wealth of research data, including unique information on scramjets transitioning from subsonic to supersonic combustion. The experiment was launched from the Pacific Missile Range Facility in Hawaii atop a newly developed three-stage sounding rocket that climbed to 90,000 ft while operating the scramjet experiment for approximately 12 sec. This was the first time a hydrocarbon-fueled scramjet was flight tested while accelerating from Mach 6 to Mach 8.

Traditionally, a rocket carries its own propellants. However, the SABRE (synergetic air-breathing rocket engine) program, funded jointly by commercial concerns and the U.K. government, is investigating a new paradigm in propulsion: The rocket engine is air breathing and is capable of flight between Mach 0 and Mach 25. It relies on deep cooling of incoming air from 1,800 F to -240 F. This year the SABRE air precooler was tested successfully.

NASA Glenn's combined-cycle engine/large-scale inlet mode transition experiment reported results from a wind tunnel test in the 10x10-ft supersonic wind tunnel. The test demonstrated smooth, stable inlet operation while simulating the transition from a turbine engine to a dual-mode scramjet engine for a turbine-based combined-cycle (TBCC) propulsion system. This test was a critical stepping stone toward enabling TBCC technology for an air-breathing access to space mission using a two-stage-to-orbit vehicle architecture.

The SCRAMSPACE (scramjet-based access to space systems) project is a multinational effort involving four universities in Australia, DLR in Germany, JAXA in Japan, CIRA in Italy, the University of Minnesota in the U.S., BAE Systems in Australia, and other industry partners. This year saw the successful completion of design reviews of the project's Mach-8 free-flyer scramjet flight experiment. The group also achieved advances in ground-based research.

At JAXA, a rocket-based combined-cycle engine model was tested under a Mach-8 flight condition, with successful operation demonstrated in scramjet mode. With this test, following previous successful efforts at JAXA, the model has finally demonstrated its ability to operate in all three modes: ejector-jet, ramjet, and scramjet.

A Brazilian team is working on a two-stage unguided rail-launched solid rocket engine for accelerating the 14-X hypersonic aerospace vehicle to preestablished conditions for scramjet operation. Four flights are planned, including two that involve a hydrogen-powered scramjet at Mach 6 and 10. Nonintrusive measurements have been obtained in hypersonic shock tunnels.

In Europe, two EC-cofunded programs involving civil hypersonic cruisers reported progress this year. ATLLAS II (aerothermodynamic loads on lightweight advanced structures II) focuses on high-speed passenger transport at Mach 5 using (cryogenic) hydrocarbon fuel. Progress in the development and testing of advanced materials and cooling techniques has been reported. Another activity, LAPCAT II (long-term advanced propulsion concepts and technologies II), focuses on propulsive and aerodynamic issues related to antipodal flights at Mach 5 and Mach 8, using cryogenic hydrogen as the fuel.

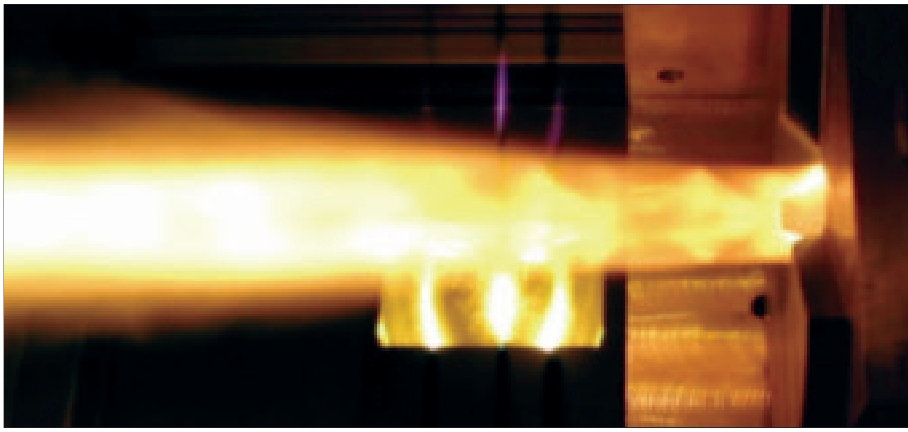
Hybrid rockets

Utah State University has successfully completed the first phase of testing on the multiple-use plug hybrid for nanosats (MUPHyN) thruster prototype. This micro-hybrid thruster, which uses safe-handling and inexpensive nitrous oxide (N_2O) and ABC (acrylonitrile-butadiene-styrene) as propellants, is being developed to fill a niche application for nanosat-scale spacecraft propulsion. The MUPHyN thruster offers several features uniquely suited to nanosat, and particularly Cubesat, applications. These features include a highly compact truncated aerospike nozzle; nonmechanical thrust vectoring using secondary fluid injection on the aerospike nozzle; a hybrid fuel grain with an embedded helical port; and a nonpyrotechnic ignition system.

In order to ensure survivability during extended-duration burns, the MUPHyN features a novel regenerative cooling design in which the N_2O oxidizer flows through a cooling path embedded in the aerospike nozzle before being injected into the combustion chamber near the nozzle base. Digital manufacturing was used to fabricate the nozzle components. When fully developed, the thruster will provide an enhanced propulsive capability that will enable multiple nanosats to be independently repositioned after deployment from the parent launch vehicle. Because the environmentally benign propellants are mixed only within the combustion chamber once the ignition is initiated, the system is inherently safe and can be piggybacked on a secondary payload without increasing overall mission risk to the primary payload.

Stanford University has developed a facility to visualize the combustion of hybrid fuels with gaseous oxygen. Both classical (high-density polyethylene and hydroxyl-terminated polybutadiene) and high regression rate (paraffin-based) fuels have been tested in this facility. Instabilities in the liquid layer of paraffin-based fuels were observed at atmospheric pressure via a high-speed video camera. A marked change in the combustion behavior was noted in paraffin at elevated pressures.

Researchers also developed a facility that allows for visualization of tank and injector dynamics of self-pressurizing oxidizers such as nitrous oxide. This system has led to new insight into the dynamics of high vapor pressure propellant. Students in a graduate course in propulsion system design have concieved, constructed, and ground tested a small hybrid rocket that uses nitrous oxide and paraffin.



Utah State University's MUPHyN micro-hybrid thruster is under development for nanosat-scale spacecraft propulsion.

The rocket is designed to have thrust vector control capabilities by injecting oxidizer into several ports in the divergent section of the nozzle, but this feature has not yet been tested.

Stanford is also continuing its partnership with JPL to conduct systems studies for hybrid rocket applications. The current focus is on hybrid motors for outer planet orbit insertion, with targets including Europa and Uranus.

Sierra Nevada is developing the Space Vehicle hybrid rocket engine.

At Hindustan University in India, researchers have been studying the effects of various grain configurations, such as star, helical, and cylindrical, on regression rate. Static test firings have been performed.

Sierra Nevada's Space Systems has two current contracts for space vehicle hybrid rocket engine development; the focus is on safety and low-toxicity green fuels for low-cost processing and fast turnaround times. The SpaceShipTwo hybrid main rocket engine is currently undergoing full-duration hot-fire testing in San Diego County (development) and Mojave, California (qualification), with 16 test fires to date for Scaled Composites/Virgin Galactic commercial suborbital flight. The effort is on track to support flight tests late this year and at the start of commercial service in 2013.

Scaled Composites continued development of the hybrid rocket motor for the SpaceShipTwo program with numerous ground firings, including the first firing of the motor on the flight-weight hardware test stand in Mojave.

by **Martin Chiaverini**

Liquid propulsion

by **the AIAA Liquid Propulsion Technical Committee**

A scale Space Launch System (SLS) core stage engine single thruster was hot-fire tested at NASA Marshall for the SLS scale model acoustic test. This test program comprises a 5% scale model of the SLS vehicle and launch complex to determine liftoff acoustics and ignition overpressure environments. In addition, an updated liquid rocket engine turbopump dynamic transfer function, derived from the space shuttle main engine and J-2X oxygen inducer-impeller pulsed waterflow test, has been incorporated into SLS core stage pogo stability models. Engine test programs at NASA Stennis include J-2X (Pratt & Whitney Rocketdyne, 294-klbf LO_2/LH_2, including a 550-sec test in July); RS-68/RS-68A (PWR, 650/702-klbf LO_2/LH_2); AJ-26 (Aerojet, 400-klbf LO_2/RP for use on Orbital Sciences' Antares launch vehicle); and the BE3 (Blue Origin's 120-klbf LO_2/LH_2 engine).

United Launch Alliance continues pushing propulsion forward. Major successes for the year included the first flight of the PWR RS-68A, on a Delta IV-Heavy; the completion of development and the start of qualification for the PWR RL10C-1; and initial testing of an innovative H_2/O_2 thruster. Other advanced development activities aimed at significant cost reductions for upper stage propulsion also were completed.

Garvey Spacecraft and California State University, Long Beach (CSULB) successfully extended burn duration to 60 sec on a 4.5-klbf-thrust first-stage engine currently in development for a nanosat launch vehicle. The team also continued its research with hyper-therm high-temperature composites in advanced CMC-lined ablative chambers, conducting a 5-min static-fire test of a 400-lbf LOX/methane engine.

Major successes for the year included the first flight of the RS-68A, on a Delta IV-Heavy. Credit: ULA.

Aerojet propulsion supported the Mars Science Laboratory with Centaur upper stage thrusters, spacecraft cruise thrusters, and attitude control and throttling descent engines during the actual Sky Crane delivery of Curiosity. NASA selected Aerojet for SLS advanced booster engineering demonstration/risk reduction negotiations in July.

During SpaceX's historic first Dragon mission to the ISS, all 18 SpaceX Draco engines fired in support of vehicle attitude control, maneuvering, ISS approach and departure, and deorbit. This year SuperDraco development engine testing completed more than 45 firings for a total duration longer than 89 sec, including throttling over 20-100% thrust. The advanced SuperDraco launch abort and landing system will be integrated with the current on-orbit propulsion system for crew transport.

Development of the 180-kN Vinci expander cycle engine for a new European Ariane 5 upper stage continued with the testing of engine M4 on the P4.1 high-altitude test bench at DLR, including the full extendable nozzle. The thrust chamber testing included going far beyond the flight operational domain, accumulating 61 ignitions and a total 4,800 sec run-time. The 1,400-kN LOX/LH_2 SCORE-D (staged-combustion rocket engine demonstrator), a development of Avio, EADS Astrium, Snecma Safran, and other partners in Europe, has entered the preliminary design phase. A particular milestone includes the subscale preburner hot-fire test at DLR beyond chamber pressures of 300 bar, marking a European first in this category. A manufacturing readiness review conducted in the development of an integrated liquid rocket engine demonstrator by EADS Astrium focused on key technologies for storable propellant engines in the 3-8-kN thrust range.

JAXA is upgrading the H-IIA launch vehicle. The second stage, powered by the LE-5B engine, will be able to transport satellites to the GTO apogee point and carry out the third burn with 60% throttling condition, mitigating the delta-V required for satellites to go to GEO. JAXA adopted new domestic thrusters for its recently completed HTV-3 mission to the station. Four main thrusters named HBT-5 and 28 RCS (reaction control system) thrusters named HBT-1 were developed by JAXA and IHI Aerospace.

Nuclear and future flight propulsion

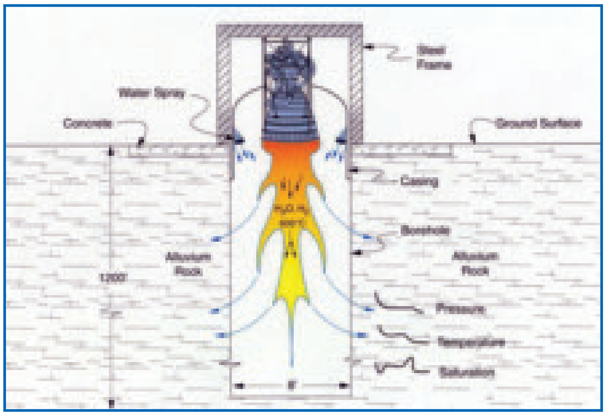
One attractive concept for nuclear and future flight propulsion is atmospheric mining in the outer solar system. The atmospheres of Uranus and Neptune offer very large amounts of atmospheric gases for nuclear rocket and air-breathing propulsion. Based on past studies by NASA Glenn, aerospacecraft cruisers have been identified as a 'best' solution for atmospheric mining.

To power these vehicles, atmospheric hydrogen gas would be liquefied and used as a rocket propellant for the ascent to orbit. Gaseous or liquid hydrogen would be used to power the engines during atmospheric mining operations. A closed-cycle gas core rocket propulsion option is a likely candidate for the aerospacecraft. Helium 3 would be separated from the atmospheric hydrogen, and helium 4 would be captured, liquefied, and stored as a payload to be returned to orbit. The helium 3 carried to orbit along with other hydrogen isotopes (such as deuterium) could power nuclear fusion vehicles for fast interplanetary and future interstellar flight.

Researchers have conducted studies of the gas capture rate and its influence on mining time in the atmosphere. During helium 3 capturing, large amounts of hydrogen and helium 4 are produced. Analyses were performed to quantify the mass production rates of these other potential fuels. For example, if the atmospheric capture rate were 4 kg/sec, the required amount—500 kg of helium 3—would be captured in 95.2 days. During that time, 293,000 kg of hydrogen would be produced per day. To fully fuel a 1,800-sec-I_{sp} nuclear gas core mining aerospacecraft, 270,000 kg is required. Therefore an enormous amount of excess hydrogen and helium 4 is produced each day.

Capturing the excess hydrogen and helium 4 to fuel additional exploration and exploitation vehicles was addressed as well. New options for fleets of aerospacecraft for exploration and exploitation missions are possible. Deep diving and far-ranging aircraft carried to the outer planets could be released from the main mining aerospacecraft to explore a diverse set of atmospheric targets.

With this added hydrogen and helium 4 resource, many vehicles could be fueled.



Schematic of the SAFE concept shows an NTR sealed over a standard hole at NTS.

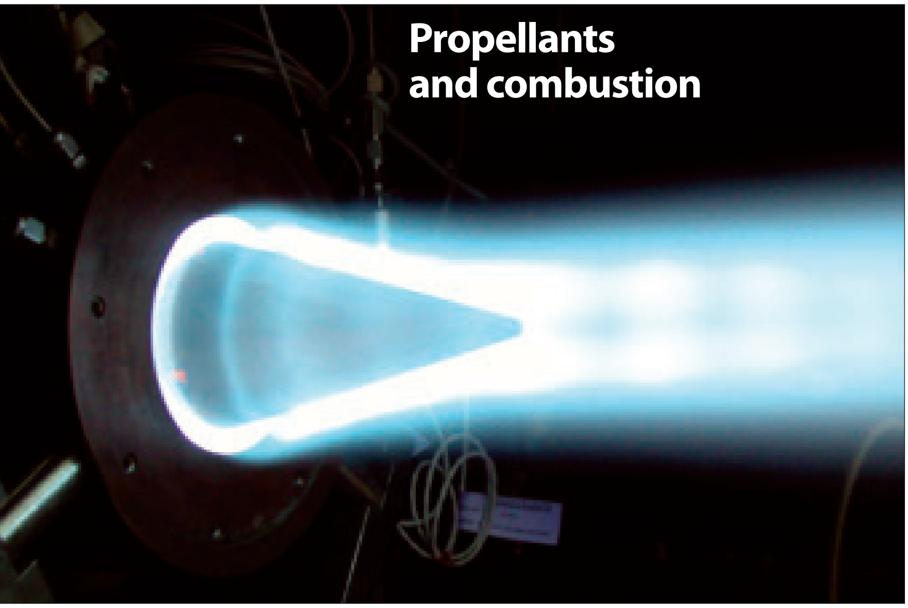
Entire fleets of uninhabited aerial vehicles including balloons and rockets could fly through the outer planet atmospheres for activities such as global weather observations, localized storm or other disturbance investigations, wind speed measurements, and polar observations.

Extensive analyses of nearer term nuclear rocket options were also conducted this year. Planning for nuclear testing in the Nevada Test Site showed options for testing nuclear thermal rocket (NTR) engines while minimizing any release of exhaust gases into the Earth's atmosphere. A team consisting of the Center for Space Nuclear Research, Nuclear Security Technologies, the Desert Research Institute, Aerojet, and NASA Glenn addressed the methods of delivering and testing the NTR engines.

One major issue with developing an NTR for future missions is the ability to test the full system on the ground economically. In the late 1990s, the SAFE (subsurface active filtering of exhaust) concept was first proposed as a method for testing an NTR at full power and at full duration. The SAFE concept relied on firing an NTR into nuclear test holes at the Nevada Test Site, which had been constructed to test nuclear weapons. The estimate included preparation of the site (providing roads, power, and so on); drilling and casing of the four holes; constructing an earthen berm around the test site; installing the instrument trailers; placing the instrumentation in the diagnostic holes; installing the various gas tankers and the water cooling system; and constructing a safety fence.

by **Bryan Palaszewski**

Propellants and combustion

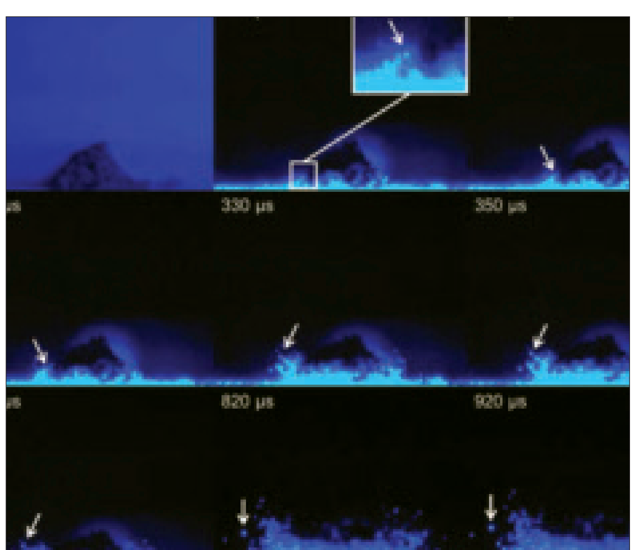


The PWR/HyPerComp continuous detonation engine hot-fire test took place in March.

by **Joanna Austin** and **Yiguang Ju**

Under a DARPA contract, Pratt & Whitney Rocketdyne and HyPerComp conducted a test program focused on producing data from well-defined rotating detonation waves to improve CFD modeling of continuous detonation engines (CDEs). Over the course of five weeks, 197 hot-fire tests of a CDE were conducted on 21 injector/chamber combinations using methane fuel and gaseous oxygen propellants. Water-cooled hardware enabled 20-sec-duration tests and calorimetry. The data from the test program indicate that continuous detonation behavior is highly dependent on injector design. HyPerComp expanded its CFD models by dispensing with conventional idealizations and focusing on those processes that are most relevant to sustained detonations in practical chambers. This has led to an understanding of the stability and efficiency of the system.

Researchers at the University of Tennessee and the Air Force Research Laboratory (AFRL) have demonstrated that aluminum nanoenergetic particles can serve as an active photothermal medium to enhance and control local heat generation, particle motion, and ignition via the photothermal effect induced by localized surface plasmon resonance (LSPR). Collaborating on this are the University of Tennessee, Spectral Energies, and AFRL's Aerospace Systems Directorate, supported by the Air Force Office of Scientific Research. The photothermal effect is initiated by a xenon flash powered by two AA batteries. The extent of the photothermally activated movement of the nanoenergetic particles can be up to 7 mm, which is about 10^5 times greater than that of passive laser-induced photothermal ejection of gold nanodroplets. Ignition delay can be around 0.12 msec, which is about 100 times shorter than that attainable with conductive heating.



The photothermally driven ignition of Al nanoparticles by a single xenon flash pulse was captured at a frame rate of 100 kHz at incident power of 1.6 J/cm^2. Ignition was identified in the second image, which was acquired around 0.12 msec after the flash incidence. Ignition is spatially localized. Each frame size is 3.8 mm high and 4.9 mm wide.

Electromagnetic simulations indicate that local heat generation is significantly enhanced by LSPR. The positive-feedback effects from the local heat induced by Al oxidation produce a large increase in local temperature and pressure, further enhancing movement and accelerating ignition.

Hydroperoxyl radicals (HO_2) and hydrogen peroxide (H_2O_2) are among the most important compounds governing high-pressure combustion. By using molecular beam mass spectrometry, some researchers at Princeton Combustion Laboratory have successfully quantified the H_2O_2 formation in flow reactor experiments. By using continuous wave cavity ring-down spectroscopy, the Combustion Laboratory at Université de Lorraine also achieved measurement of H_2O_2 in a jet stirred reactor.

More recently, a collaborative team at Princeton Combustion Laboratory and Laser and Electronics Laboratory successfully developed a new platform to measure HO_2 radicals in combustion by using midinfrared (7.1 µm) Faraday rotation spectroscopy with sensitivity below 5 ppm. This success will open a new dimension in developing validated high-pressure combustion chemistry for transportation fuels.

Solid rockets

Throughout the year, ground and flight tests demonstrated increased capability with new and enhanced solid rocket motor (SRM) products for tactical, strategic, and launch applications, building on an industrial base enhanced by several production milestones.

Northrop Grumman and ATK successfully tested a Minuteman III Stage I for the Air Force. Over 4,000 Minuteman SRMs have been produced since the 1960s. The test, part of the USAF's 'warm line' production program, strives to produce motors representative of the deployed motors while maintaining the critical skills, infrastructure, and supplier base necessary for producing ICBM propulsion hardware in the future.

In May and June, Raytheon's Standard Missile-3 Block IB successfully intercepted and destroyed a ballistic missile target during two separate flight tests. The all-solid propulsion missile—consisting of the Mk 72 and Mk 104, both built by Aerojet, and the Mk 136, manufactured by ATK—features an upgraded onboard signal processor and TDACS (throttleable solid divert and attitude control system). Aerojet also developed and manufactured the TDACS. The success of this interceptor was critical for meeting the second-phase goals of the president's European Phased Adaptive Approach using the Aegis Ashore system (the land-based component of the ballistic missile defense system).

The USAF and ATK successfully tested a new large class of Stage II SRM (92-in.-diam.) at the Arnold Engineering Development Center. The motor used emerging technologies from the propulsion application program and the integrated high-payoff rocket propulsion technology program. This configuration supports future missions such as conventional strike missile and operationally responsive space.

On February 9, Vega successfully launched from the space center in Kourou, French Guyana. Courtesy Avio.

United Launch Alliance (ULA) and ATK successfully tested an upgraded GEM-60 SRM in May. Used to boost ULA's Delta IV medium launch vehicle, this GEM-60 now uses a vectorable nozzle and was qualified during a 90-sec burn delivering approximately 270,000 lbf of thrust at 30 F.

The May 4 launch of United Launch Alliance's Atlas V rocket marked the 16th successful Atlas V flight with Aerojet solid rocket boosters. Each SRB is 67 ft long and provides an average of 250,000 lb of thrust. Aerojet SRBs have flown in previous vehicle configurations using one, two, three, and five boosters. Furthermore, in April, Aerojet delivered the 50th SRB to ULA in support of the Atlas V.

On April 14 and 16, the Navy conducted successful test flights of four Trident II D5 fleet ballistic missiles built by Lockheed Martin. The tests marked the 139th, 140th, 141st, and 142nd successful test flights of the Trident II D5 since the completion of its design in 1989—a reliability record unmatched by any other large ballistic missile or space launch vehicle.

Lockheed Martin delivered the 20,000th guided multiple launch rocket system's Unitary rocket to the Army, while Raytheon delivered the 2,000th Evolved SeaSparrow Missile to the NATO SeaSparrow Consortium. Raytheon tested a new propulsion system for the TOW (tube-launched, optically tracked, wireless) missile. Developed by ATK, the enhanced system doubles TOW's range and reduces the missile's flight time by a third, advancing the technology readiness level of an insensitive-munitions-compliant system.

On April 30, Safran announced the merger of its two subsidiaries, SME and Snecma Propulsion Solide, creating a new company named Herakles. On February 9, Vega was successfully launched from the space center in Kourou, French Guyana. Vega is the first launcher designed and developed in Italy. The Avio Group, through its subsidiary ELV, led Vega's development, which has involved 42 organizations from 12 different countries with more than 1,000 engineers.

A Trident-II (D-5) missile breaches the ocean surface.

by **Barbara A. Leary, Robert E. Black III,** and **Clyde E. Carr Jr.**

Terrestrial energy systems

Research on renewable energy systems has grown with the increasing demand from consumers and governments to produce more 'green' energy. Solar energy systems have been in the spotlight—both in a negative sense, with the closing of several U.S. manufacturers, and in a positive sense, with many new R&D initiatives to bring cost effective solar to the marketplace. Response to market demand takes many forms, from new battery technologies to innovative manufacturing processes to new government initiatives, all to help make solar a more viable energy choice.

This year the European Photovoltaic Industry Association reports that the growth rate for installed capacity of photovoltaics (PV) is 70%. The group found that in 2011, 29.7 GW of PV were connected to the grid (including Europe, at 21.9 GW; China, at 2.2 GW; and the U.S., at 1.9 GW). With this growth, there are now six markets that have more than 1 GW of solar-supplied energy: Italy, Germany, France, China, Japan, and the U.S. These changes highlight the emphasis that governments are placing on solar energy and the financial viability of new technology that is reaching the market.

The Dept. of Energy's SunShot Initiative focuses on lowering the total cost of solar energy systems by 75%, to about $0.06/kW-hr, before the end of the decade, and enabling solar-generated power to account for 15-18% of U.S. electricity generation by 2030. The DOE is supporting testing and validation of new technologies through partnerships with organizations such as the DOD's Installation Energy Test Bed.

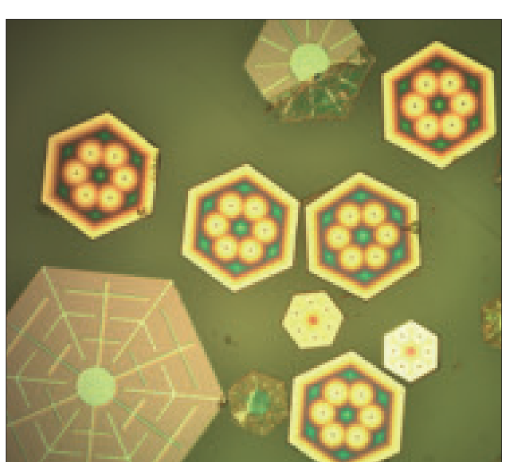
One of the big challenges for the viability of large, grid-connected PV systems is energy storage, to decouple generation from market demand. In the past, pumped hydro or lead-acid batteries have been used to fill this need. Unfortunately, both of those solutions are cost prohibitive, and pumped hydro also has large space requirements, unknown environmental impacts, and long implementation lead times. Ways of addressing the integration challenge include use of lower cost alternatives such as advanced controls, improved predictions of climate and weather variations, and better load management.

Research trends for PV devices include new materials and manufacturing methods that reduce the cost of creating raw silicon wafers, use less silicon in a more energy-efficient manner, and enable different form factors.

This year's R&D 100 Awards recognized two such innovations in PV technology. Sandia National Laboratories was recognized for microsystems-enabled photovoltaics that can be manufactured using MEMS techniques common to today's electronic foundries. Their technology consists of tiny glitter-sized photovoltaic cells that are printed on a low-cost substrate with embedded contacts and microlenses for focusing sunlight onto the cells. These cells are 10 times thinner than conventional cells, yet perform at about the same efficiency. The National Renewable Energy Laboratory, in partnership with Solar Junction, was recognized for a triple-junction solar cell called SJ3, which achieves a world-record conversion efficiency of 43.5% under lens-focused light. The SJ3 cell captures different light frequencies, ensuring the best conversion of photons to electrons at different times of the day.

In other recent developments, a research team at UCLA describes a new transparent solar cell made from photoactive polymers that convert infrared light into electricity and can be integrated into building windows.

Photovoltaics are becoming a cost-effective source of energy through advances in materials, manufacturing processes, and supporting technology. A better understanding of how to manage PV and other distributed energy sources on the grid will enable these energy sources to become a larger part of the world energy portfolio. Further progress requires continued collaboration between government laboratories, academics, and commercial firms.



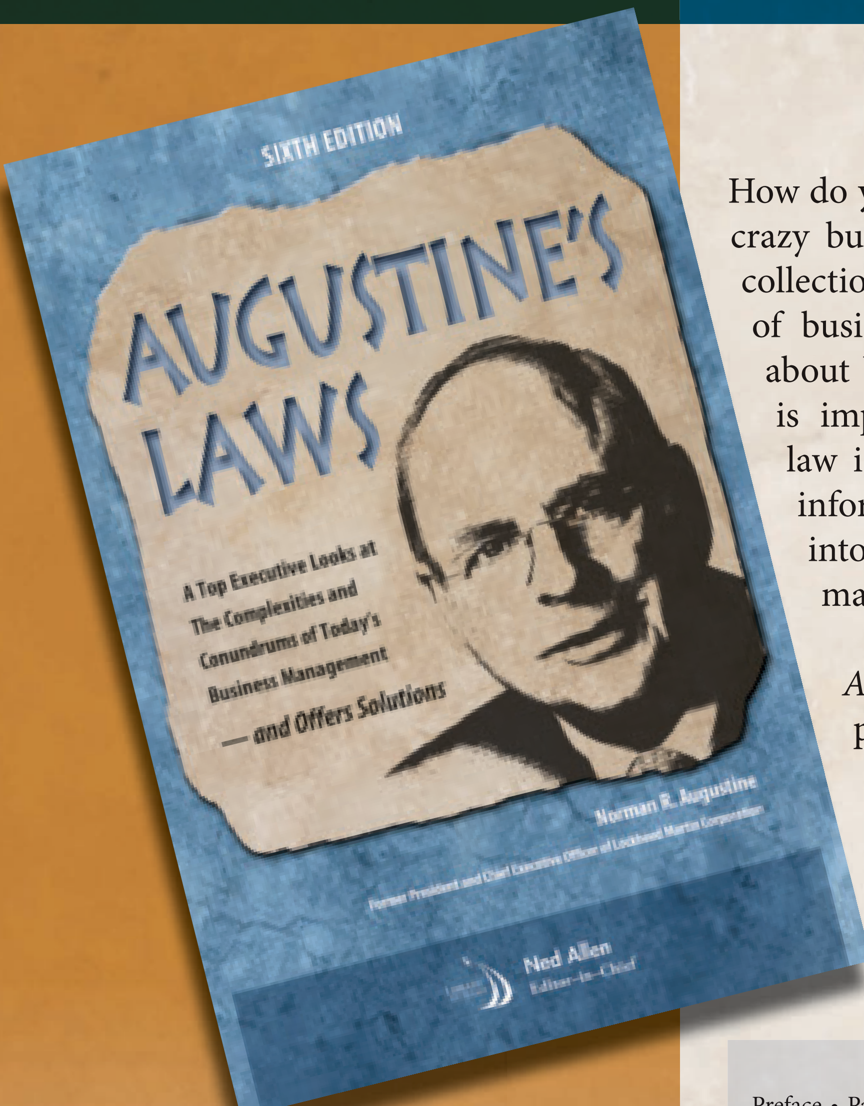
Sandia National Laboratories has developed 'solar glitter' technology; representative thin crystalline-silicon photovoltaic cells are 14-20 μm thick and 0.25-1 mm across.

by **Doug McCorkle** and **Chris Moen**

BEST SELLER!

Augustine's Laws

Sixth Edition



Norman R. Augustine

How do you keep your sense of humor in the crazy business world? *Augustine's Laws* is a collection of 52 laws that cover every area of business. Each law formulates a truth about business life that, once pointed out, is impossible to forget or ignore. Each law is imbedded in an entertaining and informative text whose humor brings into sharp focus all the complexities a manager is ever likely to face.

Augustine's Laws has been widely praised and quoted in the national media. The book's humor brings solace to all of us trapped in the coils of business perplexity; its sanity and brilliance will suggest multiple escapes and solutions.

"This is the only book that ever made me mutter, 'we're all doomed,' while laughing at the same time. I enjoyed it thoroughly."

Scott Adams, creator of *Dilbert*

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Life sciences and systems

Astronaut Don Pettit has some fun with the CAMRAS demonstration unit during its installation on the ISS.

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

From our international partners, one of the most ambitious human experiments ever undertaken, the Mars500 Project, was completed in November 2011. After spending nearly 18 months in a pod mimicking a spacecraft traveling to and from Mars, the participants simulated return to Earth on November 4, 2011, as families awaited their 'arrival.' Results are available at http://mars500.imbp.ru/en/index_e.html.

Russia has since announced plans to start a Mars mission simulation on the ISS in 2015. Coordination with ISS partners is under way.

Another example of ESA/NASA cooperation in life sciences is the start of a contract for the ISS biology experiment NIH.1a (http://www.kayser.it/index.php/pressreleases/204-nih-1a-a-biology-experiment-for-the-iss), planned for launch in July 2013. Also in preparation is an analysis of an ESA experiment called BICE (biomechanical quantification of bone and muscle loading to improve the quality of 0-*g* countermeasure prescriptions for resistive exercise). This involves a combined use of NASA's advanced resistance exercise device and the Italian Space Agency's (ASI) ELITE S2 (elaboratore immagini televisive-space 2).

In the U.S., NASA implemented AES (advanced exploration system) and NIAC (NASA innovative advanced concept) projects during FY12 for the following LSS-related areas: the multimission space exploration vehicle, EVA suit and life support, suitport, habitat systems, analog missions, logistics reduction and repurposing, water recovery, spacecraft fire safety demonstrations, radiation protection, atmosphere resource recovery, and environmental monitoring. Each of the projects made progress toward FY14 integrated testing to validate that these technologies are ready to be considered for exploration vehicle designs. For more information, see http://www.nasa.gov/directorates/heo/aes/index.html and http://www.nasa.gov/offices/oct/early_stage_innovation/niac/.

The AES habitation systems (HS) project held a series of forums between December 2011 and April of this year to address critical issues facing development of deep space habitats. The first forum focused on radiation, including protecting astronauts from its effects. The second focused on life support and included AES project planning and status from each of the AES projects associated with the ECLSS (environmental control and life support system) and with EVA. The third forum focused on human health and performance issues associated with long-duration deep space missions. The AES HS project completed mission operational testing in September using the Habitat Demonstration Unit to simulate the end of exploration of a near-Earth asteroid and the return voyage to Earth.

The Mars Science Laboratory Curiosity rover landed safely in August, carrying with it the RAD (radiation assessment detector), the first radiation monitor to operate on the surface of Mars. For more about the detector, go to http://www.boulder.swri.edu/~hassler/rad/.

Also from NASA, the CO_2 and moisture removal amine swingbed (CAMRAS) technology received a boost as a demonstration payload was delivered to the ISS for long-term microgravity study, and ground testing continued. To date, the CAMRAS, which will control humidity and carbon dioxide on the multipurpose crew vehicle, had undergone extensive ground-based testing at NASA Johnson, including operation at various cabin pressures (14.7, 10.2, and 8.3 psia) and oxygen levels (21, 30, and 35%). At the end of 2011, ambient pressure suit integration testing focused on operating the CAMRAS when integrated with two developmental soft suits (ACES, advanced crew escape suit; and C-SAFE, Constellation space suit system). Human subjects were used in this test, with emphasis on the user experience resulting from changing flow rates, cycle times, and dynamic pressure effects within the loop.

All of this ground testing paved the way for a CAMRAS payload to be delivered to the ISS for testing that began this year.

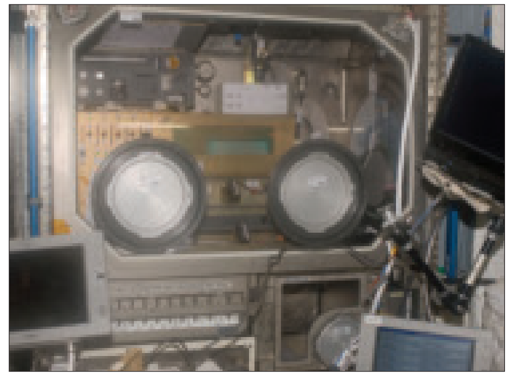
by **Joe Chambliss**

Microgravity and space processes

The past year has been a very active period for microgravity research, particularly on the international space station. In the area of microgravity fluids research, continued advances have been made on a number of fronts. Successful conclusion of two binary colloidal alloy tests (BCAT 5 and 6) provided insight into the question of how small 'foreign objects' influence the rate of crystal nucleation. A follow-on series of experiments called advanced colloids experiment kicked off this year to image Janus particles; one-half of their surfaces are composed of hydrophilic groups and the other half of hydrophobic groups. Another colloidal experiment called Investigating the Structure of Paramagnetic Aggregates From Colloidal Emulsions (InSPACE-3) was installed in the microgravity science glovebox (MSG) facility in late August. The InSPACE-3 experiment continues InSPACE-2 studies to determine the lowest energy configurations of the 3D structures of a magnetorheological fluid under the influence of pulsed magnetic fields. Finally, the Capillary Flow Experiment (CFE-2) also continued on the ISS. CFE is a suite of fluid physics flight experiments designed to investigate large-length-scale capillary flows and phenomena in low gravity. Seven additional CFE-2 units are in preparation and are scheduled to launch early in 2013.

In micrgrovity materials research, the NASA Marshall Microgravity Science Program is dedicated to promoting understanding of materials processing by conducting relevant experiments in the microgravity environment and supporting related modeling efforts with the intent of improving ground-based practices. Current investigations include research on dopant distribution and defect formation in semiconductors, microstructural development and transitions in dendritic casting alloys, coarsening phenomena, competition between thermal and kinetic phase formation, and formation of glassy vs. crystalline material.

Facilities for conducting experiments on board the ISS include the European Space Agency Low Gradient Facility and the solidification and quench modular inserts to the materials research rack/Materials Science Laboratory (MSL) and are primarily used for controlled solidification studies. The French space agency CNES DECLIC facility allows direct observation of morphological development in transparent materials that solidify analogously to metals. The ESA-provided electromagnetic levitator is designed to levitate, melt, and then cool samples in order to determine material properties, study nucleation behavior, and document phase transitions. Finally, the MSG serves as an on-board facility for supporting the hardware required to conduct a number of smaller, short-term investigations.



The microgravity science glovebox is one of the major dedicated science facilities inside Destiny. It has a large front window and built-in gloves to provide a sealed environment for conducting science and technology experiments. It is particularly suited for handling hazardous materials when the crew is present.

The Canadian Space Agency (CSA) continues to innovate in microgravity science research to advance our understanding of gravity and the space environment on material processes, fluid physics, combustion and flame systems, protein crystal growth, and fundamental physics. Current investigations include gravitational research on semiconductor and metal alloys, evaporation and condensation processes, phase transitions and interactions, colloidal liquids, stability of liquid bridges, thermodiffusion of binary and ternary liquid hydrocarbon mixtures, surface-tension-driven convection, and dust combustion. Also, unique scientific contributions are pursued to advance our understanding of quantum entanglement, measurement and analysis of acceleration levels onboard multiple space research platforms, the role of vibrations on liquid systems, and on-orbit operations of active vibration isolation technologies in the space station.

Canada uses many of the research facilities onboard the ISS to achieve Canadian scientific objectives. These include the MSG; acceleration measurement systems; fluid science laboratory, which integrates the CSA's microgravity vibration isolation subsystem, the material science research rack, and the MSL; the selectable optical diagnostic instrument; the electromagnetic levitator, and Japan's fluid physics experiment facility and microgravity measurement apparatus.

by **the AIAA Missile Systems Technical Committee**

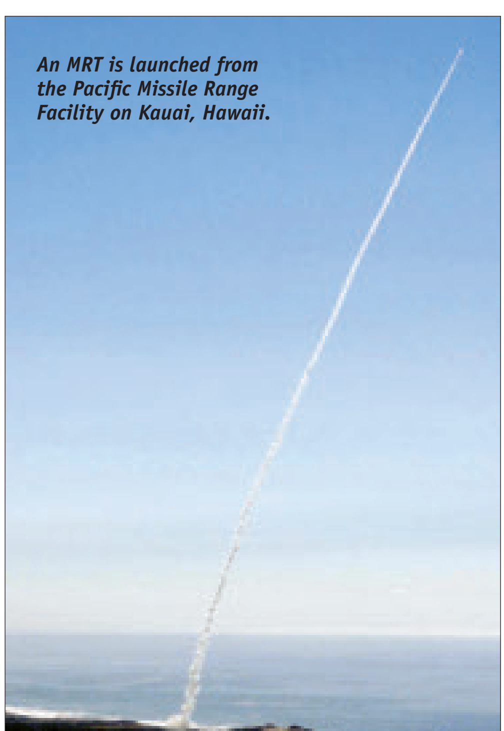
Missile systems

by **the AIAA Missile Systems Technical Committee**

This year saw significant accomplishments in tactical, strategic, and missile defense programs. The advanced precision kill weapon system II, developed by BAE Systems, turns legacy unguided 2.75-in. rockets into guided missiles by adding a semiactive laser guidance and control section that integrates with current motors and warheads. China Lake Naval Air Warfare Center (NAWC) completed initial operational testing in January, and the weapon was first used in combat aboard Marine Corps helicopters in March.

The advanced antiradiation guided missile (AARGM), designed by Alliant Techsystems, incorporates a multisensor system capable of selectively engaging time-sensitive and enemy air defense targets even after radar emissions are shut down. NAWC demonstrated AARGM's capabilities with 12 live-fire tests, leading the Navy to authorize full-rate production in August.

Development continues on AGM-154C-1, a new variant of Raytheon's Joint Standoff weapon. The C-1 variant will become the U.S. military's first production network-enabled weapon by adding a Link 16 weapon data link capable of receiving target updates in flight. Upgraded seeker software can autonomously target a specific aim point on a moving ship. Performance has been verified by successful launches against moving ship targets at the Point Mugu Sea Range.


An MRT is launched from the Pacific Missile Range Facility on Kauai, Hawaii.

In April, an MBDA Aster-30 missile fired by France's Forbin air defense ship intercepted an Orbital Sciences GQM-163 Coyote supersonic sea-skimming target. This successful test marked the conclusion of a foreign military sale case involving purchase of the single GQM-163A target, support equipment, and range integration.

A Northrop Grumman-led ICBM prime team supported successful testing of the Minuteman III ICBM weapon system in April. The operational test launch proceeded as planned, with the missile traveling roughly 4,800 mi. in 30 min. A single Mk21 reentry vehicle landed on target within the Ronald Reagan Ballistic Missile Defense Test Site. Operational tests were conducted by the 90th Missile Wing at F.E. Warren AFB, with oversight from the 576th Test Squadron.

In late 2011 the Army conducted a remarkable test of the Advanced Hypersonic Weapon (AHW) demonstrator. The AHW, a long-range, high-speed glide vehicle, was launched from the Pacific Missile Range Facility to a target on Kwajalein Atoll, traveling 2,300 mi. in less than half an hour. AHW flew a hypersonic, nonballistic glide path within the atmosphere while space, air, sea, and ground platforms collected performance data on all phases of flight. The results support development of prompt global strike technology.

The Navy conducted two successful tests of its next-generation Aegis ballistic missile defense system. In May, a Standard Missile (SM-3, Block 1B) fired by the USS Lake Erie intercepted a short-range ballistic missile target. This was the first successful flight test of Raytheon's SM-3 Block IB. In June, another Block 1B missile intercepted a medium-range target (MRT) in exoatmospheric flight. The MRT vehicle, developed by Orbital Sciences, is capable of being launched from ground, sea, or air.

The Army conducted successful tests of the Raytheon Patriot air defense system, incorporating Lockheed Martin's PAC-3 missile. PAC-3 includes an upgraded seeker, improved maneuverability, and miniaturization to quadruple the number of missiles per canister. Patriot's new capabilities were demonstrated during an April flight to destroy a cruise missile target at the Utah Test and Training Range, and an August test that intercepted a tactical ballistic missile over White Sands Missile Range.

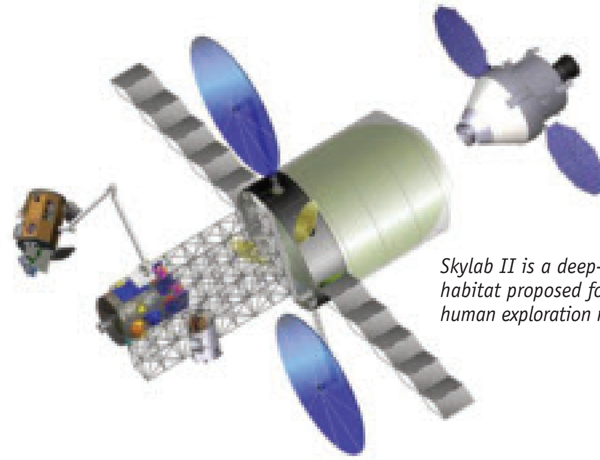
Space architecture

This year witnessed a diversity of projects by architects working in the space architecture field. Skylab II, following in the footsteps of the single-launch Skylab experimental space station of the 1970s, is an advanced concept for using the upper stage hydrogen tank of the Space Launch System as a deep space habitat. Skylab II focuses on human missions to asteroids or Earth-Moon Lagrangian points.

Conceived by Brand Griffin with David Smitherman, Kriss Kennedy, Larry Toups, Tracy Gill, and Scott Howe, Skylab II offers 495 m^3 of pressurized volume for a four-person crew. Its tank, like that of Skylab I, can be launched fully provisioned for a 500-day mission. Solar arrays, radiators, and a multipurpose truss structure project from the tank's aft ring segment, which contains avionics, communications, and an EVA airlock. With a two-launch configuration featuring technology that is twice used, Skylab II could offer an economical and early vehicle for the next generation of human exploration missions.

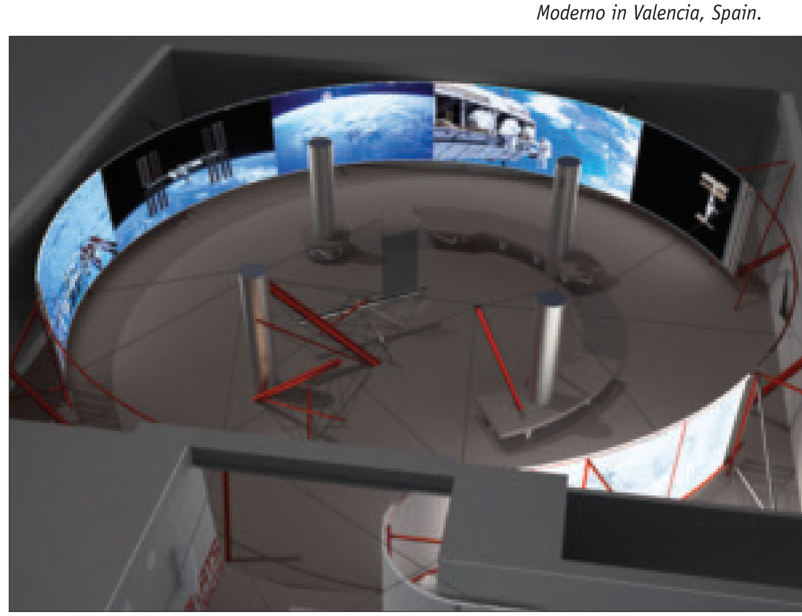
Habitat prototypes and mockups are very useful educational tools, and the Crystal inflatable habitat is aimed at stimulating student participation in development of space inflatables. The Crystal prototype was designed and fabricated by Ondrej Doule and Vratislav Saleny in Europe and was on display at an International Space University summer program in Florida. Low-pressure airwalls rigidize the habitat's simple hedron structure. An integrated fan delivers continuous airflow through a triple-layer wall envelope that includes a solar radiation-resistant layer. The habitat deployment takes less than a minute, and the fan runs for 3-4 hr off a single battery.

Carolyn Sumners, vice president for astronomy and the physical sciences at the Houston Museum of Natural Science, has been leading a project for the design of a lunar settlement. Participating in the effort are faculty members Olga Bannova and Larry Bell and students at the University of Houston's Sasakawa International Center for Space Architecture. Sumners has developed a 3D interactive environment of a lunar colony for 80 persons. The concept is displayed in the museum's Discover Dome, where full-dome video presentations on the solar system, Earth science topics, and the human body take visiting student groups on learning adventures. The project envisions the need for an international effort in the distant future to deliver a lunar colony with an emphasis on economic feasibility and operational sustainability.



Skylab II is a deep-space habitat proposed for new human exploration missions.

Another museum, this time in Europe, held an exhibition that showed how space architecture has now established itself as a design field alongside terrestrial architecture. "Building Technological Habitats" is the name given to the first of four exhibitions under the theme title, "Inhabiting Cosmos." Curated by Raul Polit Casillas, it opened in March at the Instituto Valenciano de Arte Moderno in Valencia, Spain. The exhibition is an audiovisual display of continually changing images on multiple screens arranged in a circle. It offers visitors a dynamic panorama of leading-edge construction technology for structures ranging from office buildings to space stations. Plans are afoot to bring the exhibition to museums in the U.S. in 2014.



"Building Technological Habitats" is one of a series of exhibitions at the Instituto Valenciano de Arte Moderno in Valencia, Spain.

by **David Nixon**

Space automation and robotics

by **Kate Stambaugh**
and **Gregory P. Scott**

This year has been a strong one for space robotics. With the successful landing of the Curiosity rover on Mars, on-orbit demonstrations by the Robotic Refueling Mission, Robonaut's continued presence on the space station, and the initialization of the DARPA Phoenix program, the field of space automation and robotics continues to move forward with exciting developments.

In the most widely covered space science mission of the year, the Mars Science Laboratory successfully landed and delivered the Curiosity rover to the surface of Mars on August 6, 2012. After deploying the mast and checking out the rover's systems, Curiosity drove away from its landing site and began its trek across Gale Crater. Curiosity's robotic arm has scooped several surface samples for analysis, and pictures from its cameras have already revealed further evidence of a wet past on Mars as the rover makes its way upstream in what appears to be an ancient riverbed.

On October 31, Curiosity used its hand lens imager to capture a set of 55 high-resolution images, which were stitched together to create a full-color self-portrait. The mosaic shows the rover at 'Rocknest,' the spot in Gale Crater where the first scoop sampling took place. Four scoop scars can be seen in the regolith in front of the rover. The Martian landscape appears inverted within the round, reflective ChemCam instrument at the top of the rover's mast.

Meanwhile, elsewhere on the planet, the Mars Exploration Rover Opportunity continues to return scientific data to Earth while investigating clay minerals on the inside rim of the Endeavour Crater. Opportunity has driven over 35 km on the surface of Mars and continues to be active after over eight years of hard work.

On March 8, NASA's Robotic Refueling Mission (RRM) demonstrated the first use of specialized tools for intricate satellite servicing tasks in orbit. The tasks for the demonstration called for extremely precise robotic movements, which Canada's Dextre robotic arm performed by using the RRM multifunction tool to remove the launch locks securing four RRM tool adapters. This demonstration also verified the ability of a robotic system to overcome the challenges of dynamic on-orbit lighting conditions and jitter and allowed NASA to improve its machine vision algorithms. Then Dextre proceeded to use the RRM wire cutter tool to cut two thin wires and remove gas fittings that are common for filling spacecraft with special coolant gases or propellant.

RRM was developed and is managed by NASA Goddard's Satellite Servicing Capabilities Office. The RRM module launched in July 2011 aboard the final space shuttle flight, STS-135, and is attached to the EXPRESS Logistics Carrier 4 on the ISS as an external investigation. RRM has several specialized tool adapters designed to perform specific servicing tasks. Demonstrations will continue with the highly anticipated refueling activity, during which Dextre will open a fuel valve and transfer liquid ethanol through a fueling hose. Additional planned servicing activities include thermal blanket manipulation, screw removal and electrical cap removal.

Also on the station, Robonaut 2 (or R2) continues to perfect its duties as a robotic crew member on board. R2 not only looks like a human, but was designed to have dexterity and movement abilities similar to a human's. Over the past year, R2 has practiced accessing task panels using tools that ISS crewmembers use and performing 'housekeeping' chores. R2 has been on the ISS for over a year and a half and continues to perform admirably. It is leading NASA to new advances in dexterous robotic operations and demonstrating ways that humans and robots can work together in space.

DARPA has a new satellite servicing program under way called Phoenix, which will seek to demonstrate the capability of capturing and reusing or repurposing space assets that already exist near geosynchronous orbits. Although the program's first flight mission is not scheduled until 2015, technology development initiatives and trade study efforts have been increasing throughout 2012. This will be an interesting program to watch out for as further developments unfold.

Space colonization

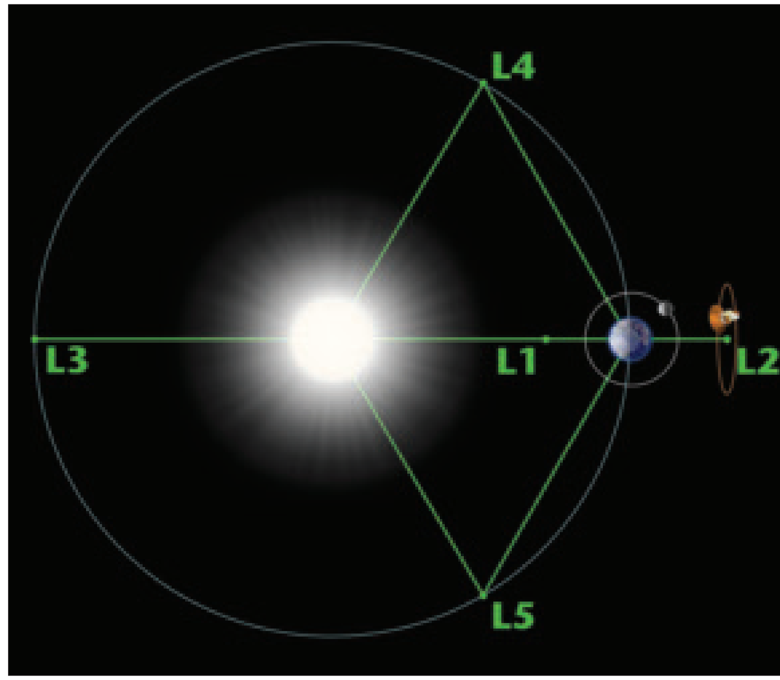
Throughout the history of human interest in space settlements, one constant has been the struggle to justify the huge expenditures required to move and maintain thousands of people in space. Early assumptions that construction of solar power satellites for a power-hungry world would pay for large orbital communities were invalidated by energy conservation and development of new energy supplies. Subsequent triggering events—whether for economic, political, or survival imperatives—failed to materialize.

This year, however, saw the first indications of a new economic direction that may provide a path toward large-scale human habitation in space: At an AIAA conference in January, several industry and government leaders described ideas for infrastructure enabling on-orbit repair and upgrades of GEO and other satellites, retaining heavy satellite structures and realizing cost savings through launch only of components for replacement or upgrade. This is a trend that bears watching.

The concept of space infrastructure received attention this year with discussions showing how space station elements can be repurposed to provide orbital services throughout cis-lunar space, including for operations on the lunar surface. Studies of orbital options are revealing loiter or parking orbit possibilities involving Earth-Moon libration points L1 and L2, including orbits around L2 that stray sufficiently from the discrete point to enable direct communication with Earth, and complicated patterns that oscillate between L1 and L2. Solar power satellites also remain in the infrastructure picture, with a $100,000 grant created for further research.

Commercial space was in the news, most notably with the successful berthing of a SpaceX Dragon cargo vehicle with the ISS. Development of commercial crew delivery to the space station continues, with the announcement of 'two and a half' contracts for the third phase of NASA Commercial Crew Development vehicles: Boeing and SpaceX received approximately equal contracts for their capsule-based concepts; Sierra Nevada received approximately half funding for winged vehicle development.

CCDev contractors are intending flexible uses of their vehicles; NASA mission requirements presume that some crew seats may be replaced by cargo installations.



When one large body is in orbit around another, there are five points in orbits around the larger body where gravitational forces balance out to enable satellites to be placed where they could not stay if the smaller of the large bodies were not present. These are called libration or Lagrangian points.

Downweight options from the ISS are being recognized as a priority, as the agency is encouraging the development of commercial products in the ISS environments.

A commercial enterprise not connected with NASA was established by Planetary Resources, which announced plans to mine asteroid resources.

Simultaneously, work continues on traditional NASA contracts for development of the Orion crew vehicle, capable of enduring more severe environments associated with return from higher than LEO orbits, and the Space Launch System (SLS), intended to launch Orion. Contractors for Orion and SLS are creatively investigating how their vehicles can be used for multiple types of missions, especially missions to asteroids, Mars, and the Moon. Mars captured public interest with the landing and early operations of the Curiosity rover, which pioneered an innovative Sky Crane technique for landing large, heavy cargo in the slight Martian atmosphere.

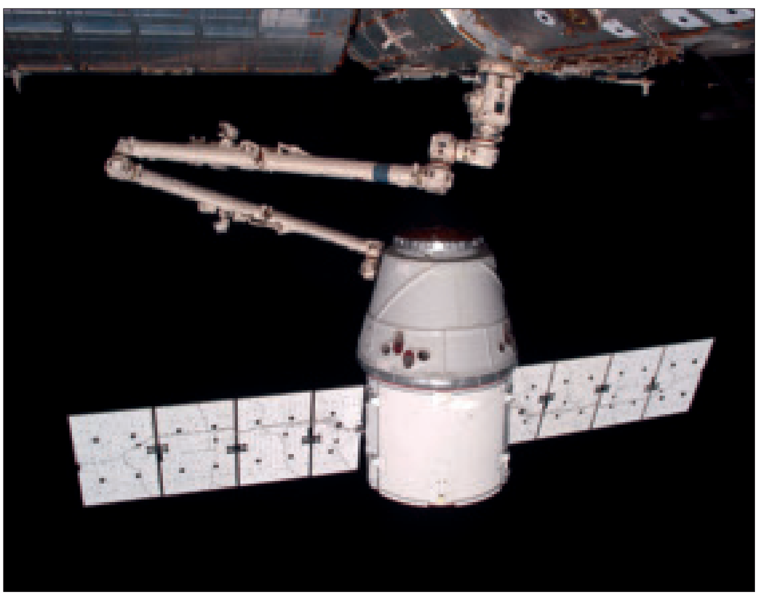
Potentially the greatest penetration of space settlement concepts into the public consciousness occurred with publication of a special edition of *U.S. News & World Report* on "Mysteries of Space," including an article titled "Home on the Final Frontier." Statements included "living on Mars or the Moon is not such a far-fetched idea" and "the first pilot settlements could begin construction in little more than a decade."

Previously established space settlement programs also continued this year.

by **Anita Gale** and **Mark Benton**

Space operations and support

This year three new countries joined the the list of satellite operators, with the first successful Hungarian and Romanian Cubesat launches and the successful BelKA 2 launch for the Belarussians after BelKA-1 was lost on launch in 2006. China also continued its record set in 2011, when it overtook the U.S. for the first time, with an equally impressive 2012 launch schedule.



SpaceX made history in May when its Dragon capsule successfully berthed with the ISS.

In addition to a number of ongoing Beidou (Compass) satellite launches adding to its navigation constellation, China continues to develop its human spaceflight capabilities, delivering the first Chinese woman to space on Shenzhou-9 in June.

The HTV and the third ATV missions continued to show European and Japanes heavy-lift capabilities. Japan and Europe also saw launch firsts—Japan's first commercial launch and the first Vega launch for Europe. The Vega launch also highlighted the continuing growth of Cubesat mission opportunities, launching seven Cubesats on its maiden flight.

In space science, the successful launches of the two radiation belt storm probe satellites in August joined the successful departure of Dawn from its orbit around Vesta to head to the companion asteroid Ceres. And the successful execution of the incredibly complex entry sequence for the Curiosity lander on Mars clearly marks a highlight in space operations activity.

History was made in May when SpaceX became the first in the private sector to visit the international space station, during a nine-day mission that combined demo flights 2 and 3 of NASA's Commercial Orbital Transportation Services Space Act Agreement (SAA). The company's Dragon spacecraft, carrying supplies for the ISS and riding atop a Falcon 9 rocket, departed Cape Canaveral Air Force Station on May 22 and arrived at the ISS on May 25, when it was captured by station's remote manipulator arm and was mated to the Harmony module. The mission met all its milestones and made it possible for SpaceX to begin regular resupply flights under a $1.6-billion resupply contract with NASA. The first flight took place in October.

U.S. human spaceflight moved forward in August when NASA announced the selection of SpaceX, Sierra Nevada, and Boeing as the winners of the third round of the Commercial Crew Development (CCDev3) SAA. SpaceX now moves ahead with further development of Dragon, which the company had designed from the start with crew in mind, and is demonstrating a lead in the push to field a commercial space transportation system that will replace the shuttle. Crew vehicles designed and built by all three CCDev3 winners are crucial if the U.S. is to regain its ability to fly astronauts to orbit and do so more safely and cost effectively than in the past.

ESA's third ATV continued to demonstrate its prowess at delivering cargo to the ISS.

Capitalism and the introduction of competition into space transportation services have already changed the paradigm for human spaceflight and brought to bear an array of technologies—two capsules and one lifting body—to dramatically lower the cost of access to space and place the U.S. once again at the head of the pack.

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

Space resources

In-situ resource utilization (ISRU) facilitates planetary exploration by drawing needed resources, such as water, from the local environment. Developments this year include technologies for prospecting, drilling, excavating, processing, and manufacturing. The most widely reported news was the April announcement by Planetary Resources that it is joining Shackleton Energy and Google Lunar X-Prize teams Astrobotic and Moon Express in creating commercial business plans to bring the natural resources of space within humanity's economic sphere of influence.

In July, the Third International ISRU Analog Field Test brought many tons of technology to the tephra slopes of Mauna Kea, Hawaii. The analog test was performed jointly by NASA and the Canadian Space Agency with support from industry, academia, and the Pacific International Space Center for Exploration Systems. The test simulated a 7-day lunar RESOLVE polar ice/volatiles mission and combined robotic science/prospecting instrument and operation evaluations.

The RESOLVE (regolith and environment science and oxygen and lunar volatile extraction) payload was carried by an Artemis Jr. rover to a 2,750-m elevation site near Hale Pohaku. RESOLVE presently includes a neutron spectrometer and near-infrared spectrometer to locate volatiles in the regolith, a 1-m drill to sample the subsurface, an oven to heat samples for analysis, and a mass spectrometer/gas chromatograph to identify the volatiles driven from the regolith grains by the heat.

MMAMA (Moon and Mars analog mission activities) events occurred at 3,350-m elevation at Apollo Valley. The volatile analysis by pyrolysis of the regolith project analyzed tephra samples with a mass spectrometer to identify minerals, using samples prepared by the mechanized sample processing and handling system. A Juno II rover carried ground-penetrating radar and a magnetometer to compare robotic mapping to human surveying, and a miniaturized Mossbauer spectrometer and a combined miniaturized Mossbauer and X-ray fluorescence spectrometer to assess the equipment capabilities in the field. The rover, with its innovative wheel design, traversed 5 km without failure over extremely rough terrain.

Meanwhile, NASA's Small Business Innovative Research project is helping advance several ISRU technologies including a gas chromatograph/mass spectrometer for RESOLVE by Creare Engineering, a concept for combined ice drilling and water extraction from Moon, Mars, and asteroid soils by Honeybee Robotics, a microchannel Sabatier reactor by UMPQUA Research, a carbon dioxide electrochemical reactive capture device by Reactive Innovations, and a microgravity regolith transfer concept by Grainflow Dynamics.

In the large vacuum chamber dedicated to tests involving large amounts of regolith simulant at NASA Glenn the soil bin rests in the lower, fixed base of the chamber.

Engineers at NASA Glenn are reworking a Mars hopper concept, switching its propellant from atmospheric carbon dioxide to methane produced by mixing Martian atmosphere with Martian groundwater. A ballistic hopper smaller than the Mars exploration rovers could carry a suite of science instruments, along with its own propellant production plant, and hop 2 km every 30 days. To test the feasibility, a gas-gas, self-throttling propulsion system was tested to simulate the burn-coast-throttling-burn profile needed for a ballistic hop on Mars.

Also at Glenn, a 6.5-m^3 vacuum chamber has been dedicated for tests involving large amounts of regolith simulant. A 0.7-m^3 simulant bed was installed and pump-down procedures developed, and methods to remotely till and compact the simulant have also been demonstrated. Currently, a 1.2-m-long drill tube is being installed.

In September, NASA and the University of Texas at El Paso officially opened the Center for Space Exploration Technology Research at UTEP's College of Engineering. In-situ resource utilization is a major research direction of this center, including combustion of regolith/metal mixtures for structural materials production on the Moon and Mars, extraction of volatiles from lunar regolith, and remote sensing approaches to resource discovery and characterization.

by **Leslie Gertsch**

Space systems

This was a year of multiple mission successes: The first of five advanced Navy geosynchronous communications satellites was successfully deployed, U.S. companies demonstrated new cargo and crew transportation designs, a paradigm shift dramatically lowering payload cost to orbit was completed, and the most complicated robotic Mars mission ever was successfully initiated by a suspense-filled landing.

In February, a United Launch Alliance Altas V lifted the first of five U.S. Navy Geosynchronous Mobile User Objective System (MUOS) satellites from SLC-41 at Cape Canaveral AFS. The successful mission marked the 200th launch of a Centaur upper stage. MUOS-1 will replace the current UHF SATCOM system, providing military users with 10 times more communications capability than current systems, including simultaneous voice (full-duplex), video, and data, leveraging 3G mobile communications technology.

SpaceX achieved a major milestone in June 2012 with the successful Falcon 9 launch and rendezvous of its Dragon cargo ship with the international space station, delivering supplies to the ISS crew. Several months later, SpaceX successfully launched the first commercial cargo ISS resupply mission. The Dragon capsule was recovered after its return to Earth.

Three companies continued to develop and successfully field test capabilities to replace the space shuttle for crew transportation under the NASA Commercial Crew Development (CCDev) program initiated in 2010. SpaceX's Dragon adopts a blunt cone ballistic capsule design similar to its cargo vehicle; Sierra Nevada's Dream Chaser applies a spaceplane configuration derived from NASA's HL-20; and Boeing's CST-100 is reminiscent of Apollo and NASA's Orion. Blue Origin also received CCDev funds for its Space Vehicle, a biconic reentry spacecraft design. The companies are expecting to begin crew transportation services starting in the 2014-2016 timeframe.

In June, Orbital Sciences successfully launched the Nuclear Spectroscopic Telescope Array (NuSTAR) into low Earth orbit using a Pegasus XL L-1011 aircraft-launched rocket. NuSTAR deployed the telescope and has provided significant images of distant galactic events.

by Carl Schueler

The CHIRP payload rests on the nadir deck of the SES-2 host spacecraft.

A commercially hosted infrared payload (CHIRP) flight demonstration launched in September 2011 successfully completed its nine-month base contract in July with extended operation. CHIRP commanded a continuous quarter-disc Earth view north of the equator and westward to the horizon from SES-2's 87° west longitude geostationary slot. It was the first time the USAF integrated a payload onto a commercial satellite, and the first commercially hosted overhead persistent infrared sensor (OPIR). It validated dramatically reduced commercially hosted mission cost and abbreviated development schedule compared to a dedicated spacecraft mission, with launch just 39 months from contract initiation. The mission demonstrated wide-field-of-view OPIR for future missile warning/defense, intelligence gathering, and battlespace awareness.

Going beyond Earth orbit, the Mars Science Laboratory Curiosity rover launched in November 2011 completed its journey to Mars and successfully landed in August. The rover landing involved the most complicated set of automated procedures yet devised to place a robotic system on Mars. The results proved a number of novel techniques that will no doubt be used in future missions to other planets, as well as back to Mars. MSL is part of NASA's Mars Exploration Program, a long-term effort for the robotic exploration of Mars, managed by the Jet Propulsion Laboratory of the California Institute of Technology.

Space tethers

The space tethers community continues to prepare several spacecraft for upcoming flights as well as to develop new technologies and applications.

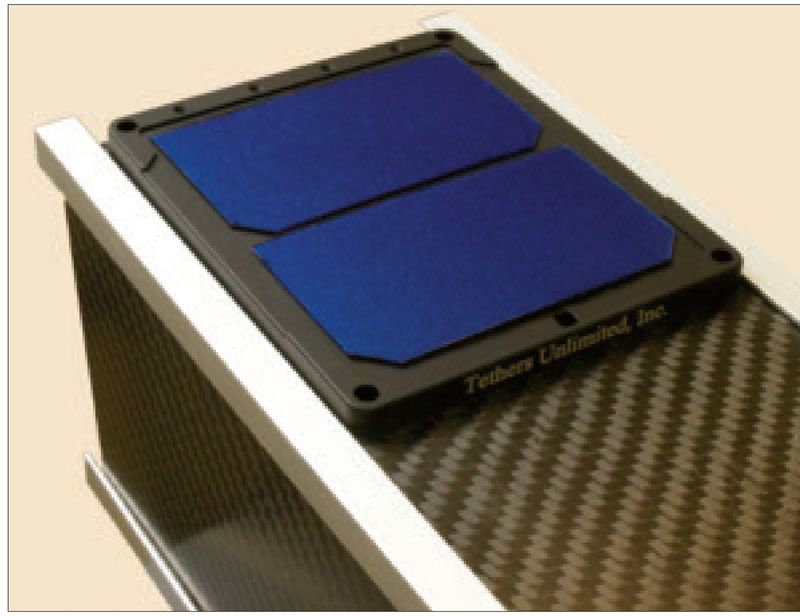
Tethers Unlimited announced the commercial release of their Cubesat tether deorbit module. The compact, lightweight Cubesat Terminator Tape module enables a Cubesat to comply with postmission orbital lifetime requirements with minimal impact to mass, volume, footprint, cost, and risk. The module deploys a 20-m conducting tape, which generates neutral particle drag and passive electrodynamic drag to hasten Cubesat deorbit.

The three-year BETs (bare electrodynamic tethers) project financed by the European Commission under its Seventh Framework program finished its second year of effort. Work on BETs, which focuses on universal design of electrodynamic tether (EDT) systems for deorbiting satellites at end of life, is being carried out by a consortium of universities (Politecnica de Madrid, Padova, Colorado State University), research institutes (ONERA-Toulouse, DLR-Bremen, Fundacion Tecnalia), and a small private Spanish company (emxys).

After completion of design and manufacturing phases for a representative mission involving a 500-kg satellite at 900-km altitude and mid-inclination, work will begin on ground testing of multiple subsystems: deployer, hollow cathode, power control module, and tape tether.

Tether Applications and Star Technology and Research began work in February for NASA's Office of the Chief Technologist on a two-year program to develop hardware for the ElectroDynamic Delivery Express (EDDE) propellantless spacecraft. Electrodynamic propulsion enables EDDE to deliver microsat and nanosat payloads to multiple orbits on a single launch. An 80-100-kg EDDE spacecraft can be packaged as a secondary payload, along with about 100 kg of nanosats such as 6U Cubesats. A follow-on program to build and fly a mini-EDDE vehicle is the next step.

York University, in collaboration with Communication Research Centre Canada, University of Toronto Institutes of Aerospace Studies, and McGill University, is working on mission concepts for the Nanosatellite Electrodynamic Tether Experiment. NETE is comprised of two nanosatellites in LEO linked by a 500-m-long bare EDT in order to demonstrate EDT propulsion technology for space debris removal and spacecraft orbital maneuvers, and to calibrate the coherent backscatter cross section for long-range HF radars and validate theory on electromagnetic radiation from conducting tethers. Such nanosatellite EDT systems can also serve as orbital calibrators for long-range radars. The study has proven that the concept is feasible through rigorous astrodynamical analysis.



Tethers Unlimited's commercially available TerminatorTape module is mounted within the rails of a 3U Cubesat.

Work at Glasgow University has continued on motorized momentum exchange tethers (MMETs), and the orbital mechanics of the dumbbell tether model was reexamined because of anomalies observed during analysis of the motion of an MMET about Earth. Detailed investigation revealed that the resulting motion can be inconsistent with the treatment of the system as a point mass orbiting with the velocity and position of the system's center of mass. For tether lengths ranging up to hundreds of kilometers, the tether's motion can be well approximated by a point mass located at the position of mean potential energy, which they have termed its "center of potential," and the velocity at this point.

An AFOSR-funded team from Penn State, the University of Michigan, and Tethers Unlimited has continued its research on the use of energy-harvesting EDT systems, focusing during the past year on experimental tests of components and geometries that would be relevant to Cubesat- and femtosat-scale EDT systems.

by **Sven G. Bilén**

Space transportation

by **Carl Ehrlich, Doug Zimpfer**, and the **AIAA Space Transportation Technical Committee**

This was a year of transition. NASA retired its iconic and first-of-its-kind space shuttle fleet, leaving the U.S. without a homegrown means to transport astronauts and their cargo to space. But while worldwide launch systems continue to operate with remarkable success, a new generation of U.S. private and public launch systems is on the horizon, with their sights set on both suborbital and orbital space, including providing cargo and crew transportation services to NASA.

As of this writing, there were nine U.S. launches this year. United Launch Alliance Delta IV rockets delivered the WGS 4 satellite for the Air Force and two NRO satellites. ULA Atlas V rockets launched five payloads—AEHF 2, MUOS 1, the RBSP, and two NRO satellites. A Pegasus XL deployed NASA's NuSTAR spacecraft, in its first launch since 2008.

Microsoft cofounder Paul Allen teamed up with pioneer aerospace engineer Burt Rutan on a venture called Stratolaunch Systems. The company plans to launch rockets into space from a carrier plane that would be the biggest aircraft in history, with a wingspan of 385 ft (117 m).

Internationally, Sea Launch carried out two launches for Intelsat, while India and Iran each had one launch.

As of the end of October, there were five Ariane 5 launches; two more are scheduled before year's end. The third ATV carried supplies to the ISS. Vega's maiden flight lofted a LARES payload. Two Soyuz launches are on the manifest in 2012, one carrying two Galileo navigation satellites.

Japan launched its third HTV cargo carrier to the space station and a pair of satellites using its H2A. Russia had eight Soyuz launches; seven Proton launches, of which five were for ILS; and one Rockot launch. Soyuz launches included three Progress cargo deliveries to the ISS and two with ISS crewmembers.

China completed an ambitious schedule this year, with 11 Long March launches. One delivered the Shenzhou 9 spacecraft, a crewed capsule that docked with the orbiting Tiangong 1 laboratory module. Crew and capsule were successfully recovered.

NASA made significant progress in its development of a heavy-lift Space Launch System, completing development and risk reduction tests for Orion Exploration Flight Test 1 and awarding advanced booster demonstration and risk reduction efforts.

The emerging commercial transportation market achieved several milestones toward providing suborbital and orbital services. Under the NASA Commercial Orbital Transportation Services (COTS) program, SpaceX successfully launched its Dragon capsule on a demonstration mission to the ISS. It exchanged cargo, reentered, and was recovered successfully—the first time for a private company. It followed up this success by conducting CRS-1, the first commercial resupply mission to the ISS, using the Falcon 9 and Dragon systems, the first of at least 12 such missions. Orbital Sciences completed development of its Antares launch vehicle and initial Cygnus cargo vehicle, with plans to complete its COTS demonstration mission early in 2013.

NASA awarded Space Act Agreements (SAA) for further development to SpaceX for its Falcon 9/Dragon, Boeing for its CST-100 capsule, and Sierra Nevada for the Dream Chaser lifting body under the Commercial Crew Integrated Capability program. Both CST-100 and Dream Chaser will launch from ULA Atlas rockets. ATK also made progress on its Liberty launch system under an unfunded SAA.

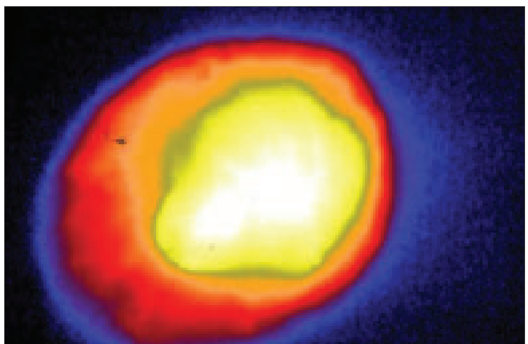
Virgin Galactic hopes to begin rocket-powered testing of SpaceShipTwo by year's end and commercial flights of space tourists in 2013. XCOR announced plans for a Florida operations base. Blue Origin has continued development of New Shepard, conducting successful pad escape and recovery tests of its crew capsule..

Under the NASA Flight Opportunities program, Armadillo, Masten Space, Near Space, UP Aerospace, Virgin Galactic, Wittinghill, and X-COR offer payload opportunities for suborbital missions.

DARPA's Airborne Launch Assist Space Access program awarded launch system development concept contracts to Lockheed Martin, Boeing, and Virgin Galactic for systems capable of delivering 100 lb to LEO for less than $1 million. Microsoft cofounder Paul Allen teamed up with pioneer aerospace engineer Burt Rutan on a venture called Stratolaunch Systems for airlaunch of much larger payloads.

Weapon system effectiveness

Development and testing of U.S. ballistic missile defense capabilities continues. On October 25, 2012, Flight Test Integrated-01 was conducted. Five threats were launched. An extended long-range air-launch target missile was airdropped over the Pacific Ocean north of Wake Island. A short-range ballistic missile was launched from a mobile launch platform located in the ocean northeast of Kwajalein Atoll. Two low-flying cruise missiles were launched, again over water. Finally, a second short-range ballistic missile was launched.



A missile is intercepted during Flight Test Integrated-01. Image courtesy Missile Defense Agency.

A THAAD missile successfully intercepted the first threat, a medium-range ballistic missile. One Patriot PAC-3 intercepted a short-range ballistic missile; a second one intercepted a low-flying cruise missile over water. These constituted three hard intercepts of the five targets. In addition, the USS Fitzgerald successfully engaged a low-flying cruise missile over water, though the warhead was not detonated. The Aegis system also tracked and launched an SM-3 Block 1A interceptor against the final short-range ballistic missile; however, an intercept did not occur. Thus, the test had four successful intercepts of five targets, showing operation integration against multiple targets and target types while employing multiple platforms.

Israel's Iron Dome air-defense system has been recently deployed and used in missile and artillery defense. Iron Dome falls under the heading of a counter rocket, artillery, and mortar (C-RAM) system. Although some in the missile defense community were disappointed that Israel chose to go with a missile system instead of directed energy weapons (which had shown considerable promise and undergone extensive development), the design was begun in 2006 and was first deployed in 2011. The system was developed by Israel with support from the U.S.

The focus of the system is on short-range defense against rockets and 155-mm shells. It uses coordinated radar systems for identifying threats and employs a proximity-fuzed warhead. Design specifications include all weather conditions and ranges up to 70 km. According to news reports, in March the Iron Dome system was used against 71 rockets fired against civilian centers, intercepting 56.

Complicated electromechanical systems, such as weapon systems, are continually getting more expensive and taking more time to design and build. DARPA has an ambitious program to reduce by a factor of five the time it takes a military ground vehicle to go from concept to production. An important part of this Adaptive Vehicle Make (AVM) program is accurate modeling of vehicle systems' behaviors, with the goal that the vehicle be "correct by construction." This includes survivability context models for ballistic and blast protection, where there is considerable focus on both answer accuracy and uncertainty. The models are all undergoing an extensive verification and validation process. Each model is undergoing uncertainty qualification.

AVM includes collaborative design challenges as part of the effort to revolutionize the design and manufacturing process for complex defense systems. As described at vehicleFORGE.org, DARPA has sponsored the creation of new product development tools and processes intended to enable the development of complex defense systems faster than ever before. The ultimate test of these tools and processes will be their deployment within a series of prize-based design competitions for a new heavy, amphibious infantry fighting vehicle (IFV) referred to as FANG—the fast, adaptable, next-generation ground vehicle. There will be three FANG challenges, each focusing on progressively more complex vehicle subsystems, culminating in the design of a complete IFV. They are mobility/drivetrain, chassis/structural, and full vehicle. The first two design challenges have prizes up to $1 million and the third up to $2 million. The AVM project is in its third year; the first FANG challenge begins in January 2013.

by **James D. Walker**

Directed energy systems

NASA continued to sponsor and conduct research into the nonweapons aspects of directed energy systems involving beamed energy propulsion and beamed energy power transmission. In late 2011 the agency awarded approximately $3 million in contracts to multiple companies for the first phase of its Ride the Light project under NASA's Game Changing Technology Development program. Under NASA's program, LaserMotive, partnered with Lockheed Martin, demonstrated the first-ever outdoor flight tests of an unmanned aircraft system (UAS) powered by laser power beaming. Announced in August, these flight tests of the Stalker UAS further validated the performance of a ground-based solid-state laser and beam control system and demonstrated that the laser-powered Stalker could perform well in a near-operational environment, flying during both day and night without incident. Stalker is a small, silent UAS used by special operations forces since 2006 to perform intelligence, surveillance, and reconnaissance missions.

Stalker flight tests validated the performance of a ground-based solid-state laser and beam control system.

In earlier wind tunnel tests, the Stalker demonstrated 48 hours of continuous flight powered by this innovative laser system. For the demonstration, the UAS was fitted with a lightweight photovoltaic receiver and onboard power management hardware. The ground-based laser transmitter was based on the hardware LaserMotive had developed for its winning entry in the 2009 NASA Centennial Challenge.

Accomplishments of these proof-of-concept flights include demonstration of net positive power to Stalker in flight, at ranges up to 600 m; proof that the laser did not damage the Stalker and that the addition of the laser receiver did not impact its normal flight operations or aerodynamics; operation of multiple test flights in a range of desert conditions (day and night, high temperatures, strong winds); demonstration of the ruggedness of the Stalker-mounted laser receiver power system; beam director tracking of the receiver for long periods, with centimeter accuracy at 500 m, despite turbulence and aircraft maneuvers; and coordination with the Laser Clearinghouse and FAA flight operations centers to meet all operational and safety requirements.

Directed energy weapon system development saw a continuing shift of emphasis toward tactical systems in Dept. of Defense programs, as in previous years. The Airborne Laser Testbed platform was retired in February and made its last flight on February 14 to the USAF Aircraft Maintenance and Regeneration Center at Davis-Monthan AFB, Arizona.

In response to congressional interest, including language in the Senate Appropriations bill, the Navy's pursuit of developing a "broader affordable strategy on laser systems" focused on maturation of solid-state laser technology for tactical shipboard deployments, through research sponsored by the Office of Naval Research. Tactical laser weapon systems are of interest to the Army and Navy because they reduce the use of costly missiles and hit targets almost instantaneously. Only recently have solid-state lasers reached strengths of hundreds of kilowatts of power—enough to destroy a vehicle or negate an incoming warhead. The solid-state laser weapon system the Navy envisions could be installed on combatant-class ships of all sizes.

The Air Force Research Laboratory continued with progress and testing of its Boeing/Raytheon Ktech radio frequency high-power microwave demonstration project, CHAMP (counter-electronics HPM advanced missile project). Testing of the Army high-energy laser mobile demonstrator (HEL-MD) continued at the White Sands Missile Range, and the Army sought sources for a 100-kW-class laser to be integrated with the HEL-MD. The High Energy Laser Joint Technology Office continued its robust electric laser initiative developments with different approaches and concepts from Lockheed/Acculight, Raytheon, Northrop Grumman, General Atomics, and Boeing; 25-kW demonstrations are due by year's end.

by **James A. Horkovich**

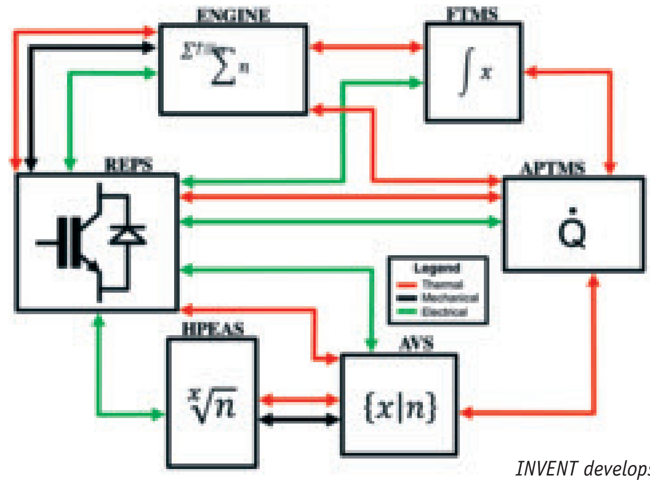
Energy optimized aircraft and equipment systems

The Air Force Research Laboratory's integrated vehicle energy technology (INVENT) program is an effort conducted under the triservice energy optimized aircraft (EOA) initiative. The EOA initiative focuses on developing an integrated suite of adaptive, smart aircraft systems and model-based design tools, along with platform-level energy optimization. These are aimed at achieving performance goals and objectives that will improve mission capability, affordability, and energy efficiency for next-generation energy optimized aircraft.

The EOA emphasizes vehicle and engine integration to address future challenges arising from the dynamic interfaces of adaptive cycle engines and aircraft power and thermal management subsystems. EOA systems are adaptive in that they operate on demand, running only when needed, at variable speeds and power levels. Thus they efficiently deliver required mission capability by actively selecting the optimal power sources, heat sinks, and so on. EOA systems are also smart, using adaptive controls that facilitate platform level power generation, distribution, energy storage, and thermal management.

The EOA initiative provides benefits in three primary areas: performance, energy, and acquisition. Removing thermal restrictions has improved performance and enabled full mission capability. Energy optimized architectures contribute to reduced fuel consumption as well as enhanced mission capability. Model-based design reduces aircraft acquisition time and cost by improving architecture design decisions early in the systems engineering process.

One key technology to consider is the high-power, high-speed solid-state silicon carbide electrical power distribution that replaces today's mechanical- and silicon-based approaches, to isolate faults prior to catastrophic consequences. These new distribution networks also incorporate built-in prognostics that holistically monitor the power system instead of waiting for a failure. This makes it possible to predict and fix impending faults. Other key technologies include electrical accumulators for transient/regenerative energy management, wide temperature electric actuation for primary flight control and engine actuation, and adaptive power and thermal management systems that eliminate aircraft-level thermal constraints.



INVENT develops adaptive, smart aircraft power and thermal management systems to improve performance, reduce energy consumption, and improve affordability.

The current emphasis of the INVENT effort is on developing modeling and simulation toolsets to enable rapid model-based design and platform-level energy optimization. These design tools and energy optimization processes apply systems engineering principles for iterative, rapid conceptual design evaluation. These methodologies incorporate verified, multifidelity models and are validated through integrated ground demonstration and hardware-in-the-loop simulation.

Standardized modeling practices to address model interaction and fidelity are documented in the program's publicly available model requirements and implementation plan.

INVENT recently completed preliminary integrated subsystem design of a future Air Dominance Concept vehicle with prime contractor Boeing and major subcontractors General Electric and Rolls-Royce Liberty Works. This effort focuses on design, modeling, simulation, risk mitigation, and validation through an integrated ground demonstration of key power and thermal management aircraft systems. The design results indicate that benefits are achievable in the three areas of performance, energy, and design time.

Complementary studies were also conducted with Northrop Grumman and Lockheed Martin for subsonic long-range strike and mobility platforms. In the coming year INVENT will conduct final design and begin fabrication of the critical technology concepts. Subsystem testing will begin in two years and will be followed by integrated system-level testing.

by **Andrew J. Fleming**

Gossamer systems

This was a productive year for the gossamer spacecraft community, with exciting developments ranging from mission design and fundamental research to fabrication of hardware.

Deorbitsail is a Cubesat mission that will develop an aerodynamic drag-inducing gossamer sail system for deorbiting satellites at end-of-life. For missions having deorbiting time constraints of 25 years, this device is predicted to be effective at altitudes lower than 1,000 km for minisatellites (20-500 kg). The project is a pathfinder mission that seeks to create options for deorbiting satellites and to advocate for solar sail propulsion. The sail itself will be deployed from a standard 10x10x30-cm, three-axis-controlled Cubesat platform that will rely on the stored strain energy of coiled booms for deployment. After a design review earlier this year, the Deorbitsail booms and deployment system are being built for testing by year's end. The project is funded by the EU's Framework 7 program, a project with 10 partners from Europe and the U.S. led by the University of Surrey in the U.K. (see www.deorbitsail.com). This program builds on the successful NanoSail-D drag sail mission launched by NASA in November 2010.

JWST's first sunshade undergoes initial inspection prior to testing.

In an artist's depiction, the Sunjammer sets sail toward Lagrange Point 1.

The deployable structures team in the Space Vehicles Directorate of the Air Force Research Laboratory spent the past year conducting research in the area of thin foldable elastic composite structures. A novel pure moment-curvature flexure testing apparatus that does not use surface strain gauging was devised to characterize bending stiffness and failure strain of typical high-strength carbon and glass composite materials. This testing led to the discovery that thin flexural-loaded unidirectional composites fail at higher strains than would be expected from standard tension test regimes. To test the practical feasibility of using these materials as foldable primary structures in space, four separate prototypes were prepared; three of these are planned space-based experiments, among them a Cubesat diffractive telescope support structure that was assembled using carbon composite rollable tape elements.

In response to a technology demonstration mission call from NASA's Office of the Chief Technologist, L'Garde proposed an ambitious solar sail flight that will demonstrate the usefulness of such sails for future missions. L'Garde, with its partners the National Oceanic and Atmospheric Administration and Space Services Holdings, will develop a 1,200-m^2 solar sail with an anticipated launch date in the fourth quarter of 2014, and will subsequently fly it to a sub-L1 location. The preliminary design of Sunjammer (the sailcraft is named after a short story by Arthur C. Clarke) calls for it to be boosted to geostationary transfer orbit as a secondary payload. Once Sunjammer is released from the booster vehicle, it will perform a propulsive burn and boost itself to an Earth escape orbit. Upon reaching this trajectory, the sail will be deployed and the demonstration mission will begin (see http://www.lgarde.com/programs/space-propulsion/sunjammer/).

This year, testing of the full-sized James Webb Space Telescope sunshield has begun. The five Webb sunshield layers, each the size of a tennis court, are made of specialized Kapton material, a very thin high-performance polymer with a reflective metallic coating. Once they are tensioned, the relative separations and alignments of each of the five membrane layers are critical to achieving the desired cryogenic operating temperature of the telescope and instruments. After all five layers of the full-sized sunshield complete test and model analysis, they will be sent to Northrop Grumman's high bay in Redondo Beach, California, for tests characterizing how the sunshield deploys from its folded shape in the launch vehicle (see www.jwst.nasa.gov).

by **Gregory L. Davis, Vaios Lappas, Nathan C. Barnes, James D. Moore,** and **Jeremy A. Banik**

Hypersonic technologies and aerospace planes

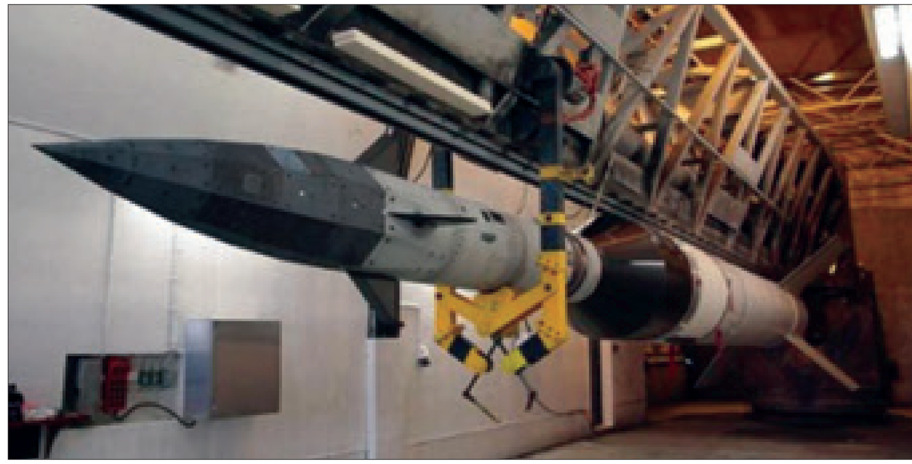
The Air Force's second X-37B orbital test vehicle (OTV-2) landed after 469 days in space, more than double the time clocked by the OTV-1. The Boeing-built, 29-ft-long, small-winged OTV-2 conducted on-orbit experiments while in space. It touched down at Vandenberg AFB, California, at 5:48 a.m. PDT on June 16, marking the end of a 15-month mission.

HIFiRE-5 (hypersonic international flight research experimentation 5) was flown from the Andøya Rocket Range in Norway on April 23 using a two-stage booster stack consisting of a Brazilian S-30 first stage and an improved Orion second stage. The primary objective of HIFiRE-5 was to measure boundary-layer transition on an elliptic cone as a means of investigating the effects of 3D flow on transition in flight. Unfortunately, the second stage of HIFiRE-5 failed to ignite. However, 200 sec of high-fidelity supersonic data were gathered, and boundary-layer transition was observed.

IRVE-3 (inflatable reentry vehicle experiment 3), an inflatable heat shield that could be used to protect spacecraft entering a planet's atmosphere or returning to Earth, was launched from NASA's Wallops Flight Facility. The technology demonstrator successfully inflated and fell into the Atlantic about 100 mi. East of Cape Hatteras, North Carolina.

A third flight test of the X-51A Waverider, an experimental unmanned vehicle designed to fly at hypersonic speeds, ended in failure, according to the Air Force. The aircraft was dropped from a B-52 bomber and launched by a rocket booster as planned, but the flight was over in seconds after a control fin malfunctioned, said the USAF statement. The faulty control fin meant that the vehicle's flight ended before a specially designed scramjet engine could be ignited.

Reaction Engines in the U.K. has successfully demonstrated a range of technologies for the Mach 0-25-capable SABRE (synergetic air-breathing rocket engine). The effort is part of a program designed to elevate the engine's technology readiness levels to 4-5. The program's main focus has been the testing of a SABRE air precooler in a working environment. According to an ESA statement, the agency is "confident that a ground test of a subscale engine can be successfully performed," and will be "a major breakthrough in propulsion worldwide."



SHEFEX II enabled researchers to collect data during flight for the first time. That flight lasted 10 min and the craft reentered at Mach 7. It reached a speed of 11,000 km/hr as it reentered the atmosphere. It attained an altitude of approximately 180 km.

DLR launched the SHEFEX II (sharp-edge flight experiment II) reentry vehicle and its payload from the Andøya Rocket Range on June 22. As the 7-ton, roughly 13-m-long experimental rocket reentered the atmosphere, it withstood temperatures exceeding 2,500 C and sent measurement data from over 300 sensors to a ground station. SHEFEX is angular and sharp-edged; its structure consists of planar surfaces, which are aerodynamically advantageous. DLR researchers have developed various thermal protection systems to withstand the high temperatures that the edges encounter during reentry.

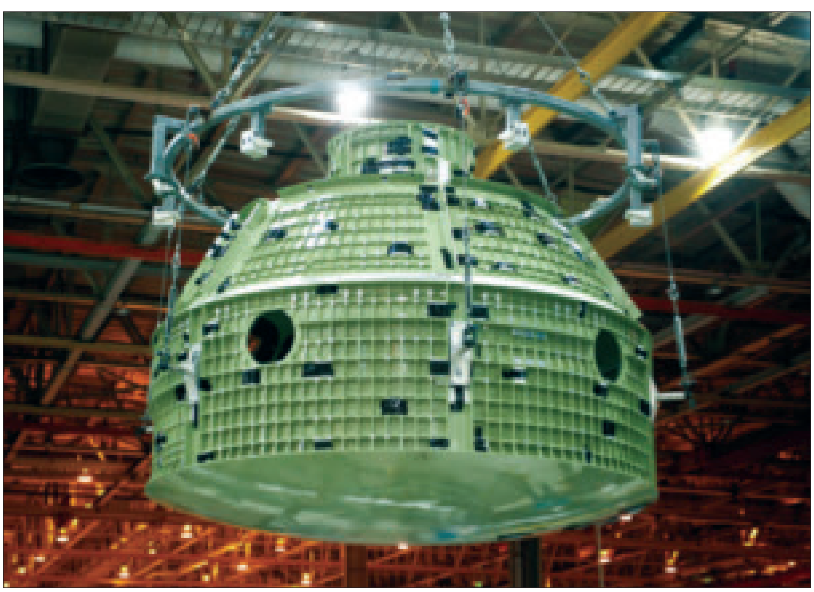
As part of an unmanned space vehicle project, a recent agreement between JAXA and ASI with support from the Italian Aerospace Research Center has provided the framework for a joint binational investigation of advanced concepts for unmanned reentry vehicles. The aerospace vehicle features a winged body, a landing gear suitable for conventional runway landing, an autonomous guidance, navigation, and control system using low-cost avionics, and an advanced thermal protection system. The current mission scenario is based on the use of the Vega launcher and a landing on Christmas Island after orbital activity.

The 14-X hypersonic aerospace vehicle is part of the continuing effort of the Brazilian Dept. of Aerospace Science and Technology to design, develop, manufacture, and demonstrate, in free flight, a technology demonstrator using 'waverider' technology to provide lift to the aerospace vehicle, and scramjet technology to provide a hypersonic air-breathing propulsion system based on supersonic combustion.

by **Carl Ehrlich**
and the **AIAA Hypersonic Technologies and Aerospace Planes Program Committee**

Space exploration

This year NASA's strategy of stimulating the development of commercial capabilities to launch crew and cargo to the ISS began to pay off. In May, the SpaceX Dragon capsule became the first commercial spacecraft to visit the ISS and return safely to Earth. Dragon's first ISS cargo resupply mission followed in October. Building on this success, NASA's Commercial Crew Program chose Boeing, SpaceX, and Sierra Nevada to develop integrated crew transportation systems under a third round of funded Space Act agreements. NASA also initiated processes for certifying that commercial crew launch systems meet the safety standards for human spaceflight.



The primary structure of the first Orion multipurpose crew vehicle was fabricated and delivered to Kennedy Space Center.

Progress continued in the development of transportation systems for exploration beyond Earth orbit. The primary structure of the first Orion multipurpose crew vehicle was fabricated and delivered to NASA Kennedy, where it is being prepared for the Exploration Flight Test-1 mission in 2014. Orion will be launched on a Delta IV rocket and will orbit the Earth twice before reentering. Tests of the heat shield and the parachute recovery system are the main objectives of this first flight.

In July, the Space Launch System (SLS) passed a major milestone with the completion of its system requirements and system definition reviews. The program is proceeding with the preliminary design of the Block 1 version of SLS that will be capable of lofting a payload of 70 metric tons. Six industry proposals were selected for early risk reduction activities to enable future development of advanced boosters with increased performance. Ground systems to support launches of SLS and Orion are being refurbished at Kennedy Space Center. Shuttle hardware was removed from Pad 39-B and lightning towers were erected. The crawler-transporter is being upgraded to carry the heavier SLS stack.

The first SLS launch, without crew, is planned for 2017, followed by the first crewed mission in 2021. NASA is considering the possibility of sending the SLS test flights to the Earth-Moon L2 point using the Moon for gravity assist. These flights could enable a future crew-tended habitat at L2 that would be a waypoint to more distant destinations.

When the Mars Science Laboratory arrived on Mars on August 6, it carried two payloads to gather crucial information needed for the design of future human missions. The MSL entry, descent, and landing instrumentation (MEDLI) experiment measured the temperatures, pressures, and material ablation rates at various points on the heat shield during Mars atmospheric entry. The engineering data acquired by MEDLI will be used to improve analytical models that predict aerodynamics and thermal protection system performance. The radiation assessment detector (RAD) on the Curiosity rover is characterizing the Mars surface radiation environment to increase understanding of the risks to human health. RAD also detected several major solar particle events during MSL's cruise to Mars.

Advanced exploration systems development included the NASA extreme environments mission operations underwater test to simulate human exploration of a low-gravity asteroid; demonstration of a prototype in-situ resource utilization experiment that will prospect for lunar ice; tethered flight tests of the Morpheus lander with an autonomous precision landing and hazard avoidance system; and imaging of 16 near-Earth asteroids with the Goldstone radar to identify potential targets for missions.

Finally, we honor the memories of two space explorers who achieved historic firsts: Sally Ride, the first American woman to orbit the Earth, and Neil Armstrong, the first person to walk on the Moon. We will follow in their heroic footsteps as we strive to push the frontiers of human exploration ever deeper into space.

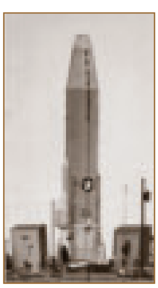
by **Chris Moore**

Out of the

25 Years Ago, December 1987

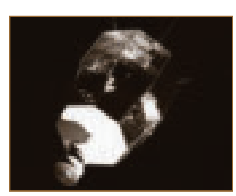
Dec. 11 NASA Ames in Mountain View, Calif., begins operation of the world's largest wind tunnels at the National Full-Scale Aerodynamics Complex. A 40x80-ft tunnel and an 80x120-ft open-circuit tunnel will be used to test full-scale aircraft and large-scale models, particularly V/STOL designs. NASA, *Astronautics and Aeronautics, 1986-1990*, p. 141.

Dec. 21 Soyuz TM-4, carrying cosmonauts Vladimir Titov, Musakhi Manarov, and Anatoly Levchenko, is launched successfully from Baikonur Space Center in Soviet Central Asia. They plan to rendezvous with the orbiting Mir space station on December 23 and relieve Yuri Romanenko, who has been in space for 326 days. The replacement crew will stay a full year if all goes according to plan. Romanenko and Levchenko return on December 29. NASA, *Astronautics and Aeronautics, 1986-1990*, pp. 142-3.



50 Years Ago, December 1962

Dec. 5 The Atlas-F missile flight test program ends with the last of 153 launches from Cape Canaveral, Fla., and a landing 5,000 mi. away in a target area near Ascension Island. Of these launches, 87 were R&D missions, with 59 successful and 20 partly successful; the remainder were failures. D. Daso, *U.S. Air Force: A Complete History*, p. 431; *Aviation Week*, Dec. 10, 1962, p. 37; *Missiles and Rockets*, Dec. 10, 1962, p. 12.

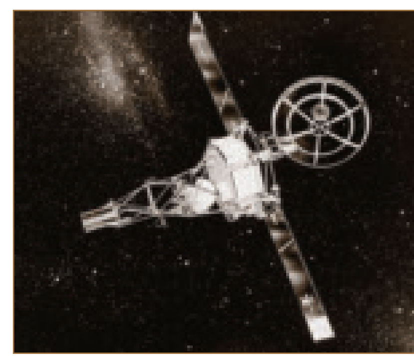


Dec. 11 Relay 1, a NASA experimental communication satellite built by RCA, is launched by a Delta B rocket from Cape Canaveral and later provides the first television transmissions across the Pacific Ocean, from the U.S. to Japan. It is also designed as the first active repeater satellite to link three continents—North America, South America, and Europe. Relay thus makes important steps toward global communications. Its payload includes radiation experiments to map the Earth's radiation belts. *Flight International*, Dec. 20, 1962, pp. 990-991.

Dec. 13-14 Project Stargazer, for providing the clearest view of the stars up to this time, begins with the launch of a special stratospheric balloon piloted by Air Force Capt. Joseph A. Kittinger and assisted by Navy civilian astronomer William C. White. The balloon, sent up from southwestern New Mexico, carries a telescope and reaches 82,000 ft, where it conducts observations for more than 18 hr. D. Daso, *U.S. Air Force: A Complete History*, p. 431.

Dec. 14 The Mariner 2 spacecraft flies by Venus at 21,994 mi., or within 400 mi. of the predicted distance, and returns "exceptionally high quality telemetry data." This is the first closeup of another planet and provides the first close measurements of the environment around Venus, including its atmospheric temperature. *Aviation Week*, Dec. 24, 1962, p. 16.

Dec. 16 The Explorer 16 micrometeoroid satellite is launched from NASA's Wallops Island site by an all-solid-fuel four-stage Scout launch vehicle. The 222.2-lb satellite is designed to obtain data on the hazards of cosmic dust. *Aviation Week*, Dec. 24, 1962, p. 123.



Dec. 31 DOD announces cancellation of Skybolt, an air-launched two-stage solid-propellant ballistic missile with nuclear warheads. The missile was designed to be launched from B-52s. A series of test failures, along with progress in the development of SLBMs, led to the cancellation. *Aviation Week*, Jan. 7, 1963, p. 29.

Dec. 31 President John F. Kennedy names Theodore von Kármán, the famed Hungarian-born aerodynamicist, as the first recipient of the National Medal of Science for leadership in the science and engineering of aeronautics.

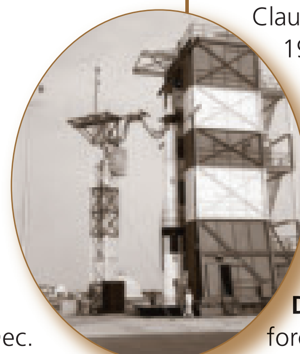
Beginning in 1936, von Kármán led a rocket research development that led to the creation of JPL, just

Past

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

one of his many accomplishments. NASA, *Astronautical and Aeronautical Events of 1962*, p. 282.

And During December 1962



—The Minuteman all-solid-fuel ICBM becomes operational, along with the 10th Strategic Missile Wing at Malmstrom AFB in Great Falls, Montana. The occasion is marked by formal ceremonies. *Missiles and Rockets*, Dec. 17, 1962, p. 14.

75 Years Ago, December 1937

Dec. 2 An RAF reconnaissance squadron of five Saro London flying boats flies to Australia from Plymouth, England, to help celebrate the 150th anniversary of New South Wales. *The Aeroplane*, Dec. 8, 1937, p. 696.

Dec. 3-27 Capt. J.W. Burgess pilots Imperial Airways' first flying-boat survey flight from Britain to Australia and New Zealand, using a Short C-class Centaurus equipped with extra fuel tanks. *The Aeroplane*, Dec. 8, 1937, p. 710.

Dec. 8 Consolidated Aircraft of San Diego unveils its new XPB2Y-1 four-engined patrol bomber flying boat. In service with the Navy during WW II, the aircraft is known as the Coronado. *Aviation*, January 1938, p. 31.

Dec. 10 Germany's air minister, Hermann Goering, appoints a committee of 23 of the leading men in German aviation to act as 'defense industry leaders,' including Claude Dornier, Ernst Heinkel, and Willie Messerschmitt. *The Aeroplane*, Dec. 29, 1937, p. 803.

Dec. 14 Germany's Bayer chemical company, which produces medicines, sends its new 'medicine special,' a trimotored Junkers Ju 52, on its first visit to England. The aircraft carries more than a ton of the firm's 250 medicinal products and a large contingent of Bayer officials, including the general manager. *The Aeroplane*, Dec. 22, 1937, p. 791.

Dec. 24 A prototype of the Macchi C.200 Saetta (Lightning), the Italian air force's first monoplane fighter with fully enclosed cockpit and retractable landing gear, makes its maiden flight. It was designed by Mario Castoldi, who attained fame designing several successful floatplanes for the Schneider Trophy competition. W. Green, *War Planes of the Second World War, Vol. 2*, p. 157.

Dec. 27 Pan American Airways' Sikorsky S-42B Samoa Clipper flying boat and the British Short Brothers Empire flying boat Centaurus of Imperial Airways are moored alongside each other for the first time at Auckland, N.Z. On December 29 the Clipper will start its return flight to Honolulu, thus opening the U.S.-New Zealand route after a year's preparation. *Interavia*, Jan. 3, 1938, p. 10.

Dec. 28 President Franklin Roosevelt proposes an increase in the defense budget with an eye toward expansion of the naval air arm, in consideration of Japanese military activities in the Far East. The Army Air Corps has a total of 1,352 planes, a number that will be increased to 2,320 by 1940. *Interavia*, Jan. 3, 1938, p. 14.

And During December 1937

—Navy Midshipman Robert C. Truax begins his initial static rocket thrust tests, using compressed air and gasoline. The chamber is partly water cooled. Thrusts of about 10-25 lb are obtained. E. Emme, ed., *Aeronautics & Astronautics 1915-60,* p. 35; R. Truax memoir paper, *Smithsonian Annals of Flight No. 10*, pp. 295-298.

100 Years Ago, December 1912

Dec. 5 From France, Jacques Schneider declares his intention to promote seaplanes through an international air race competition. The Schneider trophy competition becomes the most significant air race for almost two decades, spurring the development of radical new designs and technologies in airframes, powerplants, and fuels. D. James, *Schneider Trophy Aircraft, 1913-1931,* pp. 9-14.

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University of Windsor

The University of Windsor MAME Department is seeking applications for two tenure-track faculty positions at the level of Assistant Professor in a newly established program in Aerospace Engineering. The successful candidates are expected to engage in establishing and leading an exciting and innovative undergraduate program in Aerospace Engineering along the following themes 1) airplanes and related systems repair and maintenance, 2) aerospace composite materials and manufacturing, 3) control and dynamics of aerospace systems. In particular, consideration will be given to applicants with teaching experience and research expertise in areas including but not limited to Aerospace Engineering Fundamentals, Flightworthiness, and Aerospace Controls and Avionics. Concurrently, we are interested in candidates whose research interest is aligned with one or more of the above specified teaching themes. It is expected that the successful candidates will establish a dynamic externally funded research program that complements existing Mechanical and Materials Graduate programs, offer graduate courses, supervise graduate students and engage in department and university service activities. Applicants must have a doctoral degree, preferably from an aerospace engineering department and must have or be eligible for PEng licensure. The selection will be primarily based on the applicants' potential for excellence in teaching and research. For further details about the job description review our website at http://www.uwindsor.ca/facultypositions. Contact: Professor A. Sobiesiak (asobies@uwindsor.ca), Head, Department of Mechanical, Automotive and Materials Engineering, University of Windsor, 401 Sunset Ave, Windsor, Ontario, Canada N9B 3P4.

Faculty Position in Computational Combustion: Mechanical and Aerospace Engineering The Ohio State University

THE OHIO STATE UNIVERSITY

The Department of Mechanical and Aerospace Engineering at The Ohio State University invites applications from outstanding individuals for a tenure-track faculty position at the junior level in the area of computational combustion. The successful candidate may have specialization in one or more of the following areas: direct numerical simulation or large-eddy simulation of turbulent combustion; application of modeling approaches (e.g., large-eddy simulation and/or RANS-based approaches) to complex engineering problems including power-generation or propulsion systems; multi-phase reactive flows including spray combustion; combustion instability; advanced/alternative fuels and chemical kinetics. Outstanding candidates with expertise in other aspects of combustion also will be considered. The successful applicant for the faculty position will complement and augment our significant strengths in the areas of energy, fluid, and thermal sciences, which include research expertise in turbulence and turbulent combustion, chemical kinetics, heat transfer, plasma-assisted combustion, high-speed flows and propulsion, plasma physics, fuel cells, flow control, aero-optics, microfluidics and micro-scale power generation, and gas turbine research. The Department of Mechanical and Aerospace Engineering is housed within Scott Laboratory, a new 240,000 ft2 complex equipped with modern teaching and research resources, including state-of-the art computing facilities and access to the Ohio Supercomputer Center.

Qualifications:
Candidates must have earned a doctoral degree in mechanical engineering, aerospace engineering, or in a closely related field by the start date. The new faculty member will be expected to teach core undergraduate and graduate courses in his/her discipline, develop new graduate courses related to his/her research expertise, develop and sustain active sponsored research programs, and become a recognized leader in his/her research field. The anticipated start date is fall 2013 or earlier. Screening of applicants will begin immediately and continue until the position is filled. Interested candidates should upload complete curriculum vitae, statements of research and teaching goals, and the names, address, and e-mail addresses of four references. The website link is http://www.mecheng.osu.edu/faculty_positions. In addition, a copy of the application materials should be emailed to Professor Jeffrey A. Sutton at sutton.235@osu.edu. To build a diverse workforce Ohio State encourages applications from individuals with disabilities, minorities, veterans, and women. Ohio State is an EEO/AA Employer. Columbus is a thriving metropolitan community, and the University is responsive to the needs of dual career couples.

For more information about the Department of Mechanical and Aerospace Engineering at OSU, please visit http://mae.osu.edu/.

FACULTY POSITION IN AERONAUTICS DEPARTMENT OF MECHANICAL ENGINEERING McGill University

The Department of Mechanical Engineering at McGill University invites applications for a tenure-track position in Aeronautics, particularly from persons in the areas of aerodynamics and aeroelasticity. The position is expected to be filled at the Assistant Professor level, although exceptional applications may be considered at the Associate Professor level.

McGill University is a research intensive academic institution, attracting over one-half billion dollars in competitive research funding each year and consistently ranked in the top 25 worldwide. The Department of Mechanical Engineering is particularly strong in the areas of experimental and computational fluid dynamics, fluid-structure interaction, materials engineering, robotics, shock wave physics, and MEMS. The successful candidate will be expected to eventually play a major role in maintaining and enhancing our international reputation of excellence in research and teaching.

Applicants must have a Ph.D., preferably with a first degree in Mechanical or Aerospace Engineering, and a strong commitment to excellence in research and teaching. Evidence of outstanding research achievements, or research potential, is indispensable. Membership or eligibility for membership in a Canadian professional engineering association is required.

All qualified applicants are encouraged to apply; however, Canadians and permanent residents will be given priority. McGill University is committed to equity in employment and diversity. It welcomes applications from indigenous peoples, visible minorities, ethnic minorities, persons with disabilities, women, persons of minority sexual orientations and gender identities and others who may contribute to further diversification.

Applications will be reviewed as they are received, but must be received by January 15, 2013 in order to be considered. The position is expected to be filled by August 1, 2013. Applications must include a resume, a two-page statement of teaching and research interests, names and contact information (mail, phone, and email) of three referees, and copies of 3-5 most relevant publications. Please reference the source of the ad when applying for, or enquiring about, this position. Qualified candidates should submit applications to:

Professor Meyer Nahon
Chair, Departmental Search Committee
Department of Mechanical Engineering
McGill University
817 Sherbrooke Street West
Montreal, Quebec, H3A 2K6 Canada
E-mail (preferred): Facultysearch.mecheng@mcgill.ca
Web site: http://www.mcgill.ca/mecheng/

Tenured Faculty Position No. (52181)
Department of Mechanical Engineering
Southern Methodist University

SOUTHERN METHODIST UNIVERSITY, Bobby B. Lyle School of Engineering invites nominations and applications for the position of Professor and Chair of Mechanical Engineering Department (Position No. 52181). The successful candidate will be an educator and a recognized scholar with distinguished accomplishments in both engineering education and scientific research demonstrated by a strong record of external funding and publication. The candidate is expected to be the intellectual leader of the Mechanical Engineering Department with strong interest in educational programs at the BS, MS and PhD levels and develop a world renowned interdisciplinary research program synergistic with the ongoing research in the Department and the Lyle School of Engineering. He/she will possess strong administrative skills and will be an outstanding communicator representing the Mechanical Engineering Department and the Lyle School on- and off-campus. The anticipated starting date is August 2013. Candidates must have a Ph.D. degree in mechanical engineering or a closely related field and must be qualified for a tenured appointment at the full Professor level.

With over 10,000 students, SMU is a leading private University located in the Dallas-Fort Worth Metroplex, a dynamic region with leading high-technology companies in the aerospace, defense, energy, information technology, life sciences, semiconductors, telecommunications, transportation, and biomedical industries. Some of the top companies include Texas Instruments, Raytheon, Bell Helicopter, Lockheed-Martin, Turner Construction, Trinity Industries, Baylor Research Institute and University of Texas Southwestern Medical Center.

The Mechanical Engineering Department resides within the Lyle School of Engineering and is located in the Embrey Engineering Building, a LEED Gold designed facility. The Department offers B.S., M.S., and Ph.D. degrees in mechanical engineering and is home to the Research Center for Advanced Manufacturing, the NSF Industry/University Cooperative Research Center for Lasers and Plasmas for Advanced Manufacturing. It is also the home of several other research laboratories in the areas of mechanics of materials; dynamics, systems and controls; porous materials applications; nanoscale electro-thermal sciences; opto-electronics packaging; laser micromachining; micro-optical sensor technology and experimental fluid mechanics (http://www.lyle.smu.edu/me/).

Applications received by January 15, 2013 will be given full consideration but the search committee will continue to accept applications until the position is filled. The applicants should send, a cover letter, curriculum vitae, list of five references and a statement of interest and capabilities related to academic leadership, education and research to MEChair@lyle.smu.edu. SMU will not discriminate on the basis of race, color, religion, national origin, sex, age, disability, or veteran status. SMU is committed to nondiscrimination on the basis of sexual orientation. Hiring is contingent upon the satisfactory completion of a background check.

THE DEPARTMENT OF AEROSPACE ENGINEERING & ENGINEERING MECHANICS AT THE UNIVERSITY OF TEXAS AT AUSTIN is hiring a tenure-track position at the rank of Assistant Professor in the area of Computational Mechanics. The expected start date for the position is September 2013.

We are looking for exceptional candidates doing multi-disciplinary research in computational mechanics; however, particularly strong candidates working in broader areas of computational engineering and science will be considered. Candidates working in emerging areas are of particular interest and so a statement of the growth potential of the candidate's research area should be included in the research statement. Possible application areas include, but are not limited to, solid mechanics, nanotechnology, fluid mechanics, biomedicine, energy and geophysics.

The successful candidate for this position is 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, 2012** are assured full consideration, but the search will continue until the position is filled. To apply submit an application online at **http://www.ae.utexas.edu/faculty/faculty-openings** Only complete applications will be considered. Applicants for this position should have received, or expect to receive a doctoral degree prior to September 2013.

For more information about The Department of Aerospace Engineering and Engineering Mechanics, please visit **http://www.ae.utexas.edu**.

WHAT STARTS HERE CHANGES THE WORLD

The University of Texas at Austin is an affirmative action, equal opportunity employer. This position has been designated as security-sensitive, and a criminal background check will be conducted on the applicants selected.

Faculty Position Aeronautical Engineering: Rotary Wing and Vertical Takeoff and Landing (RW/VTOL)
UNITED STATES NAVAL ACADEMY

The Aerospace Engineering Department seeks candidates for a tenure-track faculty position starting in August 2013. Appointments at all ranks will be considered, but the preference is for junior faculty at the rank of Assistant Professor. The department is expanding its undergraduate rotary wing/vertical take-off and landing (RW/VTOL) curriculum and related research program and is seeking faculty with RW/VTOL expertise. Candidates must have an earned doctorate in aeronautical engineering (or related field) with a concentration in rotary-wing aircraft. Experience in aeromechanics, aircraft structures, and aircraft propulsion is preferred; exceptional candidates with experience in related fields will be considered. Industry experience in rotorcraft design is desired but not required.

Successful candidates will participate in all aspects of the department's mission. The candidate is expected to develop and teach undergraduate level courses including helicopter performance, stability and control, and design (to include RW/VTOL design-build capstone projects). For a complete position description and instructions visit http://www.usna.edu/JobInfo. For further information contact Scott Davids at 410-293-6412 or davids@usna.edu

Candidates are encouraged to submit promptly. Review of applications will commence in February 2013 and will continue until the position is filled.

The United States Naval Academy does not discriminate in employment on the basis of race, color, religion, sex (including pregnancy and gender identity), national origin, political affiliation, sexual orientation, marital status, disability, genetic information, age, membership in an employee organization, retaliation, parental status, military service, or other non-merit factor.

UNIVERSITY OF WASHINGTON
Department of Aeronautics & Astronautics
Tenure-Track Faculty Position

The Department of Aeronautics & Astronautics at the University of Washington invites applications for a full-time tenure-track faculty position at the level of Assistant, Associate, or Full Professor in the general area of aerospace structures. The successful candidate will complement our existing research strengths, interact with various research groups within the department, and provide a bridge between Aeronautics & Astronautics and other disciplines. University of Washington faculty engage in teaching, research and service.. The successful candidate will be expected to build and lead a vigorous and innovative externally-funded research program and to provide high-quality teaching that integrates research with instruction at both the undergraduate and graduate levels. An earned doctorate degree in an appropriate engineering or related discipline is required.

Applications should include a letter of application, a CV with a list of publications, concise statements of research and teaching interests and goals, the names and contact information of five professional references, and a statement of specific plans for securing extramural funding for at least two research projects, including contacts already made with funding agencies. The research statement should include current and potential interdisciplinary aspects of the applicant's work. All application materials must be submitted via our faculty search website: http://www.engr.washington.edu/facsearch/?dept=AA. The position will be open until filled, but we expect interviews to begin in January 2013. For any administrative issues related to this search, please, contact the A&A Department Search Committee, at search@aa.washington.edu. For information about the department, please visit http://www.aa.washington.edu.

The University of Washington is an affirmative action, equal opportunity employer. The University is building a culturally diverse faculty and staff and strongly encourages applications from women, minorities, individuals with disabilities and covered veterans. The University is the recipient of a 2006 Alfred P. Sloan Award for Faculty Career Flexibility and a 2001 National Science Foundation ADVANCE Institutional Transformation Award to increase the advancement of women faculty in science, engineering, and mathematics (www.engr.washington.edu/advance). Filling this position will be contingent on budgetary approval at the University of Washington.

SAN JOSÉ STATE UNIVERSITY

ASSISTANT PROFESSOR, AEROSPACE ENGINEERING
DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING
CHARLES W. DAVIDSON COLLEGE OF ENGINEERING

Applications are invited for a tenure-track faculty position at the rank of Assistant professor in the Aerospace Engineering Program in the Department of Mechanical and Aerospace Engineering at San Jose State University starting in Fall 2013. Qualified individual must have an earned Ph.D. degree in Aerospace Engineering or closely related field, and specialization either in flight vehicle dynamics/controls or structures/materials with multidisciplinary, emerging technology applications.

Salary range is commensurate with qualifications and experience. Starting date is August 19, 2013. Employment is contingent upon proof of eligibility to work in the United States. For full job announcement including qualifications and responsibilities, please visit our website at **http://apptrkr.com/280327** (JOID 22437). For full consideration, please send a letter of application, complete curriculum vitae, statement of teaching and research interests, and academic leadership experiences, and at least three original letters of reference with contact information by February 1, 2013 to:

Chair, AE Faculty Search Committee
Department of
Mechanical and Aerospace Engineering
San Jose State University
One Washington Square
San Jose, CA 95192-0087

SAN JOSÉ STATE
UNIVERSITY

San Jose State University is an Equal Opportunity/Affirmative action employer committed to the core values of inclusion, civility, and respect for each individual.

Located in the heart of Toronto, the largest and most culturally diverse city in the country, Ryerson University is committed to diversity, equity and inclusion. The University is known for innovative programs built on the integration of theoretical and practically oriented learning. Our undergraduate and graduate programs are distinguished by a professionally focused curriculum and strong emphasis on excellence in teaching, research and creative activities. Ryerson is also a leader in adult learning, with the largest university-based continuing education school in Canada.

TENURE-TRACK FACULTY POSITION

DEPARTMENT OF AEROSPACE ENGINEERING

The Department of Aerospace Engineering at Ryerson University invites applications for a tenure-track position at the Assistant Professor level, effective August 1, 2013. The successful candidate is expected to have teaching and research expertise in aerospace engineering and to have an established research program in one or more associated areas such as aircraft design, multidisciplinary design optimization (MDO), green propulsion technology, unmanned aerial vehicles (UAV), systems engineering, and intelligent aerospace systems.

The primary qualifications for this position, in addition to an earned doctorate in Aerospace Engineering or a closely related discipline, are demonstrated ability to perform high-quality research, an established record of, or potential for, outstanding teaching and supervising of students at undergraduate and graduate levels, and participating in departmental academic affairs, and ability to establish viable externally funded research programs. Specifically, applicants must have demonstrated outstanding research and an aptitude in teaching in the designated aerospace engineering fields. Both analytical and experimental research is of strong interest. Some experience in or with industry is desirable. Applicants should be registered or eligible for registration as a professional engineer in Ontario.

Ryerson's Department of Aerospace Engineering is one of the fastest growing programs of its kind in Canada. Committed to offering the best environment for academic growth, the Department has grown to become a powerhouse of innovative research and teaching. With 450 outstanding undergraduate and graduate students, the Department plays a key role in preparing the next generation of Aerospace Engineers while promoting education and research across Canada. The Department maintains strong relationships with Canada's top aerospace companies, and has tripled its industrial research funding since 2009. It is committed to developing further research collaborations built on the three main pillars: universities, government and industry. The Department of Aerospace Engineering has a complement of 17 faculty members and offers a four-year accredited program leading to a Bachelor of Engineering degree in Aerospace Engineering. In addition, the Department offers a graduate program leading to either an MASc or MEng and PhD degrees in Aerospace Engineering.

Applications with a curriculum vitae, a research statement outlining current and future research interests and a specific research plan, a teaching statement, selected reprints of not more than three publications, and the names and addresses of three referees, should be sent to: Dr. Paul Walsh, Chair, Department of Aerospace Engineering, Ryerson University, 350 Victoria Street, Toronto, Ontario, Canada, M5B 2K3. Fax: 416-979-5056. E-mail: aero.eng@ryerson.ca. Review of applications will begin December 1, 2012, and will continue until a suitable candidate is found.

This position falls under the jurisdiction of the Ryerson Faculty Association (www.rfa.ryerson.ca). For details on the Ryerson Faculty Association Collective Agreement and the University's RFA Benefits Summary, please visit http://www.ryerson.ca/teaching/employment_resources/rfa.html and http://www.ryerson.ca/hr/benefits/benefits_by_group/rfa/index.html respectively.

Ryerson University is strongly committed to fostering diversity within our community. We welcome those who would contribute to the further diversification of our faculty and its scholarship, including, but not limited to, women, visible minorities, Aboriginal people, persons with disabilities, and persons of any sexual orientation or gender identity. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

RYERSON UNIVERSITY

www.ryerson.ca Everyone Makes a Mark

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EMBRY-RIDDLE Aeronautical University

FACULTY POSITIONS, DEPARTMENT OF AEROSPACE ENGINEERING

The Department of Aerospace Engineering at Embry-Riddle Aeronautical University in Daytona beach, FL invites applications for several tenure-track faculty positions at the ranks of Assistant, Associate, and Full Professor. The department o ers bachelor's and master's degrees in Aerospace Engineering. A Ph.D. program will begin in Fall 2013. An earned doctorate in Aerospace Engineering or a closely related field is required. Industrial experience and design experience are highly desirable. Rank and salary will be commensurate with qualifications. Applicants must submit a cover letter, curriculum vitae, a detailed research and teaching plan and the names of at least three references. Please submit these materials by applying online to www.erau.edu/jobs. Search for Faculty positions in Daytona Beach, FL and reference **IRC49067.** Questions may be directed to Human Resources, mazzarer@erau.edu.

Embry-Riddle is an equal opportunity 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:

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

AIAA

AIAA Bulletin

On 31 October 2012, NASA's *Curiosity* rover used the Mars Hand Lens Imager (MAHLI) to capture this set of 55 high-resolution images, which were stitched together to create this full-color self-portrait. The mosaic shows the rover at "Rocknest," the spot in Gale Crater where the mission's first scoop sampling took place. Four scoop scars can be seen in the regolith in front of the rover.

The base of Gale Crater's 5-kilometer sedimentary mountain, Mount Sharp, rises on the right side of the frame. Mountains in the background to the left are the northern wall of Gale Crater. The Martian landscape appears inverted within the round, reflective ChemCam instrument at the top of the rover's mast. (*Image Credit: NASA/JPL-Caltech/Malin Space Science Systems*)

DECEMBER 2012

AIAA Directory

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www.aiaa.org

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Customer Service: 800/639-AIAA†

Other Important Numbers: ***Aerospace America*** / Greg Wilson, ext. **7596*** • ***AIAA Bulletin*** / Christine Williams, ext. **7500*** • **AIAA Foundation** / Suzanne Musgrave, ext. **7518*** • **Book Sales** / **800.682.AIAA** or **703.661.1595**, Dept. 415 • **Corporate Members** / Merrie Scott, ext. **7530*** • **International Affairs** / Megan Scheidt, ext. **3842***; Emily Springer, ext. **7533*** • **Editorial, Books and Journals** / Heather Brennan, ext. **7568*** • **Education** / Lisa Bacon, ext. **7527*** • **Honors and Awards** / Carol Stewart, ext. **7623*** • **Journal Subscriptions, Member** / **800.639.AIAA** • **Exhibits / Journal Subscriptions, Institutional / Online Archive Subscriptions** / Chris Grady, ext. **7509*** • **Professional Development** / Patricia Carr, ext. **7523*** • **Public Policy** / Steve Howell, ext. **7625*** • **Section Activities** / Chris Jessee, ext. **3848*** • **Standards, Domestic** / Amy Barrett, ext. **7546*** • **Standards, International** / Nick Tongson, ext. **7515*** • **Student Programs** / Stephen Brock, ext. **7536*** • **Technical Committees** / Betty Guillie, ext. **7573***

* Also accessible via Internet. Use the formula first name last initial@aiaa.org. Example: megans@aiaa.org.
† U.S. only. International callers should use 703/264-7500.

Addresses for Technical Committees and Section Chairs can be found on the AIAA Web site at **http://www.aiaa.org**.

We are frequently asked how to submit articles about section events, member awards, and other special interest items in the *AIAA Bulletin*. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the *AIAA Bulletin* Editor.

Meeting Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	CALL FOR PAPERS (*Bulletin* in which Call for Papers appears)	ABSTRACT DEADLINE
2013				
7–10 Jan	**51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition** (Oct)	Dallas/Ft. Worth, TX	*Jan 12*	**5 Jun 12**
28–31 Jan†	**Annual Reliability and Maintainability Symposium (RAMS)**	Orlando, FL (Contact: Patrick M. Dallosta, 703.805.3119, Patrick.dallosta@dau.mil, www.rams.org)		
10–14 Feb†	**23rd AAS/AIAA Space Flight Mechanics Meeting**	Kauai, HI	*May 12*	**1 Oct 12**
2–9 Mar†	**2013 IEEE Aerospace Conference**	Big Sky, MT (Contact: David Woerner, 626.497.8451; dwoerner@ieee.org; www.aeroconf.org)		
19–20 Mar	**Congressional Visits Day**	Washington, DC (Contact Duane Hyland, duaneh@aiaa.org)		
25–27 Mar†	**3AF-48th International Symposium of Applied Aerodynamics Aerodynamics of Small Bodies and Details**	Saint-Louis, France (Contact: Anne Venables, secr.exec@aaafasso.fr, www.3af-aerodynamics2013.com)		
25–28 Mar	**22nd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar** (Dec) **AIAA Balloon Systems Conference** **20th AIAA Lighter-Than-Air Systems Technology Conference**	Daytona Beach, FL	*May 12*	**5 Sep 12**
8–11 Apr	**54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference** **21st AIAA/ASME/AHS Adaptive Structures Conference** **15th AIAA Non-Deterministic Approaches Conference** **14th AIAA Dynamic Specialist Conference** **14th AIAA Gossamer Systems Forum** **9th AIAA Multidisciplinary Design Optimization Conference**	Boston, MA	*Apr 12*	**5 Sep 12**
10–12 Apr†	**EuroGNC 2013, 2nd CEAS Specialist Conference on Guidance, Navigation and Control**	Delft, The Netherlands (Contact: Daniel Choukroun, d.choukroun@tudelft.nl, www.lr.tudelft.nl/EuroGNC2013)		
15–19 Apr†	**2013 IAA Planetary Defense Conference**	Flagstaff, AZ (Contact: William Ailor, 310.336.1135, william.h.ailor@aero.org, http://www.pdc2013.org)		
23–25 Apr†	**Integrated Communications Navigation and Surveillance 2013**	Herndon, VA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, www.i-cns.org)		
17–17 May†	**Seventh Argentine Congress on Space Technology**	Mendoza, Argentina (Contact: Pablo de Leon, 701.777.2369, Deleon@aate.org, www.aate.org)		
27–29 May	**19th AIAA/CEAS Aeroacoustics Conference (34th AIAA Aeroacoustics Conference)**	Berlin, Germany	*Jul/Aug 12*	**31 Oct 12**
27–29 May†	**20th St. Petersburg International Conference on Integrated Navigation Systems**	St. Petersburg, Russia (Contact: Prof. V. Peshekhonov, +7 812 238 8210, icins@eprib.ru, www.elektropribor.spb.ru)		
29–31 May†	**Requirements for UTC and Civil Timekeeping on Earth: A Colloquium Addressing a Continuous Time Standard**	Charlottesville, VA (Contact: Rob Seaman, 520.318.8248, info@futureofutc.org, http://futureofutc.org)		
6 Jun	**Aerospace Today ... and Tomorrow: Disruptive Innovation, A Value Proposition**	Williamsburg, VA (Contact: Merrie Scott: merries@aiaa.org)		
12–14 Jun†	**6th International Conference on Recent Advances in Space Technologies (RAST 2013)**	Istanbul, Turkey (Contact: Suleyman Basturk, rast2013@rast.org.tr, www.rast.org.tr)		
17–19 Jun†	**2013 American Control Conference**	Washington, DC (Contact: Santosh Devasia,devasia@u.washington.edu,http://a2c2.org/conferences/acc2013)		
24–27 Jun	**43rd AIAA Fluid Dynamics Conference and Exhibit** **44th AIAA Plasmadynamics and Lasers Conference** **44th AIAA Thermophysics Conference** **31st AIAA Applied Aerodynamics Conference** **21st AIAA Computational Fluid Dynamics Conference** **5th AIAA Atmospheric and Space Environments Conference** **AIAA Ground Testing Conference**	San Diego, CA	*Jun 12*	**20 Nov 12**
14–17 Jul	**49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit** **11th International Energy Conversion Engineering Conference (IECEC)**	San Jose, CA	*Jul/Aug 12*	**21 Nov 12**
14–18 Jul	**43rd International Conference on Environmental Systems (ICES)**	Vail, CO	*Jul/Aug 12*	**1 Nov 12**

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	CALL FOR PAPERS (*Bulletin* in which Call for Papers appears)	ABSTRACT DEADLINE
11–15 Aug†	**AAS/AIAA Astrodynamics Specialist Conference**	Hilton Head Island, SC (Contact: Kathleen Howell, 765.494.5786, howell@purdue.edu, www.space-flight.org/docs/2013_astro/2013_astro.html)		
12–14 Aug	**AIAA Aviation 2013: Charting the Future of Flight Continuing the Legacy of the AIAA Aviation Technology, Integration, and Operations (ATIO) Conference and Featuring the 2013 International Powered Lift Conference (IPLC) and the 2013 Complex Aerospace Systems Exchange (CASE)**	Los Angeles, CA	*Oct 12*	**28 Feb 13**
19–22 Aug	**AIAA Guidance, Navigation, and Control Conference** **AIAA Atmospheric Flight Mechanics Conference** **AIAA Modeling and Simulation Technologies Conference** **AIAA Infotech@Aerospace Conference**	Boston, MA	*Jul/Aug 12*	**31 Jan 13**
10–12 Sep	**AIAA SPACE 2013 Conference & Exposition**	San Diego, CA	*Sep 12*	**31 Jan 13**
6–10 Oct†	**32nd Digital Avionics Systems Conference**	Syracuse, NY (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, www.dasconline.org)		
2014				
13–16 Jan	**AIAA Science and Technology Forum and Exposition (SCI TECH 2014)**	National Harbor, MD		
2–10 Aug†	**40th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events**	Moscow, Russia http://www.cospar-assembly.org		

To receive information on meetings listed above, write or call AIAA Customer Service, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344; 800.639.AIAA or 703.264.7500 (outside U.S.). Also accessible via Internet at www.aiaa.org/calendar.

†Meetings cosponsored by AIAA. Cosponsorship forms can be found at https://www.aiaa.org/Co-SponsorshipOpportunities/.

AIAA Courses and Training Program

DATE	COURSE	VENUE	LOCATION
2012			
6 Dec	**Advanced Composite Materials and Structures**	Webinar	
18 Dec	**Lessons from Subsonic Ultra Green Aircraft Research (SUGAR) Study**	Webinar	
2013			
5–6 Jan	**Specialist's Course on Flow Control**	ASM Conference	Grapevine, TX
5–6 Jan	**Six Degrees of Freedom Modeling of Missile and Aircraft Simulations**	ASM Conference	Grapevine, TX
5–6 Jan	**Systems Engineering Verification and Validation**	ASM Conference	Grapevine, TX
1 Feb–30 Jun	**Introduction to Computational Fluid Dynamics**	Home Study	
1 Feb–30 Jun	**Advanced Computational Fluid Dynamics**	Home Study	
1 Feb–30 Jun	**Computational Fluid Turbulence**	Home Study	
1 Feb–30 Jun	**Introduction to Space Flight**	Home Study	
1 Feb–30 Jun	**Fundamentals of Aircraft Performance and Design**	Home Study	
28 Feb–1 Mar	**Mathematical Introduction to Integrated Navigation Systems, with Applications**	The AERO Institute	Palmdale, CA
28 Feb–1 Mar	**Optimal State Estimation**	The AERO Institute	Palmdale, CA
4–5 Mar	**Modeling Flight Dynamics with Tensors**	National Aerospace Institute	Hampton, VA
15–16 Apr	**A Practical Introduction to Preliminary Design of Air Breathing Engines**	The Ohio Aerospace Institute	Cleveland, OH
15–16 Apr	**Computational Heat Transfer (CHT)**	The Ohio Aerospace Institute	Cleveland, OH
10–11 Jun	**Introduction to Spacecraft Design and Systems Engineering**	The Ohio Aerospace Institute	Cleveland, OH
10–11 Jun	**Aircraft and Rotorcraft System Identification: Engineering Methods and Hands-on Training Using CIFER®**	The Ohio Aerospace Institute	Cleveland, OH
29–30 Jul	**Introduction to Space Systems**	National Aerospace Institute	Hampton, VA
29–30 Jul	**Phased Array Beamforming for Aeroacoustics**	National Aerospace Institute	Hampton, VA
29–30 Jul	**Turbulence Modeling for CFD**	National Aerospace Institute	Hampton, VA
23–24 Sep	**Gossamer Systems: Analysis and Design**	The AERO Institute	Palmdale, CA

**Courses subject to change*

To receive information on courses listed above, write or call AIAA Customer Service, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344; 800.639.2422 or 703.264.7500 (outside the U.S.). Also accessible via the internet at www.aiaa.org/courses or www.aiaa.org/SharpenYourSkills.

From the Corner Office

CHANGE IS THE CONSTANT

Sandy H. Magnus, Executive Director

First of all, let me say how excited I am to be serving AIAA as Executive Director. With Bob's departure I know I have some big shoes to fill. For the last six weeks I have been trying to absorb as much as I can. He set AIAA on a forward-facing course. Using that momentum, we will continue to stride confidently into the future. I know you will join with me in thanking Bob for his many years of tireless service to the Institute!

As Bob mentioned last month, he and I have a few things in common, most notably a passion for the aerospace industry. I have been involved, one way or another, in aviation or space for 20+ years and have loved every minute of it. At McDonnell Douglas, fresh out of college as a "rookie" engineer, I learned what it took to design a complex, advanced airplane from scratch. The unique aspects associated with a "stealth" design just made it that much more interesting, broadening my horizons beyond the bounds of electro-magnetics. I was exposed to areas as diverse as the aerodynamics of propulsion systems and the structural design of canopies, and gained an appreciation of the variety of sensors in existence as well as the importance of materials in all aspects of design and manufacturing. Aerospace truly covers a broad range of topics.

At NASA I saw another side of our industry—no longer was I in the middle of a design process, but rather I interacted as an operator. I was not using my education to produce a product or system, but as a tool to absorb everything that was required to use the complex systems associated with space travel. The resultant perception shift, from designer to user, was actually very helpful and, in the end, was useful for providing a different set of inputs and perspectives to the design community. Certainly my career has gone off in different, unforeseen directions, encompassing a wide range of experiences which, I think, reflect a bit of what we are all going through in the aerospace industry—there is always something new to learn!

We live in a rapidly changing world with the rate of change ever increasing. My grandmother, for example, once told me she remembered as a young girl the spectacular headlines that were splashed across the newspapers when the Wright brothers flew at Kitty Hawk. She also lived to see her granddaughter launch into space on one of the most amazingly complex flying machines ever built. I am sure she never could have imagined seeing so many advancements in her own lifetime. Children growing up today experience air travel as a common everyday mode of transport. In addition, they do not know a world where people have not lived and worked in space and benefitted from its contributions. These things define their norms—it illustrates how the aerospace industry has woven itself into the very fabric of modern life and will continue to do so in ways we cannot anticipate.

As technology advances, the lines between traditional engineering disciplines have become blurred. Today we are all pressed to learn aspects of areas outside of our "traditional" fields. It is challenging to be an engineer, scientist, and technology professional in such a mad-paced, quickly changing time. Uber-disciplines such as system engineering have evolved, emphasizing the importance of achieving the best overall performance for the resultant complex product, be it advanced aircraft, engines, or space vehicles, and forcing a parallel evolution in how we approach problems. Design, manufacturing, and operational priorities all need to be balanced. It is important to speak the language not only of other engineers but also of operators and users, who are the final customers, as well as the technicians and skilled craftsmen who are responsible for keeping the machines in operation. More dialogue and discussions among such diverse groups leads to better designs and more reliable systems. This paradigm is playing out across the industry in many different ways.

It is hard to predict which technological advancements of today will be the "norms" of tomorrow, but it is certain that the aerospace industry will continue to play a major role. Our members are leading the charge in the technology areas and their success will continue to be a driving force of societal change.

AIAA is an organization that has been intimately involved with the growth and evolution of both the aviation and space industries from their very beginnings. Today our organization spans the world and our members are involved in a diversity of areas at the forefront of discovery. AIAA must keep up with the pace of change and ensure that we are providing our members with the tools and information to be successful. Building on our rich history of technical excellence, we can continue to lead the way, assisting and supporting the needs of the dynamic aviation and space industries. We must contribute to translating that constantly changing technological landscape into sound public policy and communicate to society the capabilities and benefits of the products of our industry.

The new event model coming online in 2014 is a first step in the process of ensuring AIAA community engagement in the issues of the future. With the incorporation of related disciplines into "themed" conferences, the possibility for cross-pollination and the generation of new ideas is rich with potential. As I attend each one of these conferences I expect that my horizons will continue to expand in multiple directions. So much to learn, so little time....

I look forward to working with each and every one of you in the coming years and am very energized about the possibilities! Tell me what your vision is for AIAA and let's make it happen—together!

To submit articles to the *AIAA Bulletin*, contact your Section, Committee, Honors and Awards, Events, Precollege, or Student staff liaison. They will review and forward the information to the *AIAA Bulletin* Editor. See the AIAA Directory on page **B1** for contact information.

AIAA CONGRESSIONAL VISITS DAY

Duane Hyland, AIAA Public Policy

The 2013 AIAA Congressional Visits Day (CVD) program will be held 19–20 March in Washington, DC. Attendees will have the chance to engage the newly elected Congress on many issues related to critical issues in civil aeronautics, civil astronautics, and defense.

As always, our goal is to educate members of Congress, congressional staffers, key administration officials, and other decision makers about the long-term value that science, engineering, and technology brings to the United States. This will be our first chance to educate Congress on the value of aerospace after the 2012 elections! Only your participation, enthusiasm, and passion remind our lawmakers that aerospace is a key component of an economically strong and secure nation. If you are interested in the future of your profession, the advancement of technology, the furthering of scientific research, and the strengthening of our nation's security, this event is for you!

Make sure, regardless if you are a student member, young professional member, or professional member of AIAA, that you do not miss this vital opportunity to have your congressional representative hear your voice—register for CVD today at **https://www.aiaa.org/cvd2013**.

If you have any questions about CVD, or are looking for materials for this year's event, please contact Duane Hyland at 703.264.7558 or duaneh@aiaa.org.

Maj. Gen. (ret) James B. Armor (left) and Klaus Dannenberg, AIAA Deputy Executive Director (right)

ARMOR RECEIVES THE VON BRAUN AWARD

AIAA Associate Fellow Maj. Gen. (ret) James B. Armor received the von Braun Award for Excellence in Space Program Management at the joint meeting between the National Capital Section and NDIA. The award was given "for insightful leadership and strong strategic planning for national security space systems and for delivering revolutionary enhanced capabilities to operational users."

JOSEPH FREITAG, SR. SCHOLARSHIP AWARDED

Stephen Brock

The AIAA Foundation Joseph Freitag, Sr. Scholarship was awarded to **Tim Oldekamp**, who completed his studies at the Daimler Training School. The prize was extremely well appreciated by Mr. Oldekamp, his family, the administration, and faculty of the Daimler Training School in Stuttgart, Germany. Daimler recognizes the value of the AIAA Foundation Joseph Freitag, Sr. Award and the inspiration it brings to their students.

The award is given in honor of Joseph Freitag, Sr., a 1922 graduate of the Daimler Vocational Training School who left Germany in 1926 to become eventually a leader in the field of advanced aircraft instrumentation, flight control, radar, and marine stabilization design at Sperry Gyroscope. The award is given to foster and recognize the educational values and inspiration acquired by Mr. Freitag from the learning experiences at the Daimler school. The faculty selects a student to receive the award based on the values that characterized his life and admired by family, his colleagues, and friends.

On 18 July 2012, Tim Oldekamp, who became an Automotive Mechatronics Engineer as a graduate of the Daimler Training School in Stuttgart, Germany, received the 6th Annual AIAA Foundation Joseph Freitag Sr. Award. Daimler prepares their students to take leadership roles in various departments in the factory producing Mercedes Benz vehicles. Mr. Oldekamp was selected by the faculty for his academic performance, his demonstration of self-initiative to bring forth new approaches and ideas to technical problems, his craftsmanship approach to his professional, and family and leisure activities. He is a team player and led a team to equip a Mercedes Benz off-road vehicle with equipment that will be used by a charity group working in Columbia, South America. In addition he demonstrated his determination and perseverance to overcome the challenges of his life by winning a role on a racing team as a very young man. He is already enrolled at the University of Esslingen to receive his Bachelor of Engineering in 2015.

Joe Freitag presented the scholarship to Tim Oldekamp (right).

Mrs. Marion Pietsch, the Director of the School opened the award ceremony by welcoming Tim's parents, Joe Freitag (representing the Freitag family) and AIAA, and the faculty that had mentored his studies and special projects.

Mr. Freitag presented the award certificate to Mr. Oldekamp and a check for €1,000. It will be used to defray the costs of his university tuition. In his remarks, Mr. Freitag congratulated Oldekamp for being selected by the faculty and repeated the criteria stated on the certificate that was used to select him from the other members of his class. He also congratulated Mr. and Mrs. Oldekamp for raising a fine young man and sacrificing so that he could attend the Daimler School. A special recognition was given to the faculties that are dedicated to producing graduates that are ready for either further studies or factory employment. After the ceremony, a celebratory dinner was held.

A celebratory dinner following the award ceremony: Left side: Dr. Eng. Manuel Koelz (first Freitag scholarship winner in 2007, currently a Ph.D. candidate); Thomas Meier (fifth Freitag scholarship winner in 2011); Eberhard Ernst (Eng. Special Projects); Mr. Robina (Instructor, Auto Mechtronics); Mr. and Mrs. Oldekamp.
Right side: Oldekamp friend; Tim Oldekamp (sixth Freitag scholarship winner in 2012); Michael Lachnit (fourth Frietag scholarship winner in 2010); Rene Findeisen (third Frietag scholarship winner in 2009); Mrs. Marion Pietsch (Dir. Daimler School).

AIAA PUBLISHES NEW BOOK ON AIRCRAFT AND ROTORCRAFT SYSTEM IDENTIFICATION

AIAA recently published a new book by M. B. Tischler with R. K. Remple entitled *Aircraft and Rotorcraft System Identification: Engineering Methods with Flight Test Examples, 2nd Edition*. Author **Mark B. Tischler** (AIAA Associate Fellow), a Flight Control Group Leader and Senior Scientist at the U.S. Army Aeroflightdynamics Directorate at NASA Ames Research Center, (who headed the development of CIFER® and CONDUIT®), along with **Robert K. Remple**, presents proven methods, practical guidelines, and real-world flight-test results for a wide range of state-of-the-art flight vehicles in *Aircraft and Rotorcraft System Identification.* This book addresses the entire process of aircraft and rotorcraft system identification from instrumentation and flight testing to model determination, validation, and application of the results. The second edition includes in-depth chapters presenting extended model structures and identification results for large flexible transport aircraft, as well as the detailed methodology to develop a continuous full flight envelope simulation model from individual system identification models and trim test data.

Special features of the book include a student version of CIFER® with updated graphical user interface using MATLAB®. Also included are numerous flight-test results illustrating the wide-ranging roles of system identification, and extensive problem sets at the end of each chapter, with many exercises based on flight-test data provided for the XV-15 in hover and cruise. For more information or to order the book, please go to **http://arc.aiaa.org/doi/book/10.2514/4.868207**.

BRODSKY HAILED FOR STELLAR SERVICE TO THE UNIVERSITY OF SOUTHERN CALIFORNIA'S VITERBI SCHOOL OF ENGINEERING

AIAA Fellow **Dr. Bob Brodsky** recently was hailed by the University of Southern California (USC) as a pioneer in his field. The citation from the university's president, C.L. Max Nikias, mentioned Brodsky's innovations in spacecraft design as well as space engineering education. Dr. Nikias hailed Brodsky's work as a scientist, engineer, and teacher, which had a profound impact on astronautics engineering. Mr. Brodsky's work at USC helped lead to the creation of an independent Department of Astronautical Engineering.

Prior to receiving his Ph.D. degree from New York University in 1950 at the age of 25, Dr. Brodsky was a pilot (before his 18th birthday) and served over two years in the U.S. Navy during World War II. Dr. Brodsky was Professor and Head of the Aerospace Engineering Department at Iowa State University and a Professor of Astronautical and Space Technology Engineering at the University of Southern California, from which he retired in 1996. His 46-year professional career in aerospace has been devoted equally to university teaching and working in industry. In industry, he has held executive engineering positions at Sandia Corporation, Aerojet, Convair, and TRW Space and Technology.

A 66-year AIAA member, Dr. Brodsky served 25 years on the Los Angeles Section Executive Council, following a year as Chair. He is the author of several books, including his newest, *Catch a Rocket Plane*, which fills in gaps in the story of his 2006 book, *On the Cutting Edge*.

CALL FOR NOMINATIONS

Nominations are now being accepted for the following awards, and must be received at AIAA Headquarters no later than **1 February**. Awards are presented annually, unless other indicated. However AIAA accepts nominations on a daily basis and applies them to the appropriate year.

Any AIAA member in good standing may serve as a nominator and strongly are urged to read award guidelines carefully to view nominee eligibility, page limits, letters of endorsement, etc. AIAA members may submit nominations online after logging into **www.aiaa.org** with their user name and password. You will be guided step-by-step through the nomination entry. If preferred, a nominator may submit a nomination by completing the AIAA nomination form, which can be downloaded from www.aiaa.org.

Beginning in 2013, all nominations, whether submitted online or in hard copy, must comply with the limit of 7 pages for the nomination package. The nomination package includes the nomination form, a one-page basis for award, one-page resume, one-page public contributions, and a minimum of 3 one-page signed letters of endorsement from AIAA members. Up to 5 signed letters of endorsement (include the 3 required from AIAA members) may be submitted and increase the limit to 9 pages. Nominators are reminded that the quality of information is most important.

Aerospace Guidance, Navigation, and Control Award is presented to recognize important contributions in the field of guidance, navigation, and control. (Presented even years)

Aerospace Power Systems Award is presented for a significant contribution in the broad field of aerospace power systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and processing of aerospace power.

Aircraft Design Award is presented to a design engineer or team for the conception, definition, or development of an original concept leading to a significant advancement in aircraft design or design technology.

Daniel Guggenheim Medal honors persons who make notable achievements in the advancement of aeronautics. AIAA, ASME, SAE, and AHS sponsor the award.

de Florez Award for Flight Simulation is presented for an outstanding individual achievement in the application of flight simulation to aerospace training, research, and development.

Energy Systems Award recognizes a significant contribution in the broad field of energy systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and conservation of energy.

F. E. Newbold V/STOL Award recognizes outstanding creative contributions to the advancement and realization of powered lift flight in one or more of the following areas: initiation, definition, and/or management of key V/STOL programs; development of enabling technologies including critical methodology; program engineering and design; and/or other relevant related activities or combinations thereof that have advanced the science of powered lift flight.

George M. Low Space Transportation Award, honors the space transportation achievements of Dr. Low, and is presented for a timely outstanding contribution to the field of space transportation. (Presented even years)

Haley Space Flight Award is presented for outstanding contributions by an astronaut or flight test personnel to the advancement of the art, science, or technology of astronautics. (Presented even years)

Hap Arnold Award for Excellence in Aeronautical Program Management is presented to an individual for outstanding contributions in the management of a significant aeronautical- or aeronautical-related program or project.

Hypersonic Systems and Technologies Award recognizes sustained, outstanding contributions and achievements in the advancement of atmospheric, hypersonic flight and related technologies. (Presented every 18 months)

J. Leland Atwood Award recognizes an aerospace engineering educator for outstanding contributions to the profession. AIAA and ASEE sponsor the award. ***Note: Nominations due to AIAA by 1 January.***

Mechanics and Control of Flight Award is presented for an outstanding recent technical or scientific contribution by an individual in the mechanics, guidance, or control of flight in space or the atmosphere.

Multidisciplinary Design Optimization Award is given to an individual for outstanding contributions to the development and/or application of techniques of multidisciplinary design optimization in the context of aerospace engineering. (Presented even years)

Otto C. Winzen Lifetime Achievement Award is presented for outstanding contributions and achievements in the advancement of free flight balloon systems or related technologies. (Presented odd years)

Piper General Aviation Award is presented for outstanding contributions leading to the advancement of general aviation. (Presented even years)

Space Automation and Robotics Award recognizes leadership and technical contributions by individuals and teams in the field of space automation and robotics. (Presented odd years)

Space Science Award is presented to an individual for demonstrated leadership of innovative scientific investigations associated with space science missions. (Presented even years)

Space Operations and Support Award is presented for outstanding efforts in overcoming space operations problems and assuring success, and recognizes those teams or individuals whose exceptional contributions were critical to an anomaly recovery, crew rescue, or space failure. (Presented odd years)

Space Systems Award is presented to recognize outstanding achievements in the architecture, analysis, design, and implementation of space systems.

von Braun Award for Excellence in Space Program Management honors outstanding contributions in the management of a significant space or space-related program or project.

William Littlewood Memorial Lecture, sponsored by AIAA and SAE, perpetuates the memory of William Littlewood, who was renowned for the many significant contributions he made to the design of operational requirements for civil transport aircraft. Lecture topics focus on a broad phase of civil air transportation considered of current interest and major importance.

For further information on AIAA's awards program, please contact Carol Stewart, Manager, AIAA Honors and Awards, carols@aiaa.org or 703.264.7623.

OBITUARIES

AIAA Associate Fellow Ehresman Died in August

Charles M. "Chuck" Ehresman, 90, died on 22 August 2012.

Mr. Ehresman received his Master's Degree in Aeronautical Engineering from Purdue University in 1951. After graduating, he went on to Aerojet General Corporation in California, before being recruited back to Purdue University in 1964. He initially was a visiting professor and in 1966 was promoted to associate professor of Mechanical Engineering. He was given responsibility for the design and construction of the High Pressure Rocket Laboratory. From 1977 to 1981, Mr. Ehresman served as Operations Manager of the Thermal Sciences & Propulsion Center. He was currently Professor Emeritus of Mechanical Engineering.

An AIAA member for 63 years, Mr. Ehresman was an Emeritus Member and Associate Fellow. He was very involved with AIAA and worked with several committees: Historic Aerospace Sites Committee (1999); STEM K–12 Outreach Committee (1993–1997); Board of Director (Director, Region III, 1988–1994); and the Institute Development Committee (1988–1989). He received the AIAA Sustained Service Award in 2001 "for outstanding service and contribution to the AIAA and Region III and for revitalizing the Region III Student Paper Competition."

AIAA Senior Member Metzger Died in October

John D. Metzger, a founder of the University of Pittsburgh nuclear engineering program, died on 12 October. He was 59.

Dr. Metzger, director of the nuclear engineering program in the University of Pittsburgh's Department of Mechanical Engineering and Materials Science, was known for his down-to-earth and caring attitude with his students. He could teach even the most complicated material in layman's terms they could understand and he made the extra effort to encourage students to push themselvesh to achieve the impossible.

Dr. Metzger earned a bachelor's degree from the University of Tennessee at Knoxville in 1975, a master's degree from the University of Illinois at Champaign-Urbana in 1975, and his doctorate from the University of New Mexico in 1989, all in nuclear engineering. He worked at the Los Alamos National Lab in New Mexico (1984–1990), before he was a research engineer at the Westinghouse Savannah River Company (1990–1991). He also worked as a senior technical specialist for the Space Nuclear Thermal Propulsion Program at Northrop Grumman (1991–1998), and then as a research associate professor at the State University of New York at Stony Brook (1998–2005).

In 2007, Dr. Metzger joined the University of Pittsburgh as a part-time lecturer and became a full-time associate professor in 2010. He helped develop the curriculum for the university's nuclear engineering program with colleagues Larry Foulke and Minking Chyu. They launched the program in 2007, making it the first and only nuclear track in western Pennsylvania.

Dr. Metzger's research focused on nuclear power and propulsion system designs, analysis and modeling, along with thermal-hydraulic designs. He was responsible for securing substantial grant funding, including $2.4 million this year to support computer-modeling research into future generations of high-temperature nuclear reactors, a new radiation detection and measurement laboratory, and a fellowship for a student.

Dr. Metzger held several patents and was a member of several professional associations, including AIAA, the National Society of Professional Engineers, and the National Heat Transfer Conference. With his students he started a local chapter of the American Nuclear Society, of which he served as adviser. Dr. Metzger had been a member of the AIAA Nuclear & Future Flight Propulsion Technical Committee from 1996 to 2001.

AIAA Associate Fellows Dinner

179 Institute members have recently been elected to the grade of Associate Fellow. These new Associate Fellows will be inducted during the Associate Fellows Dinner, which will be held at 1930 hrs, Monday, 7 January 2013, at the **Gaylord Texan Hotel and Convention Center,** Grapevine, Texas. Each year, the Institute recognizes exemplary professionals for their accomplishments in engineering or scientific work, outstanding merit and contributions to the art, science, or technology of aeronautics or astronautics.

Please support your colleagues, and join us for the induction of the 2013 Associate Fellows. Tickets to this celebrated event are available on a first-come, first-served basis and can be purchased for $97 via the 51st AIAA Aerospace Sciences Meeting registration form or on site based on availability. Business attire is requested.

AIAA
The World's Forum for Aerospace Leadership

22nd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar

AIAA Balloon Systems Conference

20th AIAA Lighter-Than-Air Systems Technology Conference

25–28 March 2013
Hilton Daytona Beach
Daytona, Florida

Event Overview

AIAA is pleased to announce the co-located 22nd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, AIAA Balloon Systems Conference, and 20th AIAA Lighter-Than-Air Systems Technology Conference, to be held 25–28 March 2013 at Hilton Daytona Beach in Daytona Beach, FL. This event provides an unrivaled opportunity to gather the world's leading parachute, flexible structure, airship, balloon, and aerostat scientists, engineers, researchers, and managers from all over the globe for technical interchange and technology advancement.

The co-location of these related AIAA events provides attendees with a unique opportunity to expand their knowledge of technological advances of these interrelated disciplines and explore areas of common technical expertise.

Co-located with the PIA Meeting and Symposium!

The 2013 AIAA event will be held in conjunction with the Parachute Industry Association (PIA) Meeting and Symposium (www.pia.com)! PIA's primary areas of interest are the manufacture of parachute systems and materials, along with the more hands-on aspects of rigging, maintenance, and operation. The AIAA and PIA events will complement each other by providing a broader perspective of the field of aerodynamic decelerators.

Joint activities will offer interaction between the groups and increase the value to all participants! AIAA attendees will have access to a limited number of PIA technical sessions that are most relevant to your disciplines; PIA attendees will have access to a limited number AIAA technical sessions of their interest. In addition, AIAA attendees will have access to the PIA exhibit hall throughout the week and the ability to purchase tickets to the PIA networking functions! Tickets may be purchased upon registration.

Networking and Special Events

ADS Seminar

On Monday, 25 March 2013, the ADS Technical Committee will host a one-day seminar on Entry, Descent, and Landing (EDL). Engineers presently involved in EDL research, development, and flight missions will present this seminar. The objective of this seminar is to introduce the attendees to the challenges associated with EDL, the technologies used to address these challenges, and the nomenclature typically used to discuss EDL. Topics will include trajectories, hypersonic aerodynamics and aerothermodynamics, rigid and deployable aerodynamic decelerators, supersonic retropropulsion, and landing systems. The seminar will conclude with a case study: The Mars Science Laboratory/Curiosity Rover EDL System. *Registration and separate ticket purchase is required to attend*. Tickets for the seminar may be purchased upon registration.

Best Student Paper Competition

The AIAA Aerodynamic Decelerator Systems Technical Committee (ADS TC) is sponsoring a Best Student Paper Competition at this year's conference. Papers are sought from students on all research topics related to aerodynamic decelerators. Up to five finalists will be selected to make presentations at the conference. Finalists will present their papers during technical sessions at the conference and all finalists will be recognized at the conference awards dinner. All finalists will receive a $1,250 award (to offset travel expenses and conference registration) and a complimentary ticket to the awards dinner after attending and presenting their paper. An overall best paper and presentation will be selected from the finalists, and the overall winner will be presented with an additional $1,250 prize. All prizes are provided by the ADS TC. Questions about the ADS Best Student Paper Competition should be referred to the chair, Nathan Slegers, University of Alabama in Huntsville, at slegers@mae.uah.edu.

Benefits of Attendance

Why Attend?

- Present recent advances before a knowledgeable international audience
- Educate industry customers and providers on their latest research and product developments
- Extract lessons learned from past system applications and programs to result in increased technical success, cost savings, and schedule savings for current or ensuing projects or programs
- Network to engage new contacts and refresh old ones
- Recognize significant achievements from within the community

Who Should Attend?

- All levels of engineers, researchers, and scientists from government, industry, and academia
- Engineering managers and executives
- Government and industry program managers
- Business development professionals
- Young professionals
- Educators and students
- Press/media

What to Expect?

• *Program*
– Plenary sessions on ADS Air Systems (Airdrops in Afghanistan, U.S. Air Force's Precision Airdrop Program, and Lessons Learned from the Space Shuttle Orbiter Drag Parachute) and ADS Space Systems (Mars Science Laboratory/Curiosity Rover EDL System, NASA Game Changing Development Program, and NASA Low Density Supersonic Decelerators for Mars Missions)
– Joint Balloons/LTA plenary session featuring keynotes on Airships as Multi-Functional Platforms and NASA's Super Pressure Balloon Development, and a panel discussion on Hydrogen as Lifting Gas
– Technical sessions on all aspects of aerodynamic decelerator, balloon, and lighter-than-air systems, structures, and technologies
– Access to more than 150 technical papers and presentations
– ADS seminar on Entry, Descent, and Landing (EDL) research, development, and flight missions
– Student paper competition to encourage and engage young minds as they enter the aerospace the industry

• *Networking*
– Industry reception
– Awards reception and banquet
– Networking coffee breaks
– Young Professional Networking Luncheon
– Access to PIA Symposium attendees, sessions, and events

22nd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar

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AIAA Balloon Systems Conference

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Technical Program Chair
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20th AIAA Lighter-Than-Air Systems Technology Conference

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Technical Program Chair
Mark E. Beyer
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	Monday, 25 March 2013		Tuesday, 26 March 2013	
0700 hrs			Speakers' Briefing	
0730 hrs				
0800 hrs	ADS Seminar (Separate Ticket Required)		Plenary Session (ADS Space Systems)	
0830 hrs				
0900 hrs				
0930 hrs				
1000 hrs			Networking Coffee Break	
1030 hrs			Technical Sessions	
1100 hrs				
1130 hrs				
1200 hrs			Lunch Break	
1230 hrs				
1300 hrs				
1330 hrs			Technical Sessions	
1400 hrs				
1430 hrs				
1500 hrs				PIA Exhibits Open
1530 hrs			Networking Coffee Break	
1600 hrs	PIA Opening Reception (Separate Ticket Required)	PIA Exhibits Open	Technical Sessions	
1630 hrs				
1700 hrs				
1730 hrs				
1800 hrs				
1830 hrs				
1900 hrs			Industry Reception	
1930 hrs				
2000 hrs				
2030 hrs				
2100 hrs				
2130 hrs				
2200 hrs				
2230 hrs				
2300 hrs				

Networking Coffee Breaks

Stand-alone networking coffee breaks are included in the program to allow even more time for making new contacts, continuing the discussions from technical sessions, or checking emails and voicemails to keep in touch with the office while you are at the conference. Times are indicated in the program.

Young Professional Networking Luncheon

The AIAA Young Professional Committee will host a young professional mentoring/networking luncheon on Tuesday, 26 March, 1200–1300 hrs. This event will be a great opportunity for young professional members of the Institute, members aged 35 and under, to meet other members and gain access to other industry professionals. Check the event website and final program for further details.

Industry Reception

There will be an industry-sponsored reception on Tuesday, 26 March 2013, starting at 1900 hrs at the Hilton Daytona Beach. All conference attendees and their guests are welcome to attend.

Awards Reception and Banquet

The awards reception and banquet will be held on Wednesday, 27 March, 1900–2200 hrs, at the Hilton Daytona Beach. The Theodor W. Knacke Aerodynamic Decelerator Systems Award and Otto C. Winzen Lifetime Achievement Award will be presented during the awards dinner. The winner of the Aerodynamic Decelerator Systems Technology Best Student Paper Competition also will be recognized. Join us and celebrate the achievements of your peers. A ticket for the reception and banquet is included in the conference registration fee where indicated. Additional tickets may be purchased upon registration or on site.

Conference Proceedings

Proceedings for these conferences will be available in online proceedings format. The cost is included in the registration fee where indicated. The online proceedings will be available on **25 March 2013**. Attendees who register in advance for the online proceedings will be provided with instructions on how to access them. Those registering on site will be provided with instructions at that time.

	Wednesday, 27 March 2013		Thursday, 28 March 2013	
0700 hrs	Speakers' Briefing		Speakers' Briefing	
0730 hrs				
0800 hrs	Plenary Session (Balloons and LTA)		Plenary Session (ADS Air Systems)	
0830 hrs				
0900 hrs				
0930 hrs				
1000 hrs	Networking Coffee Break		Networking Coffee Break	
1030 hrs	Technical Sessions		Technical Sessions	
1100 hrs				
1130 hrs				
1200 hrs	Lunch Break		Lunch Break	
1230 hrs				
1300 hrs				
1330 hrs	Technical Sessions		Technical Sessions	
1400 hrs				
1430 hrs				
1500 hrs		PIA Exhibits Open		PIA Exhibits Open
1530 hrs	Networking Coffee Break		Networking Coffee Break	
1600 hrs	Technical Sessions		Technical Sessions	
1630 hrs				
1700 hrs				
1730 hrs				
1800 hrs			PIA Closing Reception and Banquet (Separate Ticket Required)	
1830 hrs				
1900 hrs	Awards Reception and Banquet			
1930 hrs				
2000 hrs				
2030 hrs				
2100 hrs				
2130 hrs				
2200 hrs				
2230 hrs				
2300 hrs				

Meeting Site

Daytona Beach, Florida, is famous for its beaches and motorsports, but the area also offers an abundance of shopping, nightlife, cultural events, and sporting activities. The beaches in the Daytona Beach area are always open and free to pedestrians! Cars are allowed on the beach in designated areas from sunrise to sunset depending on tidal conditions. Major Central Florida attractions located within driving distance from Daytona Beach include NASA Kennedy Space Center (51 miles), Sea World (66 miles), and Walt Disney World (74 miles). For more information, visit www.daytonabeachcvb.org.

Hotel Information

This event will be held at the Hilton Daytona Beach, 100 N. Atlantic Avenue, Daytona Beach, FL 32118, Phone: +1.386.254.8200. Room rates are $129 per night. Cabana rooms are available for $229 per night. There is complimentary Internet access in all rooms. When making your reservation, please identify yourself as being with the PIA/AIAA conference (use group code PIA13). Make your reservations online at **http://www.hilton.com/en/hi/groups/personalized/D/DABDHHF-PIA13-20130320/index.jhtml?WT.mc_id=POG**. These rooms will be held for AIAA and PIA until **22 February 2013** or until the block is full. After 22 February 2013, any unused rooms will be released to the general public. You are encouraged to book your hotel room early.

Government Employees—There are a limited number of sleeping rooms available at the government per diem rate. You are strongly encouraged to book your hotel room as soon as possible. Government ID is required upon check-in.

Help Keep Our Expenses Down (And Yours Too!)

AIAA group rates for hotel accommodations are negotiated as part of an overall contract that also includes meeting rooms and other conference needs. Our total event costs are based in part on meeting or exceeding our guaranteed minimum of group-rate hotel rooms booked by conference participants. If we fall short, our other event costs go up. Please help us keep the costs of presenting this conference as low as possible—reserve your room at the designated hotel listed in this Event Preview and on

	Registration Type	Conference Rate Before 25 Feb 2013	AIAA Member Before 25 Feb 2013	Conference Sessions	Online Proceedings	Awards Reception and Banquet	ADS Seminar	PIA Opening Reception	PIA Closing Reception and Banquet
Option 1	**Full Conference with Online Proceedings**	**$905**	**$745**	●	●	●			
Option 2	**Full-Time Undergraduate Student**	**$60**	**$25**	●					
Option 3	**Full-Time Undergraduate Student with Networking**	**$185**	**$150**	●		●			
Option 4	**Full-Time Graduate or Ph.D. Student**	**$110**	**$75**	●					
Option 5	**Full-Time Graduate or Ph.D. Student with Networking**	**$235**	**$200**	●		●			
Option 6	**Full-Time Retired AIAA Member Only**	**N/A**	**$60**	●		●			
Option 7	**Group Discount***	**N/A**		●	●	●			
	Extra Tickets				**$200**	**$125**	**$275**	**$20**	**$60**

Pricing subject to change.

*10% discount off early bird member rate for 10 or more persons from the same organization who register and pay at the same time with a single form of payment. Includes sessions, awards reception and banquet, and single-user access to online proceedings for each registrant. A complete typed list of registrants, along with individual registration forms and a single payment, must be received by the preregistration deadline of **24 March 2013**.

our website, and be sure to mention that you're with the AIAA conference. Meeting our guaranteed minimum helps us hold the line on costs, and that helps us keep registration fees as low as possible. All of us at AIAA thank you for your help!

Airport Information

Daytona Beach is within driving distance of three airports:

Daytona Beach International Airport (DAB)—5 miles/10 minutes from hotel
Orlando International Airport (MCO)—70 miles/70 minutes from hotel
Jacksonville International Airport (JAX)—95 miles/90 minutes from hotel

Car Rental

AIAA members can save up to 15% off your car rentals with Hertz. Wherever your travel takes you close to home or around the world, your discount CDP#66135 is the key to special savings. Be sure to include it in all of your reservations. Visit Hertz at www.hertz.com for the lowest rates, special offers, and information about Hertz locations, vehicles, and services. Or call Hertz at 1.800.654.2210.

Registration Information

AIAA is committed to sponsoring world-class conferences on current technical issues in a safe and secure environment. As such, all delegates will be required to provide proper identification prior to receiving a conference badge and associated materials. All delegates must provide a valid photo ID (driver's license or passport) when they check in. For student registrations, a valid student ID is also required. We thank you for your cooperation.

All conference participants are urged to register online at **www.aiaa.org/daytona2013**. Registering in advance saves conference attendees time and up to $200. A check made payable to AIAA or credit card information must be included with your registration form. A PDF registration form is also available on the AIAA website. Print, complete, and mail or fax the form with payment to AIAA. Address information is provided. Payment must be received in order to process registration.

Early-bird registration forms must be received by **25 February 2013**, and standard registration forms will be accepted until **24 March 2013**. Preregistrants may pick up their materials at the advance registration desk at the conference. All those not registered by **24 March 2013** may do so at the on-site registration desk by paying the on-site registration fee. All nonmember registration fees include a one-year AIAA membership.

Cancellations must be received no later than **11 March 2013**. There is a $100 cancellation fee. Registrants who cancel beyond this date or fail to attend the conference will forfeit the entire fee.

For questions, please contact Sandra Turner, conference registrar, at +1 703.264.7508 or sandrat@aiaa.org.

Notice on Visas

If you plan to attend an AIAA conference or course held in the United States and you require a visa for travel, it is incumbent upon you to apply for a visa with the U.S. Embassy (consular division) or consulate with ample time for processing. To avoid bureaucratic problems, AIAA strongly suggests that you submit your formal application to U.S. authorities a minimum of 120 days in advance of the date of anticipated travel.

To request a letter of invitation, please fill out and submit the online Invitation Letter Request Form. You can also request a letter of invitation by contacting:

ATTN: Customer Service
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive
Suite 500
Reston, VA 20191-4344
703.264.7500 • 703.264.7657 FAX
Email: custserv@aiaa.org

AIAA cannot directly intervene with the U.S. Department of State, consular offices, or embassies on behalf of individuals applying for visas.

AIAA Programs

On-Site Check-In

Partnering with Expo Logic, we've streamlined the on-site registration check-in process! All advance registrants will receive an email with a registration barcode. In order to pick up your badge and conference materials, make sure to print the email that includes your ExpressPass Barcode, and bring it with you to the conference. Simply scan the ExpressPass barcode at one of the ExpressPass stations in the registration area to print your badge and receive your meeting materials.

AIAA Registration and Information Center Hours

The AIAA Registration and Information Center will be located at the Hilton Daytona Beach.

Hours are as follows:

Monday, 25 March 2013	0700–1700 hrs
Tuesday, 26 March 2013	0700–1700 hrs
Wednesday, 27 March 2013	0700–1700 hrs
Thursday, 28 March 2103	0700–1200 hrs

Sessions at a Glance

Current session titles below. For the full conference program, including paper and presentation titles and speakers, go to **www.aiaa.org/daytona2013** and click on "Detailed Program."

22nd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar

- Plenary: Space Systems
  - Reconstruction of the Mars Science Laboratory Parachute Performance and Comparison to the Descent Simulation
  - NASA Game Changing Development Program: An Overview of Entry, Descent, and Landing Projects with a Focus on Aerodynamic Decelerator Innovation
  - Development and Testing of a New Family of Low-Density Supersonic Decelerators
- Plenary: Air Systems
  - History and Challenges of Airdrops in Afghanistan
  - Overview of the U.S. Air Force's Precision Airdrop Program: From Mission Planning to Bundle Recovery
  - Space Shuttle Orbiter Drag Chute Summary
- Army Programs
- Avionics
- Computational Fluid Dynamics
- Deployable Heat Shields
- Descent Rate Control
- Student Paper Competition Finalists
- Fluid-Structure Interaction
- Guidance, Navigation, and Control
- Hypersonic Decelerators
- Supersonic Decelerators
- Materials
- Modeling
- Mars Science Laboratory
- Orion
- Recovery Systems
- Statistical Methods
- Testing
- Wind Tunnel Testing

AIAA Balloon Systems Conference

- Joint Balloons/LTA plenary session featuring keynotes on Airships as Multi-Functional Platforms and NASA's Super Pressure Balloon Development, and a panel discussion on Hydrogen as Lifting Gas
- Flight Operations
- Launch Systems
- Materials and Small Balloons
- Modeling and Analysis
- Programs
- Systems

20th AIAA Lighter-Than-Air Systems Technology Conference

- Joint Balloons/LTA plenary session featuring keynotes on Airships as Multi-Functional Platforms and NASA's Super Pressure Balloon Development, and a panel discussion on Hydrogen as Lifting Gas
- LTA Modeling and Analysis
- Fundamentals of Airship and Aerostat Design
- Current and Planned LTA Projects, Systems, and Initiatives

2013 AAS/AIAA Astrodynamics Specialist Conference

11–15 August 2013
Hilton Head Marriott Resort and Spa
Hilton Head, South Carolina

Abstract Deadline: 12 April 2013

The 2013 AAS/AIAA Astrodynamics Specialist Conference will be held 11–15 August 2013 at the Hilton Head Marriott Resort and Spa in Hilton Head, SC. The conference is organized by the American Astronautical Society (AAS) Space Flight Mechanics Committee and cosponsored by the AIAA Astrodynamics Technical Committee. Manuscripts are solicited on topics related to space-flight mechanics and astrodynamics, including but not necessarily limited to:

- Asteroid and non-Earth orbiting missions
- Atmospheric re-entry guidance and control
- Attitude dynamics, determination, and control
- Attitude-sensor and payload-sensor calibration
- Dynamical systems theory applied to space flight
- Dynamics and control of large space structures and tethers
- Earth orbital and planetary mission studies
- Flight dynamics operations and spacecraft autonomy
- Orbit determination and space-surveillance tracking
- Orbital debris and space environment
- Orbital dynamics, perturbations, and stability
- Rendezvous, relative motion, proximity operations, and formation flying
- Reusable launch vehicle design, dynamics, guidance, and control
- Satellite constellations
- Spacecraft guidance, navigation, and control (GNC)
- Space Situational Awareness (SSA), Conjunction Analysis (CA), and collision avoidance
- Trajectory/mission/maneuver design and optimization

Manuscripts will be accepted based on the quality of the extended abstract, the originality of the work and/or ideas, and the anticipated interest in the proposed subject. Submissions that are based on experimental results or current data, or report on ongoing missions, are especially encouraged. Complete manuscripts are required no later than **6 August 2013**. English is the working language for the conference.

Additional and up-to-date information can be found at the conference website: **http://www.space-flight.org/docs/2013_astro/2013_astro.html**.

Special Sessions

Proposals are being considered for suitable special sessions, such as topical panel discussions, invited sessions, workshops, mini-symposia, and technology demonstrations. A special session proposal should include the session title and a brief description of the topic(s). As applicable, the proposal should also include a list of the invited speakers and their qualifications, a list of proposed activities, and/or paper titles. Prospective special session organizers should submit their proposals to the Technical Chairs.

Breakwell Student Travel Award

The AAS Space Flight Mechanics Committee announces the John V. Breakwell Student Travel Award. This award covers travel expenses up to $1000 for one or more U.S. and Canadian students presenting at this conference. Students wishing to apply for this award are strongly advised to submit their completed manuscript by the abstract submittal deadline. Additional details and the application may be obtained via **www.space-flight.org**.

Information for Authors

Because the abstract submission deadline of **12 April 2013** has been fully extended for the convenience of contributors, there are no plans to defer this deadline. Notification of acceptance will be sent via email by **14 May 2013**. Detailed author instructions will be sent by email following acceptance. By submitting an abstract, the author affirms that the manuscript's majority content has not been previously presented or published elsewhere.

Authors may access the web-based abstract submittal system using the link available via the official website, **http://www.space-flight.org**. During the online submission process, authors are expected to provide:

1) A paper title, as well as the name, affiliation, postal address, telephone number, and email address of the corresponding author and each co-author,

2) An extended abstract in the Portable Document File (PDF) format of at least 500 words that includes the title and authors, and provides a clear and concise statement of the problem to be addressed, the proposed method of solution, the results expected or obtained, and an explanation of its significance to astrodynamics and/or space-flight mechanics, with pertinent references and supporting tables and figures as necessary, and

3) A condensed abstract (100 words) to be included in the conference program, which is directly typed into the text box provided on the web page and avoids the use of special symbols or characters, such as Greek letters.

Foreign contributors requiring an official letter of acceptance for a visa application should contact the Technical Chairmen by email at their earliest opportunity.

Technology Transfer Notice

Technology transfer issues can substantially extend the time required to prepare abstracts and manuscripts by private enterprises and government agencies. It is the responsibility of the author(s) to manage this process to ensure a timely submission.

No-Paper/No-Podium Policy

A complete manuscript must be electronically uploaded to the website prior to **6 August 2013** in PDF format, be no more than 20 pages in length, and conform to the AAS manuscript format. If a complete manuscript is not received on time, then its presentation at the conference shall be forfeited; and if a presentation is not made by an author at the conference, then the manuscript shall be omitted from published proceedings.

Questions concerning the submission of manuscripts should be addressed to the technical chairs:

AAS Technical Chair
Dr. Stephen B. Broschart
Jet Propulsion Laboratory
818.354.4073 • Stephen.B.Broschart@jpl.nasa.gov

AIAA Technical Chair
Dr. James D. Turner
Texas A&M University
979.458.1429 • turner@aeromail.tamu.edu

All other questions should be directed to the General Chairs:

AAS General Chair
Dr. Kathleen Howell
Purdue University
765.494.5786 • howell@purdue.edu

AIAA General Chair
Dr. Felix Hoots
The Aerospace Corporation
571.307.4206 • Felix.R.Hoots@aero.org

Upcoming AIAA Professional Development Courses

6 December 2012
This 90-minute webinar will take place at 1300–1430 EST

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

AIAA Members	Nonmembers	Students
$99	$139	$50

Advanced Composite Materials and Structures

(Carl Zweben, Ph.D.)

Advanced composites are critical, and in many instances enabling, materials for a large and increasing number of aerospace and commercial applications. Historically considered primarily structural and thermal protection materials, they also have great potential in virtually all subsystems, including propulsion, mechanisms, electronics, power, and thermal management. Physical properties are increasingly important. For example, composites with low densities, low CTEs and thermal conductivities higher than copper are now in production. Materials of interest include not only polymer matrix composites (PMCs), currently the most widely used class of structural materials, and carbon-carbon composites (CCCs), which are well established for thermal protection, but also ceramic matrix composites (CMCs), metal matrix composites (MMCs) and other types of carbon matrix composites (CAMCs). In this presentation we consider key aspects of the four classes of composites, including properties, key manufacturing methods, design considerations, analysis overview, lessons learned and applications. We also consider future directions, including nanocomposites.

18 December 2012
This 90-minute webinar will take place at 1300–1430 EST

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**
Cost: FREE

Lessons from Subsonic Ultra Green Aircraft Research (SUGAR) Study **(Dr. Marty Bradley, The Boeing Company)**

This webinar summarizes the work accomplished for NASA by the Boeing Subsonic Ultra Green Aircraft Research (SUGAR) team during a continuing two-phase study that began in 2008. Results through February 2012 are reported.

In Phase I, the team completed the development of a future scenario for worldwide commercial aviation in 2030, selected baseline and advanced configurations, generated technology suites for each, conducted detailed performance analysis, calculated noise and emissions, assessed technology risks, and developed technology roadmaps. Five concepts were evaluated in detail including a high span strut braced wing concept, a gas turbine battery electric concept, and a hybrid wing body.

In Phase II, the study was extended to the N+4 2040 timeframe and considered the following additional technologies: liquefied natural gas (LNG), hydrogen, fuel cell hybrids, low energy nuclear (LENR), boundary-layer ingestion propulsion (BLI), unducted fans, and advanced propellers.

5–6 January 2013
The following Continuing Education courses are being held at the 51st AIAA Aerospace Sciences Meeting in Grapevine, TX. Registration includes course and course notes; full conference participation: admittance to technical and plenary sessions; receptions, luncheons, and online proceedings.

To register for one of the ASM 2013 courses, go to
www.aiaa.org/asm2013.

	Early Bird by 10 Dec	*Standard (11 Dec–4 Jan)*	*On-site (5 Jan)*
AIAA Member	$1295	$1395	$1495
Nonmember	$1400	$1500	$1600

Specialist's Course on Flow Control **(Instructor: David Williams, Professor of Mechanical, Materials & Aerospace Engineering Department, Director of Fluid Dynamics Research Center, Illinois Institute of Technology, Chicago, IL; Daniel Miller, Technical Lead and PI for Propulsion Integration R&D, Lockheed Martin Skunk Works, Bainbridge Island, WA; Dr. Kunihiko Taira, Assistant Professor, Department of Mechanical Engineering, Florida A&M/Florida State University, Tallahassee, FL)**

The techniques of active flow control are becoming more sophisticated as fluid dynamics, control and dynamical systems theory merge to design control architectures capable of solving challenging flow control applications. The two-day course will examine advanced topics in active flow control, placing particular emphasis on "how to do flow control." This new course will complement the more fundamental AIAA Short Course on "Modern Flow Control." Modern dynamical systems and control theory related to closed-loop flow control and performance limitations will be discussed. State-of-the-art actuator and sensor design techniques will be covered. Two case studies will be presented that describe recent success stories about the implementation of active flow control on advanced aircraft. The six course lecturers have extensive backgrounds in flow control, coming from industry and academia.

Six Degrees of Freedom Modeling of Missile and Aircraft Simulations **(Instructor: Peter Zipfel, Adjunct Associated Professor, University of Florida, Shalimar, FL)**

As modeling and simulation (M&S) is penetrating the aerospace sciences at all levels, this two-day course will introduce you to the difficult subject of modeling aerospace vehicles in six degrees of freedom (6 DoF). Starting with the modern approach of tensors, the equations of motion are derived and, after introducing coordinate systems, they are expressed in matrices for compact computer programming. Aircraft and missile prototypes will exemplify 6 DoF aerodynamic modeling, rocket and turbojet propulsion, actuating systems, autopilots, guidance, and seekers. These subsystems will be integrated step by step into full-up simulations. For demonstrations, typical fly-out trajectories will be run and projected on the screen. The provided source code and plotting programs lets you duplicate the trajectories on your PC (requires FORTRAN or C++ compiler). With the provided prototype simulations you can build your own 6 DoF aerospace simulations.

Systems Engineering Verification and Validation (Instructor: John C Hsu, CA State University, The University of CA at Irvine, Queens University and The Boeing Company, Cypress, CA)
This course will focus on the verification and validation aspect that is the beginning, from the validation point-of-view, and the final part of the systems engineering task for a program/project. It will clarify the confusing use of verification and validation. Familiarize yourself with validating requirements and generating verification requirements. Start with the verification and validation plans. Then learn how to choose the best verification method and approach. Test and Evaluation Master Plan leads to test planning and analysis. Conducting test involves activities, facilities, equipments, and personnel. Evaluation is the process of analyzing and interpreting data. Acceptance test assures that the products meet what intended to purchase. There are functional and physical audits. Simulation and Modeling provides virtual duplication of products and processes in operational valid environments. Verification management organizes verification task and provides total traceability from customer requirements to verification report elements.

1 February–30 June 2013
2013 Home Study Courses

Introduction to Computational Fluid Dynamics (Instructor: Klaus Hoffmann)
This introductory course is the first of the three-part series of courses which will prepare you for a career in the rapidly expanding field of computational fluid dynamics.

Advanced Computational Fluid Dynamics (Instructor: Klaus Hoffmann)
This advanced course is the second of the three-part series of courses that will prepare you for a career in the rapidly expanding field of computational fluid dynamics.

Computational Fluid Turbulence (Instructor: Klaus Hoffmann)
This advanced course is the third of the three-part series of courses that will prepare you for a career in the rapidly expanding field of computational fluid dynamics with emphasis in fluid turbulence. Completion of these three courses will give you the equivalent of one semester of undergraduate and two semesters of graduate work.

Introduction to Space Flight (Instructor: Francis J. Hale)
By the time you finish this course, you will be able to plan a geocentric or interplanetary mission to include the determination of suitable trajectories, the approximate velocity budget (the energy required), the approximate weight (mass) and number of stages of the booster, and the problems and options associated with the terminal phase(s) of the mission.

Fundamentals of Aircraft Performance and Design
(Instructor: Francis J. Hale)
This course will give you an introduction to the major performance and design characteristics of conventional, primarily subsonic, aircraft. At the end of the course, you will be able to use the physical characteristics of an existing aircraft to determine both its performance for specified flight conditions and the flight conditions for best performance.

Introduction to Computational Fluid Dynamics

	Early Bird by 1 Jan	*Standard (2 Jan–1 Feb)*
AIAA Member	$1165	$1275
Nonmember	$1285	$1395

Advanced Computational Fluid Dynamics

	Early Bird by 1 Jan	*Standard (2 Jan–1 Feb)*
AIAA Member	$1210	$1320
Nonmember	$1330	$1440

Computational Fluid Turbulence

	Early Bird by 1 Jan	*Standard (2 Jan–1 Feb)*
AIAA Member	$1270	$1380
Nonmember	$1390	$1500

Introduction to Space Flight

	Early Bird by 1 Jan	*Standard (2 Jan–1 Feb)*
AIAA Member	$1075	$1185
Nonmember	$1195	$1305

Fundamentals of Aircraft Performance and Design

	Early Bird by 1 Jan	*Standard (2 Jan–1 Feb)*
AIAA Member	$1075	$1185
Nonmember	$1195	$1305

28 February–1 March 2013
The following standalone course is being held at The AERO Institute in Palmdale, California.

Mathematical Introduction to Integrated Navigation Systems, with Applications (Instructor: Robert M. Rogers)
Integrated Navigation Systems is the combination of an on-board navigation system solution for position, velocity, and attitude as derived from accelerometer and/or gyro inertial sensors, and navigation aids providing independent/redundant data to update or correct this on-board navigation solution. In this course, and described in the accompanying textbook, this combination is accomplished with the use of the Kalman filter algorithm.

This course is segmented into two parts. In the first part, elements of the basic mathematics, kinematics, equations describing navigation systems and their error models, aids to navigation, and Kalman filtering are reviewed. Detailed derivations are provided. The accompanying textbook provides exercises to expand the application of the materials presented.

Applications of the course material, presented in the first part, are presented in the second part for actual Integrated Navigation Systems. Examples of these systems are implemented in the MATLAB/Simulink™ commercial product, and are provided for a hands-on experience in the use of the mathematical techniques developed

The AIAA textbook, *Applied Mathematics in Integrated Navigation Systems, Third Edition*, is included in the registration fee.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 18 Jan	*Standard (19 Jan–17 Feb)*	*On-site (18–28 Feb)*
AIAA Member	$995	$1125	$1220
Nonmember*	$1115	$1245	$1340

*Includes a one-year AIAA membership

28 February–1 March 2013
The following standalone course is being held at The AERO Institute in Palmdale, California.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 18 Jan	Standard (19 Jan–17 Feb)	On-site (18–28 Feb)
AIAA Member	$995	$1125	$1220
Nonmember*	$1115	$1245	$1340

*Includes a one-year AIAA membership

Optimal State Estimation **(Instructor: Dan Simon)**
The instructor presents state estimation theory clearly and rigorously, providing the right balance of fundamentals, advanced material, and recent research results. After taking this course, the student will be able to confidently apply state estimation techniques in a variety of fields. The features of this course include:

- A straightforward, bottom-up approach that begins with basic concepts, and then builds step by step to more advanced topics.
- Simple examples and problems that require paper and pencil to solve—leading to an understanding of how theory works in practice.
- MATLAB®-based state estimation source code for realistic engineering problems—enabling students to recreate state estimation results and experiment with other simulation setups and parameters.

After being given a solid foundation in the fundamentals, students are presented with a careful treatment of advanced topics, including H-infinity filtering, unscented filtering, high-order nonlinear filtering, particle filtering, constrained state estimation, reduced order filtering, robust Kalman filtering, and mixed Kalman/H-infinity filtering.

The textbook *Optimal State Estimation: Kalman, H Infinity, and Nonlinear Approaches* is included in the registration fee.

4–5 March 2013
The following standalone course is being held at the National Aerospace Institute in Hampton, Virginia.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 1 Feb	Standard (2–25 Feb)	On-site (26 Feb–4 Mar)
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

Modeling Flight Dynamics with Tensors **(Instructor: Peter Zipfel)**
Establishing a new trend in flight dynamics, this two-day course introduces you to the modeling of flight dynamics with tensors. Instead of using the classical "vector mechanics" technique, the kinematics and dynamics of aerospace vehicles are formulated by Cartesian tensors that are invariant under time-dependent coordinate transformations

This course builds on your general understanding of flight mechanics, but requires no prior knowledge of tensors. It introduces Cartesian tensors, reviews coordinate systems, formulates tensorial kinematics, and applies Newton's and Euler's laws to build the general six degrees of freedom equations of motion. For stability and control applications, the perturbation equations are derived with their linear and nonlinear aerodynamic derivatives. After taking the course you will have an appreciation of the powerful new "tensor flight dynamics," and you should be able to model the dynamics of your own aerospace vehicle.

15–16 April 2013
The following standalone course is being held at The Ohio Aerospace Institute in Cleveland, Ohio.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 14 Mar	Standard (15 Mar–8 Apr)	On-site (9–15 Apr)
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

A Practical Introduction to Preliminary Design of Air Breathing Engines **(Instructor: Ian Halliwell)**
The objective of the course is to present an overview of the preliminary design of air-breathing engine systems that is determined primarily by the aircraft mission, which defines the engine cycle—and different types of cycle are investigated. Preliminary design activities are defined and discussed in the context of the overall engine development process and placed in perspective. Some basic knowledge of aerodynamics and thermodynamics is assumed so the mathematical material that appears in many good textbooks is minimized and the question "What do you actually do as an engine designer?" is addressed. The practical means and processes by which thermodynamic concepts are turned into hardware are covered and some design techniques are demonstrated. Finally, the fact that an air breathing engine is much more than the flowpath component is discussed and the future of engine design methods is raised. Class participation is encouraged throughout. This is your course; please try to get from it whatever you want!

15–16 April 2013
The following standalone course is being held at The Ohio Aerospace Institute in Cleveland, Ohio.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 14 Mar	Standard (15 Mar–8 Apr)	On-site (9–15 Apr)
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

Computational Heat Transfer (CHT) **(Instructor: Dean Schrage)**
This CHT (Computational Heat Transfer) course provides a singular focus on the thermal modeling and analysis process, providing a unique perspective by developing all concepts with practical examples. It is a computational course dedicated to heat transfer. In the treatment of the general purpose advection-diffusion (AD) equation, the course material provides a strong introductory basis in CFD. The present course attempts to couple both the computational theory and practice by introducing a multistep modeling paradigm from which to base thermal analysis. The first six lectures form a close parallel with the modeling paradigm to further

ingrain the concepts. The seventh lecture is dedicated to special topics and brings in practical elements ranging from hypersonic CHT to solidification modeling. The CHT course is also designed around an array of practical examples and employs real-time InterLab sessions. The overall goal of the CHT course is to form a unison of theory and practice, emphasizing a definitive structure to the analysis process. The course has a strong value added feature with the delivery of a general purpose CHT-CFD analysis code (Hyperion-TFS) and a volume Hex Meshing tool (Hyperion-Mesh3D).

10–11 June 2013

The following standalone course is being held at The Ohio Aerospace Institute in Cleveland, Ohio.

Introduction to Spacecraft Design and Systems Engineering (Instructor: Don Edberg)

This course presents an overview of factors that affect spacecraft design and operation. It begins with an historical review of unmanned and manned spacecraft, including current designs and future concepts. All the design drivers, including launch and on-orbit environments and their affect on the spacecraft design, are covered. Orbital mechanics is presented in a manner that provides an easy understanding of underlying principles as well as applications, such as maneuvering, transfers, rendezvous, atmospheric entry, and interplanetary transfers. Considerable time is spent defining the systems engineering aspects of spacecraft design, including the spacecraft bus components and the relationship to ground control. Design considerations, such as structures and mechanisms, attitude sensing and control, thermal effects and life support, propulsion systems, power generation, telecommunications, and command and data handling are detailed. Practical aspects, such as fabrication, cost estimation, and testing, are discussed. The course concludes with lessons learned from spacecraft failures.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 10 May	*Standard (11 May–3 Jun)*	*On-site (4–10 Jun)*
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

10–11 June 2013

The following standalone course is being held at The Ohio Aerospace Institute in Cleveland, Ohio.

Aircraft and Rotorcraft System Identification: Engineering Methods and Hands-on Training Using CIFER® (Instructor: Dr. Mark B. Tischler)

The objectives of this two-day short course is to 1) review the fundamental methods of aircraft and rotorcraft system identification and illustrate the benefits of their broad application throughout the flight vehicle development process; 2) provide the attendees with an intensive hands-on training of the CIFER® system identification, using flight test data and 10 extensive lab exercises. Students work on comprehensive laboratory assignments using student version of software provided to course participants (requires student to bring NT laptop). The many examples from recent aircraft programs illustrate the effectiveness of this technology for rapidly solving difficult integration problems. The course will review key methods and computational tools, but will not be overly mathematical in content. The course is highly recommended for graduate students, practicing engineers, and managers. The AIAA textbook, *Aircraft and Rotorcraft System Identification: Engineering Methods with Flight-Test Examples, Second Edition*, is included in the registration fee.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 10 May	*Standard (11 May–3 Jun)*	*On-site (4–10 Jun)*
AIAA Member	$995	$1125	$1220
Nonmember*	$1115	$1245	$1340

*Includes a one-year AIAA membership

29–30 July 2013

The following standalone course is being held at the National Aerospace Institute in Hampton, Virginia.

Introduction to Space Systems (Instructor: Mike Gruntman)

This two-day course provides an introduction to the concepts and technologies of modern space systems. Space systems combine engineering, science, and external phenomena. We concentrate on scientific and engineering foundations of spacecraft systems and interactions among various subsystems. These fundamentals of subsystem technologies provide an indispensable basis for system engineering. The basic nomenclature, vocabulary, and concepts will make it possible to converse with understanding with subsystem specialists. This introductory course is designed for engineers and managers—of diverse background and varying levels of experience—who are involved in planning, designing, building, launching, and operating space systems and spacecraft subsystems and components. The course will facilitate integration of engineers and managers new to the space field into space-related projects.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 1 Jul	*Standard (2–22 Jul)*	*On-site (23–29 Jul)*
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

29–30 July 2013

The following standalone course is being held at the National Aerospace Institute in Hampton, Virginia.

Phased Array Beamforming for Aeroacoustics (Instructor: Robert Dougherty)

This course presents physical, mathematical, and some practical aspects of acoustic testing with the present generation of arrays and processing methods. The students will understand the capabilities and limitations of the technique, along with practical details. They will learn to design and calibrate arrays and run beamform-

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ing software, including several algorithms and flow corrections. Advanced techniques in frequency-domain and time-domain beamforming will be presented. The important topics of electronics hardware and software for data acquisition and storage are outside the scope of the course, apart from a general discussion of requirements.

29–30 July 2013
The following standalone course is being held at the National Aerospace Institute in Hampton, Virginia.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 1 Jul	*Standard (2–22 Jul)*	*On-site (23–29 Jul)*
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

Turbulence Modeling for CFD **(Instructor: David Wilcox)**
This course on turbulence modeling begins with a careful discussion of turbulence physics in the context of modeling. The exact equations governing the Reynolds stresses, and the ways in which these equations can be closed, is outlined. The course starts with the simplest turbulence models and charts a course leading to some of the most complex models that have been applied to a nontrivial turbulent flow problem. It stresses the need to achieve a balance amongst the physics of turbulence, mathematical tools required to solve turbulence-model equations, and common numerical problems attending use of such equations.

23–24 September 2013
The following standalone course is being held at The AERO Institute in Palmdale, California.

To register, go to **www.aiaa.org/CourseListing.aspx?id=3200.**

	Early Bird by 23 Aug	*Standard (24 Aug–15 Sep)*	*On-site (16–23 Sep)*
AIAA Member	$950	$1075	$1175
Nonmember*	$1070	$1195	$1295

*Includes a one-year AIAA membership

Gossamer Systems: Analysis and Design
(Instructor: Chris Jenkins)
An evolving trend in spacecraft is to exploit very small (micro- and nano-sats) or very large (solar sails, antenna, etc.) configurations. In either case, success will depend greatly on ultra-lightweight technology, i.e., "gossamer systems technology." Areal densities of less than 1 kg/m2 (perhaps even down to 1 g/m2!) will need to be achieved.

This course will provide the engineer, project manager, and mission planner with the basic knowledge necessary to understand and successfully utilize this emerging technology. Definitions, terminology, basic mechanics and materials issues, testing, design guidelines, and mission applications will be discussed. A textbook and course notes will be provided.

Standard Information for all AIAA Conferences

This is general conference information, except as noted in the individual conference preliminary program information to address exceptions.

Photo ID Needed at Registration

All registrants must provide a valid photo ID (driver's license or passport) when they check in. For student registration, valid student ID is also required.

Conference Proceedings

This year's conference proceedings will be available in an online format only. The cost is included in the registration fee where indicated. If you register in advance for the online papers, you will be provided with instructions on how to access the conference technical papers. For those registering on-site, you will be provided with instructions at registration.

Young Professional Guide for Gaining Management Support

Young professionals have the unique opportunity to meet and learn from some of the most important people in the business by attending conferences and participating in AIAA activities. A detailed online guide, published by the AIAA Young Professional Committee, is available to help you gain support and financial backing from your company. The guide explains the benefits of participation, offers recommendations and provides an example letter for seeking management support and funding, and shows you how to get the most out of your participation. The online guide can be found on the AIAA Web site, **www.aiaa.org/YPGuide**.

Journal Publication

Authors of appropriate papers are encouraged to submit them for possible publication in one of the Institute's archival journals: *AIAA Journal*; *Journal of Aircraft*; *Journal of Guidance, Control, and Dynamics*; *Journal of Propulsion and Power*; *Journal of Spacecraft and Rockets*; *Journal of Thermophysics and Heat Transfer*; or *Journal of Aerospace Computing, Information, and Communication*. You may now submit your paper online at **http://mc.manuscriptcentral.com/aiaa**.

Speakers' Briefing

Authors who are presenting papers, session chairs, and co-chairs will meet for a short briefing at 0700 hrs on the mornings of the conference. Continental breakfast will be provided. Please plan to attend only on the day of your session(s). Location will be in final program.

Speakers' Practice

A speaker practice room will be available for speakers wishing to practice their presentations. A sign-up sheet will be posted on the door for half-hour increments.

Timing of Presentations

Each paper will be allotted 30 minutes (including introduction and question-and-answer period) except where noted.

Committee Meetings

Meeting room locations for AIAA committees will be posted on the message board and will be available upon request in the registration area.

Audiovisual

Each session room will be preset with the following: one LCD projector, one screen, and one microphone (if needed). A 1/2" VHS VCR and monitor, an overhead projector, and/or a 35-mm slide projector will only be provided if requested by presenters on their abstract submittal forms. AIAA does not provide computers or technicians to connect LCD projectors to the laptops. Should presenters wish to use the LCD projectors, it is their responsibility to bring or arrange for a computer on their own. Please note that AIAA does not provide security in the session rooms and recommends that items of value, including computers, not be left unattended. Any additional audiovisual requirements, or equipment not requested by the date provided in the preliminary conference information, will be at cost to the presenter.

Employment Opportunities

AIAA is assisting members who are searching for employment by providing a bulletin board at the technical meetings. This bulletin board is solely for "open position" and "available for employment" postings. Employers are encouraged to have personnel who are attending an AIAA technical conference bring "open position" job postings. Individual unemployed members may post "available for employment" notices. AIAA reserves the right to remove inappropriate notices, and cannot assume responsibility for notices forwarded to AIAA Headquarters. AIAA members can post and browse resumes and job listings, and access other online employment resources, by visiting the AIAA Career Center at http://careercenter.aiaa.org.

Messages and Information

Messages will be recorded and posted on a bulletin board in the registration area. It is not possible to page conferees. A telephone number will be provided in the final program.

Membership

Professionals registering at the nonmember rate will receive a one-year AIAA membership. Students who are not members may apply their registration fee toward their first year's student member dues.

Nondiscriminatory Practices

The AIAA accepts registrations irrespective of race, creed, sex, color, physical handicap, and national or ethnic origin.

Smoking Policy

Smoking is not permitted in the technical sessions.

Restrictions

Videotaping or audio recording of sessions or technical exhibits as well as the unauthorized sale of AIAA-copyrighted material is prohibited.

International Traffic in Arms Regulations (ITAR)

AIAA speakers and attendees are reminded that some topics discussed in the conference could be controlled by the International Traffic in Arms Regulations (ITAR). U.S. Nationals (U.S. Citizens and Permanent Residents) are responsible for ensuring that technical data they present in open sessions to non-U.S. Nationals in attendance or in conference proceedings are not export restricted by the ITAR. U.S. Nationals are likewise responsible for ensuring that they do not discuss ITAR export-restricted information with non-U.S. Nationals in attendance.