December 2013

AEROSPACE AMERICA

Budget battles, test flights, lawsuits...

2013 IN REVIEW

PREEMINENCE AT RISK

AIAA President-Elect Jim Albaugh on the industry's future, **page B5**

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December 2013

THE YEAR IN REVIEW

BULLETIN

Aerospace America (ISSN 0740-722X) is published monthly, except August, by the American Institute of Aeronautics and Astronautics, Inc. at 1801 Alexander Bell Drive, Reston, Va. 20191-4344 [703/264-7500]. Subscription rate is 50% of dues for AIAA members (and is not deductible therefrom). Nonmember subscription price: U.S. and Canada, $163, foreign, $200. Single copies $20 each. **Postmaster: Send address changes and subscription orders to address above, attention AIAA Customer Service, 703.264.7500.** Periodical postage paid at Herndon, Va. and at additional mailing offices. 40,000 copies of this issue printed. This is Volume 51, No. 11.

AEROSPACE AMERICA®

is a publication of the American Institute of Aeronautics and Astronautics

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December 2013, Vol. 51, No. 11

AIAA
The World's Forum for Aerospace Leadership

Editor's Notebook

Defending conferences

A safe bet is that no clowns or mind-readers were hired at the Volta Conference in Rome in 1935 to entertain the likes of German aerospace engineer Adolph Busemann, who aired a proposal to sweep back the wings of aircraft for speed, or American aerodynamicist Eastman Jacobs, who presented the first photo of shockwaves coming off an airfoil.

A gathering as impactful as Volta would be hard to pull off today. A May 2012 White House memo ordered a 30 percent travel cost reduction for staff, after revelations that in 2010 the General Services Administration spent $822,751 on a conference near Las Vegas, where clowns and mind-readers reportedly provided entertainment. Sequestration is now taking its toll, too.

Just when collaboration and innovation are needed the most, the U.S. has made it difficult for people to come together. The end of a year and the start of a new one marks an opportunity for lawmakers and White House officials to reflect on this travel policy. Organizers of events including AIAA's January SciTech 2014 conference have heard the government's message, and they are working to ensure that conferences are cutting-edge, relevant and appropriate. The government can help by looking for ways to make travel easier in the New Year.

As things stand, the understandable revulsion at wasted tax dollars has morphed into skepticism about the value of experts gathering together.

A Nov. 6 Defense Department guidance instructs managers to consider teleconferencing, videoconferencing, and online apps as possible alternatives to attending conferences.

The problem with this guidance is that information technology is no substitute for the chance encounters and informal brainstorming that happen when human beings meet at one location.

The entire bureaucratic culture shifts at a well-planned event. Thought leaders suddenly find themselves outside the bubble chatting with journalists, scientists and entrepreneurs. The scrum learns a lot, but so do the thought leaders and their entourages.

Most of the year, strict protocol governs the interplay among scientists, engineers, executives and government officials. They work in enclaves sarcastically called cylinders of excellence. For a few glorious hours or days, attendees air ideas they would never put in emails or memos.

The Defense Department guidance assumes that it's always possible to divine whether attendance at a conference is "critical to the day-to-day execution of our national security mission." By that metric, the many civilian applications of GPS would have come much more slowly.

This is not to say that social media, videoconferencing and other technologies aren't valuable. People use them to prepare for events, to share information in real time during them and to capitalize on the brainstorming afterwards.

At the end of the day, there is no substitute for human presence. Your entire family might be on Facebook, but your family reunion is where you'll learn what's really happening.

Lawmakers and government managers should think about these issues as they gather with their families for the holidays and look forward to 2014.

Ben Iannotta
Editor-in-Chief

Beyond climate change

Philip Butterworth-Hayes gave us an excellent article on climate change and aviation (November, “Climate change and aviation: Forecasting the effects,” p. 30). However, there is another much larger and broader problem coming that will have dramatic effects on civilization as a whole, including aviation and space: The depletion of natural resources is going to cause the decline of mankind.

Isn’t it time for Aerospace America to alert our members to the inevitable and overwhelming fate of humanity? The business world will never do it, therefore the scientific and technical world must.

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✈✈✈

Asteroids vs. the Moon

As an ex ICBM crew commander and PhD in engineering who has spent his career in Silicon Valley and new space research, I take a very different message away from the developments (and leaked pictures) than Dr. Aldrin and Mr. Cernan do (November, “China’s bold lunar plan,” p. 24). I have the utmost respect for these men and agree with them that the moon should be on the national agenda. But this should be done on our terms and in proportion with other potentially more productive endeavors (like Near Earth Object asteroid missions).

The Chinese program is clearly shaped by a classic “get in your competition’s mind”-style technical intelligence. It seems we do this well, and even boast about it, but then seem to not assess it rationally when we see others doing it to us. [Chinese engineers] are clearly trying to get in the heads of the Grumman Team of 40 years ago, right down to the fact that their bunny suits are labeled first in English. I don’t think that’s an accident. What would be an accident is to fall for it, and spend our resources on it rather than looking forward with our limited resources.

This [Chinese lunar] development is in fact the best possible reason for the U.S. to go for the NEO asteroid retrieval mission. Asteroids are where all the resources for the next 500 years of human space development can be found, and the U.S. should make [China] spend the big bucks on going back to the surface of the Moon, rather than being reflexively distracted by romantic notions of our national past. This is certainly not incompatible with also collaborating with the Chinese and treating them with more respect.

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The leading edge of next-generation technology

by Louis Centolanza

*The **Adaptive Structures Technical Committee** supports work to enable aircraft to adapt to changing environmental conditions during flight.*

July saw the first flight of the **X-56A**, a modular, unmanned research vehicle designed to demonstrate active control of structural modes for flutter suppression and gust load alleviation. Developed by Lockheed Martin for the Air Force Research Laboratory, the X-56A is 'multi-use'—capable of hosting various wing and tail configurations. NASA Dryden will take ownership late this year after AFRL's initial flight research. The aircraft should be ideal for future research in adaptive structures, flight sensors, and control schemes.

AFRL also designed, fabricated, and tested an adaptive variable camber compliant wing. A compliant mechanism/structure with a single-piece carbon fiber skin gives active camber change between the **NACA 2410** and **NACA 8410** airfoil shapes without discrete control surfaces. The skin is nonstretchable and gives a smooth outer mold line for improved aerodynamic performance. A test in the Vertical Wind Tunnel at Wright-Patterson AFB is planned.

To make air travel more environment-friendly, the **German Aerospace Center DLR**, together with Airbus, EADS Innovation Works, and Cassidian Air Systems, is reducing aircraft aerodynamic drag by developing an alternative to the traditional leading-edge slat. A morphing leading edge replaces slats, creating an innovative high-lift system that significantly reduces drag and noise during landing. Tests at the Russian Central Aerohydrodynamics Institute's Zhukovsky research facility demonstrated the ability to carry the aerodynamic loads, even though the skin is flexible enough to lower the leading edge by up to 20 deg.

The MH-60R Sea Hawk helicopter seat suspension system is designed to mitigate cockpit vibrations. Credit: Sikorsky Aircraft.

Leading-edge-slat noise reduction solutions are under development at NASA Langley. The highly deformable slat-cove filler is enabled by pseudoelastic shape memory alloys. Models developed in collaboration with **Texas A&M University** resulted in an optimized design for the airframe configuration studied on the bench-top at NASA Langley.

The Naval Air Warfare Center, Techno Sciences, and the University of Maryland developed a semiactive magnetorheological seat suspension system to mitigate cockpit vibrations. It is a direct retrofit to the **MH-60R Seahawk** crew seat. These MR dampers are on the same vertical stroking tubes on which the seat slides for crash protection, preserving crash safety capability. Testing showed over 90% reduction of the dominant rotor-induced vertical vibration at the blade passage frequency transmitted to the occupant. Initial flight tests took place in late 2012, and a fully instrumented flight test is scheduled for FY14.

The **University of Maryland** is researching **robotic manipulation** with pneumatic artificial muscles, extremely lightweight actuators that provide high power-to-weight ratios but are also naturally compliant. This combination enables robots that can perform safer heavy lifting operations around humans. A visual system was integrated to track a user's body orientation and mimic human arm motions.

One issue with the use of adaptive aerostructures in aircraft primary structure is that they are without an FAA-recognized materials database. The **University of Kansas** recently developed **pressure adaptive honeycomb**, or PAH, materials, which not only use FAA-certified materials but also are among the highest work-energy density adaptive materials. With funding from NASA Ames, these materials were built up from single cells to sheets to structures and wing sections. When integrated into wings, PAH was shown to reduce airframe fatigue by an order of magnitude, increase ride quality, and significantly enhance survivability in gust fields like those associated with microbursts.

Work continues in structural health monitoring. **Arizona State University** developed Lamb wave interrogation methods to identify and localize **fatigue crack damage** in complex structural components subjected to unknown temperatures. ASU also developed stochastic multiscale models for fiber-reinforced composites, focusing on the propagation of uncertainty across the length scales. The methodology may affect the design and modeling of next-generation adaptive composite structures.

Quiet flight, Curiosity, station resupply mark the year in design

by Sidney Rowe

*The **Design Engineering Technical Committee** promotes the development and dissemination of technologies that assist design engineers in defining practical aerospace products.*

The X-48C, a modification of the previously flown X-48B Blended Wing Body unmanned plane, was flown for the first time in 2013.

One objective of the X-48C flight test program at NASA Dryden is to evaluate the low-speed stability and control of a future **Hybrid Wing Body** design. The HWB design grew out of the need for a low-noise version of the aircraft. Noise reduction is one major objective of the NASA Environmentally Responsible Aviation project, an effort aimed at reducing the impact of future aircraft on the environment.

The changes to the X-48C from the X-48B were made to transform it into an aircraft that improves the shielding of engine noise on the ground—a benefit for airports as well as their surrounding communities. These modifications include moving the wingtip winglets in next to the engines—basically turning them into twin tails. The aft deck of the C version also was lengthened about 2 ft toward the rear relative to the B version. The X-48B's three 50-lb-thrust jet engines were replaced with two 89-lb-thrust engines on the X-48C.

The first launch of Antares took place on April 21. Credit: Orbital Sciences.

Because the handling qualities of the X-48C are different from those of the earlier version, the flight control system software also has been modified. These changes make for a stronger and safer prototype flight control system. They also enable future hybrid and blended wing airframes. The X-48C is measurably similar to the B version, with a wingspan of around 20 ft and a weight of roughly 500 lb. The aircraft has an estimated top speed of about 140 mph and a maximum altitude of 10,000 ft.

Meanwhile, on Mars, the **Curiosity Mars Mission** continues almost two years after its launch and more than a year after it landed the rover on the planet's surface. During the spacecraft's mission to Mars its instruments measured radiation levels in the natural environment. Radiation and weather are two of the parameters being monitored while the rover is on the Martian surface. The resulting environmental data will be useful in planning for human missions to Mars in the future. The Curiosity Rover is also using lasers to determine the composition of materials on the surface of the planet.

SpaceX, a partner in NASA's **Commercial Orbital Transportation Services** program, is preparing for its third supply flight to the International Space Station using a Falcon 9 rocket and Dragon supply capsule. In September, Orbital Sciences, the second COTS partner, launched its first mission to the ISS. One of the company's Antares rockets lifted off from NASA's Wallops Flight Facility in Virginia carrying a Cygnus cargo capsule that docked with the station. OSC is now expected to begin regular ISS resupply missions. A goal of the COTS program is to develop safe, reliable, and cost-effective transportation for space cargo. 𝔸

The NASA-Boeing X-48C Blended-Wing Body technology demonstrator has inboard vertical stabilizers. Credit: NASA.

Multidisciplinary design use expands

by Karen Willcox and Gulshan Singh

The ***Multidisciplinary Design Optimization Technical Committee*** *provides a forum for advancing a formal design methodology based on the integration of disciplinary and sensitivity analyses, optimization, and artificial intelligence.*

The increased maturity of Multidisciplinary Design Optimization architectures and formulations has led to growing application across the aerospace industry. In an *AIAA Journal* survey paper, the **University of Michigan** represented existing MDO architectures in a unified notation with a new visualization of data dependency and process flow for each MDO architecture. **Penn State** and the Applied Research Laboratory identified four use cases for trade space exploration (exploration, discovery, explanation, and requirements feasibility) and are investigating set-based design, preference construction, and multifidelity modeling strategies to support each case.

Scalability of MDO methods remains a challenge and is being addressed through new formulations and advanced optimization methods. **UC Berkeley** developed new design formulations that exploit underlying convex structure in design relations. For aircraft conceptual design, with hundreds of variables and constraints, this enables solution in milliseconds. **The University of Michigan** and **McGill University** developed a new approach to solving decomposed multiobjective optimization problems by using quasiseparable MDO problem formulations and nonhierarchical analytical target cascading coordination, with application to vehicle suspension design.

The University of Southampton continues to develop novel MDO technologies and apply them to the design of gas turbines and unmanned systems. This has brought advances in surrogate modeling of nonstationary and transient responses, quantification of design uncertainties, utilization of cost within design, topology optimization in designing for 3D printing, and the capture/reutilization of designer decisions, knowledge, and best practice.

The University of Toronto's AeroVelo helicopter team used Multidisciplinary Design Optimization to win the Igor I. Sikorsky Human Powered Helicopter Competition. Credit: Jake Reed.

Surrogate modeling and multifidelity strategies (the systematic use of multiple models at different fidelity levels) also address scalability of MDO methods. **MIT** developed a new multifidelity optimization under uncertainty method, using control variates to exploit correlation between low- and high-fidelity models. MIT and **Aurora Flight Sciences** developed a multifidelity strategy using dynamic data to inform online adaptation of structural damage and reduced-order models. **University of Illinois** developed an optimization method for nonlinear dynamic systems using surrogate modeling of time-derivative functions. When applied to wind turbine codesign, it resulted in an order of magnitude reduction in computational expense.

Multi-information source optimization expands on previous multifidelity methods. It concerns how an optimizer should dynamically choose among multiple information sources (such as multifidelity simulators or experiments) to optimize the final solution and the cost of finding that solution. **The Santa Fe Institute** hosted several meetings focused on this topic, with particular emphasis on potential synergies between machine learning methods and MDO.

Military aircraft concepts featuring embedded engines and hypersonic vehicles continue to present new design challenges related to hot structures and thermal stresses. Researchers at **Wright State University** are investigating topology optimization to address these challenges using MDO formulations, including thermal and structural design responses to manage thermal behavior.

The **Air Force Research Laboratory**/**Virginia Tech**/Wright State University Collaborative Center on Multidisciplinary Sciences continued its work on efficient supersonic air vehicles; micro-air vehicles, in collaboration with the **University of Maryland**; and the SensorCraft, in collaboration with **Quaternion** and the **University of Victoria**. Research included multifidelity modeling and uncertainty quantification in structural, aeroelastic, and flight dynamic modeling; flight testing of scaled models for understanding nonlinear aeroelastic behavior; and an extended markup language that will improve the way the technical information is exchanged at the conceptual and preliminary design stages.

NASA's OpenMDAO project continues to make it easier to apply MDO methods to new problems. It has a growing user community and is being downloaded an average of 100 times a week. The most recent release of OpenMDAO includes a new browser-based GUI and geometry integration features.

The **University of Toronto**'s AeroVelo team made history by achieving 1 min of self-powered helicopter flight and winning the longstanding **Igor I. Sikorsky Human Powered Helicopter Competition**. The student team used MDO extensively in their design process.

The art and science of prognosticating

by Shyama Kumari, Masoud Rais-Rohani, Shankar Sankararaman and Vicente Romero

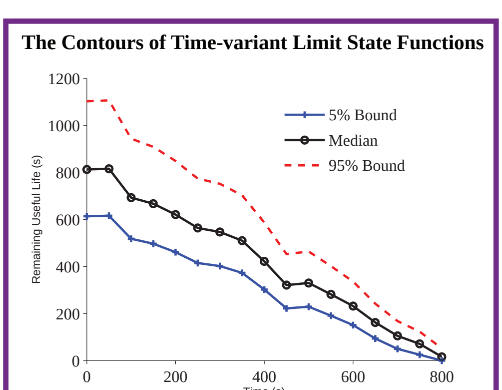
*The **Non-Deterministic Approaches Technical Committee** advances the art, science and cross-cutting technologies required for applying non-deterministic modeling and analysis to aerospace systems.*

Continuous development of **uncertainty quantification** or **UQ** and propagation methods, supported by exponential growth in computing power in recent decades, has greatly facilitated the modeling and analysis of aleatory and epistemic uncertainties in natural and engineered systems. Recent advances in UQ research are also helping to overcome many challenges related to validation of theories and application of tools and techniques.

UQ application is increasing in various fields of engineering, including structures, fluids, energy and power systems, propulsion, and many others. Implementation of the improved UQ capabilities into practical, user-friendly, and high-performance design and analysis tools continues to grow.

UQ is a relatively new area in terms of development of the theory, methods, and codes that identify the origins of uncertainties and model different sources for them. UQ with an appropriate confidence level relies on advanced mathematical, statistical algorithms and computational models that require multicore high-performance computing systems. The Dept. of Energy, through its **Office of Advanced Scientific Computing Research**, has shown interest in extreme-scale computing capabilities by announcing programs in advanced mathematical, statistical, and computing platform research. The goal is to enhance accuracy, reliability, and computational efficiency to seed the next paradigm shift in methodologies and tools for the extreme-scale computing and enhanced predictive capabilities.

At **Mississippi State University**, researchers are working to extend the application of both probabilistic and nonprobabilistic UQ approaches. Application areas include physics-based material models as well as problems involving coupled material-product and process-product analysis and optimization. For example, evidence theory has been used to represent and propagate uncertainty in the macro-level material constants that stems from both random variability in the experimental data and incertitude in capturing history effects. Calculation of uncertainty bounds on plastic deformation through belief and plausibility estimates is used in evidence-based design optimization of various structural components. The results are paving the way for integration of UQ into a multilevel design optimization framework.



Use of nondeterministic approaches in prognostics and system health monitoring has also been increasing. Researchers from Arizona State University, the University of Florida, and Vanderbilt University have developed computational methods to systematically account for uncertainty in structural health monitoring. The Prognostics Center of Excellence at **NASA Ames** focuses on providing an umbrella for prognostic technology development, specifically addressing gaps within the application areas of aeronautics and space exploration.

The most important goal in prognostics is the continuous online prediction of remaining useful life, which facilitates decision-making activities such as maintenance/replacement planning, mission replanning, and fault mitigation. **Prognostics** are significantly affected by different sources of uncertainty. Thus recent research has investigated different types of sampling techniques and analytical methods for quantifying the uncertainty in remaining useful life prediction of components used in avionics and aerospace systems. These methods are being evaluated through application of a suite of testbeds, including power systems of planetary rovers and unmanned aircraft.

At **Wichita State University**, a nested extreme response surface, or NERS, approach is developed and integrated with dynamic RBRDO—reliability-based robust design optimization—for robust design of engineered systems with time-variant probabilistic constraints. Time-variant fatigue and corrosion effects are assessed by dynamic reliability analysis conducted using iterative approaches. The discretization of time greatly simplifies the dynamic reliability analysis by allowing conversion of the dynamic reliability problem into several instantaneous static problems. The NERS technique, combined with a Kriging or approximation-based nested time prediction model, predicts the time when the performance function is at its extreme values for any given system.

Continuous uncertainty quantification in remaining useful life: Power system of an unmanned aircraft. Credit: Shankar Sankararaman/NASA Ames.

Quest for electricity helps power space structures work

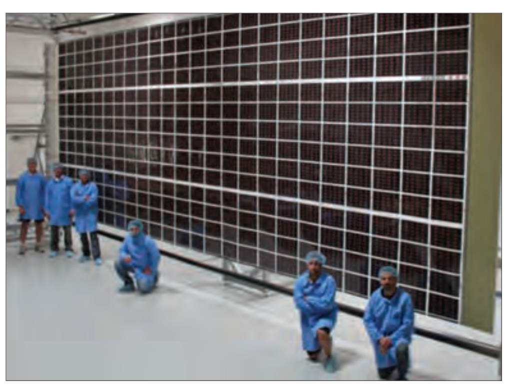
by Gregory L. Davis, Amir Gohardani, Dave Murphy, and Steve White

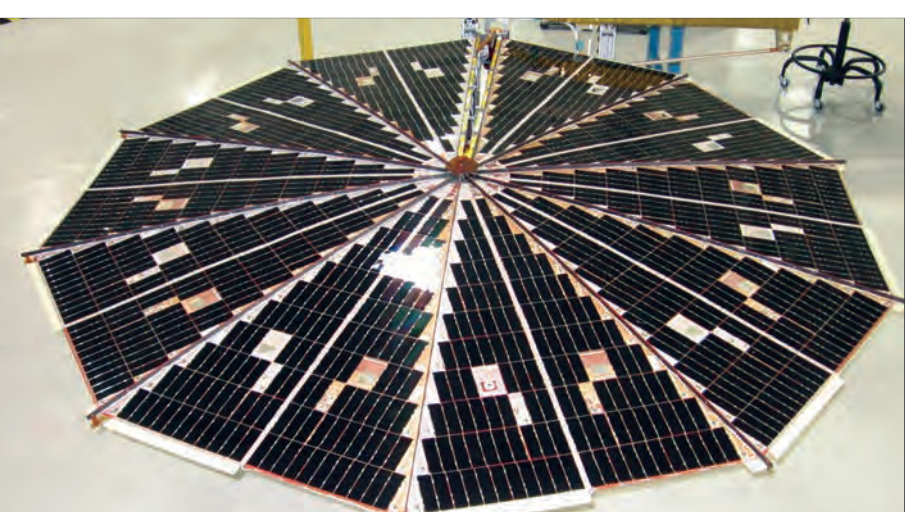
*The **Spacecraft Structures Technical Committee** is focused on the unique challenges associated with developing novel structural systems that operate in space environments.*

The year brought progress toward the **Sunjammer** solar sail technology demonstration mission planned for late 2014 by NASA's Space Technology Directorate. Sunjammer, named after a short story by Sir Arthur C. Clarke, seeks to demonstrate the feasibility of using state-of-the-art technologies to navigate a solar sail in space. The mission plans to deploy a 1,200-m^2 sail and subsequently fly it to a sub-L1 location. The program demonstrated the deployment of a quadrant of the sail in a test facility earlier in the year. Sunjammer will be boosted to geostationary orbit as a secondary payload and will employ an onboard propulsion system to reach an Earth escape orbit before deployment of the sail. The mission is a collaboration by L'Garde, NASA, Space Services Holdings, Micro Aerospace Solutions, the National Oceanic and Atmospheric Administration, Imperial College London, and the University College London.

Lightweight space power deployables have also seen significant progress this year. ATK Space Systems, also under NASA's Space Technology Program, has tested and delivered the first two of 10 **UltraFlex wings** that will fly on Orbital Sciences' Cygnus spacecraft for resupply missions to the ISS. Key subsystems of this latest UltraFlex flight assembly are being directly leveraged to develop and demonstrate that the power and performance of this heritage membrane array technology can be scaled up significantly. It could then support near-term missions requiring 30-50 kW of power, such as the planned **Asteroid Redirect Mission**, and also future 250-kW-class **solar-electric propulsion** (SEP) systems. A 10-m MegaFlex wing has been built and is being validated with a full complement of standard system and subsystem tests. These tests will conclude with complete full-system end-to-end deployment and deployed dynamic testing, both within a thermal vacuum environment.

The Roll-Out Solar Array's flex-blanket configuration enables high power levels. Credit: NASA.





ATK's MegaFlex solar array is based on the UltraFlex technology that powered NASA's Mars Phoenix Lander. Credit: NASA.

Deployable Space Systems of Goleta, California, is also developing an advanced high-powered solar array system under the same program to support future SEP missions. SEP is a key capability required for extending human presence throughout the solar system. The company's development work focuses on drastically reducing the weight, stowed volume, and cost of solar array systems relative to current systems, and on enabling potentially hundreds of kilowatts of power production. The company designed, analyzed, and tested a scalable 10-15-kW-size **Roll-Out Solar Array** wing system, known as **ROSA**, to validate deployment functionality, deployed dynamics, and vibration survivability. Efforts now focus on the design, analysis, and testing of a larger ROSA wing system capable of generating more than 30 kW at BOL (beginning of life). This effort is supplemented by the design, analysis, and testing of supporting deployable structural elements to demonstrate extensibility to 300 kW and higher.

The past year has also marked an important transition within the structures community as the AIAA **Gossamer Spacecraft Program Committee** formally converted to the new Spacecraft Structures Technical Committee. This newly formed technical committee is focused on the unique challenges associated with the design, analysis, fabrication, and testing of spacecraft structures. The committee is actively recruiting AIAA members interested in advancing the state of the art in this field.

Harnessing flight dynamics

by D. Todd Griffith

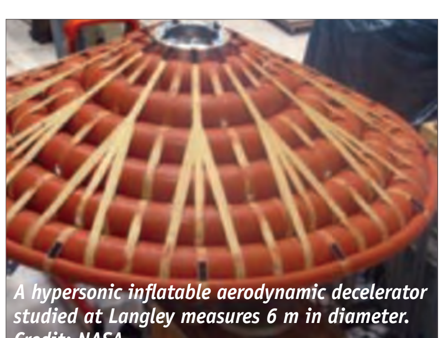
*The **Structural Dynamics Technical Committee** focuses on the interactions among a host of forces that impact aircraft, rockets and spacecraft.*

As part of NASA's game-changing technology for space exploration, Langley is studying the use of **inflatable aeroshell structures** for planetary missions. This research includes modal tests aimed at understanding the dynamic characteristics of hypersonic inflatable aerodynamic decelerator structures. The design will reduce the volume and diameter of the launched payload while increasing the available payload mass delivered to a planetary surface.

The modal test results are used to verify and update the finite-element modeling techniques for these complex structures to enable improved predictions of the structural dynamic response and aid in controller design for the actual flight environment. Future tests will investigate the dynamic behavior of the loaded structure with the thermal protection system.

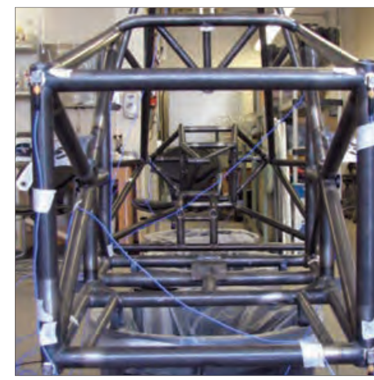
The recent success of JAXA's solar sail, known as IKAROS for **Interplanetary Kite-craft Accelerated by Radiation of the Sun**, has renewed NASA's interest in ultra-large, helicopter-like heliogyro solar sail architectures. Although full-scale ground validation dynamics testing of the heliogyro is impossible, some aspects of the problem can be experimentally studied using small-scale models. Researchers at Langley conducted vacuum chamber testing of a 1-m-scale heliogyro dynamics pathfinder model. Membrane blade responses were measured using hub-mounted digital cameras and videogrammetry techniques. The data are being used to validate analytical dynamics models of a full-scale 440-m-diam. heliogyro flight demonstration solar sail.

Sandia National Laboratories' Wind Energy Technology Dept. is researching large-scale **vertical-axis wind turbine**, or VAWT, rotor technology for deep-water offshore siting. Historically, structural resonance has been a key design challenge for VAWT rotor development. Sandia is developing a modular aerohydroelastic design code for VAWT analysis. The code has been used to demonstrate the sensitivity of VAWT structural dynamics response to design variables including support structure type, rotor size, and architecture. These analyses will guide future VAWT rotor development and cost studies.



A hypersonic inflatable aerodynamic decelerator studied at Langley measures 6 m in diameter. Credit: NASA

For the **Formula SAE design competition**, a structural dynamics group from Sandia took its modal testing laboratory on the road this spring to help the University of New Mexico's team. The goal of the experiment was to identify the torsional stiffness of the team's designed chassis. Once the fundamental frequency of this stiffness was identified, a finite-element model was calibrated with the test data. The model can be used for design studies to help increase the torsional stiffness of a race car's chassis. This improves vehicle handing by allowing the suspension components to control a larger percentage of the vehicle's kinematics and enhance suspension dynamic performance.



Sandia rocket engineers and structural dynamicists helped University of New Mexico students improve the race car chassis they created for the Formula SAE design competition. Credit: SAE International.

NASA Marshall engineers have been measuring the response of launch vehicle panels during ground acoustic tests. The goal is to verify the tools and techniques used to develop vibroacoustic environments. The test cell consists of reverberant and anechoic chambers, separated by a partition/panel. An air horn develops acoustic energy in the reverberant chamber exiting the test article. Different sets of equipment have been integrated to the panel, simulating a variety of launch vehicle and subsystem vibroacoustics responses. The results help to establish damping schedules, frequency resolution, and adequate patch density for analysis. Also provided are validations establishing transmission loss estimates and the damping contribution from cable harnesses.

Final results of a vibroacoustics prediction study were presented to the **NASA Engineering and Safety Center** Review Board. This vibroacoustics working group was formed in 2009 with participation from the safety center's Loads and Dynamics Technical Discipline Team, NASA JPL, and NASA Goddard. The goal was an improved method for random vibration mass attenuation and force limiting prediction to reduce over- or underspecification risk to current and future NASA programs. The study showed that the generalized mass attenuation method presented a significant improvement over the current state-of-the-art Norton-Thevenin (N-T). Comparisons of GMA and N-T to JPL acoustic testing demonstrated this decisive improvement. ▲

Lighter, stronger, *safer*

by Harry H. Hilton

The ***Structures Technical Committee*** *works on the development and application of theory, experiment, and operation in the design of aerospace structures.*

Learn more at the
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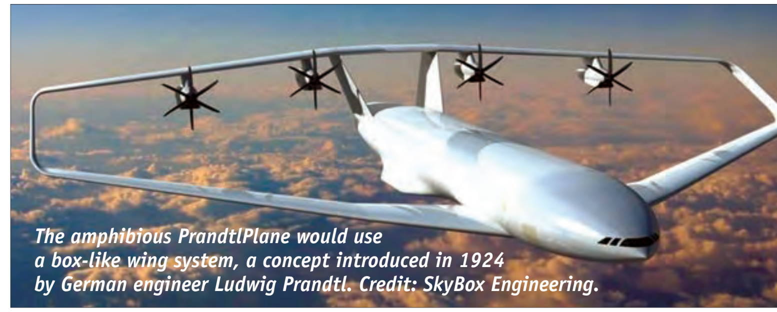


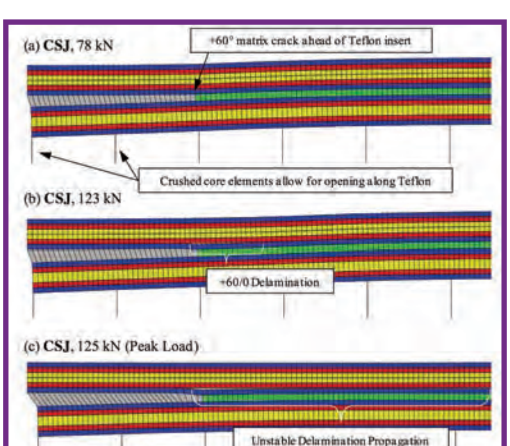
The amphibious PrandtlPlane would use a box-like wing system, a concept introduced in 1924 by German engineer Ludwig Prandtl. Credit: SkyBox Engineering.

MIT's advances in synthesis, manufacturing, and modeling are bringing nanomaterials closer to readiness for use in aerospace structures. **Nanocomposites** and **carbon nanotube-based materials**, both used in the Lockheed Martin F-35, are on their way to Jupiter's moon on NASA's Juno mission. These and other materials, including **nanoclay-reinforced polymer nanocomposites**, continue to draw attention, while **graphene** has become this decade's material of prime interest for its light weight, high strength, and conductivity.

The Aerospace Engineering Dept. at **Mississippi State University** is developing original concepts for shielding spacecraft from impacts by micrometeoroids and orbital debris. The longer a missions lasts, the greater the likelihood of these impacts, which can be catastrophic. Mississippi State is using novel materials and designs to devise shielding that offers not just impact mitigation but also thermal conductivity, environmental barrier formation, and radiation shielding. The researchers are using a two-stage light gas gun for hypervelocity impact testing of these concepts.

The Aerospace Systems Directorate at the **Air Force Research Laboratory** has partnered with Vanderbilt University, Miami University, the University of Massachusetts, Materials Sciences, and the University of Utah to study composite damage progression. This work has yielded several advances. The lab recently showed Vanderbilt's **multiscale damage progression** simulation accurately captures both matrix cracking and delamination as a function of monotonic loads.

Researchers used finite-element method analysis to determine the evolution of failures in a conventional splice joint. Credit: NASA, North Carolina State University, and Boeing.



Miami and Massachusetts completed an experimental comparison of **z-pinning and flocking**, two different through-thickness reinforcement techniques. It showed that z-pins perform better in Mode 1 loading (where a crack's surfaces move directly apart), while flocking performs better in Mode 2 (where the crack's surfaces slide over each other).

Materials Sciences and Utah developed a new experimental method that enables **compression-after-impact** test samples to be efficiently scaled up to large-sized stiffened structural elements, aided by the team's damage progression tool.

Project Idintos, financed by the Tuscany regional government in Italy, is designing the **PrandtlPlane**, an amphibious light aircraft. It would have a box wing in the front view, with proper design of the horizontal and vertical wings; horizontal wings are loaded by the superposition of constant and elliptical lift distributions, and the lift on the vertical wings is butterfly shaped. The hull was designed using computational fluid dynamics codes with a biphasic fluid, taking a dozen parameters into account. Results were verified in the water tank of INSEAN-CN, a naval research organization in Rome. The project includes scaled model wind tunnel tests.

Ball Aerospace developed a method for passively moving modes of complex structures away from critical frequencies and **reducing on-orbit jitter**. The team designed tunable spring masses that fit a small standard interface and envelope. These are tunable to a range of frequencies and can also survive test and launch environments. During testing the devices have shown great success for use on complex structures.

The **Air Force Institute of Technology** Aeronautics and Astronautics Dept. began studying a **lighter-than-air craft** with an internal vacuum. Initial research has shown that for certain designs it is possible to achieve a weight-to-buoyancy ratio of less than one. The group also studied isogrid spheres and craft with two rotating cylinders.

NASA Johnson tested advanced carbon fiber composite and **inflatable prototype habitable modules**. Designed and fabricated in-house, they were proof tested to 8.30 psig (pounds per square inch gage) internal pressure.

NASA Langley, North Carolina State, and Boeing are studying modeling of **progressive damage, including failure, in durable bonded composite joints**. Details are available in three 2013 papers of the Society for the Advancement of Material and Process Engineering.

Stretching survivability

by Ameer G. Mikhail, Gregory J. Czarnecki, Adam E. Goss, and John J. Murphy Jr.

*The **Survivability Technical Committee** promotes air and spacecraft survivability as a design discipline that includes such factors as crashworthiness and repairability.*

Lasers and their effects on composite materials have been an active area of research for military aircraft survivability. High-energy laser tests have been conducted at **Wright-Patterson Air Force Base** on composites typically used in remotely piloted planes. The trials took place in simulated flight conditions including high-speed airflow. The tests were performed with and without fuel backing, with and without laser-hardened coatings, and with and without explosive backing. The results will advance laser hardening and fire suppression design.

One equipment readiness issue involved parachute design. Wright-Patterson's **Aerospace Survivability and Safety Operating Location** designed, tested, and evaluated a low-profile parachute to replace currently fielded chutes that are so heavy and intrusive that aircrews do not wear them throughout missions.

The new parachute has a complete emergency bailout system to be worn for the full mission. This eliminates time-consuming donning procedures and reduces impediments to the crew's movements. The tests, which also addressed inadvertent opening, are among the final steps in evaluations for performance certification.

For space systems, survivability applies as much to the crew as to the spacecraft's structure and operations. NASA's newly developed **human rating certification/oversight system** now applies not just to its own Orion capsule but also to commercial craft—SpaceX's Dragon, Boeing's CST-100, Sierra Nevada's winged Dream Chaser, and Blue Origin's orbiter. NASA's crew survivability requirement for the **abort-at-any-time strategy** is particularly demanding. To meet the NASA standards, SpaceX is now modifying the Dragon, which has been delivering cargo to the International Space Station.

Survivability techniques area also required father from Earth. Engineers working to improve survivability of future planetary landers in 2013 had two distinct examples to begin studying.

NASA's 2,000-lb Curiosity robotic rover landed on Mars on August 16, 2012, using the new Sky Crane apparatus/module instead of airbags, which were used for the much smaller 23-lb Pathfinder rover that had landed on Mars in 1997. The Sky Crane itself, which must also be jettisoned immediately at landing so as not to damage the rover itself, landed 2,100 ft from the rover and now sits on the Martian surface, where it will remain.

The second example concerns the building of the 15-ft diameter heat shield that protected the Curiosity capsule during its 3-4-min entry into the Martian atmosphere. The capsule reached a peak temperature of 3,800 F. The shield worked as planned and was jettisoned 4,900 ft away on the planet's surface, where it will remain forever. Though heat shielding is not new, the new size is much more demanding and is also a prelude for use on other vehicles such as NASA's Orion capsule, currently in development

The Curiosity descent vehicle's heat shield. Credit: NASA JPL/Caltech/Lockheed Martin.

Flying more quietly

by David Alvord

*The **Aeroacoustics Technical Committee** addresses the noise produced by the motion of fluids and bodies in the atmosphere and the responses of humans and structures to this noise.*

The aeroacoustic community has continued to conduct cutting-edge research to determine, assess, and mitigate noise-generated risks and their impact on flight and launch vehicles. Areas of progress include combustion noise, environmentally responsible aviation, jet noise, rocket noise, and launch acoustics.

To address **combustion noise**, work on environmentally friendly combustors is currently under way for the German Research Foundation. The Technical University of Berlin, RWTH Aachen University, the Technical University of Darmstadt, and Karlsruhe Institute of Technology are investigating the thermoacoustic noise sources of unconfined turbulent premixed flames. The team is assessing compressible and efficient hybrid incompressible numerical modeling with experimental data.

The HWB model aircraft was tested in the NASA Langley Wind Tunnel.

One subcomponent of the Space Launch System subscale model currently under test at NASA Marshall is the quad thruster engine system.

NASA Langley is at the forefront of ERA research, which focuses on reducing noise, emissions, and fuel burn. Using an upgraded 14x22-ft subsonic wind tunnel and a 97-microphone array, Langley researchers measured the side and streamwise noise generated by the 12.3-ft-span **Hybrid Wing Body** aircraft model. Noise generated by the airframe, turbomachinery, and jets is being investigated in variable positioning with respect to ground observers. The Twin Compact Jet Engine Simulators depict takeoff, cutback, and landing conditions while undergoing operating temperatures above 1,000 F.

A Georgia Tech flight test measured the generated launch acoustic environment.

Additional HWB research at Langley includes work in auralization of flyover noise by an HWB aircraft. The modeling uses a combination of Aircraft Noise Prediction Program software, experimentally determined shielding, and a new approach to source noise synthesis. Maturation of this modeling software will allow subjective assessment of future aircraft in terms of noise impacts and benefits.

A team of engineers from Lockheed Martin Aeronautics, BAE Systems, and the U.S. government is investigating the acoustics generated by the F-35A and F-35B aircraft. To characterize the external sound environment, data are collected in the near and far fields for static engine tests as well as conventional flight, short takeoff, and vertical landing conditions.

State-of-the-art acoustic research in the field of rocket noise and launch acoustics is under way at NASA Marshall and the Georgia Tech Research Institute, GTRI. At Marshall, engineers are testing a 5% scale model of the Space Launch System in preparation for the first SLS flight in 2017. The primary objectives of the **SLS** model acoustic test are to determine the vehicle-generated launch environments and optimize the sound suppression system design.

One subcomponent of the model currently under test is the quad thruster engine system, which simulates the SLS core stage engines. When testing of this system is complete, the team will make final preparations to begin the integrated model testing at the NASA Marshall test range.

GTRI engineers are conducting noteworthy research in supersonic jet flow visualization, plume impingement and transient wave characterization, nontraditional sound suppression of plume noise, and nonlinear jet noise propagation. Testing in the latter area focuses on characterizing a wide array of jet noise sources and environments. It also addresses anomalous effects including internal rig noise, impact due to a jet nozzle's surroundings, impacts to propagation due to varying Reynolds numbers, and nozzle exit layer boundary.

GTRI conducted its first launch acoustics flight test in April, boosting a fully instrumented 8.5-ft **rocket** in Talladega, Ala., to gather flight data. A 10-microphone combined linear and radial array was used in conjunction with a high-speed camera to measure the rocket's external launch acoustic environments. The resulting data are being compiled and used for prediction model development and comparison with in-lab testing.

Breakthrough year for flight mechanics

by Jared Grauer, Mujahid Abdulrahim, Mudassir Lone, Scott Miller, and Thomas Nicoll

*The **Atmospheric Flight Mechanics Technical Committee** addresses the aerodynamic performance, trajectories, and attitude dynamics of aircraft, spacecraft, boosters, and entry vehicles.*

The **X-56A** began flight tests on June 26 at NASA Dryden. The unmanned test vehicle weighs 480 lb and has a 28-ft wingspan, two small turbojets, and long swept-back wings. In addition to nominal stiff wings, it has three sets of interchangeable flexible wings that allow testing near targeted aeroelastic instabilities. This could lead to improved flutter suppression and gust-load alleviation. The goal is for active controls to achieve a 25% decrease in wing weight and a 30-40% increase in aspect ratio to reduce aerodynamic drag.

On July 10, the Northrop Grumman **X-47B** completed two arrested landings on the USS George H.W. Bush, marking the first time a tailless, unmanned autonomous aircraft has landed on a modern aircraft carrier. The program has conducted 16 precision approaches to the carrier flight deck, including five planned waveoffs, nine touch-and-go landings, two arrested landings, and three catapult launches.

Sierra Nevada and NASA completed a captive-carry test of the **Dream Chaser** aircraft on August 22. Raised by an Erickson air-crane helicopter to an altitude of 12,400 ft, the craft flew a descent path into NASA Dryden. The Dream Chaser is one of three craft designed to transport crews to the ISS.

Northrop Grumman completed the first flight test of the **MQ-4C Triton** unmanned aircraft on May 22. An updated version of the company's Global Hawk, the Triton will use advanced sensor packages to scan the Earth from heights of 53,000 ft with a range of 11,500 mi.

In July, the Surfing Aircraft Vortices for Energy, or **$AVE**, program conducted an operational demonstration of autonomous formation flight for drag reduction using two C-17s. A modified C-17A flew 4,000 ft behind an operational C-17A on a training mission from Edwards AFB, California, to Hawaii and back. The trail aircraft was able to track the wake from the lead plane. Fuel savings exceeding 10% were measured on the trail aircraft for parts of the mission.

On May 1 Boeing's unmanned **X-51A WaveRider** separated from a B-52H using a booster rocket and achieved Mach 4.8. Upon engine ignition, it accelerated to Mach 5.1 and provided 370 sec of usable flight telemetry data. The WaveRider exploits the shock waves it creates to generate lifting forces.

SpaceX launched its Dragon cargo capsule on multiple missions to the International Space Station. A March 1 Dragon mission, called CRS-2, was the first launch in which the spacecraft's trunk section was used to carry cargo.

The **Speed Agile Concept Demonstration** team received *Aviation Week's* 56th Annual Laureate Award in the Aeronautics and Propulsion category. The goal was to design a next-generation U.S. Air Force tactical mobility transport with speed agility enabled by an advanced hybrid powered-lift system. Team member Boeing's shaped planform design had four embedded engines and a powered high-lift system. The high-lift system included upper surface blowing and steady-state, active flow control flaps to enable low approach speeds and facilitate operations in austere, short fields. The design used traditional aerodynamic control effectors as well as multiaxis and segmented surfaces.

AeroVelo received the American Helicopter Society's Sikorsky prize for winning the **Human Powered Helicopter Competition**. The company had won the latter award for being first entrant that, within a single flight, could pilot a human-powered helicopter for 1 min, reach an altitude of 3 m, and maintain the center within a 10x10-m area. AeroVelo's winning quadrotor aircraft flew for 65 sec, reached a height of 3.3 m, and remained within the required boundary.

The Triton unmanned plane completed its first flight on May 22 in Palmdale, Calif. Credit: U.S. Navy/Northrop Grumman.

Measuring what can't be seen

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

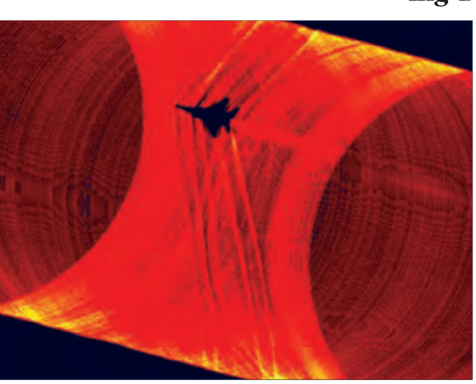
*The **Aerodynamic Measurement Technology Technical Committee** advances measurement techniques for ground facilities and aircraft in flight.*

Schlieren photography, which depicts changes in air density, can be elusive for planes in flight, but such images were captured this year by a new ground based camera system. The images show supersonic shock waves emanating from NASA F-15 and F/A-18 aircraft during pilot proficiency flights.

The images were gathered by a twin telescope and digital camera system at NASA Dryden during a manual test of the **Ground-to-Air Schlieren Photography System**, or GASPS, which was developed by MetroLaser.

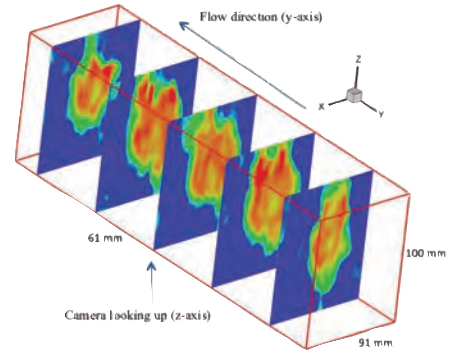
MetroLaser's schlieren imaging system uses the distorting effect of a flow field upon images of the Sun behind it to visualize the flow field itself. The project led to development of a novel and revolutionary schlieren-for-aircraft-in-flight system that is far superior to conventional schlieren systems in versatility, applicability, reliability, and quality of data. These advances could be extremely important in flight testing, where few such instruments can perform in a flight environment.

Background-oriented schlieren, or BOS, optical flow visualization has been applied at the Air Force's **Arnold Engineering** Development Complex for use in transonic wind tunnels, which cannot accommodate the large-sized optics of standard schlieren systems. The BOS technique requires only a small optical port in the test section wall, through which a digital camera obtains a view of the opposite wall, a view that is minutely distorted from shocks and other factors. These slight distortions are made obvious through digital image processing, and high-quality BOS imagery is now routinely available at Arnold.



With the Sun as the light source, supersonic shock waves are visible in this schlieren image of a NASA F-15B flying at 40,000 ft. Credit: NASA.

In other developments, researchers at **Sandia National Laboratories** have developed an experimental program aimed at understanding what drives potentially damaging aircraft vibrations. Aircraft bays are harsh aeroacoustic environments that produce large pressure fluctuations leading to structural vibrations. The effort uses Sandia's Trisonic Wind Tunnel and focuses on measurements of the coupling found in fluid-structural interactions. High-frequency pressure data provide the aeroacoustic loading inside a model aircraft bay, while simultaneous structural vibration measurements are made using miniature, triaxial accelerometers and scanning laser Doppler vibrometry. This combination of fluid and structural diagnostics has produced the first-ever direct measurement of the aerodynamic-structural coupling inside a model aircraft bay. This is providing physical insight to aid engineers engaged in store-carriage design.



This image of a sample 3D velocity field was obtained in a 2-in.-diam. supersonic jet seeded with alumina particles. The y-axis is stretched by a factor of five to illustrate different cross-sections of jet flow. Color corresponds to the streamwise (y) component of velocity. Credit: Auburn University.

JAXA is developing an unsteady pressure-sensitive paint measurement technique for low-speed flow. The agency has applied the technique to unsteady flow fields near the trailing edge of a two-dimensional NACA0012 airfoil model. Its fundamental frequency and peak-to-peak amplitude of pressure fluctuation were 940 Hz and about 150 Pa, respectively, at a freestream velocity of 28.6 m/sec. The model was coated by a fast-response anodized-aluminum PSP, and its illumination images were acquired by a CMOS—complementary metal oxide semiconductor—high-speed camera. Thousands of time-series luminescence images were processed for studies of quantitative unsteady pressure distributions, including power, phase, coherence, and phase velocity, on the model.

Researchers at **Auburn University** recently demonstrated the ability to make instantaneous, volumetric particle image **velocimetry measurements** in a heated (stagnation temperature of 1,005 K), supersonic (Mach 1.74) jet using a plenoptic camera. Plenoptic cameras use a microlens array mounted in front of a high-resolution image sensor to measure both the position and angle of light entering the camera. The researchers used computed tomography and conventional particle image velocimetry concepts to measure 3D/three-component velocity. The experiment took place at the Center for Physical Acoustics at the University of Mississippi. The jet diameter was 50.8 mm and the measurement volume spanned from 1.5 to 2.5 jet diameters downstream.

New tools for applied aerodynamics

by Nathan Hariharan

*The **Applied Aerodynamics Technical Committee** emphasizes the development, application, and evaluation of concepts and methods using theories, wind tunnel experiments, and flight tests.*

The NASA **Rotary Wing Program**, in cooperation with the **Army**, conducted an extensive wind tunnel campaign to examine the reduction of fuselage drag and download on a generic helicopter fuselage and rotor using active flow control. Researchers tested three different active flow control actuators and documented significant reductions in both drag and download in a forward flight configuration. In addition to the force and moment data, extensive particle image velocimetry datasets were acquired immediately behind the fuselage. Analysis of these additional data will provide a deeper understanding of the flow physics responsible for the load reductions.

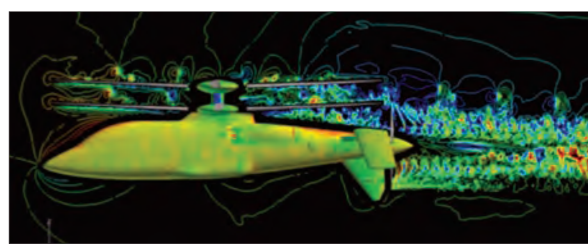
The Computational Research and Engineering Acquisition Tools and Environments program, known as **CREATE**, is developing and deploying scalable, multi-disciplinary, physics-based computational engineering products for the design and analysis of ships, air vehicles, and RF antennas. CREATE is part of the Defense Department's High Performance Computing Modernization Program. The Air Vehicles program, known as HPCMP CREATE-AV, released three products in 2013: the fixed-wing analysis tool Kestrel 4.0; the rotorcraft analysis tool Helios 4.0; and the conceptual design tool DaVinci 2.0.

Sikorsky Aircraft is evaluating HPCMP CREATE-AV Helios software by using it on the Sikorsky coaxial X2TD aircraft. The simulation includes the full fuselage, coaxial main rotor blades with the hub fairing system, and the propeller used for high-speed propulsion. The evaluation focuses on the off-body grid adaptation to capture the details of the main rotor wake system and its interaction with the propeller.

Researchers at **Georgia Tech** are working on quantifying the major contributors to helicopter airframe drag—especially the hub. Large-eddy simulation and transition models are being developed to capture the complex interplay between rotor and hub wake flows. Georgia Tech is also working on rotorcraft icing models that combine computational fluid dynamics, vehicle dynamics, structural dynamics, and NASA Glenn-based LEWICE analysis. This methodology is being used to compute the aerodynamic and structural loads for the **UH-60A** helicopters in forward flight and maneuver.

The second high-lift prediction workshop was held in June, with a total of 26 participants from 11 countries. Computational fluid dynamics comparisons were made against forces, moments, surface pressures, and off-surface velocity profiles for the DLR F11 high-lift model. The workshop focused on Reynolds number, grid convergence/type, and turbulence model effects on simulation predictions. Wake profiles were generally captured better by structured grids than unstructured grids.

NASA, Boeing, Lockheed, General Electric, Rolls-Royce, and Stanford University are nearing completion of contracts to design efficient supersonic aircraft with lower sonic boom and airport noise. Designs resulting in significantly improved capability have been validated in the **NASA Ames** 9x7 and **NASA Glenn** 8x6 wind tunnels. These tests indicate that analysis tools have reached a high enough maturity level for the successful design of low boom configurations that exhibit good integrated aerodynamic and propulsion performance.

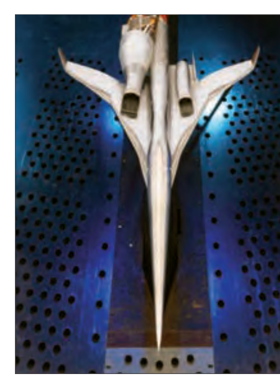


Sikorsky conducted a full-configuration rotor/fuselage/propeller simulation of its coaxial X2TD aircraft.

The Air Force Research Laboratory and Lockheed Martin collaborated on **wind tunnel tests** of a C-5M scale model to validate the computational fluid dynamics-predicted drag reduction effects of winglets. The test confirmed the predicted 4% fuel burn reduction, equivalent to a savings of approximately 4 million gal a year for the C-5M fleet.

Lockheed Martin and the Air Force Research Lab are evaluating over wing nacelle, or OWN, configurations to improve aircraft energy efficiency, threat avoidance, noise abatement, and speed agility. Results from this study indicate that OWN engine installations could improve aerodynamic efficiency as much as 5% compared to conventional under wing nacelle engine installations at transonic cruise conditions (above Mach 0.80).

The **NASA Fixed Wing** project is currently developing performance adaptive aeroelastic wing—PAAW—technology. This work will enable flexible wings that adapt aerodynamically to changing flight environments by using adaptive aeroelastic shape control. NASA and Boeing are currently conducting a joint study on a variable-camber continuous trailing-edge flap design for PAAW technology.



An N+2 low-noise supersonic transport model was tested at NASA Glenn.

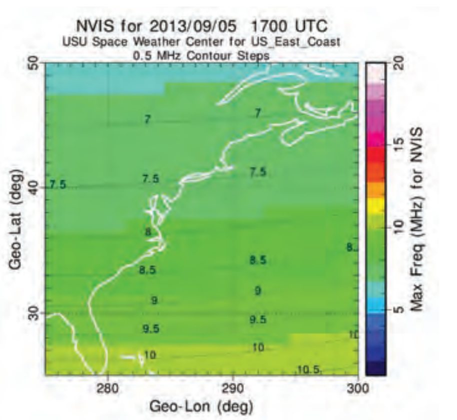
Predicting ice accretion, comms availability

by Dustin Crider, Andy Broeren, Kent Tobiska, and Dale Ferguson

*The **Atmospheric and Space Environments Committee** encourages the exchange of information about the interactions between aerospace systems and the atmospheric and space environment.*

Atmospheric and space environments is a field covering a broad spectrum of disciplines, and this year's accomplishments reflect that variety. NASA has added a new tool for ice accretion studies. New system applications were demonstrated for space weather, which remains an area of intense interest.

NASA Glenn has adapted a commercial 3D laser scanning system to capture and quantify the 3D features of ice accretion on aircraft. The surface data can be used to validate 3D **ice accretion** code and to generate computational fluid dynamics grids for computational aerodynamic analysis. The data can also be used to manufacture artificial ice shapes for aerodynamic testing using rapid prototyping or 3D printing. An extensive validation and verification study was performed to ensure the system was capable of capturing all the relevant features of the ice accretion, including roughness.



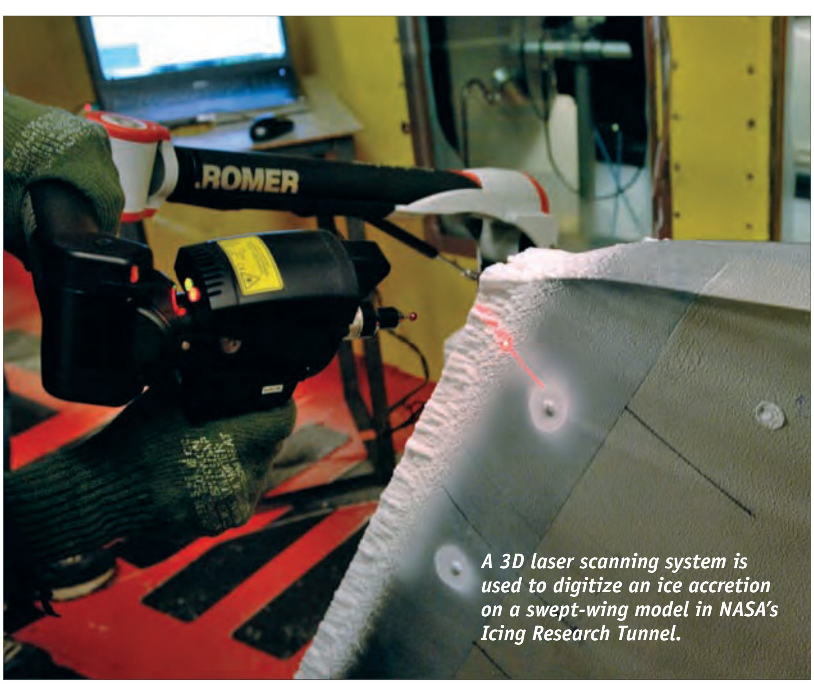
A radio communications forecast was provided for the U.S. East Coast as part of hurricane preparedness.

Test results showed that the artificial ice shapes from the scan/rapid prototype method were aerodynamically equivalent to those from the mold/casting method. Researchers now have an additional tool for documenting highly 3D ice accretion geometries in icing tunnel tests.

System-level applications for mitigating **space weather** effects on the radio communication and radiation environments of commercial aircraft have been successfully deployed. First, the **Utah State University Space Weather Center**, through its commercial partner, **Q-up**, is providing global forecasts of high frequency radio link signal strengths, including 3-hr forecasts of the near vertical incidence skywave signal strength for selected regions around the world. NVIS is used by emergency responders during disasters, most recently during the East Coast hurricane season. Second, the Automated Radiation Measurements for Aviation Safety project has demonstrated, for the first time, real-time radiation dose and dose rate measurements in aircraft above 8 km. The flight data are processed and integrated into the Nowcast of the Atmospheric Ionizing Radiation System, or NAIRAS. Incorporation of the radiation data into NAIRAS represents the start of 'radiation weather' specification. There have been over two dozen successful flights this year. Users can access ARMAS measurements through the web (http://sol.spacenvironment.net/~ARMAS/index.html) or via the SpaceWeather iPhone and SpaceWx Android apps.

The U.S. Round-Robin Test on Plasma Propagation Speed, led by Dale Ferguson of AFRL, is making significant progress. This effort involves 12 U.S. agencies, companies, and universities and aims to clarify the current profile expected from a solar array arc on an orbiting satellite. Three participants (NASA Glenn, Lockheed Martin, and Princeton Plasma Physics Laboratory) have shown that the degree of discharge is dependent on highly variable conditions at the vacuum arc site, which can be misinterpreted as variations in the plasma propagation speed. In the end, the program expects to produce realistic arc current profiles that can be used as constraints on solar array design.

The Air Force's new ground-based space test and evaluation system reached initial operational capability. The Space Threat Assessment Testbed, or STAT, at the Arnold Engineering Development Complex in Tennessee enables testing of space assets in high-fidelity simulated orbital environments. STAT can emulate numerous features of space weather simultaneously, including atomic oxygen, protons, electrons, and solar radiation. It can also reproduce self-induced effects such as material outgassing and thruster backflux. The design allows the space industry to gain knowledge about the combined effects on their components or small satellite prototypes.



A 3D laser scanning system is used to digitize an ice accretion on a swept-wing model in NASA's Icing Research Tunnel.

New missions, discoveries for astrodynamics

by Ryan S. Park

*The **Astrodynamics Technical Committee** advances the science of trajectory determination, prediction, and adjustment, and also spacecraft navigation and attitude determination.*

NASA's **Asteroid Redirect Mission** concept raised the possibility that small natural bodies can be redirected so that astronauts can visit them more easily. On June 18, NASA announced a request for information seeking system ideas and innovative approaches for the ARM and an increased emphasis on defending Earth against catastrophic asteroid collisions. The agency also announced a Grand Challenge focused on finding all asteroids that threaten human populations and determining what to do about them. NASA released Trajectory Browser, software that calculates requirements for missions to asteroids, comets, planets, and other destinations in the solar system (http://trajbrowser.arc.nasa.gov/).

Astrodynamics techniques were used to observe and characterize bodies approaching the Earth-Moon system. On January 17, NASA's **Deep Impact** spacecraft acquired its first images of comet C/2012 S1 (ISON) from a distance of 800 million km and showed that the comet already has a coma and tail. On February 15, an 18-m asteroid entered Earth's atmosphere over **Chelyabinsk, Russia**. This incoming object exploded in an airburst and generated small fragmentary meteorites and a powerful shock wave. About 16 hr later, asteroid **2012 DA14** passed about 28,000 km above Earth's surface with an uncertainty region of only a few kilometers. It was determined later that the two objects were unrelated to each other. This year through August, there have been six additional asteroids that passed Earth to within a half lunar distance.

Asia's space programs continued to grow. On December 13, 2012, **China's Chang'e 2** spacecraft made a 3-km flyby of the asteroid Toutatis with a relative velocity of 10.7 km/sec, making China the fourth nation to conduct a successful asteroid mission. China's fifth manned space mission, Shenzhou 10, was launched on June 11 and performed automatic and manual dockings with the space laboratory module Tiangong-1. On January 30 from the Naro Space Center, Korea Aerospace Research Institute launched STSAT-2C on the Naro-1 carrier rocket with a Russian first stage. This was the first successful orbital launch conducted by South Korea. In November, the Indian Space Research Organization launched its first mission to Mars, using the four-stage Polar Satellite Launch Vehicle. The mission's main objective is to demonstrate technology needed for future interplanetary missions.

The commercial industry also made advances in astrodynamics capabilities. The **Inspiration Mars Foundation** was founded in January and aims to launch a manned mission to fly by Mars and perform a free return to Earth. On March 3, SpaceX's **Dragon** cargo spacecraft was captured by the robotic arm of the ISS and attached to an open docking port. On March 6, the arm removed the grapple bars from Dragon's trunk. This was the first delivery of unpressurized cargo from a commercial spacecraft to the ISS.

SpaceX's Grasshopper rocket completed a divert test on Aug. 13, flying to a 250-m altitude with a 100-m lateral maneuver before returning to the center of the launch pad. Credit: SpaceX.

SpaceX also flew its **Grasshopper** experimental reusable rocket five times in 2013 to demonstrate the maneuverability of a re-usable launch vehicle. In August, the modified Falcon 9 performed a 100-m lateral maneuver, reached an altitude of 250 m, and safely returned to the center of the launch pad, making it the first test flight to include a lateral component. Grasshoppper has reached an altitude of 744 m in the flights from the company's Rocket Development Facility in McGregor, Texas.

On July 1, the 14th moon of Neptune was discovered during postprocessing of images taken by the **Hubble Space Telescope** between 2004 and 2009. The moon, designated S/2004 N 1, is likely to be captured by Neptune. On September 6, NASA's Lunar Atmosphere and Dust Environment Explorer mission was launched on a Minotaur 5 carrier rocket from the Wallops Flight Facility in Virginia and was the first lunar mission to be sent aloft from that site. On October 9, the Juno spacecraft conducted a 550-km Earth flyby, received an energy boost, and then continued on its path toward Jupiter.

Progress in fluid dynamics

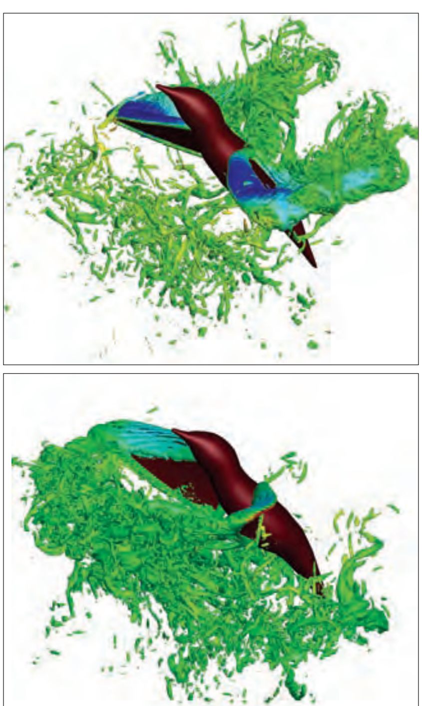
by Michael W. Plesniak and the AIAA Fluid Dynamics TC

The ***Fluid Dynamics Technical Committee*** *focuses on the behaviors of liquids and gases in motion, and how those behaviors can be harnessed in aerospace systems.*

Researchers at **NASA Ames** are exploring an innovative first-principles-based control of free shear layers. The control is achieved rapidly in a closed loop by manipulating amplitude and/or phase of unstable perturbations calculated from the linear stability theory. Ongoing research explores techniques of system identification for real-time free shear layer control.

CalTech researchers have employed a gain analysis of the resolvent formulation of the Navier-Stokes equations to understand scaling behavior of velocity fluctuations, coherent vortical structure, and strategies for control of wall turbulence. This formulation permits treatment of wall-bounded turbulent flow using the elegant theoretical tools of systems theory, revealing information about how the system behaves as a whole, inclusive of the nonlinearity, but in tractable and compact form.

At **Syracuse University**, researchers are using a Lagrangian coherent structure analysis to investigate vortex shedding in both passive (bluff body shedding) and active (pitching and heaving panels/airfoils) fluid-structure interactions. This method yields time-varying transport barriers in the flow field, allowing the researchers to identify the timing of fluid entrainment into consecutive vortex structures more precisely. Flow control methods will be developed to manipulate the evolving flow topology to promote or delay the shedding, depending on the application.



Images of the flow around a hummingbird in hovering flight show downstroke and upstroke. The color indicates pressure in the flow. Credit: Haoxiang Luo and Tyson Hedrick.

The **University of Illinois**, supported by the Air Force Research Lab, is exploring the interaction between compressible turbulent boundary layers and thin metallic panels commonly found on aircraft skins. Using **direct numerical simulation** techniques in both the fluid and solid domains, researchers have found that the panel motion asymmetrically affects the near-wall Reynolds stresses and modifies the turbulence production. These findings indicate that current Reynolds-averaged Navier-Stokes turbulence models may need modification to account for the interaction, and that panel tailoring can be used to modify turbulent boundary layer development.

State-of-the-art output-based adaptive algorithms for **computational fluid dynamics** are being developed at the University of Michigan. These algorithms use sensitivities from auxiliary adjoint solutions to identify regions in space and time that require more (or less) resolution for predicting an output. They produce tailored meshes containing a small fraction of cells compared to 'standard' meshes for varied applications including the AIAA Drag Prediction Workshop.

Researchers at **North Carolina A&T** have developed an adjoint-based methodology for combined optimization of shape and kinematics of a wing undergoing flapping motion governed by the 3D unsteady Reynolds-averaged Navier Stokes equations. This could significantly improve the flapping wing propulsive efficiency and controllability and serve as a powerful tool for design of an entire **flapping-wing micro aerial vehicle**.

Vanderbilt University researchers have performed accurate numerical simulations to study the aerodynamics of biological wings such as those of a hummingbird, including the force production and efficiency of these amazing flyers. The research aids development of biomimetic unmanned aircraft and micro aerial vehicles. The approach involves reconstructing the realistic wing kinematics of the bird from high-speed imaging data and direct numerical simulation using a low-dissipation technique. The simulations have captured details of the **3D vortical structures** in the flow and the force characteristics.

Researchers at **Missouri University of Science and Technology** and **NASA Langley** have performed direct numerical simulation of broadband acoustic radiation from high-speed turbulent boundary layers, and of transition due to stationary crossflow instability in a transport-relevant swept-wing boundary layer. The former simulations will deepen understanding of the disturbance environment in conventional high-speed wind tunnels, which is known to dominate boundary-layer transition over test articles. The knowledge gained will improve ground-to-flight scalability of transition data and eventually enable holistic models for the transition process. The latter contribute toward high-fidelity analysis of boundary-layer transition over practical configurations.

Air Force Research Lab Edwards has completed an extensive data set on nonreacting shear coaxial jets, typical of cryogenic liquid rocket engines, focused on the mixing behavior at different thermodynamic states and the response of these flows to external transverse acoustic fields.

Collaboration a theme for ground testing

by Ben Mills

*The **Ground Testing Technical Committee** focuses on evaluating aircraft, launch vehicles, spacecraft, structures and engines in wind tunnels, environmental or engine test facilities.*

Facility owners are enhancing capabilities and working together as a result of ever declining budgets.

The CESTO model, short for Cruise Efficient Short Take Off and Landing, completed testing in the National Full-scale Aerodynamics Complex (**NFAC**) 40x80-ft facility. Funded by NASA's Environmentally Responsible Aircraft initiative, the model was a simplified configuration of a medium-weight transport aircraft nicknamed **AMELIA**, for Advanced Model for Extreme Lift and Improved Aeroacoustics. The NASA-Cal Poly program proved to be a successful collaboration by education and government research entities and was cited as one of the most efficient examples of data collection in the NFAC in recent years.

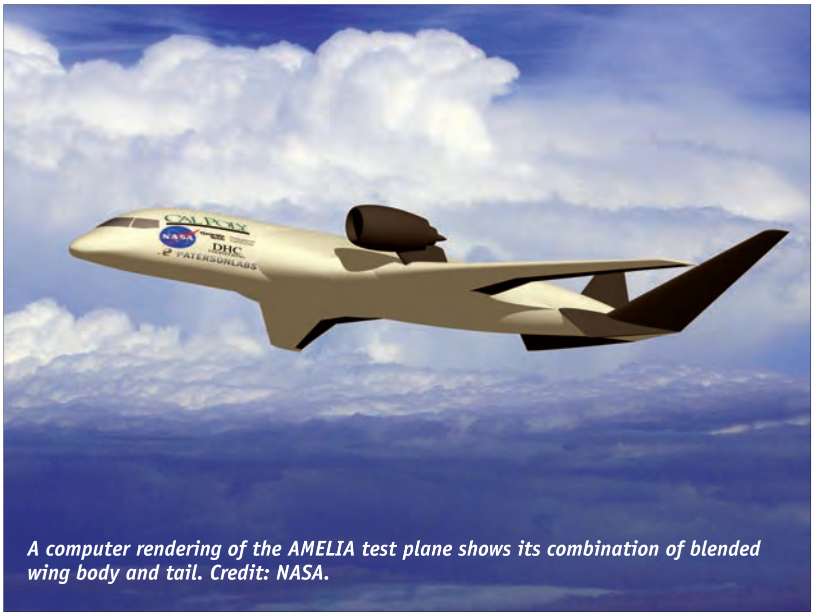
A new wind tunnel was designed and built at the **Thermo-Fluid for Transport Laboratory** of the École de Technologie Supérieure in Montréal, Canada. The facility enabled detailed experimental analysis of the physics of turbulent boundary-layer separation and reattachment. The wind tunnel has a 3-m-long test section and provides a maximum velocity of about 30 m/sec.

Aeroacoustic testing of a scaled model of a G550 Gulfstream aircraft was performed in the NASA Langley 14x22-ft wind tunnel as part of the **NASA-Gulfstream partnership** on airframe noise research. This effort focused on concepts for noise reduction in aircraft flaps and landing gear during approach to landing. The test produced one of the most comprehensive aeroacoustic datasets available to NASA.

An 80%-scaled copy of the NASA Common Research Model was tested in the 2x2-m transonic wind tunnel at the Japanese aerospace agency JAXA's Institute of Aeronautical Technology. Aerodynamic force and surface pressure distribution were measured, along with optical wing deformation. Initial results show that when deformation corrections are made, the measured lift and pressure distribution compares favorably with CFD estimates.

The NASA Glenn 8x6-ft Supersonic Wind Tunnel supported two successful efforts this year. First, evaluation tests were conducted to determine the suitability of the tunnel for sonic boom and performance testing. The Fundamental Aeronautics Program High Speed Project sponsored the test, which was a cooperative effort of Boeing, Lockheed Martin, and NASA. Second, an inlet performance test was completed on the Boeing N+2 vehicle configuration. This test supported concept development for future supersonic transports whose **sonic boom** would be low enough for overland flight.

The Holloman High Speed Test Track performed its most ambitious test to date on its magnetic levitation track. Members of HHSTT were able to use the **Maglev** track in conjunction with a new propulsion system to reach an astounding speed of more than 500 mph. The Maglev's success allows the HHSTT to provide a ground-based test environment that can accurately simulate the vibrations of a real flight test while preserving a payload's most delicate components.



A computer rendering of the AMELIA test plane shows its combination of blended wing body and tail. Credit: NASA.

At the Arnold Engineering Development Complex von Kármán Gas Dynamics Facility, the first major modernization program was completed since the facility became operational in 1958. With the new plant and data system upgrades, the site will continue to meet the demands of future test programs, providing improved reliability and greater commonality across facilities.

An aerodynamic test on a scale model of the C-5M aircraft was performed in the Arnold complex's Propulsion Wind Tunnel facility. The test validated computational fluid dynamics CFD predictions of drag reduction resulting from the use of **winglets**. Also, testing in the facility's wind tunnel 16-T played a key role in support of NASA's upcoming Exploration Flight Test-1. The purpose of the test was to gather dynamic and steady-state pressure data on a scaled model of the Orion crew capsule mounted on a Delta 4 booster.

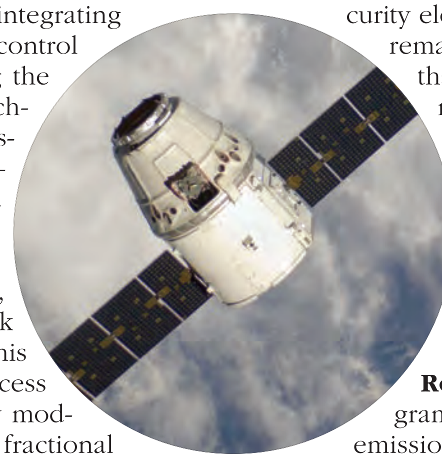
Guiding the way

by Luisella Giulicchi and Leena Singh

*The **Guidance, Navigation, and Control Technical Committee** advances techniques, devices, and systems for guiding and commanding flight vehicles.*

The fourth European Space Agency's **Automated Transfer Vehicle**, named Albert Einstein, rendezvoused with the International Space Station on June 15, docking smoothly with the 420-tonne station. The 20-tonne ferry, the heaviest spacecraft ever launched by Europe, flew autonomously and completed the docking with a precision of about 1 cm. The rendezvous and docking were performed autonomously by ATV's own computers. The operation was closely monitored by controllers from ESA and the French space agency CNES at the ATV Control Centre, and by astronaut Luca Parmitano and his crewmates on the ISS.

ESA has presented the first results of an innovative, robust AOCS—attitude and orbital control systems—technology program, in collaboration with EADS Astrium and Canadian NGC Aerospace Ltd., for the **Biomass Earth Explorer Core Mission**. The program aims to modernize attitude control of Earth observation satellites with large flexible elements using optimized structure-control systems. By integrating structural sizing and control system synthesis during the design process, this technology realizes a multidisciplinary design to compensate for the expected control-structure interaction effects. The Integrated Modeling, Control, and Analysis framework developed to support this innovative design process incorporates uncertainty modeling via LFTs (linear fractional transformations), robustness analysis via the structured singular value μ, and various robust control synthesis techniques.



The SpaceX Dragon capsule carries supplies to the International Space Station. Credit: NASA.

SpaceX's **Dragon** spacecraft continued carrying supplies to and from to the ISS following its first missions to the station in 2012. In a first for Orbital Sciences, the company's **Cygnus** capsule delivered supplies to ISS in September.

Motivated by the loss of **flight AF447**, an Air France Airbus A330, the **European Aviation Safety Authority** has taken the lead in defining a total systems approach to loss-of-control management to robustly handle cases when automation elements fail and flight control and display systems operate in degraded states. Flight AF447 crashed when air turbulence-induced intermittent failures in the air data system caused automatic disengagement of the autopilot and auto-throttle, leaving the pilots to suddenly take control of the aircraft with an unfamiliar cockpit director interface. Both the FAA's NextGen and the European Union's Single European Sky Air Traffic Management Research initiatives are formulated on a network-centric design based around the concept of trajectory-based operations. In this concept, an operator chooses the preferred aircraft trajectory; the aircraft flight director and air traffic management then continuously update each other and this nominal trajectory to ensure total system safety and predictability.

Such network-centric air traffic management systems have already shown significant reductions in holding times, distance flown per flight, potential conflicts registered, and fuel consumption. The current focus is to design a unified technical framework to support trajectory-based operations common to all participants and authorized users. Work has begun to define requirements, protocol definition, and security elements. However, vital work remains to be done to ensure that all the network management systems can safely interoperate through the differences in the coordination approaches and can integrate loss-of-control management architectures into the air traffic management systems.

NASA's **Environmentally Responsible Aviation** program, aimed at reducing noise, emissions, and fuel consumption, recently selected eight integrated large-scale technology demonstrations to advance aircraft concepts and technologies within the next two years. One of these eight, an "active flow control enhanced vertical tail flight experiment," effectively integrates control algorithm and control surface designs to realize the environmental goals. In scaled wind tunnel experiments conducted at Caltech, NASA found that active flow control on key control surfaces and lift-enhancing flaps yield significant advantages, such as a decrease in the size and weight of wings and control surfaces, and a reduction in noise. The latter results from the enhanced flight envelope enabled by the active flow control capability as the aircraft can attain steeper angle-of-attack and glide path trajectories during climb and descent.

Learn more at the
Guidance, Navigation, and Control Conference
aiaa.org/scitech2014/
SCITECH 2014
January 13-17, 2014
National Harbor, Maryland

New models for aerodynamic progress

by Ed Burnett and Sunjoo Advani

The ***Modeling and Simulation Technical Committee*** *focuses on simulation of atmospheric and spaceflight conditions to train crews and support design and development of aerospace systems.*

The **X-56A** Multi-Utility Technology Testbed demonstrator flew for the first time on July 26. This unmanned research aircraft will enable studies of active aeroelastic control technologies such as active flutter suppression and gust load alleviation. Lockheed Martin built the aircraft under contract to the Air Force Research Laboratory, with NASA supporting the fight test program.

The plane's high-aspect-ratio, flying wing design is extremely flexible. Most aircraft can be simulated as rigid planes with aerodynamics derived from wind tunnel tests, and flex-to-rigid ratios added to account for flexure. Accurate modeling of the aircraft's dynamics has required **Lockheed Martin** to devise models that include not just the typical six degrees of freedom of rigid aircraft but also numerous additional degrees of freedom to capture the structural modes.

The demonstrator is designed to allow for the testing of a wide range of advanced aerodynamic concepts and technologies. The plane has twin **JetCat P400 turbojets**, a 28-ft wing span, and a maximum weight of 480 lb.

After the Air Force flight tests, **NASA's Fundamental Aeronautics Program** will use the X-56A for continuing research on lightweight structures and advanced technologies for future low-emissions transport aircraft.

Loss of control in flight remains a major concern in civil aviation training, having **claimed nearly 1,500 lives** during the past decade. ICATEE, the International Committee for Aviation Training in Extended Envelopes, developed its training and technology recommendations and presented them this year to the FAA and the International Civil Aviation Organization. The committee's report notes that approach-to-stall and stall training will be required in simulators in the near future, in accordance with U.S. **Public Law 111-216**. Current simulators can provide nearly 60% of the committee's required training tasks. Another 30% can be achieved by enhanced modeling of stall aerodynamics, motion buffet, and control forces.

To investigate the level of stall model fidelity required for effective prevention and recovery training, the FAA is comparing current models with both a 'type representative' stall model and one that is fully flight-test-developed. The ICATEE findings also stressed the role of proper instruction and feedback to the pilot. ▲

The X-56A Multi-Utility Technology Testbed takes off on its inaugural flight on July 26 at Edwards AFB, California. The unmanned aircraft will enable studies of active aeroelastic control technologies. Credit: NASA.

Visualizing success

by Vincent Charles Betro

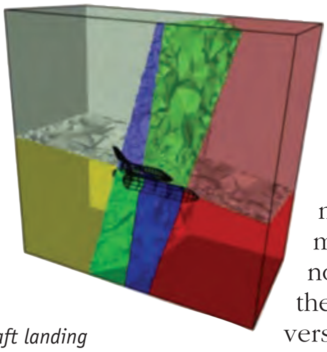
*The **Meshing, Visualization, and Computational Environments Technical Committee** is concerned with interactive computer graphics systems and their application to aerospace design and computer-aided manufacturing.*

To a computational fluid dynamics engineer working with a geometric mesh element, often the mesh's only relevant quality is whether it gives the "right" solution when used with a given solver algorithm. Determining how to achieve this optimal mesh for the numerous available solvers for a range of applications is a major focus of the meshing, visualization, and computational environments, or MVCE, community. What becomes clearer each year is that there is not one universal path to the right mesh; rather, there are **several ways** to achieve the same end.

For instance, one technology that is always being used and improved is overset meshing. With researchers from the Japanese aerospace agency JAXA, NASA, and everywhere in between weighing in on interpolation schemes, it is clear that this technology is here to stay and has great value even beyond the structured mesh community. In fact, problems requiring **mesh movement**, such as a moving rudders case discussed at JAXA and the Research Center of Computational Mechanics, are perfect for overset meshing. This is because it facilitates moving independent structured meshes, and the user needs to reinterpolate only after the mesh is shifted.

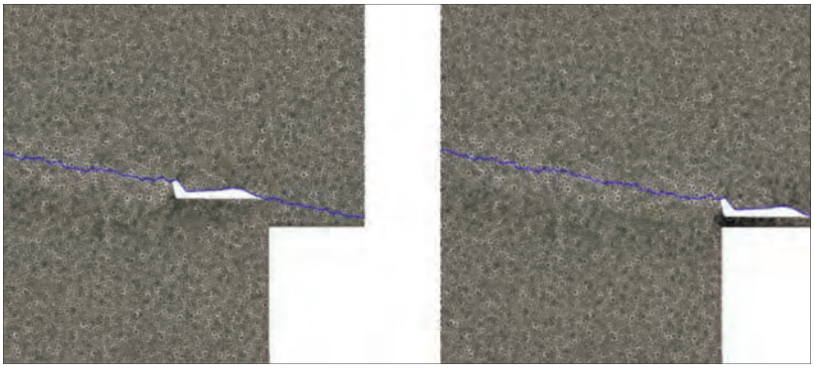
A tiltrotor aeroacoustic model wake features different levels of Richardson extrapolation error control.

On another front, Pointwise has concluded an Overset Grid Assembly Integration Small Business Innovation Research Phase 2 effort with the Air Force. It provides the ability to **adapt** structured and unstructured grids based on grid assembly data for automated remediation of orphan data.



A shuttle mesh domain decomposition used the parallel advancing front technique.

In the unstructured mesh community, mesh movement is certainly not out of the question. In the Sim Center at the University of Tennessee at Chattanooga, researchers have developed a method called **grid rupturing**. Here, edges are split and projected onto the geometry as it moves forward through elements of the mesh, and edges that were split are reconnected where the geometry has moved past their scope. Other types of smoothing, such as linear-elastic and Winslow, are used within this method and others to regenerate a workable mesh.



A mesh around an aircraft landing uses the grid-rupturing technique.

Another constantly evolving area is mesh adaptation. Although adjoint-based and gradient/feature-based approaches are not new, the semi-combination of these into a goal-oriented, adjoint-based adaptation scheme by researchers at Stanford University has given even more options and control to the user who wishes to generate a solution on a truly optimal mesh. **Automation** of these schemes is on the horizon, as discussed by researchers from the Army Aeroflightdynamics Directorate in "An Automated Adaptive Mesh Refinement Scheme for Unsteady Aerodynamic Wakes" (AIAA-2012-0160). The paper was this year's recipient of the AIAA MVCE Technical Committee's Shahyar Pirzadeh Best Paper Award.

In addition, researchers at the University of British Columbia have combined the alignment benefits of structured meshes with the flexibility of unstructured meshes to create an adaptation scheme that can yield the benefits of both methods. This style of **mixed adaptation** is useful not only for solving the Navier-Stokes equations but also many other sets of equations, including the lattice Boltzmann methods being used at Colorado State University, the Lawrence Livermore National Laboratory, and the Lawrence Berkeley National Laboratory.

Of course, many other mesh generation methods are being used to solve complex problems of all sorts. For instance, polyhedral and advancing front mesh generation techniques are becoming more prevalent. Researchers at George Mason University are generating meshes within meshes to assist in **partitioning** and sizing. With computational memory requirements increasing rapidly, this is a growing area of interest in the computational fluid dynamics community.

Finally, activities such as the Mesh Quality Workshop and the Drag Prediction Workshop V continue to bring the community together to hold interesting discussions on grid metrics and to posit new ideas for solving these problems efficiently. ▲

Actuators, engines, lasers benefit from plasma research

by Sergey Macheret and Timothy J. Madden

*The **Plasmadynamics and Lasers Technical Committee** works to apply the physical properties and dynamic behavior of plasmas to aeronautics, astronautics, and energy.*

The year brought increased understanding of the mechanisms by which weakly-ionized plasmas affect combustion, progress that was based on increasingly sophisticated kinetic modeling and state-of-the-art optical diagnostics.

Plasma-assisted combustion is promising for enhancement of fuel-air mixing, shortening the ignition delay and enabling stable combustion in lean mixtures. Applications to supersonic, hypersonic, and subsonic flight are under investigation.

Research also continues on **plasma actuators** for aerodynamic control. **Dielectric barrier discharge** (DBD) plasma actuators, previously shown to be effective in flow separation control under certain conditions, continued to be a popular research topic in plasma aerodynamics. A different kind of application for such actuators—**controlling laminar-to-turbulent transition**—was the focus of research by a group at Technische Universität Darmstadt, Germany. A set of proof-of-principle experiments demonstrated attenuation of the Tollmien-Schlichting waves by streamwise streaks generated by a plasma vortex generator array.

The Darmstadt group then conducted a flight test where a single DBD plasma actuator was used on the pressure side of a natural laminar flow wing section of a motorized glider. A transition delay of approximately 3% chord was achieved, and a closed-loop control enabled constant actuator performance, despite varying humidity, temperature, and pressure throughout the test flights.

Seeking a substantial increase in the control authority of plasma actuators, a group from the University of Texas at Austin proposed and experimentally studied a novel actuator, RailPAc, for **Rail Plasma Actuator**. It has an operating principle similar to that of the electromagnetic rail gun. The RailPAc repetitively discharges a free moving plasma arc (called a plasma armature) that relies on self-induced magnetic fields to move at high velocities along a pair of rail electrodes flush with a surface. Preliminary tests demonstrated a plasma-induced flow velocity of about 20 m/sec.

Military programs highlighted an active year for lasers. The Defense Department's **High Energy Laser Joint Technology Office**, HEL JTO, Robust Electric Laser Initiative, RELI, has worked to advance the state of the art in laser weapons systems. RELI-funded efforts with Lockheed Martin Aculight, Raytheon, Northrop Grumman, and General Atomics have looked at a variety of fiber and solid-state laser technologies with an eye toward achieving high efficiency and brightness in military applications.

Reflecting the overall success of the RELI is the recent Army Space and Missile Defense Command decision to award Lockheed Martin Aculight a contract to scale its 25-kW RELI laser to 60 kW for use in the Army's High Energy Laser Mobile Demonstrator. The Navy demonstrated the ability of its Laser Weapon System to destroy targets such as **unmanned aircraft** and moved forward with its deployment. Overseas, the German defense contractor Rheinmetall demonstrated a 50-kW laser weapon designed for area defense against mortars and aerial drones.

With the University of Notre Dame, the Air Force Institute of Technology, and MZA, HEL JTO has also funded the **Airborne Aero-Optics Laboratory** program, which performs in-flight aerooptics measurements of turrets.

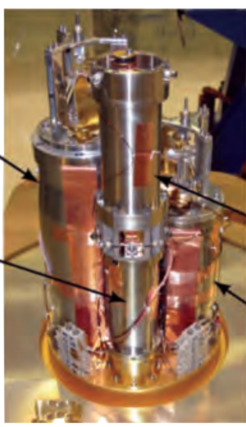
The program was so successful that it was recently renewed for five years, concentrating on flight Mach numbers above 0.8. It has migrated from the Cessna Citation Bravos, which could only achieve Mach 0.7, to **Falcon 10s**, which can cruise at Mach 0.84. The new program is designated AAOL-T to emphasize transonic, with aircraft operations remaining at Northern Jet in Grand Rapids, Michigan. The laboratory aircraft is currently being modified not only to accommodate the original AAOL turret but also to support flight tests of a scaled Lockheed Martin turret design. The modified Falcon 10 with turret is scheduled for a safety-of-flight campaign.

The Airborne Aero-Optics Laboratory performs in-flight testing of the Active Pointer Tracker, a laser pointing and tracking system. Credit: University of Notre Dame.

Surprising findings for thermophysics

by Deepak Bose, Eric Silk , Peter Shirron, and Alina Alexeenko

*The **Thermophysics Technical Committee** promotes the study and application of mechanisms involved in thermal energy transfer and storage in gases, liquids, and solids, or combinations.*



This adiabatic demagnetization refrigerator technology enables the NASA/JAXA Soft X-ray Spectrometer's detectors to operate at near-absolute zero and capture extremely high-resolution data. Credit: Mullard Space Science Laboratory.

Following 2012's delivery of the Curiosity rover to the surface of Mars, scientists are studying data from the many instruments embedded in the thermal protection system of the descent craft, called the **Mars Science Lab**. These instruments are collectively known as MEDLI for the Mars Science Lab Entry Descent and Landing Instrumentation. They include seven pressure transducers, 24 thermocouples, and six isotherm sensors. A multidisciplinary team of engineers from NASA Ames, NASA Langley, and the Georgia Institute of Technology are engaged in reconstructing the aerothermal environment and validating computational fluid dynamics and material response tools. The initial findings were presented in a special session at the 44th AIAA Thermophysics Conference in San Diego, Calif., in June.

The MEDLI data demonstrated that the phenolic impregnated carbon ablator thermal protection system, or TPS, on the descent vehicle **performed better** than expected and was adequately sized. The boundary-layer transition to turbulence occurred, as expected, on the leeside of the heat shield. The aerothermal heating and in-depth thermal response did not exceed design margins. The TPS surface recession during entry was found to be lower than model predictions.

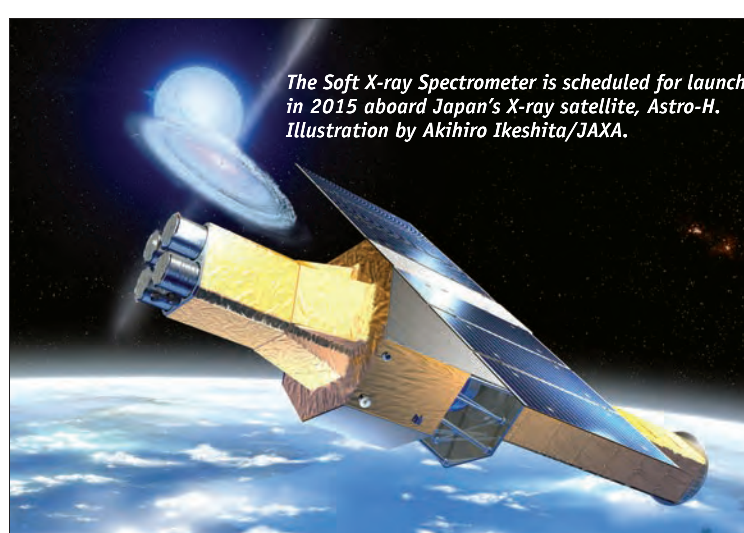
There were some **surprises** as well. The boundary-layer transition occurred earlier than predicted at some locations on the heat shield because of developing surface roughness. Also, maximum temperatures occurred close to the apex of the vehicle, a finding not predicted by the models.

In addition to meeting its science objectives, the MEDLI data are helping engineers reduce model uncertainties and margins in robust and mass-efficient TPS designs for future Mars entries.

This year the Cryogenics and Fluids Branch at NASA Goddard demonstrated an advanced **cryocooling** technology to enable the most sensitive space-based X-ray instrument to date. The Soft X-ray Spectrometer, jointly developed by NASA and the Japanese space agency JAXA will launch in late 2015 aboard Japan's sixth X-ray astronomy satellite, Astro-H. The instrument consists of a 36-pixel array of silicon detectors capable of measuring X-ray energy to better than a part in 1,000. The key to such resolution is detector operation near **absolute zero** (about 50 mK). This is accomplished via a three-stage adiabatic demagnetization refrigerator. ADRs are solid-state heat pumps that acquire and reject heat via the magnetocaloric effect.

Because of the detectors' extreme sensitivity, an engineering model was built to identify potential problems before finalization of the flight model. The overall cryogenic architecture consists of an ADR precooled by superfluid helium (at 1.3 K) and six cryocoolers. NASA had delivered the engineering model ADR and detector array to Japan in early 2012 for integration into the cryogenic system; however, a failed heat switch in the ADR precluded reaching target temperatures. To avoid major schedule impacts that would have resulted from switch replacement, NASA Goddard developed a new heat pump technique that uses **helium** gas inserted into the guard vacuum of the Dewar. At a select pressure, the gas thermally couples the ADR stages to the helium tank, allowing them to be cooled without much heat load on the tank itself or on the cryocoolers.

Afterwards the helium tank is pumped to a lower temperature to adsorb the exchange gas onto its outer surface, thus producing a high vacuum. This unconventional technique has led to over 100 hr of operation at 50 mK, with no signs of He contamination on the detectors.



The Soft X-ray Spectrometer is scheduled for launch in 2015 aboard Japan's X-ray satellite, Astro-H. Illustration by Akihiro Ikeshita/JAXA.

The science of deceleration

by Lauren S. Shook and Jean Potvin

The ***Aerodynamic Decelerator Systems Technical Committee*** *focuses on decelerating manned and unmanned vehicles via parachutes, pararotors, and inflatable decelerators.*

New or improved airdrop capabilities were developed and fielded for the Defense Department in 2013, including the **High Speed Container Delivery System**, or HSCDS used in **Afghanistan**. Managed and executed by the Army Natick Soldier Research, Development and Engineering Center, the program is a Joint Capability Technology Demonstration sponsored by the Office of the Secretary of Defense and the Transportation Command.

HSCDS uses the capability of the C-17 and C-130J aircraft to fly at airspeeds of up to 250 knots indicated air speed with the ramp open. The program's objective requirements are to air drop at speeds up to 250 knots from altitudes as low as 250 ft above ground level, and to extract between two and eight container delivery system containers with total weights between 3,000 lb and 16,000 lb.

Those requirements were successfully demonstrated on both aircraft during several operational demonstrations. This capability provides greater aircraft maneuverability during an airdrop, decreased ingress and egress time, and increased payload delivery accuracy over conventional methods. Initial capabilities have been used in Afghanistan since April and are expected to continue in **2014**.

The NASA Capsule Parachute Assembly System team completed an Orion parachute development drop test at the U.S. Army's Yuma Proving Ground in Yuma, Ariz. Credit: NASA.

The **Orion** capsule parachute assembly system or CPAS project has continued, with support from the Edwards AFB 418th Flight Test Wing. Further evolution and testing of the engineering development unit included the first airdrop of the boilerplate test article from 35,000 ft mean sea level. Tests will also use the "lawn dart" drop vehicle to attain the nominal drogue deployment conditions that follow atmospheric reentry. CPAS has also delivered the hardware for the first unmanned Orion orbital flight vehicle, called Entry Flight Test 1, scheduled to fly in 2014.

The **Aerodynamic Decelerator Systems Center** at the Naval Postgraduate School, in collaboration with the universities of Alabama-Huntsville, San Jose, Idaho, Nevada-Reno, and Missouri-Kansas City, has continued to conduct flight tests of an autonomous high-altitude, high-opening parafoil delivery system. This multi-university team is studying the challenges encountered during balloon-borne, lower stratosphere deployments of ultralight-weight payloads using 10-40 ft^2 canopies. The emphasis is on reliable canopy inflation, gliding performance, and landing accuracy. Such a system could find potential use in several aerospace applications, including the retrieval of weather balloon and sounding rocket payloads.

NASA JPL has been working to advance the state of the art in entry, descent, and landing systems for Mars applications, with the goal of increasing entry mass, landed mass, and landed altitude beyond the Mars Science Lab's capabilities. An example is the **Low Density Supersonic Decelerator** program, a multiyear effort to study three new types of supersonic decelerators capable of supporting future large robotic and human-precursor-class missions to Mars.

A 6-m Supersonic Inflatable Aerodynamic Decelerator was built and tested at the **China Lake Naval Air Weapons Station**, using a rocket sled system to perform structural and inflation tests. Also in development this year was the testing of over 50 subscale parachute designs for a new, 30.5-m supersonic parachute configuration and for an 8-m attached isotensoid.

Air transportation systems advance

by David Thipphavong and Steven J. Landry

The ***Air Transportation Systems Technical Committee*** *fosters improvements to transport systems and studies the impacts of new aerospace technologies.*

The global airline industry continued to show growth, with profits projected to expand from $7.6 billion in 2012 to **$12.7 billion** by the end of this year, according to the **International Air Transport Association**. Key factors driving this increase include lower oil prices and rising revenue streams from ancillary sources such as baggage fees. The uptick in airline orders for new, more fuel-efficient aircraft is also a strong indicator of growing business confidence within the industry.

In the U.S., the maturation of mergers in recent years between Delta/Northwest Airlines, Southwest Airlines/AirTran Airways, and United/Continental Airlines was a key contributor to airline industry profits. The trend continued this year when **American Airlines** and **US Airways** announced plans to consolidate. Unlike previous cases, however, this move was blocked when the Justice Dept. and several states filed an **antitrust lawsuit** to prevent the two companies from merging on the grounds that service would be reduced and fares and fees would increase. A trial to determine whether American and US Airways can proceed was set for November 25. If the merger is approved, four airlines will operate over 80% of all domestic commercial flights.

Meanwhile, the integration and implementation of concepts, technologies, and procedures for the nation's Next Generation Air Transportation System, or **NextGen**, continues. Although sequestration—the automatic federal spending cuts that went into effect on March 1—made this work more challenging, the program did make significant headway this year. For example, more than 500 of the roughly 700 ground stations needed for the NextGen surveillance system called **ADS-B** for (automatic dependent surveillance-broadcast) have been deployed. Aircraft equipped with ADS-B broadcast accurate state information to air traffic control and to other surrounding aircraft. This is a key enabling technology for other NextGen advances that are projected to improve efficiency by reducing fuel burn and delays, saving an estimated $38 billion.

The expanded use of other NextGen-related technologies has also yielded benefits. For example, according to Alaska Airlines, use of **Required Navigation Performance** procedures has already enabled more efficient arrival and departure procedures that have saved the carrier $17.6 million and 200,000 gal of fuel over the past year.

The FAA has also been collaborating with NASA and industry partners on developing advanced technologies to enable safer, more reliable, and more efficient operations. For instance, the **Precision Departure Release Capability** (PDRC) tool developed by NASA accurately schedules departure aircraft so that they can merge safely and efficiently into overhead traffic flows. By reducing uncertainty in tactical departure scheduling, this tool lowers controller workload and enables aircraft to fly their desired routes with fewer deviations.

NASA's Precision Departure Release Capability tool schedules departing planes more accurately. Credit: NASA.

The pressure and pace of integrating unmanned aircraft systems (UAS) into domestic airspace increased this year given the fast-approaching **September 2015 deadline** mandated by Congress. The FAA plans to release its draft regulation for the operation of small unmanned aircraft UAS by the end of this year. In addition, the FAA is in the process of selecting six test sites where UAS can operate 24 hr a day for research and commercial purposes. Significant economic activity is expected around these FAA-certified test ranges.

The **Association for Unmanned Vehicle Systems International** projects that the integration of unmanned planes into the national airspace (NAS) will add $13.6 billion to the U.S. economy in the first three years (from 2015 to 2018), creating 70,000 new jobs, of which 34,000 will be in manufacturing. However, privacy concerns could delay UAS integration and reduce these economic impacts.

Flying longer, faster, cleaner, unmanned

by Dyna Benchergui and Charlie Svoboda

*The **Aircraft Design Technical Committee** promotes optimization of aircraft systems, including analysis of their future potential.*

Northrop Grumman's **X-47B** Unmanned Combat Air System-Demonstration plane made its first carrier launch and recovery in a flight from the USS George H.W. Bush. This breakthrough is expected to lead to delivery of **UCLASS**—Unmanned Carrier-Launched Surveillance and Strike—aircraft to future Navy carrier air wings.

The **MQ-4C Triton** is continuing flight tests to demonstrate persistent intelligence, surveillance, and reconnaissance for the Navy's Broad Area Maritime Surveillance program.

The X-51A's flight advanced development of scramjet-powered hypersonic craft intended for ISR, strike, and space transportation.

Boeing's **X-51A Waverider** set another hypersonic flight record, 3.5 min at Mach 5, advancing fuel-cooled scramjet-powered aircraft. The Army successfully demonstrated the aerostat-based JLENS, short for Joint Land Attack Cruise Missile Defense Elevated Netted Sensor) system as it tracked an antiship cruise missile. The Marine Corps F-35B completed its first night landing aboard the USS Wasp as part of sea trials that have expanded its shipboard operating envelope.

Eurocopter's **X3** helicopter flew at 255 kt, following the Sikorsky X2 demonstrator's 2010 achievement of 250 kt. The X3 uses its main rotor for lift when hovering, and two propellers fixed on anhedral wings to provide thrust in high-speed forward flight.

The **Air Force Research Laboratory** demonstrated two hybrid powered-lift systems for a future short takeoff and landing "speed agile" airlifter able to carry a 65,000-lb payload and cruise at Mach 0.8. Boeing's design features an upper surface blowing system inboard and circulation control/internally blown flaps on the outboard wing sections. Lockheed Martin's system uses circulation control/internally blown flaps on the outboard wing sections and a novel ejecting, reversing nozzle inboard.

Solar Impulse achieved another milestone, a U.S. coast-to-coast solar journey. The Naval Research Laboratory's **Ion Tiger** unmanned plane flew for more than 48 hr. The new fuel system uses liquid hydrogen fuel stored in a lightweight, insulated tank to allow for a threefold increase in hydrogen density. DLR is flight testing the all-electric Antares DLR-H2 testbed for qualification of fuel cells. Boeing's liquid hydrogen-powered **Phantom Eye** unmanned plane completed its fifth test flight, on track for demonstrating four-day continuous flight at 60,000 ft.

EADS and **Siemens** flew a hybrid-electric **DA36** powered by a small Wankel engine/generator and lithium-polymer battery. Results show a 25% lower fuel burn. EADS unveiled two other concepts—E-Fan, an all-electric battery-powered training aircraft, and E-Thrust, a 2050-era airliner hybrid electric distributed propulsion system.

Bombardier's single-aisle CSeries made its first flight, using the ultra-high-bypass (UHB) Pratt & Whitney geared turbofan. Boeing is testing the Scimitar winglet design on current 737-800 airliners for a 2% improvement in fuel efficiency. The **Airbus A350 XWB** completed its first flight, as did the **Boeing 787-9**, a fuselage stretch of the 787-8. Boeing analyzed problems caused by the 787-8 **lithium ion battery** system, redesigned the system, and made the changes rapidly, limiting the grounding of the 787-8 to about 100 days.

Bombardier's Challenger 350 business jet is in flight test, with first delivery expected in mid-2014. The all-composite Learjet 85 is preparing for first flight. Cessna completed the first production flights of its high-speed Citation X and Citation M2 and delivered the first TTx. Terrafugia's Transition flying car debuted at the annual AirVenture show in Oshkosh put on by the EAA aircraft organization.

NASA's **Environmentally Responsible Aviation** and **Subsonic Fixed Wing** programs support concept studies and enabling technology development for future aircraft designs. Boeing's X-48C Blended Wing Body low-noise version completed flight testing, evaluating low-speed stability and control. NASA selected eight technologies to undergo large-scale integrated demonstrations within the next three years: active control of flow over vertical tail, adaptive compliant trailing edge, highly loaded front block compressor, damage-arresting stitched composite structure, second-generation GTF propulsor, low-NO_x fuel flexible engine combustor, flap and landing gear noise reduction, and hybrid wing body/UHB engine integration. **Virginia Tech**'s Multidisciplinary Analysis and Design Center is working on truss-braced-wing commercial aircraft design tools, to include aeroelasticity. 𝔸

Balloon breakthroughs

by Paul Voss and the Balloon Systems Technical Committee

*The **Balloon Systems Technical Committee** supports development and application of free-floating systems and technologies for buoyant flight in the stratosphere or atmospheres of other planets.*

It has been an active year for the ballooning community with progress made in several different areas.

Google announced that it is developing a network of stratospheric balloons capable of providing near-worldwide Internet service. Raven Aerostar has been working closely with Google since the summer of 2012 on the effort, called **Project Loon**, which uses Raven's high-altitude balloons and flight control system. In an approach unlike other stratospheric communications system concepts, the Loons would fly with the winds at 20-23 km and adjust their altitudes accordingly. The balloon technology and flight operations procedures are in development by the two companies' R&D teams.

It was a record-breaking year for **NASA** scientific balloon activities. Three long-duration balloon missions—Super-Tiger; **BLAST**, the Balloon-borne Large Aperture Submillimeter Telescope; and EBEX, the E and B Experiment—were flown simultaneously from Antarctica, logging over 96 days of total flight time. The Super-Tiger flew longer than any balloon of its size, floating for over 55 days carrying an instrument that detected 50 million cosmic rays.

NASA also flew the National Center for Atmospheric Research Sunrise II instrument from the Esrange Space Center in Sweden, which provided spectra and images of the Sun at resolutions down to 100 km. Other activities included fabrication of a 532,000-m^3 superpressure balloon scheduled for launch from Antarctica this month; the third test flight of the WASP, Wallops Arc Second Pointer; and testing of the Low-Density Supersonic Decelerator, LDSD, launch tower. The LDSD payload will be lifted into the stratosphere and then undergo a rocket-powered trajectory to reach supersonic speeds before testing of the decelerator systems' deployment and performance.

Engineers from **JPL**, in collaboration with **Wyle Laboratories** and **Near Space Corp.**, demonstrated leak-free performance of a 1.5-m-diam. spherical helium superpressure balloon at the cryogenic temperature of 92 K. This paves the way for use of such a craft on a long-duration exploration flight in the cold atmosphere of the Saturn moon Titan.

JPL engineers are also studying the potential of helium-compression altitude control for a future balloon mission to Venus. Smith College researchers developed this efficient altitude control and have flown such balloons for atmospheric transport studies in many diverse environments. This year, two 400-g balloons shipped to Aboa Station in **Antarctica** were flown for more than seven days via satellite from the U.S.

Near Space dedicated its new Johnson Near Space Center, a $7-million commercial flight test facility in Tillamook, Oregon. The 30,000-ft^2 custom facility supports test flights of high-altitude research balloons and unmanned planes. It includes an integration hangar and control tower adjacent to a 100-acre launch and recovery area. The associated Tillamook test range is a key feature of a proposed Pan-Pacific Unmanned Aerial Systems Range Complex where Oregon, Alaska, and Hawaii would offer sites with diverse climates and geomorphology.

Near Space also conducted high-altitude balloon flights for NASA's Flight Opportunities Program, with payloads sponsored by the **FAA's Commercial Space Division**. These efforts focused on structural health monitoring of Suborbital Reusable Launch Vehicles, and testing of ADS-B Automatic Dependent Surveillance-Broadcast. Near Space also began flying its **High Altitude Shuttle System**, a hybrid balloon and lifting-body glider capable of launching and recovering payloads at the same site.

Space Data received its largest production order to date for its **SkySat** system, from the Army. The commercial **SkySite** system is being updated with a smaller 900-MHz payload capable of multiday missions. In addition, Space Data developed the ability to launch 100-lb payloads using a string of extensible balloons. This system was used to launch 4G LTE broadband payloads using standard Ericsson infrastructure. A flight test of an LTE public safety communications system took place in Colorado in conjunction with the National Institute of Standards and Technology as part of the FCC's Deployable Aerial Communications Architecture.


A Google Loon balloon awaits its first public launch in New Zealand. Credit: Aerostar International.

Space, night, unmanned flights lead year of testing

by Jay Brandon

*The **Flight Testing Technical Committee** focuses on testing of aircraft, spacecraft, missiles, or other vehicles in their natural environments.*

In the first arrested landing by an unmanned aircraft at sea, an X-47B unmanned combat air system demonstrator lands on the aircraft carrier USS George H.W. Bush. Credit: U.S. Navy.

This year saw further development of commercial spacecraft for transporting cargo and someday crews to the International Space Station. SpaceX delivered cargo to ISS in March aboard a **Dragon** capsule and returned equipment to Earth. A second mission was scheduled for December. In September, Orbital Sciences Corp. delivered roughly 1,300 lb of supplies to ISS in the first flight of its Cygnus capsule. **Cygnus** was carried by the company's **Antares** rocket, which made its first flight in April carrying a Cygnus mass simulator.

In August, Sierra Nevada completed ground tow tests of its **Dream Chaser** winged lifting body to verify performance during landing rollout. The company also conducted captive carry tests under a helicopter prior to planned glide testing. SpaceX tested a modified Falcon 9 called **Grasshopper** to study maneuvering for landing, as a precursor to possibly recovering the first stage with a powered landing after a launch.

Virgin Galactic came closer to becoming the first carrier to transport passengers into space, conducting the first powered, supersonic flight test of its SpaceShipTwo in April. The test attained a maximum Mach number of 1.3 and maximum altitude of 56,100 ft. In September, a second powered flight reached Mach 1.43 and 69,000 ft. The flight included a high-altitude deployment of the aircraft's unique feathering reentry mechanism.

Development and testing of unmanned, remotely piloted, and autonomous aircraft continued at a rapid pace. The Navy's **X-47B**, built by Northrop Grumman, landed on the aircraft carrier USS George H.W. Bush in July. This was the first time a large unmanned aircraft made both catapult takeoffs and arrested landings on a carrier. The testing paves the way for the Navy to develop unmanned aircraft for future defense needs.

The **X-51A** hypersonic scramjet-powered demonstrator made its fourth and final flight in May. The aircraft accelerated under scramjet power to speeds above Mach 5, setting a record for the longest air-breathing powered hypersonic flight. The Northrop **Triton**, based on the Global Hawk and updated for operations by the Navy over oceans and coastal areas, conducted its first flight in May from Palmdale, California. The **X-56A** Multi-Utility Technology Testbed flew for the first time at NASA Dryden in August. The 28-ft-span, 480-lb unmanned aircraft is a testbed for future fuel-efficient planforms with slender flexible wings. Its purpose is to demonstrate the prediction and suppression of fluter. Boeing's Phantom Eye liquid-hydrogen-powered, long-duration, high-altitude aircraft resumed flight testing after updates following last year's first flight, and the Naval Research Lab flew a fuel-cell-powered **Ion Tiger** unmanned plane on a flight lasting over 48 hr.

Night flight evaluations of the **F-35** included the first F-35B vertical night landing. The military services have begun operational evaluations of all three F-35 variants. Beechcraft completed the initial flight of the first production AT-6, an attack version of the single-engine turboprop T-6 trainer. The AT-6 will perform border and maritime control as well as combat attack missions.

The Army demonstrated autonomous low-altitude maneuvering and landing spot identification with a modified **Black Hawk** helicopter using laser radar for terrain sensing.

An Air Force-led team successfully demonstrated use of an aircraft's wake to reduce the fuel required for other planes flying in formation. The team used **C-17s** with modified flight control computers to fly at prescribed locations relative to a lead airplane. The test flights, from Edwards Air Force Base to Hawaii and back, used modified software in the autopilot to provide the station-keeping needed for fuel savings.

Progress and a setback for lighter-than-air vehicles

by Norman Mayer

*The **Lighter-Than-Air-Systems Technical Committee** stimulates development of knowledge related to airships and aerostats for use in a host of applications from transportation to surveillance.*

Two 243-ft-long aerostats built by TCOM completed flight testing in July. Part of **JLENS**, the Joint Land Attack Cruise Defense Elevated Netted Sensor System developed by Raytheon, the two craft are scheduled to begin hovering over the Washington, D.C., area in September 2014 to spot cruise missiles, unmanned planes, and other aircraft. One aerostat will carry a 360-degree, long-range surveillance radar to detect threats as far away as 340 mi. The other will have radar for targeting tactical ballistic large-caliber rockets as well as moving boats, cars, and trucks. The craft will fly at 10,000-ft altitude for 30-day periods. The demonstration test period will last up to three years.

TCOM and **India's Bharat Electronics** have signed an agreement to cooperate on developing advanced aerostat-based surveillance and communication systems. These would address the intelligence, surveillance, and reconnaissance needs of the Indian Defense Services, security services, and law enforcement agencies.

In May the Navy used its **MZ-3A** airship, A170, in the Caribbean area for demonstrating intelligence and surveillance operations against drug smugglers, some of whom use submarines. The airship carried **Surface Optics**' full motion spectral imagers, which find submerged targets. During the operations the Navy also tested a unique combination of sea vessel and aircraft: HSV-2, an **Australian-built Swift Ship** that has a 76-ft-long aerostat tethered on the deck and uses a small unmanned plane. The aerostat, which can reach 2,000-ft altitude, has cameras and sensors that provide a 50-mi. view.

Northrop Grumman ceased work on the **LEMV**, the Long Endurance Multi-Intelligence Vehicle, when the Army notified the company that it would cancel the contract in February. The 303-ft-long hybrid had made its first and only flight on August 7, 2012. The LEMV was designed to carry 20 tons of advanced surveillance and communication equipment at an altitude of 20,000 ft for 21 days. Failure to meet these goals and a shortage of funds led to the cancellation.

Airship Ventures at Moffett Field in California, ceased operations in August 2012, dismantling the Zeppelin NT-07 airship Eureka and returning it to its owner, ZLT Zeppelin in Germany. The cost of operation without supporting advertising was the cause of the sightseeing company's demise.

Worldwide Aeros continued to develop its hybrid rigid airship Pelican, now named **Dragon Dream**, under government funding. The ship's hull has an elliptical cross-section and an aluminum and carbon fiber composite structure. The hull's shape enables the craft to develop dynamic lift more effectively than a conventional airship. Fabric covers the outer surface. A system for compressing or expanding the lifting gas allows the airship to offload payload without taking on ballast. Three engines will propel the craft, and vectored thrust will assist in vertical takeoff and landing.

Lockheed Martin is developing the 290-ft **SkyTug**, now called the LMZ-1M. The envelope has a tri-lobe shape and a volume of 1,285,000 ft^3. The hybrid craft has thrust vectoring and fly-by-wire controls. Its air cushion system allows it to land on water or land and assist in ground operations. The gondola accommodates eight passengers and two crew. The large cargo bay and external load capacity can handle most payloads up to 500 tons.

Worldwide Aeros is developing the Dragon Dream, a hybrid, heavy-lift, rigid airship. Credit: Worldwide Aeros.

No runway necessary

by Dyna Benchergui and Charles Svoboda

*The **V/STOL Technical Committee** is working to advance research on vertical short takeoff and landing aircraft.*

The Marine Corps **F-35B** short takeoff/vertical landing aircraft completed the second phase of its developmental testing in sea trials aboard the USS Wasp. The goal was to expand the plane's shipboard operating envelope and validate its suitability for carrier takeoffs and landings. The aircraft reached a milestone on August 14, completing its **first night landing at sea**. Other trials involving two test aircraft expanded the F-35B's allowable wind envelope for launch and recovery. These tests also evaluated the aircraft's initial mission systems, dynamic interface during operations on a moving flight deck, and shipboard sustainment.

These tests provided data for the F-35B's certification, future shipboard operations, and 2015 deployment.

In the high-speed rotorcraft sector, DARPA announced that it will develop the **VTOL X-Plane**, an experimental vertical takeoff and landing aircraft that would fly at 300 kt and also hover, providing efficiency equal to rotary and fixed-wing military aircraft. The first phase of the $150-million program will mature necessary technologies; the next two phases will validate hardware and flight test a selected concept by 2017.

The Army launched the **Joint Multi-Role Technology Demonstration program**, a precursor to the Future Vertical Lift program that will demonstrate enabling technologies for next-generation rotorcraft to replace the UH-60 Black Hawk in the 2030s. Three concepts were selected, with the aim of flying one or more prototypes by 2017.

Sikorsky/Boeing proposed a high-speed helicopter design based on Sikorsky's X2 Demonstrator. Bell Helicopter/Lockheed Martin unveiled the design of the **V-280**, a third-generation tilt-rotor fly-by-wire aircraft that would cruise at 280 kt and carry 11 passengers within a 250-n.mi. radius. The craft would have a vertical tail, a large cell carbon core wing, and a composite fuselage. It would not move its engines like the V-22, but would tilt its rotor system only.

A first for the F-35B: Marine Corps Lt. Col. "Jimi" Clift pilots an F-35B to the deck of the USS Wasp on August 14. It was the plane's first night landing at sea. Credit: U.S. Navy/Lockheed Martin.

Eurocopter's hybrid high-speed helicopter demonstrator, **the X3**, flew at 255 kt. It uses a main rotor for hover and two propellers fixed on anhedral wings for high-speed forward flight.

In October 2012 EADS Cassidian unveiled the **Tanan 300**, an unmanned vertical takeoff and landing aircraft designed for maritime and land intelligence, surveillance, and reconnaissance missions. The aircraft provides 100-n.mi. range, 50-kg payload capacity, and 8-hr endurance. For mission flexibility the Tanan has maritime radar, a direction finder, electronic surveillance, automatic identification, and identification friend or foe.

Northrop Grumman's **MQ-8C Fire-X** vertical takeoff unmanned aircraft made its first flight and began a six-month flight test program before delivery to the Navy. The aircraft uses software derived from the MQ-8B Fire Scout. A Bell 407 airframe was selected for the new aircraft after payload and range concerns arose regarding the MQ-8B's Schweizer 333 airframe.

The Air Force Research Laboratory developed a **Speed Agile Configuration Demonstrator** to advance technologies for a next-generation four-engine tactical mobility aircraft. It would take off and land on short airfields, carry heavier payloads (65,000 lb) and cruise faster (Mach 0.8) than the USAF Air Mobility Command's current fleet. The high-efficiency design has a hybrid powered lift system for which two concepts were validated. The first, developed by Boeing, uses an upper surface blowing system and circulation control/internally blown flaps on the inboard and outboard wing sections, respectively. The second concept, from Lockheed Martin, uses a novel ejecting, reversing nozzle inboard, and circulation control/internally blown flaps on the outboard wing section.

Both designs completed low-speed and transonic wind tunnel validation tests. In flight control simulation that followed, the pilots gave high ratings to the Lockheed Martin's concept's handling qualities. The large-scale ground test program will include wind tunnel tests with an actual engine, advanced structural design, and actuation to measure loads, lift performance, engine operability, and thermal characteristics.

Profits buoyed by commercial sector

by Venkatesan Sundararajan

*The **Economics Technical Committee** analyzes the economic aspects of aerospace programs and technology.*

Virgin Galactic's SpaceShipTwo made its second flight in September. Credit: Virgin Galactic.

Total revenues and profits for the aerospace and defense industry in 2013 are projected to be about the same as 2012, ending three consecutive years of record-breaking revenue and profit numbers.

The numbers for 2013 are still being tallied, but 2012 saw revenues of $695 billion and operating profits of $59.8 billion, according to **PricewaterhouseCoopers**, an auditing and consulting firm.

This year, declines in the defense sector are expected to be offset by growth in the commercial aerospace sector, with the result being flat growth. For example, revenues in the global commercial airline industry were forecast by the **International Air Transport Association** to rise from $679 billion in 2012 to $708 billion this year, or a growth of 4.3%.

Commercial and business aircraft production is on track to top 1,000 aircraft a year for the third consecutive year. During the first half of 2013, Boeing delivered 306 jetliners, while Airbus delivered 295 civilian planes. In the same period, worldwide **general aviation airplane shipments** rose 8.9% over last year, from 931 shipments to 1,014, according to the General Aviation Manufacturers Association. This is the first time since 2008 that revenues for these aircraft have exceeded $10 billion in the first six months of the year.

As the **Pentagon** makes the sequestration budget cuts that took effect in March, lower spending on purchases and R&D for new systems is affecting the entire industrial supply chain. According to the Aerospace Industries Association, 88% of **smaller suppliers** surveyed earlier this year were feeling the effects. To protect the chain, large firms such as Boeing, Lockheed Martin, and BAE Systems are monitoring and helping small suppliers, providing them with capital injections, management support, and acquisitions. In the **global defense** sector, mergers and acquisitions totaled about $4.5 billion through June. For example, in August, **General Electric** acquired the aviation business of **Avio**, an aerospace and defense firm based in Italy, for $4.3 billion.

In the **space sector**, tight federal spending constraints resulted in a NASA budget of $16.87 billion for FY13. In March, SpaceX's **Merlin 1D engine** achieved flight qualification through a 28-test program. SpaceX signed new satellite launch agreements with the Air Force, Canada, Germany, and Israel. In September, Virgin Galactic's **SpaceShipTwo** broke the sound barrier on its second powered flight and climbed from 42,000 ft to 69,000 ft over the Mojave Desert. The craft descended using its tilt-wing feathering maneuver. The company expects to start commercial service in 2014 at $250,000 a seat and has reportedly sold over 600 tickets for flights on the craft.

Globalization in aerospace industry R&D and manufacturing has led to increased foreign direct investments by leading companies. Top destinations for the money are the U.S., China, India, and Mexico. **Airbus** began building a $600-million site in Mobile, Alabama. The company plans to begin aircraft assembly in 2015, with 2016 targeted for delivery of its first A320 family jetliner.

Although military budget cuts in the U.S. and declining demand in Europe cloud the global defense outlook, significant growth is expected in emerging markets. Projections for the global commercial aviation industry show robust growth valued at $4.8 trillion over the next 20 years, with a need for over 35,000 jet airplanes during that period.

Fresh evidence that history matters

by Cam Martin

The ***History Technical Committee*** *works to preserve the record of aerospace advances and recognize their impacts on modern society.*

As the 110th anniversary of Orville Wright's **historic flight** is honored this month, aviation enthusiasts have been presented with another reminder that history is never fully settled.

An **old claim** has been revived that German emigrant Gustave Whitehead flew his motorized, bird-like craft in Connecticut more than two years before the Wright Flyer left the ground in North Carolina.

In March 2012, *Jane's All the World's Aircraft* grabbed headlines by announcing support for the claim that Whitehead flew a heavier than air machine in 1901.

The media coverage inspired Connecticut state legislators to pass a resolution supporting Whitehead, who reported conducting his experiments in the state.

Gustave Whitehead poses next to his Condor No.21 aircraft. This photo was taken in 1901, the year some say Whitehead flew his "flying car" model for a mile. Credit: National Air and Space Museum.

The Whitehead story has been resurrected several times since its rediscovery in the 1930s, and each time it has suffered from a lack of documentation. **Skeptics** from Orville Wright to British historian C.H. Gibbs-Smith have provided convincing evidence against the claim. This time, leading aviation historians in America and Europe, including Dr. Tom Crouch, vice-chair of the History Technical Committee and an Associate Fellow of the AIAA, presented the evidence against the Whitehead flight. "While I hope I am always open to new evidence in this case," Crouch said, "the Whitehead proponents will have to come up with something far more persuasive than they have to date to convince me that their hero ever left the ground in powered flight."

The public's intrigue so many years after the Wright flight should not be surprising. During the past year, there have been several noteworthy developments in the field of aerospace history. **PBS's** award-winning television series *The Aviators* is now in its fourth season, with weekly audiences of over 9.3 million viewers in 100 countries. In addition, the PBS *Pioneers in Aviation* series was nominated for an Emmy. The Smithsonian's National Air and Space Museum opened its extraordinary display of Leonardo da Vinci's *Codex on the Flight of Birds*, compiled between 1505 and 1506. One of the most significant exhibitions of the year was *Arctic Flight: A Century of Alaska Aviation* at the Anchorage Museum and co-curated by the National Air and Space Museum. The 2013 AIAA Gardner-Lasser Aerospace History Literature Award went to David Mindell for *Digital Apollo: Human and Machine in Spaceflight*. The History Manuscript Award was presented to Bruce Larrimer for *Thinking Obliquely: Robert T. Jones, His Oblique Wing and Its Legacy*.

Learn more at the session,
"All is Not Lost: Keepers of the Wright Stuff"
SCITECH 2014
January 13-17, 2014 National Harbor, Maryland

Exports-imports dominate legal landscape

by James Rendleman

*The **Legal Aspects Technical Committee** fosters an understanding of legal areas unique to aerospace.*

Export controls continue to affect aerospace programs. At the urging of Congress, the State Department has proposed to amend the U.S. munitions list and **ITAR**, the International Traffic in Arms Regulations, to change their scope, clarify them, and eliminate any that are considered outdated or excessive.

In August, the French-Italian satellite builder **Thales Alenia Space** conceded that for the past 12 years its U.S. suppliers had mislabeled components as "commercial" or "dual use" when in fact they were subject to ITAR export rules. However, the State Department has agreed that the company's export controls were sufficient, according to Thales, and that the fault was with its U.S. suppliers.

One of those suppliers, **Aeroflex**, agreed to pay an $8-million fine and take remedial measures to settle government charges that it failed to obtain proper export licenses for hardware that often found its way onto satellites launched from China and India. The State Department's charging letter alleged **158 violations** it said were "derived from several voluntary disclosures" by Aeroflex. The violations "demonstrate systemic and corporate-wide failure to properly determine export control jurisdiction over commodities," the letter said.

Orbital Sciences has gone to court to try to win the right to use Russian-made RD-180 engines for its Antares rocket. Credit: NASA.

According to the State Department, Aeroflex used Commerce Department guidelines to classify its radiation-hardened products when only the State Department is authorized to determine whether these are ITAR-controlled. After obtaining a State Department ruling that one of its products was ITAR-controlled, Aeroflex reportedly did not apply the same analysis to similar products. U.S. purchasers of Aeroflex's ITAR-controlled microelectronics also reportedly made unauthorized exports based on the improper designation. Aeroflex says it is not commenting publicly on this issue.

Orbital Sciences wants to buy Russian-made **RD-180 engines** for its Antares rocket and has sued rocket integrator ULA, the United Launch Alliance, for blocking these purchases. As reported by *Space News* and others, Orbital contends that ULA has prevented open-market sale of the engine and monopolized the launch services market for certain satellites in violation of antitrust laws. At issue is a decades-old exclusivity agreement signed by Lockheed Martin, now one of ULA's parent companies, and **RD Amross**, then a joint venture between Pratt & Whitney and Russia's NPO Energomash and importer of the RD-180s. Orbital's lawsuit seeks to strike down that agreement and force ULA to pay damages.

The Voice of Russia reports that Russia's Security Council is considering **a ban on selling** the RD-180 to the U.S. This could impact launches of massive military communications satellites and deep-space exploration craft. However, the ban is considered unlikely since it would adversely affect the engine's manufacturer, NPO Energomash. Still, some in Russia reportedly complain that the RD-180s are being sold for only half their real production value.

The U.S., the Australia Department of Defence and **Italy's Ministry of Defense** signed memorandums of understanding to streamline data requests made by each through the U.S. Strategic Command's Space Situational Awareness Sharing Agreement program. The information will help them plan operations in the increasingly crowded space domain.

SpaceX and the Air Force signed a cooperative R&D contract that enables them to share data for certifying that the company's Falcon 9 v1.1 rocket is ready to launch national security satellites. The agreement protects SpaceX's proprietary information.

On September 1, the Air Force Space Command shut down the **Space Fence**, a key part of the network for tracking satellites and orbital debris. Sequestration budget cuts caused the closing, according to the Air Force. A contract for upgrading the fence has been held up by the Pentagon's review of its acquisition programs.

Officials in some U.S. states fear that the government might use unmanned aircraft technologies to monitor individuals in manners not imagined in past **Supreme Court Fourth Amendment rulings** on the presumption of privacy. States are now looking to enact legislation to address these concerns and provide privacy protection without impeding the many potential benefits of unmanned planes. Eight states have enacted laws dealing with the privacy concerns, and another 42 bills characterized as anti-unmanned planes were introduced in recent sessions of state legislatures. Nine other bills are still in play, and legislative activity is expected on six more during 2014.

Managing sequestration

by Tom Goudreau

*The **Management Technical Committee** promotes sound management practices and helps aerospace managers understand the issues that impact their success.*

The U.S. government's actions have always strongly influenced the aerospace industry, but never more so than now. Spending reductions required by the Budget Control Act of 2011, known as **sequestration**, were implemented this year. The budget cuts caused the Department of Defense to furlough some civilian employees, lay off some temporary employees and curtail nonessential services and travel. Sequestration also impacted civil agencies such as NASA and the FAA to varying degrees.

Since the president's FY14 budget did not include any sequestration spending cuts, much of the summer was spent negotiating revised spending plans with congressional committees. The Department of Defense conducted a Strategic Choices and Management Review to guide the process. The question was not if Defense Department spending was going to be reduced but by how much, how fast, and with what consequences to capability and readiness.

The aerospace and defense industry has taken notice, and industry **consolidation** planning has begun to heat up. In August, Rockwell Collins announced an agreement to purchase The Carlyle Group's ARINC, which maintains airliners and delivers voice and data communications to them. Also in August, Northrop Grumman announced that its Australian subsidiary had agreed to purchase Qantas Defence Services, which maintains Australian VIP and military aircraft. Meanwhile, United Technologies reported strong earnings in 2013, in part from its 2012 purchases of Goodrich and a majority share of jet-engine maker International Aero Engines by its Pratt & Whitney subsidiary.

In the unmanned plane realm, President Obama gave a major policy speech in May at the National Defense University in which he acknowledged the controversy over U.S. "**drone strikes**" and said he wanted to explore options for increased congressional oversight. Domestically, unmanned aircraft operating policy has become as much about addressing privacy concerns as about ensuring airspace safety.

As for the cyber domain, the *Washington Post* reported in May that the designs of major U.S. missiles and aircraft had been compromised by **hackers**. The *Post* said unnamed industry and government officials had blamed the "vast majority" of the breaches on China. Systems compromised by cyber espionage were said to include the F-35, PAC-3, Aegis, F/A-18, V-22 and others. The White House continues to warn the aerospace, banking, utility industries and others to take the cyber security threat seriously and mitigate it.

In **space**, there were both successes and disappointments. The main data-collection phase of the Kepler space telescope mission ended when one of the spacecraft's reaction wheels failed, but scientists were planning to pore over the data on 3,588 potential planets identified by Kepler. Meanwhile, steady progress continued on Northrop Grumman's development of the James Webb Space Telescope, which will allow the study of every phase in the history of the universe.

In **education**, U.S. spending reductions prompted a consolidation of federal programs for STEM education–science, technology, engineering and math. Nevertheless, U.S. aerospace leaders continue to support a range of public and private initiatives to inspire and motivate students to enter the aerospace profession. The aerospace industry provides students with opportunities for hands-on STEM experiences and guidance with the goal of inspiring future explorers, scientists and engineers.

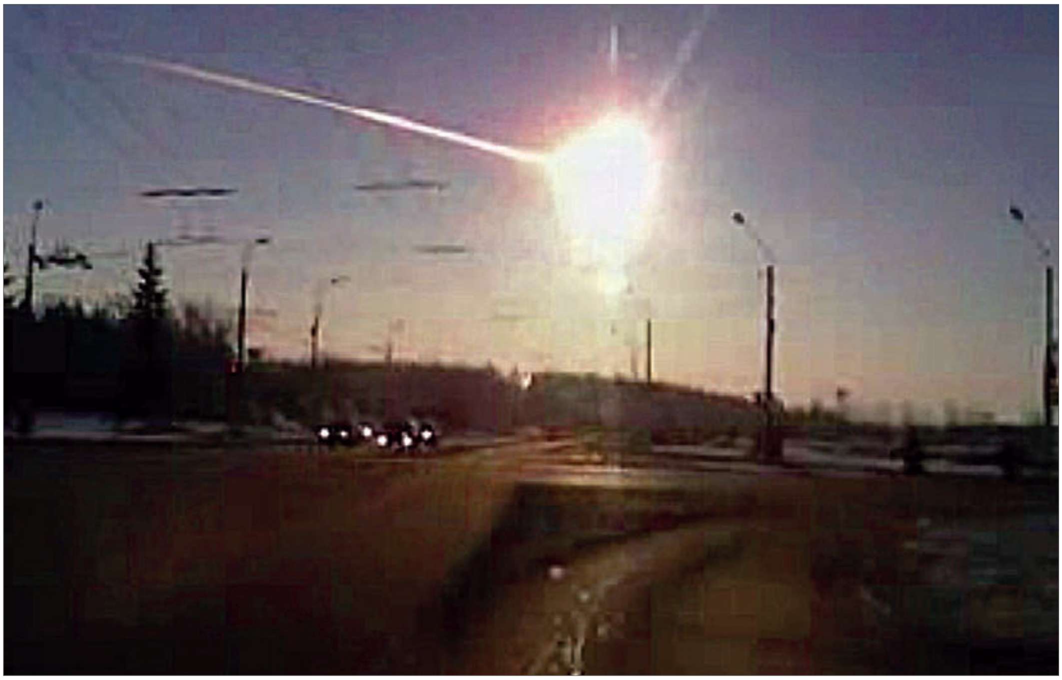
The industry's future will rely on professionals who can develop complex and critical aerospace systems that meet stakeholders' needs within planned budgets and schedules. AIAA supports this need by hosting Complex Aerospace Systems Exchange, or **CASE**, meetings that offer practical, applicable, actionable knowledge to attendees. Today's aerospace professionals have real challenges. They also have real opportunities to expand and accelerate aerospace's contribution to humanity's progress.

The James Webb Space Telescope, seen here in an artist's rendering, will allow studies of every phase in the history of the universe. Credit: Northrop Grumman.

A year of reminders

by Annie Wargetz

*The **Society and Aerospace Technology Technical Committee** promotes the transfer and use of aerospace technology for the benefit of society.*



A meteor streaks through the sky over Chelyabinsk, Russia, in this frame grab from a dashboard camera. Credit: AP.

From meteors to air crashes to privacy incursions, events in 2013 drew the public's attention to aerospace science and technology. On the morning of February 15, a **meteor** entered Earth's atmosphere, creating a bright flash and vapor trail over Chelyabinsk, Russia. The resulting shock wave broke windows and damaged buildings for hundreds of miles, sending 1,500 people to hospitals.

A host of dashboard cameras, cell phones, and other devices captured the meteor's fiery entry. More than 100,000 of these videos can be found online—the most popular has been viewed 39 million times.

On the same day as the Chelyabinsk blast, Earth had another close call: the flyby of an **asteroid** nearly half the size of a football field. The approach of the object, called 2012 DA14, was the closest ever recorded for a natural body that large.

The two events, declared a "wake-up call" by members of Congress, were a reminder of how vulnerable the Earth is to dangers from space. The House of Representatives held **hearings** to discuss defensive strategies.

Two **accidents** also shook the aerospace community. A Russian Proton rocket launch failed on July 2, causing a catastrophic explosion. Videos of the event reached viral status on the Internet, reminding the public that spaceflight still carries great risk. The failure also heightened concerns about delivering crews and cargo to the International Space Station safely and on time.

Four days later, a commercial airliner crashed. Asiana Flight 214 collided with a sea wall on final approach to San Francisco International Airport. The accident killed three and underscored the need to guard against complacency in ensuring flight safety.

Unmanned aircraft, meanwhile, offer growing benefits to society in areas such as disaster monitoring and law enforcement. Versions of the Global Hawk track hurricanes; other types are used for predicting and chasing tornados. The advance warnings these aircraft provide save many lives each year. States have begun competing for a stake in test facilities for the planes. At the same time, there is increasing concern that they could be used by the government to spy on U.S. citizens. Congress has petitioned the FAA to create rules for the use of these aircraft, and a growing number of states are proposing bills addressing privacy issues.

Much farther away, on July 19, **Cassini** captured an image of Earth from Saturn, only the third ever taken from the outer solar system. The picture drew enormous attention on the Internet, reminding viewers of their planet's place in the universe.

Sequestration and systems engineering

by Michelle Bailey

*The **Systems Engineering Technical Committee** supports efforts to define, develop and disseminate modern systems engineering practices.*

For those working for or with the U.S. government, the most influential event in 2013 was **sequestration**, the automatic budget cuts required by the **Budget Control Act of 2011**—the mandatory cuts to almost every fiscal line item. Sequestration is the result of the U.S. failure to make decisions regarding how to reign in the federal budget. The cuts amount to roughly $50 billion for the Department of Defense through 2022. Other aerospace organizations such as **NASA** and the **FAA** are experiencing similar cuts as percentages of their budgets. While many lament the immediate challenges that sequestration presents, the long-term impact will relate to how systems are sustained, modernized, replaced and disposed of. Loved or hated, sequestration is impacting acquisition, operations and maintenance, and how systems engineering supports those activities.

Historically, the U.S. has had and has exploited a technological edge in systems development, highly influenced by their economic strength. While past studies by the **International Council on Systems Engineering** have shown that programs perform best with regard to cost and schedule when roughly 15% of each budget is devoted to systems engineering, ensuring programs devote that level of funding has often been tenuous. Some blame this lack of focus on systems engineering for the frequent cost and schedule overruns of many large programs. As U.S. government programs experience budget cuts, their use of new systems engineering tools is increasing.

A combination of changes is happening across programs. First, programs have begun focusing on detailed concepts of operations prior to starting the program. Just as a normal person has an expected use of a home or a car, government programs are being much more attentive to how a system will be used by the customers. The Department of Defense and NASA are both increasing the use of model-based systems engineering at the beginning of programs in an attempt to better trace operational needs to technical requirements, and to perform early trade-offs of requirements. This is expected to greatly improve program performance since finding and fixing technical issues, or deleting technical capabilities, greatly increases costs the later in the program these changes are made. New programs are initiating much more detailed cost benefit analysis, with increased focus on operations and sustainment, to evaluate not only what technical capabilities will add the most value per dollar spent, but also to determine if a system should be built at all. New tools are being developed to improve the cost benefit analysis process, recognizing that one tool won't necessarily meet the needs of each area of aerospace.

Another impact that sequestration is having on the systems engineering community is a renewed focus on **sustainment**. This new focus includes sustaining existing systems much longer to delay replacement, and also focusing on how new systems will be sustained to decrease the cost and to accept upgrades as technologies mature. In some cases, sustainment issues are moving programs more towards using a mature subsystem and then replacing it with the latest alternative that has demonstrated the requisite technological maturity, as opposed to sustaining the system for years into the future. This change also impacts systems engineering as many components of a system will be in the upgrade process at any time, and ensuring the interoperability of these components will present technological and programmatic challenges.

Programs that continue to focus 15% of their funding on systems engineering, albeit in these new focus areas, will likely reap the benefits of improved cost and schedule performance during the sequestration era.

As government programs cope with budget cuts, the use of systems engineering tools is increasing. Credit: Defense Dept.

Satcom rebound

by Christopher F. Hoeber and Thomas C. Butash

The ***Communications Systems Technical Committee*** *is working to advance communications systems research and applications.*

Contracts for geosynchronous commercial satellites bounced back in 2013. With the year winding down, the industry was on a pace to beat the 16 awards of 2012 and return to the more traditional rate of 20 to 25 year. SSL, the Silicon Valley satellite manufacturer now owned by MDA of Richmond, British Columbia, received five satellite contracts, Boeing and Orbital Sciences three each, and Astrium, the Indian Space Research Organisation, and Thales two each. Asia Broadcast Satellite and Satmex exercised their contract options for all-electric-propulsion Boeing spacecraft. Industry interest in dual launch and all-electric satellites remains high.

Launch services are a continuing concern to operators, with Russia's **Proton** rocket experiencing a failure and **Sea Launch** unable to increase its launch rate.

Industry has high expectations for the **SpaceX Falcon 9**, which was launched successfully on September 29 with upgraded **Merlin D1 engines**. The company also promises significantly lower pricing with its Grasshopper reusable launch vehicle.

Technical issues caused the Indian Space Research Organisation to delay the launch of its updated **Geostationary Launch Vehicle**. The rocket, which has a domestically developed cryogenic upper stage, would have carried India's **GSAT-14** satellite.

Both **ViaSat** and **Hughes** procured advanced high throughput satellites, based on the success of their current broadband types. Australia's **NBNCo** started interim satellite broadband service, and Brazil selected Thales for its Geostationary Defense and Strategic Communications satellite.

Intelsat moved in a different direction for high throughput satellites, awarding Boeing its second **Epic** spacecraft with options for three more. Epic combines wide beam and spot beam technology, supports star and mesh topologies, and offers high capacity in a range of spectrum.

O3b began testing its Ka-band services after the launch of its first four Thales-built satellites on a **Soyuz**. Launch of the next four is expected in the first quarter of 2014.

Arabsat announced the purchase of a majority stake in **Hellas-Sat**. Eutelsat has nearly completed its purchase of Satmex. New regional operators appeared in the marketplace, with the governments of Mongolia, Nicaragua, and other countries planning for their own communications satellites. On the manufacturing side, MDA—formerly MacDonald, Dettwiler and Associates—acquired **Space Systems Loral** in late 2012.

Arabsat and Qatar's **Es'hailSat** announced a strategic agreement to develop the 26°E slot, and **AsiaSat** will host a meteorological payload on AsiaSat 9. A satellite built for both Eutelsat and Es'hailSat was launched in August.

Satellite operators have demonstrated **ultra high definition TV**, which is expected to roll out in the next two years. Direct broadcast satellite subscribers declined slightly in the U.S. because of competition from alternate services but is still rising in emerging regions. India's direct to home subscription growth surpassed that of the U.S. in 2012.

Inmarsat's first **Alphasat**, with its mobile services satellite payload, launched on an **Ariane 5**. Astrium and Thales jointly manufactured the satellite, which includes Q/V-band and an optical communications demonstration payload. NASA's Space Technology Office partnered with SSL on a laser communications relay demonstration for a hosted geosynchronous satellite payload.

The top four fixed satellite service operators had ordered five spacecraft as of August, a figure that is up from three in 2012. Much of the new Space Based Infrared System satellite capacity will be for Latin America. **Asia Broadcast Satellite** and **Thaicom** also ordered satellites for Asia. Terrestrial cellular build-out continues its exponential growth.

The Air Force launched the second **Mobile User Objective System satellite** for the Navy and the third **Advanced Extremely High Frequency satellite**, both on Atlas 5 rockets, and two Wideband **Global SATCOM satellites** on Deltas. All programs recorded in the service's current Future Years Defense Program are approaching production line completion, and the Space and Missile Systems Center is pursuing next-generation architectures.

U.S. export control reform is nearing reality. The government released draft regulations returning control of most satellite exports to the **Department of Commerce**. The regulations will not be in place until 2014, 15 years after Congress moved regulatory responsibility to the State Department.

The Eutelsat 25B/Es'hail 1 satellite, jointly owned by Eutelsat Communications and Es'hailSat of Qatar, was launched on an Ariane 5 rocket in August. Credit: SSL.

No sign of slowing down

by Rick Kwan

*The **Computer Systems Technical Committee** works on advancing the application of computing to aerospace programs.*

Vast increases in computing power have produced low-cost smartphones whose performance rivals mainframes of the Apollo program. This reflects Moore's Law, which says the transistor count on a die of silicon doubles every two years. If the trend continues, it could enable autonomy in space exploration missions and broader access to communications satellites.

NASA and the Air Force have agreed on the need for **a common next-generation space processor**. In 2012, a NASA high-performance spaceflight computing study looked at different computing architectures. The most promising for future missions, it said, is radiation-hard general-purpose multicore computing. This year the **Air Force Research Laboratory** sought proposals for an analysis program for the needed processor. Phase 1 would refine the computing requirements and define a multiprocessor architecture to meet them. Phase 2 would follow with chip development.

Successful demonstration would make it the processor of choice for advanced space missions through 2030. Initial requirements anticipate 24 processors providing 24 billion operations/sec and 10 GFLOPS consuming 7 W of power or less.

Meanwhile, **BAE Systems** is testing its **Radspeed** digital signal processor, which is derived from the commercial ClearSpeed CSX700. The rad-hard part retains 70% of the performance of the original. It will connect to a Radspeed host bridge, coupling it to RAD5500 processors adapted from the Freescale e5500.

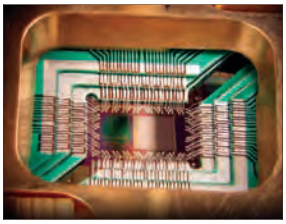
CubeSats are paving the way to orbit with lower cost computing. A trio of **PhoneSats** named Alexander, Graham, and Bell demonstrated how an Android phone could serve as the brains of a satellite. **TechEdSat**, developed by NASA Ames and San Jose State, was deployed from the International Space Station. The spacecraft demonstrated a plug-and-play architecture, and communication with **Iridium** and **Orbcomm** satellite networks.

The **Trailblazer** CubeSat from COSMIAC, the Configurable Space Microsystems Innovations and Applications Center, specifically demonstrates the **AIAA space plug-and-play** architecture. To be launched by year's end, the satellite will support space weather research. A Kickstarter-funded satellite, **ArduSat-1**, uses the popular Arduino programming framework and provides funders and users access for their own experiments. Also funded by Kickstarter are **SkyCube** and **KickSat**. They are due to fly in the next few months and, like ArduSat-1, will offer funder/user programmability.

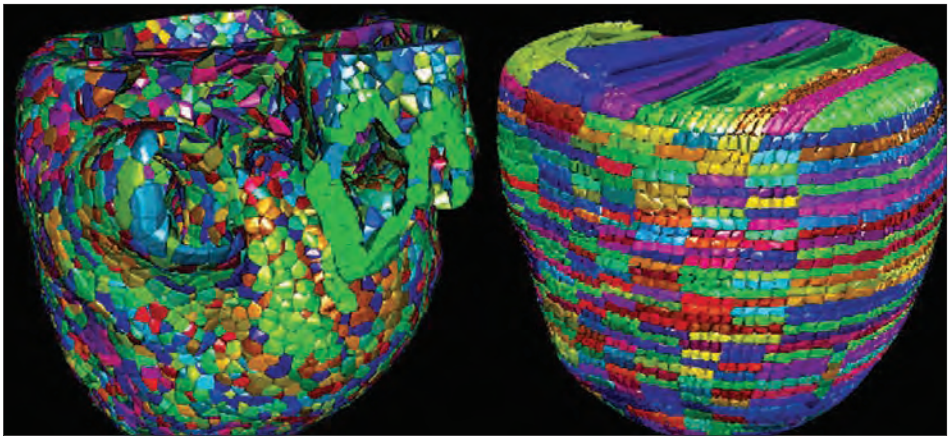
Computing for modeling and simulation continues its climb past terraFLOPS into petaFLOPS. As of June, China's **Tianhe-2**, or MilkyWay-2, is the world's fastest computer. Comprising over 3 million computing cores, it has achieved 33.8 petaFLOPS. Next is **Oak Ridge's Titan**, a Cray with 560,000 cores for 17.6 petaFLOPS, and followed by **Lawrence Livermore's Sequoia**, an **IBM BlueGene/Q** with over 1.5 million cores for 17.2 petaFLOPS. With this computing power, it is possible to apply finite-element methods to modeling sudden cardiac death of the heart, or **noise** propagated from **a jet engine**.

Quantum computing is starting to find early adopters in aerospace. **Lockheed Martin** began working with a **D-Wave One** quantum computer in 2011. In 2013, NASA Ames, Google, and USRA, the Universities Space Research Association, launched a quantum artificial intelligence lab using a D-Wave Two. While a traditional bit is on or off, a quantum bit, or qubit, may be both on and off, but subject to the quantum-mechanical properties of atoms.

In networked computing, a collision of themes is arising. Network-connected devices, still mushrooming and nearly ubiquitous, are now collectively called the **Internet of Things**, or IoT, which promises new services and conveniences. At the same time, protection of privacy and infrastructure demand cybersecurity. As NASA and the FAA, in a seemingly unrelated effort, study how to integrate unmanned aircraft into the **National Airspace System**, it seems that they cannot avoid being stuck in the middle of IoT and cybersecurity.



D-Wave built this processing chip for its quantum computers. Credit: D-Wave.



A computer code called Cardioid replicates the electrophysiology of the human heart. Credit: Lawrence Livermore National Laboratory.

More satcom for jets

by Ann Heinke

*The **Digital Avionics Technical Committee** advances the development and application of communications, navigation and surveillance systems used by military and commercial aircraft.*

This year brought important developments in the aviation community's ongoing shift toward satellite communications for the vital data links between commercial aircraft and air traffic controllers.

In September, the FAA issued a supplemental type certificate to corporate-jet operator **Chicago Jet Group LLC**, allowing the company to equip its Falcon 50 jets to communicate Controller-Pilot Data Link Communications and Automatic Dependent Surveillance-Contract messages with air traffic control sites via the **Iridium** constellation. The certificate marked a significant milestone for aviation modernization. Commercial airliners have for years relied on satellite data links to plug into the internationally approved Future Air Navigation System, or FANS, network, but corporate jet operators have not done so at the same level.

FANS provides controllers with updated location information for aircraft and allows them to reduce separations between equipped aircraft. The FANS-equipped planes are given more efficient routes as an incentive to equip. The FANS messages have traditionally been passed over data links established by Inmarsat satellites, but in 2011 the FAA approved **Iridium** as a FANS data link provider too. In 2013, Inmarsat took steps to provide FANS service over its new, higher-throughput Swiftbroadband service. A proposal by Inmarsat to standardize avionics for its **Swiftbroadband** service was advanced this year by the not-for-profit Radio Technical Commission for Aeronautics organization, which works with aviation authorities to modernize air travel.

ICG's NxtLink ICS-220A Iridium Communications System combines data modem and dual voice/data transceivers. Credit: ICG.

To make a jet FANS capable, a suite of avionics software is installed in the plane's flight management computer, communications management unit, or flight deck displays. In addition, data link transceiver hardware (SATCOM and VHF data radio) and other flight deck updates are made, depending on the original equipment aboard the aircraft. FANS 1/A or FANS 1/A+ are product names for the suites on Boeing and Airbus jets. They provide applications for Automatic Dependent Surveillance-Contract and Air Traffic Services Facilities Notifications. Controller-Pilot Data Link Communications provides messages for the controller and pilot to exchange clearances, reports and other information. Automatic Dependent Surveillance-Contract provides a reporting agreement that is formed in near-real time when an aircraft enters an authority's airspace. The contracts spell out how often planes must report their positions and other data as requested by the air traffic control authority.

FANS provides nearly instantaneous location reporting, compared to the slow, third-party high-frequency radio communications that airliner crews once relied on as the sole means of communication over oceanic routes. Controllers have been able to shrink the minimum separation among airliners from 100 n.mi. to 30 n.mi. or less, saving the airlines millions of dollars in fuel costs each year.

The global aviation community is gravitating toward making FANS a mandate. Since February, planners of the **North Atlantic Track System**, or NATS, have identified two preferred tracks for FANS aircraft crossing the Atlantic at altitudes of 36,000-39,000 feet. Operators wishing to fly these preferred tracks must be FANS-equipped. When the next mandate goes into effect in 2015, jets will have to have FANS equipment aboard to fly Minimum Navigational Performance Specification tracks. Commercial airliners that routinely cross the Atlantic nearly all carry FANS equipment because of the cost-savings the equipment provides. Details for the 2015 mandate are still under negotiations, but it is likely that the entire North Atlantic airspace, including flight levels above the tracks, eventually will require FANS technology.

Taken together, the FAA approval of FANS-over-Iridium and the recent 2013 FANS mandate over the North Atlantic have spurred a new interest in FANS 1/A by numerous business jet operators. Aircraft manufacturers **Bombardier**, **Gulfstream**, and **Embraer** have been fitting new aircraft with FANS 1/A+ avionics that use Inmarsat communications.

Iridium announced in October that the blueprint for its second-generation Iridium NEXT satellite network passed its critical design review. The company says it is on track to launch the first of these new satellites in 2015.

Safer operations through modeling

by Kristin Rozier

*The **Intelligent Systems Technical Committee** works to advance the application of computational problem solving technologies and methods to aerospace systems.*

A major cause of failures in airplanes and spacecraft involves how humans interact with automated systems. The problem, known as HAI or **human-automation interaction**, has become a major safety concern.

A team of analysts from **The University of Illinois at Chicago**, **Delft University of Technology**, the European Space Agency and IXION Industry and Aerospace has developed a new method that allows them to discover HAI problems automatically, using a process called formal verification.

The team used this method to evaluate a satellite tracking and control system and an unmanned aircraft ground control station. Their approach entails constructing formal models of human operator tasks, automation, and systems, and then integrating these models into a larger formal system model. A model checker enables verification that the system supports safe HAI.

In the analytical realm, a new toolset called **COMPASS** for correctness, modeling, and performance of aerospace systems has been used to study the software and **fault management** architectures of current European space missions. Developed by ESA, RWTH Aachen University, Fondazione Bruno Kessler, and Thales Alenia Space, COMPASS uses a model expressed in Architecture Analysis and Design Language. The model includes nominal, erroneous and degraded operations to enable rigorous, semi-automated analysis. Using model checking technology, COMPASS looks at the design's functional correctness, safety, fault management effectiveness, and other properties.

In aviation, the need for onboard **collision avoidance** systems increases as air traffic management reduces the spacing required between planes. Nonlinear flight trajectories create complexities that make these onboard systems impossible to analyze completely via testing or simulation. Researchers at Carnegie Mellon University pinpoint unexpected emergent behaviors using the theorem prover **KeYmaeraD**. This tool handles continuous and nonlinear flight trajectories and the infinite behaviors that can be generated by multiple maneuvering planes. The researchers proved **safe separation** for an arbitrary number of aircraft flying under a disc-based collision avoidance scheme. This level of verification has yet to be achieved for any other distributed and flyable collision avoidance protocol.

NASA Ames's System-wide Safety and Assurance project developed a framework for onboard uncertainty quantification and management in **automated** prognostics and **health monitoring**. The framework identifies sources of uncertainty and estimates systems' remaining useful life by analyzing possible failure scenarios and fault degradation modes. Decision-making for reducing these uncertainties then automatically enables fault recovery and mission replanning, which are vital for time- and safety-critical missions. Tests of this framework involved monitoring the power systems of mobile robots and unmanned aircraft.

Researchers demonstrated online wire chafing fault detection on C-17 engines at NASA Dryden. Credit: Ken Ulbrich, NASA Dryden.

Jet Propulsion Laboratory researchers created onboard real-time **cloud screening** for the AVIRIS-NG, or Next Generation Airborne Visible Infrared Imaging Spectrometer, demonstrating the highest execution speed yet for such screening. The spectrometers generate unprecedented volumes of data, requiring better storage and communications. Image screening could improve data volumes by a factor of two.

Hardware safety advances included a demonstration of online **wire chafing** fault detection technology on **C-17 jet engines** at NASA Dryden. Wiring is critical to aircraft safety–even minor issues can lead to serious problems including smoke, fire, and out-of-service time. A government-industry team developed advanced physics-based methods for automatically detecting sizes and locations of chafing faults in shielded and coaxial aircraft cables. The team included researchers from four NASA centers–Goddard, Dryden, Langley, and Ames–and the Air Force, Pratt & Whitney, Boeing, United Technologies Research Center, Makel Engineering, Auburn University and Kansas State.

New directions for sensor systems

by Timothy L. Howard, Wei-Jen Su, Clay Carson, and Domenico Accardo

The ***Sensor Systems Technical Committee*** *works to advance systems and technology for sensing of phenomena on or near aerospace systems.*

More than two-dozen defense companies are collaborating on development of **FACE**, the Future Airborne Capability Environment. By enabling disparate sensors to work together, FACE would improve pilots' **situational awareness**, giving them better, more timely information for assessing and responding to threats. A seamless plug-and-play interface would provide interoperability with existing sensor systems, meaning major savings for the Defense Department. FACE would also speed delivery of information to military commanders on the ground.

So far, the group has integrated about 20 different products into a seamless network at the Rotorcraft Avionics Innovation Laboratory, an industry collaboration including Northrop Grumman, Harris, L3 Communications, BAE Systems, FLIR Systems, and others. At least 100 more sensors are undergoing tests. Currently FACE is focused on aviation systems, but interoperability would benefit other domains as well, say the project's engineers.

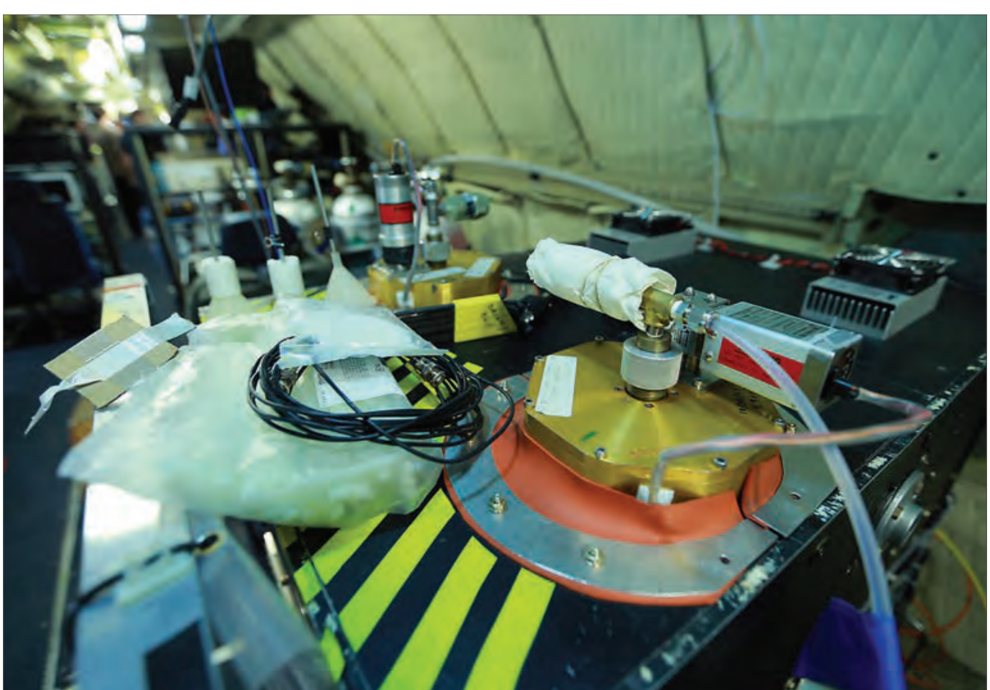
In the civil arena, NASA has developed an airborne Earth-observing program, **Discover-AQ**, which uses a Lockheed P-3B and a Beechcraft 200 King Air turboprop to make air quality measurements. The goal is "to distinguish **pollution** high in the atmosphere from that near the surface where people live and breathe," says NASA. The two planes fly at the same time and collect data over the same area from different altitudes. These measurements allow correlation between surface-level concentrations of various gases and total atmospheric column measurements of the same species. The program will enable future spacecraft to measure key trace gases and aerosols more accurately.

The King Air flies below the P-3B and carries a high spectral resolution laser radar and an ultraviolet/visible spectrometer. The P-3B has eight instruments that measure ozone, particulates, carbon monoxide, carbon dioxide, and nitrous oxide. Flights are currently under way over the continental U.S. The data will be compared with similar data from NASA's A-train satellites, which give broader scale measurements. The program also uses data from ground-based instruments and tethered balloons.

Advanced sensors are also contributing to **precision agriculture**, which uses the technology to determine crop nutrient levels, water stress, impacts from pests, and other factors that affect yield. Both multispectral and hyperspectral cameras are now available for small unmanned aircraft used in these efforts. Oregon State University plans to help potato farmers use water and chemicals more effectively. Under that program, multispectral cameras installed on 8-pound **Tetracam HawkEye** air vehicles will measure reflected light in the 520-920-nm region. Farmers will deliberately reduce water and nutrients in selected areas to help determine the time lag between plant stress and measurements. Under stress, the near-infrared components of reflected light will drop noticeably. Other companies now offer similar aircraft-based image sensing services to the agricultural industry.

2013 marked the 50th anniversary of **FLIR**—forward looking infrared—technology. FLIR cameras were initially developed in 1963 as an experiment in infrared imaging at Texas Instruments' Defense Systems and Electronics Division, now part of Raytheon. The military quickly adopted the technology, and civilian use of FLIR sensors soon expanded into new areas. Advanced FLIR is now in space on board the Suomi National Polar-orbiting Partnership satellite, as part of the Visible-Infrared Imager Radiometry Suite.

NASA's Discover-AQ project measures air pollution with instruments on the agency's P-3B Earth science aircraft. Credit: NASA.



Tactical shift for laser weapons

by James A. Horkovich

The ***Directed Energy Systems Program Committee*** *focuses on advancing military and civilian applications for laser technology.*

The Army's High Energy Laser Mobile Demonstrator will test the ability of lasers to protect troops from rockets and other threats. Credit: Boeing.

In the military realm, the Army, Navy, and Marines made more strides in 2013 toward their goal of applying directed energy lasers in tactical operations. In the civilian world, NASA and its contractors continued exploring the potential for lasers to beam power to aircraft.

On the battlefield, lasers could someday reduce the need for costly defensive missiles while offering the advantage of hitting targets almost instantaneously. The Navy and Marine Corps pursued near-term development of tactical laser weapons in 2013 through the **Office of Naval Research Solid State Laser Technology Maturation** program and the **Ground Based Air Defense** program.

The Navy's work on laser systems reflected the "broader affordable strategy" called for by the Senate Armed Services Committee in FY12. This year's efforts focused on maturation of solid-state laser technology for tactical shipboard deployments. The Office of Naval Research supported this work, which was conducted through the Laser Weapon System program of the Naval Surface Warfare Center in Dahlgren, Virginia. The system the Navy envisions could be installed on combatant-class ships of all sizes.

LaserMotive's wireless power system beamed energy to a Lockheed Martin Stalker unmanned plane in 2012. Credit: LaserMotive.

Only recently have solid-state lasers approached strengths of **hundreds of kilowatts** of power, which would be enough to destroy a vehicle or negate an incoming warhead. In the Robust Electric Laser Initiative of the High Energy Laser Joint Technology Office, industry participants demonstrated such results in their formal test programs, at the highest efficiencies ever achieved. The Navy announced its intention to take its tactical laser weapon system to sea aboard the USS Ponce in 2014.

The Army conducted tests of its **High Energy Laser Mobile Demonstrator** at the White Sands Missile Range and sought sources for a 100-kW-class laser to be integrated with the system.

NASA continued research into nonweapons use of directed energy systems, including **beamed energy propulsion** and beamed energy power transmission. The agency had awarded roughly $3 million in contracts in 2011 for the first phase of its Ride the Light project under the Game Changing Technology Development Program. In 2012, **Lockheed Martin** announced what it called the "first ever" outdoor flight of an unmanned craft powered by laser. The tests used a small **Stalker** aircraft and a wireless power system from the Seattle-based company **LaserMotive**. These research areas will be discussed at the 2014 International High Power Laser Ablation and Beamed Energy Propulsion conference, scheduled for April 21–25, in Santa Fe, New Mexico.


Skylon would be a single-stage-to-orbit spaceplane. Credit: Reaction Engines.

Progress toward reusability

by Adam Dissel, Barry Hellman, and Dennis Poulos

*The **Reusable Launch Vehicles Program Committee** brings together experts to focus on leading-edge programs and developments in this area.*

Companies and agencies made progress in 2013 toward reusable launch vehicles that someday could offer lower costs and more frequent space missions.

SpaceX flew its **Grasshopper** reusable rocket to progressively higher altitudes in a succession of test flights. These vertical takeoff and landing flights are furthering the company's goal of recovering and reusing the first stage of its Falcon 9 rocket. In July, after successful tests in March and April, the Grasshopper reached a record altitude of over 1,000 ft before landing vertically.

Several smaller startup companies have been working on reusable rocket-powered craft for suborbital spaceflight, with growth paths to orbital launch.

XCOR Aerospace made progress with its two-person **Lynx** rocket plane, having fired the craft's reusable 5K18 engine for up to 67 seconds. The tests were conducted on the Lynx's thrust structure.

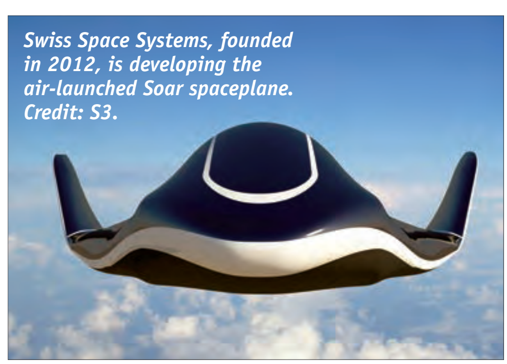
Masten Space Systems has been making plans to fly its **Xeus** vertical takeoff, vertical landing reusable demonstrator at Space Florida's Launch Complex 36 at Cape Canaveral Air Force Station.

Reaction Engines announced a £60-million investment through the U.K. Space Agency to develop the **SABRE**, or Synergistic Air-Breathing Rocket Engine, for the planned Skylon single-stage-to-orbit reusable launch vehicle.

Swiss Space Systems, founded in 2012, has been making strides toward developing its air-launched **Soar** spaceplane.

DARPA initiated a reusable first stage program called **XS-1**, the Experimental Spaceplane. As envisioned by the agency, this unmanned hypersonic craft would be comparable to traditional vehicles in terms of costs, operation, and reliability. Key goals of the project are to fly 10 times within 10 days, fly once to Mach 10, put a payload into orbit, and demonstrate the technologies needed for placing 3,000-5,000 lb into low Earth orbit for one-tenth of current costs.

This year is also the 20th anniversary of the first flight of the **DC-X**, or Delta Clipper Experimental, the reusable single-stage-to-orbit prototype spacecraft built by McDonnell Douglas. AIAA's Reusable Launch Vehicles Program Committee, along with the New Mexico Museum of Space History, Spaceport America, Virgin Galactic, and New Mexico State University-Alamogordo cosponsored a three-day workshop marking the anniversary in August. Participants inducted the DC-X team into the International Space Hall of Fame, reviewed current experimental projects, and developed recommendations for reviving X-vehicle programs.


Swiss Space Systems, founded in 2012, is developing the air-launched Soar spaceplane. Credit: S3.


SpaceX's Grasshopper reusable rocket has been flying to progressively higher altitudes. Credit: SpaceX.


The XCOR Lynx rocket plane's reusable 5K18 engine was test fired for 67 seconds. Credit: XCOR.

Controlling the environment

by Brian O'Connor and the Space Environmental Systems Program Committee

The ***Space Environmental Systems Program Committee*** *focuses on environmental and thermal control technologies for aircraft, spacecraft and exploration missions.*

During the past year, environmental and thermal control systems have been implemented on numerous flight projects using traditional and cutting-edge technologies, while work continues toward advanced, enabling technologies for future missions.

NASA's **Curiosity rover** completed its first year on Mars in 2013. At the heart of the rover's thermal control system, a mechanically pumped liquid loop is maintaining benign temperatures for the rover's avionics despite the harsh Martian environment. It does this by supplying heat from the radioisotope thermoelectric generator and rejecting excess heat through radiators.

Multilayer insulation must protect ESA's BepiColombo spacecraft from intense temperatures during its mission to Mercury. Credit: ESA.

NASA completed its preliminary design review of the **Space Launch System**, NASA's next-generation heavy-lift rocket. Preparations for the review entailed definition of the system's thermal design environments and thermal interfaces, including those of the Orion crew vehicle and ground systems. The review showed that the current thermal design meets key requirements and also identified areas for improvement.

Research that may help to enable the space missions of the future is also under way. One study uses **shape memory alloys** to deploy a passively controlled radiator surface that can turn down the amount of heat rejected by a spacecraft. Another study is investigating new formulations of thermal control **fluids** that have freeze points below -90 C and are safe in human habitats. NASA's newly formed Space Technology Mission Directorate and Small Business Innovation Research program provide much of the funding for these studies.

To accommodate a future spacecraft, a facility used in the Apollo program received major upgrades. NASA Johnson's Chamber A, one of the world's largest space environment chambers, was modified for use in the **James Webb Space Telescope** (JWST) program, which funded the modernization. The goal was to increase the chamber's efficiency and enable it to simulate the extreme environments of future deep space missions. The updates to the refrigeration and control system allow the chamber to be controlled to temperatures ranging from below -258 C (15 K) to more than 57 C (330 K), at very low vacuum pressures.

Before the JWST flight test, a JWST **Pathfinder** will be cryogenically tested three times in **Chamber A**. The Pathfinder consists of flight-like features including a backplane structure segment with two primary mirror assemblies, a secondary mirror structure, and a secondary mirror assembly. The structure will be outfitted with flight-like thermal blankets and thermal simulators for missing mirrors that enable thermal performance similar to the flight unit. Because fully instrumenting the flight unit would substantially impact launch mass, the Pathfinder test will serve as a guide for the flight test. The thermal test will allow insight into critical gradients, and produce data that will help predict the cryogenic thermal performance of the flight unit.

In Europe, ESA's **Intermediate eXperimental Vehicle**, an atmospheric reentry demonstrator, completed a drop test from 3,000 m. The test validated the entire descent and recovery phases, including the interfaces with the high-temperature thermal protection system. The demonstrator is scheduled for a launch test in the summer of 2014.

BepiColombo, ESA's planned mission to **Mercury**, completed thermal balance tests of insulation samples representative of the flight design. The multilayer insulation will protect the spacecraft from the extreme heating it will experience on the mission. JAXA, the Japan Aerospace Exploration Agency, is ESA's partner in the program.

Exploration hopes ride on new launchers

by Chris Moore

*The **Space Exploration Program Committee** brings together experts on topics relevant to future human and robotic exploration missions.*

Space exploration developments in 2013 included the launch of a new commercial rocket to deliver supplies to the **International Space Station**. Development of NASA's Space Launch System made steady progress, and space station research yielded scientific and technical dividends. NASA also unveiled a new mission to capture and redirect a small asteroid.

Orbital Sciences' **Antares** rocket lifted off from Wallops Island, Virginia, in June on its first flight. In September, Antares launched the Cygnus module, which completed its first cargo delivery mission, carrying supplies to the space station. Another commercial company, **SpaceX**, also provides station resupply missions, having launched its second one in March.

NASA signed an agreement with **ESA** to develop the **Orion** crew vehicle's service module, scheduled to fly on the Space Launch System in 2017. The module design will be based on ESA's Automated Transfer Vehicle.

Orion's first flight on a Delta 4 rocket is scheduled for 2014. Preparations for the flight included assembly of the flight test vehicle at Kennedy Space Center, pressure and structural tests of the capsule, and manufacture of the heat shield. The adapter ring that will attach the spacecraft to the Delta 4 also was fabricated.

In July, NASA completed the Space Launch System's **preliminary design review**, a key milestone for the program. A three-story-tall friction stir welding machine for construction of the launch system's core stage was installed at the Michoud Assembly Facility, and the first barrel section for this stage was built.

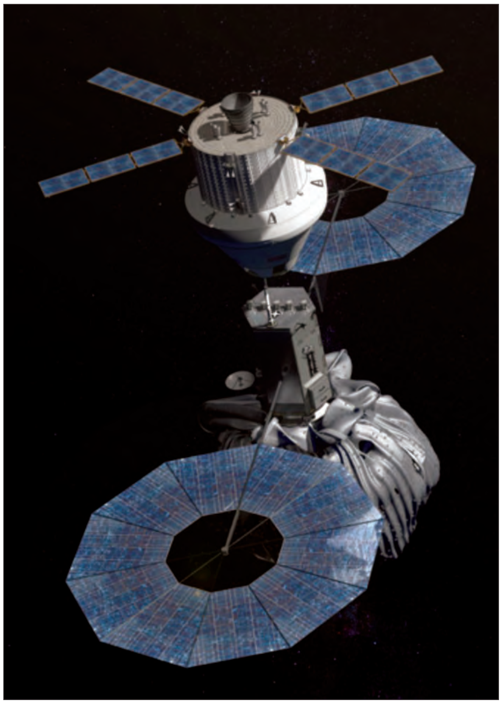
Research conducted on the space station yielded important scientific and technical results this year. Its Alpha Magnetic Spectrometer discovered an excess of positrons in the cosmic ray flux, possible signs of **dark matter** annihilation. The station's robotic refueling mission used the Dextre manipulator to test tools and techniques for satellite servicing. Astronauts on the station tele-operated a rover on the ground to simulate a crew in lunar or Mars orbit working with robots on the surface.

As the station's international partners start to consider extending its operations beyond 2020, NASA is ramping up plans to conduct human research and test new technologies for human missions to Mars. In August, the agency announced the selection of eight new astronauts. It is also planning a year-long mission involving a U.S. astronaut and a Russian cosmonaut, to study the effects of prolonged spaceflight on human **health** and performance. Other on-station activities would include testing of a **3D printer** in 2014 to fabricate replacement parts in space, and testing of an inflatable module from **Bigelow Aerospace** in 2015.

A new portable life-support system for the **Z-2**, an advanced **space suit** now in development, was assembled and tested. Z-2 will be the first new space suit since the Shuttle Extravehicular Mobility Unit, which became operational in 1981.

The Curiosity rover's Radiation Assessment Detector, operating during interplanetary cruise and on the Martian surface, has found that **radiation** doses may exceed allowable exposure limits for future human explorers on a 500-day mission.

NASA announced plans for an **asteroid** redirect mission, which would capture a small near-Earth asteroid and redirect it into a stable lunar orbit where astronauts would explore it and gather samples for return to Earth. A 40-kW solar electric propulsion system would propel the robotic spacecraft that captures the asteroid. The mission would integrate NASA's space science, human exploration, and technology programs. It could also enable technologies needed for exploiting valuable asteroid resources and for defending Earth from potentially catastrophic asteroid strikes.



On NASA's proposed asteroid redirect mission, astronauts transported on an Orion capsule would explore a captured asteroid and collect samples. Credit: NASA.

Fresh focus on transforming flight

by Mark Moore and Lynn Unrau

*The **Transformational Flight Program Committee** was established in 2013 to help emerging aviation markets capitalize on rapidly progressing technology frontiers.*

Learn more in the paper,
"Misconceptions of Electric Aircraft and their Emerging Aviation Markets"
SCITECH 2014
January 13-17, 2014
National Harbor, Maryland

The Paris Air Show showed off many of the developments in what has become a significant push toward use of electric propulsion in aviation. This included the Safran-Honeywell **Electric Green Taxiing System**, which provides fuel savings and reduced airport emissions for commercial aircraft, and also the EADS-ACS E-Fan 2 person trainer/demonstrator, which provides primary electric propulsion. This continued push from European companies follows other electric flight demonstration efforts, including the Siemens-Diamond-EADS DA36 E-Star rotary engine plus battery series hybrid electric propulsion system, and the AgustaWestland **Project Zero** fully electric tilt Fan-in-Wing.

These efforts display the potential for significant reductions in operations costs that can be achieved as this new propulsion technology works its way from small aircraft and short-range missions to larger aircraft with increased range and payload capability. The Swiss-led **Solar Impulse** plane also garnered significant attention by stopping in major U.S. cities as it flew across the country from west to east, showcasing the potential of low-speed, renewable electric propulsion.

The development of certification standards embracing these new technologies is a major factor in bringing their benefits to aviation markets. The joint effort by the American Society for Testing and Materials and the FAA continued to move Part 23 certification standards toward consensus-based standards through the ASTM F44 committee. Subgroups have already been established for digital flight controls and electric propulsion in efforts to embrace these new technologies, which can improve general aviation safety and reliability. Autonomy flight experiments continue to flourish across university, government, and industry labs as the FAA certified the first use of aerial robotics for commercial use in Alaska with the Insitu **ScanEagle** and **AeroVironment Puma**.

At the Aviation 2013 conference in Los Angeles, NASA Administrator **Charles Bolden**, the keynote speaker, outlined six key research efforts on which NASA's activities and investments will be centered. One of these is to concentrate on low-emission, environmentally friendly aircraft technologies. This will be a vital area of study that will enable more efficient and quiet forms of air travel–key enablers of transformational flight concepts such as on-demand mobility. Another strategic investment area specified by Bolden for NASA will be advances in autonomy. Autonomous vehicles, whether carrying cargo or passengers, have the potential to radically change how aviation is used in society. Focusing research efforts and dollars into these systems will help transform the already growing industry and tackle not only the technical hurdles but also the challenges of certification and integration into the national airspace system. The goals of NASA's new strategic vision are exciting developments that will help bring transformational flight concepts to reality.

The Transformational Flight Program Committee made substantial progress in its first year, with strong participation from its more than 40 members. Three Technical Working Groups were established this year to organize and align the committee's efforts into strategic thrust areas including **Technology Gaps/Challenges**, **Public-Private Partnerships**, and **Prize Competitions**. Each has established goals for the coming year for conference support, interaction across the AIAA technical committees, and specific reports and events relating to their topic. Several prize competitions are being actively worked in collaboration with other organizations, including the X-Prize Foundation, American Helicopter Society, and NASA.

Electric green taxiing from Honeywell and Safran uses electric motors to drive the main wheels, allowing jets to delay engine start until just before takeoff. Credit: David McIntosh.

Energy efficient systems advance

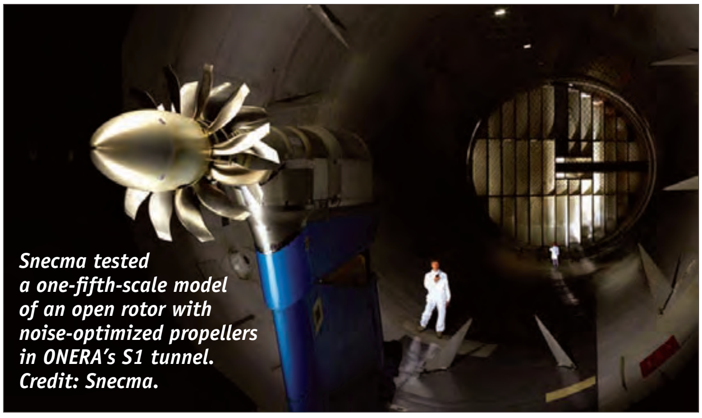
by Dyna Benchergui

*The **Air Breathing Propulsion Systems Integration Technical Committee** focuses on the application of mechanical design, fluid mechanics, and thermodynamics to the science and technology of air vehicle propulsion and power systems integration.*

Advances in energy efficient systems dominated developments in air breathing propulsion systems integration.

The **Ion Tiger**, under development by the Naval Research Laboratory, demonstrated a novel fuel cell propulsion system for small unmanned aircraft when it flew for 48 hr 1 min, shattering its previous record of 26 hr 2 minutes, set in 2009. The fuel system was upgraded from gaseous hydrogen stored at 5,000 psi to liquid hydrogen fuel stored in a lightweight, insulated tank to allow for a threefold increase in hydrogen density. Extensive thermal modeling was performed to determine the amount of insulation required to match the liquid hydrogen boil-off rate to the fuel cell consumption rate over a range of flight conditions. The hydrogen storage tank comprises an aluminum vessel surrounded by a high-quality vacuum for low thermal transfer. The insulation is nested in a second aluminum vessel. The demonstration used a custom gas regulator with lines for filling and venting.

Electric propulsion continued to advance on other fronts. **EADS** and **Rolls-Royce** are exploring hybrid electric distributed propulsion systems for commercial aircraft in the 2050 time frame. One promising concept—unveiled as **E-Thrust**—would use a gas turbine engine embedded in the tail to power several ducted fans distributed along the wing, with electric energy storage providing added takeoff power. A three-fan configuration on both sides of the fuselage was selected initially, with the number of fans to be optimized in upcoming studies. Early results indicate a single large gas power unit provides bigger system-level benefits over two or more units. The distributed architecture enables separate optimization of the gas power unit's thermal efficiency and the fans' propulsive efficiency. Enabling technologies would include a hub-mounted superconducting motor, a wake reenergizing fan and structural stator vanes that pass electrical power and cryogenic coolant.



Snecma tested a one-fifth-scale model of an open rotor with noise-optimized propellers in ONERA's S1 tunnel. Credit: Snecma.

EADS/Siemens demonstrated a novel electric series-hybrid drive system, on its two-seat DA36 aircraft. The design uses a Wankel engine/generator and EADS-designed battery, recharged during cruise for added takeoff power. The system, which the team says offers 25% lower fuel burn, is relatively quiet. In under eight months, EADS also developed **E-Fan**, an all-electric general aviation training aircraft propelled by two battery-powered electric motors, each driving a ducted, variable-pitch fan. E-fan uses an optimized electrical energy management system and electrically actuated wheels.

Several propulsion integration efforts are under way to speed development of **environmentally friendly** aircraft.

Snecma completed low-speed wind tunnel tests of its Open Rotor engine at ONERA's S1 wind tunnel. The tests, which used a one-fifth-scale model of various types of propeller pairs, evaluated low-speed aerodynamic and aeroacoustic performance. High-speed wind tunnel tests, which were scheduled to begin in the fall, aim at demonstrating the engine's potential for lowering fuel consumption by 25-30%. Full-scale testing of the open rotor is planned for 2015.

Pratt & Whitney completed 275 hours of fan rig tests on its next-generation Geared TurboFan ultra-high bypass system at NASA Glenn 9'x15' Low-Speed Wind Tunnel. Advanced computational fluid dynamics tools, used for highly coupled design and analysis of system, helped to optimize its acoustic, aerodynamic and aeromechanical performance. The company will conduct ground and flight testing in conjunction with the FAA.

The Pratt & Whitney tests were part of NASA's **Environmentally Friendly Aircraft** project. Under that program, four enabling propulsion technologies will undergo large-scale technology demonstrations and further maturation before their introduction, targeted for 2020-2030. The first of these demonstrations will focus on a highly loaded front block compressor. The second involves Pratt & Whitney's second-generation ultra-high bypass ratio Geared Turbofan propulsor integration, further maturation of the propulsor's efficiency and extension to other thrust classes. The third demonstration involves integration of a low nitrogen oxide fuel-flexible engine combustor. The fourth will focus on integrating an ultra-high bypass engine into a Hybrid Wing Body Aircraft.

Busy times for electric propulsion

by James Szabo

The ***Electric Propulsion Technical Committee*** *works to advance research, development and application of electric propulsion for satellites and spacecraft.*

This has been an eventful year for electric propulsion. NASA's **Dawn spacecraft**, propelled by ion engines, is on its way to a 2015 rendezvous with the asteroid Ceres, having left asteroid Vesta last year. ESA's Gravity field and steady-state Ocean Circulation Explorer, **GOCE**, spacecraft completed its mission in October after years of propulsion by QinetiQ ion engines. ESA's BepiColombo, also propelled by QinetiQ ion engines, will launch in 2015 to reach Mercury in 2022. JAXA's **Hayabusa-2**, propelled by four microwave discharge ion engines, will launch in 2014, rendezvous with asteroid 1999JU3 in 2018, and return to Earth in 2020.

At the end of 2012, Snecma delivered eight **Hall thruster** systems for the first SmallGEO satellite from Germany's OHB Systems. EADS Astrium's Alphasat was launched in July, carrying four Snecma PPS-1350-G Hall thrusters for station-keeping. Snecma also determined the lifetime of the PPS-1350 at 2.5 kW for orbit-raising. SSL, now owned by MacDonald, Dettwiler and Associates, is flight qualifying the EDB Fakel SPT-140. In June, GenCorp acquired Rocketdyne, forming Aerojet Rocketdyne. The Air Force's AEHF-2 satellite, built by Lockheed Martin, completed on-orbit checkout in late 2012. AEHF carries the Aerojet Rocketdyne BPT-4000 (now designated XR-5) for station-keeping. In FY13, options were exercised for the fifth and sixth **AEHF** and the third and fourth Lockheed Martin NOAA **GOES-R** satellites, which carry Aerojet Rocketdyne arcjets. Busek is building a BHT-200 for the Air Force FalconSAT-6, to launch in 2015. Moog is providing various gimbals and propellant management components for BepiColombo, Hayabusa-2, Small-Geo, Alphasat, AEHF, and others.

In August, Boeing announced that its **all-electric** 702SP satellite is headed for production; orbit-raising and positioning will be accomplished with electric propulsion. Lockheed Martin announced an all-electric A2100. ESA is also preparing all-electric spacecraft–Neosat, Electra, and Hercules–paving the way for commercial versions. Meanwhile, ESA's Navigation Directorate is assessing electric orbit-raising for Galileo navigation satellites.

The **NASA** Space Technology Mission Directorate is planning a high-power electric propulsion technology demonstration mission, and the agency's FY14 budget proposal includes an electric propulsion-enabled asteroid retrieval mission. NASA Goddard and JPL are teamed to develop a 10-15-kW Hall thruster system. Busek is developing a 15-kW Hall thruster and multiple lower power systems fueled by xenon and iodine. JAXA and Japanese universities are developing a 25-kW Hall thruster cluster that includes a smart power supply. The University of Michigan is testing a 100-kW, three-channel nested Hall thruster. Ad Astra Rocket is upgrading the VX-200 VASIMR, the variable specific impulse magnetoplasma rocket experiment. Long-duration testing including flight-like components is scheduled for 2014.

Developmental testing of the 7-kW NASA Evolutionary Xenon Thruster ion engine was completed at NASA Glenn at 50,000 hr. Glenn also completed a single-string integration test of the High Voltage Hall Accelerator. The Aerojet Rocketdyne XR-12 and Busek BHT-600 Hall thrusters also were tested at Glenn.

Many propulsion systems are under **development**. CU Aerospace and VACCO Industries demonstrated a microcavity discharge thruster. Busek is developing electrospray thrusters, radio frequency ion engines, miniature Hall thrusters, and pulsed plasma thrusters. The University of Michigan is investigating a 20-W permanent magnet helicon generated plasma thruster. NASA selected proposals by Busek, MIT, and JPL for the development of miniaturized electrospray propulsion for CubeSats. At least one technology will be selected for flight.

Research at the University of Michigan focused on high-speed, time-resolved plasma diagnostics and their application to plasma oscillations. Field reverse configuration thrusters in development at Mathematical Sciences NorthWest have demonstrated steady operation with propellants including xenon and monopropellants. Colorado State University is researching C12A7 electride hollow cathodes that can be started at room temperature. A plasma interactions facility developed at UCLA produces conditions similar to those found in electric propulsion and uses diagnostics to characterize plasma wetted surfaces.

CU Aerospace's Micro-Cavity Discharge thruster was jointly developed with partner VACCO Industries. Credit: CU Aerospace.

The VASIMR VX-200 engine can be propelled by chemicals such as argon, oxygen, and nitrogen. Credit: Ad Astra Rocket.

Energetic improvements

By Tom Blachowski

*The **Energetic Components and Systems Technical Committee** advances development of devices containing explosive materials that apply directed energy to perform precise mechanical functions in applications ranging from military and civilian aircraft to space vehicles, automotive safety, demolition and mining.*

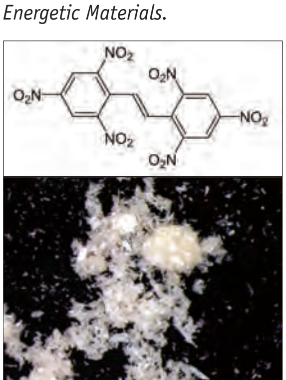
Over 172 energetic components and systems contributed to the entry, descendant and landing and post-touchdown phases of the MSL's mission. Credit: NASA

Energetic components and systems must provide safe and reliable performance over a wide range of new and emerging platform requirements. Costs for the development, qualification and lifetime sustainment of energetic components and systems remain a primary concern for program managers. The **ECS** community is striving to develop and evaluate technologies that address all of the respective platform requirements while minimizing the overall costs from every perspective. Stability within the ECS technical community has provided a strong foundation from which specific cost goals and objectives can be achieved.

These program contributions begin at the most basic level—with the energetic materials themselves. Obsolescence remains a primary concern throughout the ECS community. Ensuring the continuing availability of the raw materials, the capability to blend new energetic materials, and the availability of the manufacturing science to reliably assemble these materials into components and systems have been focus areas over the past year.

A joint industry, academia, and government team, being led by the Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Center, is working to revise the material specification for Hexanitrostilbene (HNS, U.S. Navy Weapons Specification 5003). This material is utilized in a wide range of energetic components and systems. The new specification will update the obsolete test methods required to evaluate this material and ensure its continuing availability over the long term.

The top side of this photo shows the molecular structure of Hexanitrostilbene, an explosive used in many high energy components. On the bottom is a sample of less than 10 mg of HNS crystals magnified 100X. Credit: Pacific Scientific Energetic Materials.



Also in the energetic materials area, qualification has been completed for a new primary explosive called **DBX-1**, also known as Copper (I) 5-nitrotetrazole. This primary explosive is an environmentally friendly replacement material for lead azide. This is the first primary explosive that has been qualified by the U.S. Navy in over 90 years. Introduction of DBX-1 will eliminate lead from various applications while ensuring all platform requirements are achieved utilizing a green energetic material.

Applications ranging from new cutters to new fire extinguisher cartridges could potentially benefit from the introduction of DBX-1. The **Advanced Common Ejection Seat** (ACES 2) is utilized in **F-15**, **F-16**, **B-1B**, and **B-2** aircraft among many others. A new component, which cuts away the drogue parachute from the seat prior to main parachute deployment after ejection, is being developed which utilizes DBX-1 in its detonator. Also, the fire suppression system on the **F-18** aircraft could benefit by the introduction of a new cartridge which utilizes DBX-1 in its detonator. This detonator provides the energy to rupture a closure disk and dispense the fire suppression material through the endangered area.

From a system perspective, the **Mars Science Laboratory** has exceeded its mission's expectations over the past months. Over 172 energetic components and systems contributed to the flight, entry, descent, and landing and post-touchdown phases of this mission. The rigorous preflight testing and analysis of these energetic components and systems was, once again, proven as an effective approach to ensuring overall mission success. The lessons learned from all these successful operations have been recorded and will directly benefit future missions.

In the academic realm, Suzan Koc, Burak Kizilkaya, and Muhammed Yilmaz, representing Rocketsan Missile Industries, Inc., and Abdullah Ulas of the Middle East Technical University in Ankara, Turkey, published a paper providing new data in the field of predictive and experimental analysis of a type of electrical initiator (AIAA # 2013-3817). The paper, “An Experimental and Numerical Study on Exploding Foil Initiators (EFIs),” earned the Arthur D. Rhea Award for the Best Paper at an ECS TC Joint Propulsion Conference technical session.

Gas turbines drive engine improvements

by David L. Blunck

*The **Gas Turbine Engines Technical Committee** works to advance the science and technology of aircraft gas turbine engines and engine components.*

This year brought significant advances in R&D, production and educational outreach activities involving gas turbine engines.

The Air Force is seeking to further mature and transition technologies for an adaptive versatile engine through the Adaptive Engine Technology Development program, begun in FY13. **Pratt & Whitney** and **General Electric** are developing engines for this effort.

The goal of HEETE, the Air Force's Highly Efficient Embedded Turbine Engines program, is to develop fuel-efficient, large fan/jet propulsion technologies supporting extreme endurance and range for future aircraft. The target is a 35% improvement in efficiency. As part of the program, **Rolls-Royce** completed testing of a new, advanced technology compressor focused on lowering fuel consumption. The device demonstrated its ultra-high pressure ratio performance goal and was able to manage component temperatures at design conditions. It also achieved the highest pressure ratio ever demonstrated at the laboratory's Compressor Research Facility, according to Rolls-Royce.

The company also completed two key milestone deliveries for the F-35: the 50th three-bearing swivel module and 40th LiftFan for F-35B. In related work, the **Air Force Research Laboratory** is continuing the development of the ultracompact combustor for the HEETE program. It would be the shortest combustor in the world for a class of engines. The reduced size results from use of a systems-level approach to integrating adjacent components into the combustor.

Gas turbine engine manufacturers reached several milestones in civilian applications. **GE Aviation** launched its next-generation twin-aisle engine, the GE9X, for **Boeing's** 777X. The 100,000-lb-thrust class engine is intended to offer 10% improvement in fuel burn over today's GE90-115B. The first engine is scheduled for tests in 2016. In June, the company began testing its newest business aviation engine, the Passport, which will power **Bombardier's** Global 7000 and 8000 aircraft. The engine ran for over 3 hr, reaching more than 18,000 lb of standard day sea-level takeoff thrust.

Williams International continued to expand the FJ44 family of engines. Powering the newly announced Pilatus PC-24 are twin FJ44-4A turbofan engines rated for a normal takeoff thrust of 3,435 lbf. The PC-24 will also be the first FJ44 application to use Williams' quiet power mode, a new proprietary feature designed to provide quiet, efficient ground power. The FJ44-1AP-21, which powers **Cessna's** new Citation M2 light jet, earned FAA certification on May 17. The engine produces 10-15% more altitude thrust than the preceding FJ44-1AP, depending on conditions, and consumes several percent less fuel at long-range cruise, according to Williams.

An "Improved Engine for a High Altitude Long Endurance Unmanned Air Vehicle" was the subject for round two of a **design competition** for undergraduate teams. Technical committees of AIAA and of ASME's International Gas Turbine Institute sponsor the contest. A panel of judges from industry evaluated written proposals, and the three leading teams were invited to ASME's TurboExpo2013 in San Antonio, Texas, where they presented their work to judges. Qualifying teams were from the University of Kansas, Embry-Riddle Aeronautical University and Ain Shams University, Cairo.

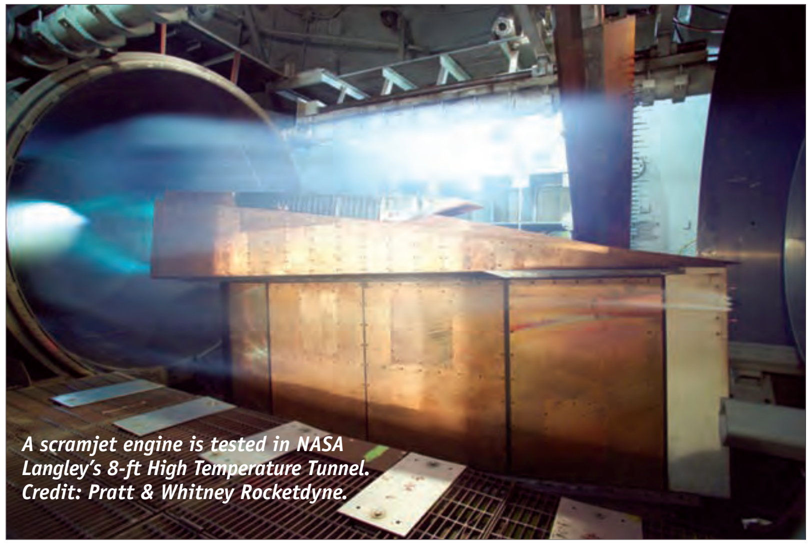
The GE9X engine, seen in an artist's illustration, will begin testing in 2016. Credit: General Electric.

The F-35B uses the Rolls-Royce LiftFan three-bearing swivel module system for vertical thrust. Credit: Lockheed Martin.

A record-setting year for hypersonic flight

by Foluso Ladeinde and Jeff Dalton

*The **High-Speed Air Breathing Propulsion Technical Committee** works to advance the science and technology of systems that enable supersonic and hypersonic air vehicle propulsion.*



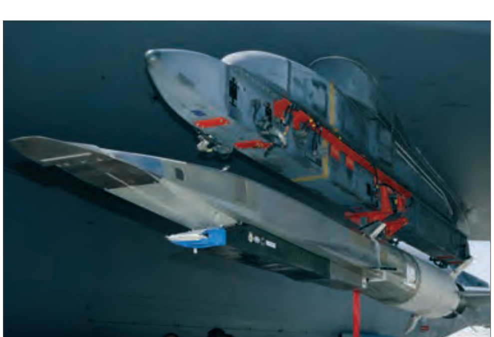
A scramjet engine is tested in NASA Langley's 8-ft High Temperature Tunnel. Credit: Pratt & Whitney Rocketdyne.

Progress made in high-speed air breathing propulsion suggests that current technology is closer to fulfilling its promise of providing efficient and cost-effective hypersonic flight.

In May, the fourth and final flight test of the **X-51A** hypersonic flight demonstrator recorded the longest-ever supersonic combustion ramjet-powered flight, covering more than 230 n.mi. in about 6 min, according to the Air Force. Powering the system was **Aerojet Rocketdyne's** SJY61 scramjet engine. The flight included accelerating the cruiser from Mach 4.8 to 5.1 while climbing, and the engine running full duration, depleting all fuel as planned. The propulsion system has accomplished all stated objectives, as lessons learned from three prior X-51A flights and data from ground tests were exploited in the final deployment.

The year also brought significant progress from the Arnold Engineering Development Complex, working with the Air Force Research Laboratory, NASA and ATK. The team conducted ground tests of a fuel-cooled, dual-mode scramjet engine at both NASA Langley and the ATK-General Applied Science Laboratory, or GASL. This effort is called **LSETT**, the Large-Scale Scramjet Engine Testing Techniques program. It is using a missile-scale, flight-weight, JP10 fuel-cooled ATK combustor and flight-representative inlet/isolator tested in free-jet, semi-free-jet and direct-connect configurations. Phase-1 free-jet testing was completed late last year at Langley's 8-ft High Temperature Tunnel. The Phase-2 semi-free-jet test campaign is currently under way in ATK-GASL's Test Bay 4, with completion expected in FY14.

The Air Force reports the X-51A WaveRider recorded the longest-ever supersonic combustion ramjet-powered flight. Credit: Boeing.



JAXA, the Japan Aerospace Exploration Agency, reported progress on a rocket-based combined-cycle engine model. It was previously tested successfully under Mach 0, 4, 6 and 8 flight conditions, according to JAXA. The agency says the model has operated at each of three modes: ejector-jet, ramjet, and scramjet. Operation at the ejector mode appears to show some performance degradation, prompting the study of a new suction model for the design of this mode.

In Australia, the University of Queensland's **HyShot Center for Hypersonics** is working to develop reusable, air-breathing scramjet-based space transport systems for deploying small satellites. Miniaturized satellites in the 50-200-kg range would be launched with a scramjet-powered second stage, boosted to scramjet takeover speeds of Mach 4-6, and accelerated to Mach 12 before a small rocket-powered upper stage provides the final boost to orbit.

The National Center for Hypersonic Combined Cycle Propulsion at the University of Virginia began its fourth year, with funding from the Air Force Office of Scientific Research and NASA. Work at the center includes a detailed fundamental investigation of ramjet-scramjet mode transition. The dual-mode hydrocarbon-fueled combustion facility enabled full Mach-5 enthalpy simulations of mode transition. A considerable level of nitrogen vibrational non-equilibrium at the facility nozzle exit was observed. The research generated data representing mean and fluctuating turbulence statistics. The data are used in validating advanced models for high-speed turbulence, combustion, turbulence-combustion interaction, progress of combustion, and cavity residence time after flame blowout. Other participating institutions include **George Washington University**, **Stanford University**, **North Carolina State University**, and **NASA Langley**.

Better rocket fuels

by Martin Chiaverini

*The **Hybrid Rockets Technical Committee** studies techniques applied to the design and testing of rocket motors using hybrid rocket systems.*

To guide a new generation of scientists, Texas has a very active hybrid rocket program called **SystemsGo**, now in 54 high schools across the state. Sixteen of these schools are at the Tsiolkovsky Level, which focuses on stable flight by testing a 1-lb payload to a 1-mi. altitude. Twenty-eight schools are at the more advanced Oberth Level, where students fly hybrid rockets to transonic speeds. Ten schools are at the "capstone" Goddard Level, where students design and develop professional-grade sounding rockets that loft 35-lb payloads to altitudes between 80,000 ft and 100,000 ft at the Army's White Sands Missile Range.

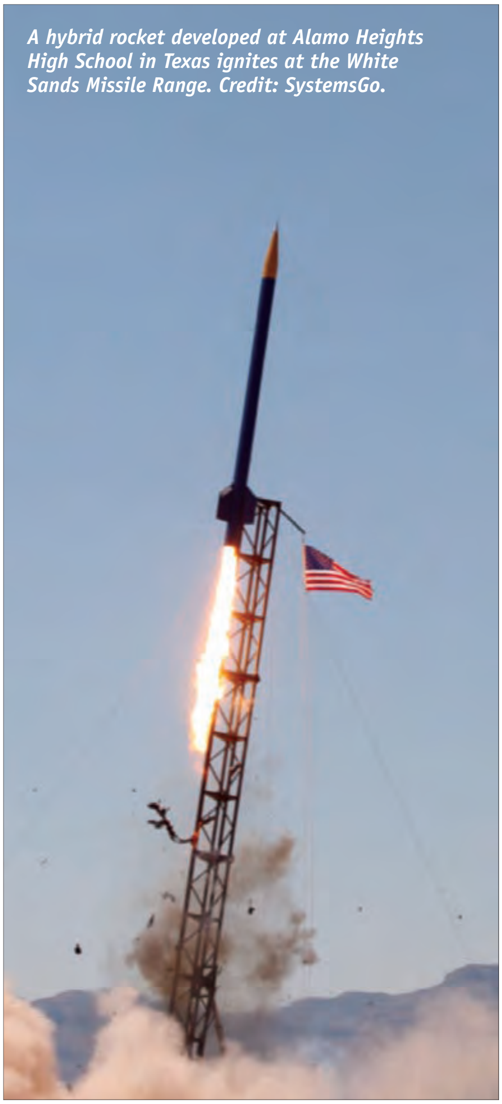
To support the Goddard-level schools' missile range testing and their hybrid motor designs, **Fredericksburg High School** in Fredericksburg, Texas, has continued tests of inert rubber and plastic fuels and alternative nozzle materials. Two rubbers and four plastics are undergoing final 40-sec burn duration testing; two additional plastics will have the tests for 20 sec. SystemsGo has been working with the University of Tennessee Space Institute and Vanderbilt University to establish funding for efforts to replicate the program both in Tennessee and nationally.

Studies at **Stanford University** focus on self-pressurizing propellant tank dynamics using nitrous oxide. Researchers evaluated existing tank models by comparing them to each other and to experimental data compiled from a variety of sources. Using a facility that allows visualization of the flow field within the tank, a detailed study was made of carbon dioxide as a substitute for nitrous oxide, with the goal of enabling safe, low-cost testing.

Injector research at Stanford involves the characterization of mass flow rate and isolation performance for nitrous oxide systems using a small-scale cold flow rig. Preliminary results suggest that injectors can potentially function as a critical flow element. These studies are a part of Stanford's ongoing support of the Peregrine Sounding Rocket project at NASA Ames.

Stanford's combustion visualization facility is being upgraded to facilitate testing at elevated pressures and enable schlieren imaging of the flow. The facility has already provided insight on the combustion of hybrid fuels with oxygen at atmospheric pressure, with early results also collected at elevated pressure.

In Italy, the University of Naples Federico II has been active for three years in two major European programs: **ORPHEE**, the Operational Research Project on Hybrid Engine in Europe, and **GRASP**, Green Advanced Space Propulsion. The first program has attempted to improve the fuel regression rate by using several fuel compositions based on a version of the polymer hydroxyl-terminated polybutadiene, or HTPB, loaded with either metallic or metal-hydride powders of different sizes, burned with oxygen. The second project studied new ceramic catalysts for the hydrogen peroxide decomposition used in either a monopropellant or hybrid rocket. More recently, the Italian Space Agency has funded the **Theseus** program for the development of a hybrid engine demonstrator fed by nitrous oxide and pure or loaded HTPB. Lab-scale rocket firing tests have taken place in Naples through all these programs, measuring regression rate, combustion efficiency and motor stability.



A hybrid rocket developed at Alamo Heights High School in Texas ignites at the White Sands Missile Range. Credit: SystemsGo.

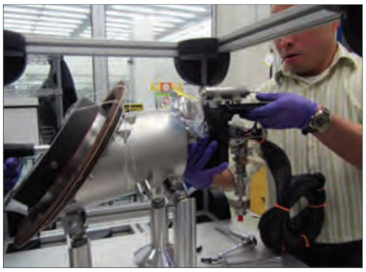
A rich mix of new liquid engines

by David L. Ransom

The ***Liquid Propulsion Technical Committee*** *works to advance the technology of reaction propulsion employing liquid or gaseous propellants.*

Interest in ORSC, oxygen-rich staged combustion, remained strong in 2013. NPO Energomash **RD-180** engines are powering United Launch Alliance's Atlas fleet, and Orbital Sciences introduced Aerojet Rocketdyne **AJ-26s** on its new Antares rockets. The RD-180 reached 50,000 sec of hot fire time, and the AJ-26 engine surpassed 10 hot fire tests at NASA Stennis. On April 21, AJ-26s powered Antares into orbit, providing 816,000 lb of vacuum thrust. The propellant system included novel devices that reduce instabilities known as pogo. Designed by Orbital Sciences and Southwest Research Institute, these pogo-suppressors rely on a fixed charge of neon gas rather than the more typical use of a level control system and helium pressurant.

U.S. research into new ORSC-based engines is also growing, mainly at the **Air Force Research Laboratory**, which is developing a 250,000-lbf technology demonstrator. Progress at AFRL includes design of a full-scale turbomachinery component, fabrication and testing a subscale pre-burner, and scaled testing of turbomachinery components.



A technician works on a reaction control system pod that will be installed on the Orion crew module for Exploration Flight Test-1. Credit: Aerojet.

In other boost engine development work, SpaceX qualified its new **Merlin 1D** engine, accumulating 1,970 sec of test time (10 full mission durations). The Merlin 1D has 147,000 lb of thrust at sea level and 161,000 lb in vacuum, says SpaceX. A Merlin 1D powered the company's reusable Grasshopper test vehicle, which reached an altitude of 2,441 feet in its highest flight. Aerojet Rocketdyne started steady production of the **RS-68A**, an RS-68 variant used on United Launch Alliance's Delta 4 rocket. The RS-68A offers increased thrust, higher specific impulse, and improved reliability. NASA Marshall, Dynetics, and Aerojet Rocketdyne continue work on lowering fabrication costs for Apollo-era F-1 engine components by using modern manufacturing techniques. Accomplishments so far include a hot-fire test of the F-1 gas generator at F-1B conditions.

Orbital Technologies completed a flight demonstration of a vortex combustion chamber on a rocket designed and built by Garvey Spacecraft. Credit: ORBITEC.

Upper stage engine developments include qualification of Aerojet Rocketdyne's **RL10C-1** engine for the Atlas/Centaur vehicle; XCOR's successful pumping of liquid hydrogen using piston pump technology developed for the company's Lynx vehicle; and continued testing of Astrium's Vinci expander cycle engine. Testing of the **Vinci M5** was performed at the DLR Lampoldshausen P4.1 facility with the goal of demonstrating operation at full (40,465 lb) and reduced 29,225 lb thrust. At NASA Stennis in September, Aerojet Rocketdyne successfully completed full motion hot-fire tests on the **J-2X** engine, destined for the upper stage propulsion of the Space Launch System. AFRL finished a computational and experimental program for improved designing of hydrogen turbopumps for upper stage engines.

Orbital Technologies flew a vortex combustion liquid propellant thrust chamber assembly. In addition to validating the performance in an operational environment, the company also demonstrated an acoustic ignition system and a lightweight composite nozzle extension provided by **ATK**. The test was conducted on a launcher designed and built by **Garvey Spacecraft** and **Cal State Long Beach**, and supported by **AFRL**.

JAXA, the Japan Aerospace Exploration Agency, and IHI Aerospace have launched a feasibility study on the **HBT-5**, a thruster using MMH/MON-3, a bipropellant consisting of monomethylhydrazine and a substance made from nitrogen tetroxide and approximately 3% nitric oxide. The thruster would be used as an apogee kick engine on HTV-3, Japan's third HII Transfer Vehicle. JAXA has already completed surface temperature measurements at the combustion chamber and the nozzle of the modified HTB-5 to check for uniformity of the combustion. Improved engine reliability would come from a reduction in the operating range.

Looking to the natural world, JAXA is also participating in work on a new concept aimed at reproducing the defense mechanism of the **bombardier beetle**. Called PulCheR, for pulsed chemical rocket with green high-performance propellants, the effort was co-founded by the EU Seventh Framework Program.

For 2014, expect to see further progress on ORSC cycle technology, more commercial development of boost engine systems, and improved component manufacturing that takes advantage of advances in **3D printing** technologies.

Empowering exploration

by Bryan Palaszewski

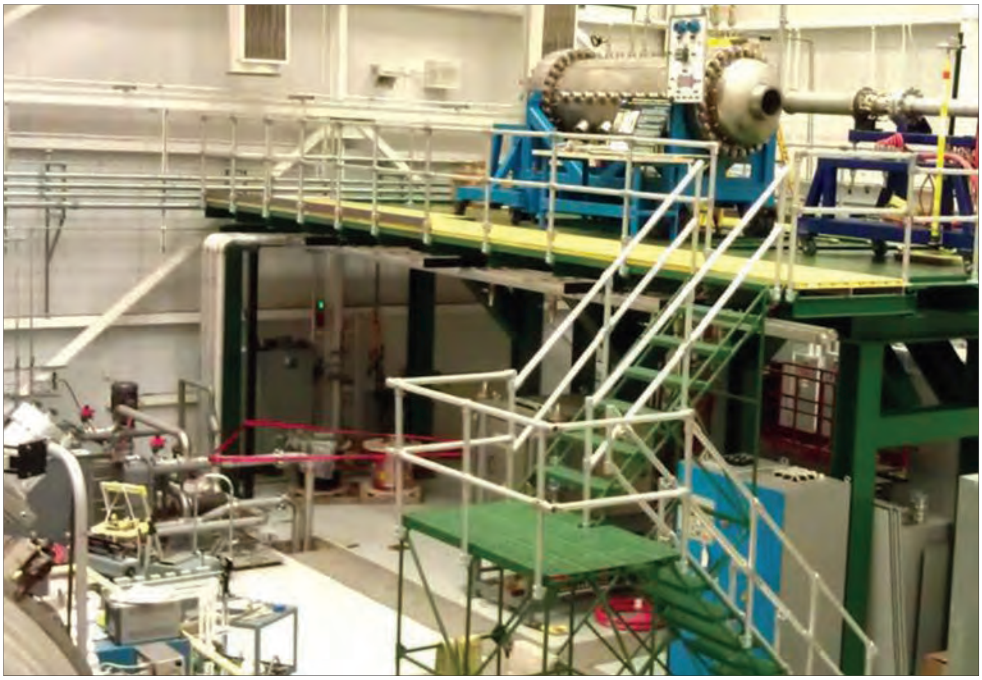
The ***Nuclear and Future Flight Propulsion Technical Committee*** *works to advance the implementation and design of nonchemical, high-energy propulsion systems other than electric thruster systems.*

Research at NASA Glenn investigated atmospheric mining in the outer solar system as a means of producing fuel for high-energy propulsion and power. **Fusion fuels** such as helium 3 and hydrogen could be wrested from the atmospheres of Uranus and Neptune and either returned to Earth or used in-situ for energy production or propulsion. **Helium 3** and hydrogen (also deuterium, an isotope of hydrogen) were the primary gases of interest, with hydrogen the main propellant for nuclear thermal solid core and gas core rocket-based atmospheric flight.

A series of analyses were completed to investigate the resource-capturing aspects of atmospheric mining in the outer solar system. In capturing helium 3, large amounts of hydrogen and helium (helium 4) are produced. With these two additional gases, there is potential for fueling fleets of exploration and exploitation craft. Aerospacecraft, unmanned aircraft, or rockets could fly through the outer planet atmospheres to conduct cloud formation dynamics studies, global weather observations, localized storm or other disturbance investigations, wind speed measurements, polar observations, and similar activities. Deep-diving aircraft built to withstand many atmospheres of pressure, and powered by the excess hydrogen or helium 4, could be designed to probe the higher density regions of the **gas giants**. Nuclear ramjet vehicles could use the raw atmospheric constituents and fly for long periods.

Concept studies identified several classes of probes and unmanned aircraft that could significantly augment future atmospheric exploration. Probes that use free fall or parachutes as they take data in the atmosphere, as Galileo did for Jupiter, are the first and most mature options. A more aggressive approach to probe- or aircraft-based exploration would be a rocket-assisted craft. Because it can take many hours to access the deeper parts of the atmosphere, the concept studies considered a **rocket assist** to accelerate the probe to great depths. A rocket return was also studied. Taking advantage of more traditional unmanned aircraft designs would provide many operational benefits as well. For example, remote sensing instruments on subsonic winged aircraft could provide extensive data on outer planet winds, cloud dynamics and localized atmospheric composition.

At NASA Marshall, the non-nuclear fuel element test rig called **NTREES**, or Nuclear Thermal Rocket Element Environmental Simulator, is being investigated for testing simulated reactor fuel elements to close conditions of operation, without the radiation environment. The test site is licensed to handle natural and depleted uranium. The fuel element is heated with an induction heater inside a pressure vessel with a nitrogen ambient environment. Hydrogen propellant flows through the element as in the engine, with the same flow rates and pressures. The facility was designed to handle up to 5-MW input power to test the material compatibility, thermodynamics, material properties and endurance of various fuel element designs. Designs that show acceptable test results from NTREES can then be tested in radiation environments to examine the effects.



The Nuclear Thermal Rocket Element Environmental Simulator would test reactor fuel elements. Credit: NASA.

Material issues for cermet and graphite **fuel elements** were compared at NASA Glenn. In particular, two issues in nuclear thermal fuel element performance are being studied: ductile to brittle transition in relation to crack propagation, and providing the proper orifice sizing of individual coolant channels in fuel elements. Their relevance to fuel element performance is supported by considering material properties, experimental data, and results from multidisciplinary fluid/thermal/structural simulations.

Learn more in the paper, **"Solar System Exploration by Lunar and Outer Planet Resource Utilization"**

SCITECH 2014

January 13-17, 2014
National Harbor, Maryland

Harnessing chemistry for propulsion

by Joanna M. Austin and Yiguang Ju

*The **Propellants and Combustion Technical Committee** works to advance the knowledge and effective use of propellants and combustion systems for military, civil and commercial aerospace systems.*

In July, Ball Aerospace and Aerojet Rocketdyne met the first milestone in demonstrating a more **environmentally friendly** spacecraft fuel, completing an end-to-end checkout of the 22-N thruster required for NASA's Green Propellant Infusion Mission, or GPIM. Ball is leading an industry and government team that will develop and fly the mission to demonstrate a high-performance, non-toxic fuel alternative to conventional hydrazine. This will bridge the gap between characterizing the functionality of an integrated propulsion system and the technology development needed for eventual use of green propellants in space.

Ball Aerospace and Aerojet Rocketdyne completed an end-to-end checkout of the 22-N thruster required for NASA's Green Propellant Infusion Mission. Credit: Aerojet Rocketdyne.

The milestone is significant because the 22-N thruster will fire simultaneously along with four smaller 1-N thrusters to initiate orbit inclination changes and altitude changes. It is also critical for de-orbit at the end of the mission. As the prime contractor and principal investigator, Ball is collaborating with Aerojet Rocketdyne, NASA Glenn, NASA Kennedy and the Air Force Research Laboratory, with additional mission support from the Air Force Space and Missile Systems Center. This will mark the first time the U.S. has used a spacecraft to test **green propellant** technology. The propellant, a hydroxyl ammonium nitrate fuel/oxidizer blend, or **AF-M315E**, offers nearly 50% better performance than traditional hydrazine. Green fuel alternatives also reduce environmental impact and operational hazards, improve launch processing capabilities, increase payload capacity, enhance spacecraft maneuverability and enable longer missions. The effort is a technology demonstration mission under the leadership of NASA's Space Technology Mission Directorate. The green propulsion system will fly aboard a Ball Configurable Platform 100 spacecraft bus.

An Aerojet Rocketdyne researcher examines a container of AF-M315E fuel/oxidizer blend for flight testing. Credit: Aerojet Rocketdyne.

The University of Illinois at Urbana-Champaign is the lead institution on **XPACC**, a new Center for Exascale Simulation of Plasma-Coupled Combustion. Funded by the Department of Energy and the National Nuclear Security Administration, it is part of the Predictive Science Academic Alliance Program. The center's goal is to leverage forthcoming heterogeneous computer architectures to enable truly **predictive simulations** of plasma-assisted ignition. Physics-targeted experiments at both Illinois and Ohio State University will be conducted in simple configurations to develop and evaluate models that will be integrated within a framework of uncertainty quantification, to enable ignition predictions in novel complex configurations.

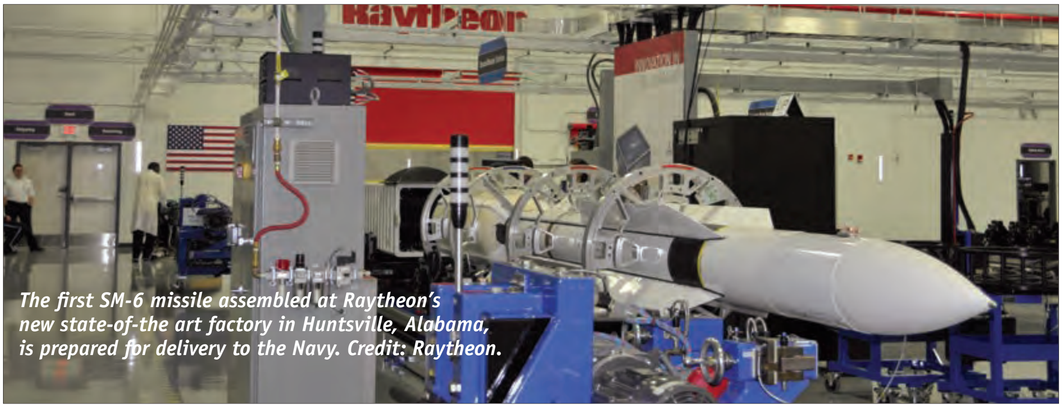
Plasmas offer unique and untapped potential for controlling turbulent combustion. Radicals produced in plasmas accelerate burning by short-circuiting standard chemical pathways; electric fields affect flame stability by accelerating charged chemical species within thin flame fronts; and plasma Joule heating—the heating effect produced by the flow of current through a resistance—affects flow via thermal expansion and chemistry via temperature. Coupling them across all the important length and time scales to make quality predictions of plasma-coupled combustion requires the co-development of simulation models with tools to harness the heterogeneous architectures of anticipated exascale computing platforms. This is the goal of the new center.

Meeting this goal will require **tools** to access the power of forthcoming computer systems. Clock rates and power consumption limitations will lead to substantially slower, simpler, and heterogeneous processing elements. System scale will necessitate resiliency to faults, and heterogeneity will necessitate special approaches for efficient use. Researchers will develop tools to exploit heterogeneous processing elements in order to provide solutions. Different physical models generally lead to discretizations that will be better suited to different programming models and hardware sub-architectures. Recognizing this and building tools from this perspective will increase their utility, both for the proposed plasma-combustion application and more broadly.

Solid rockets hit new milestones

by Barbara Leary, Clyde Carr, Mark Langhenry and Rob Black

*The **Solid Rockets Technical Committee** works to advance the art, science and engineering of solid rocket propulsion and to foster dissemination of new knowledge in this field.*



The first SM-6 missile assembled at Raytheon's new state-of-the art factory in Huntsville, Alabama, is prepared for delivery to the Navy. Credit: Raytheon.

This year brought milestones in propulsion system development, flight test successes and production infrastructure expansion.

ATK completed its solid rocket booster preliminary design review with NASA for the **Space Launch System** and is on track to support the first flight, scheduled for 2017. The rocket will support NASA's human spaceflight exploration to all destinations beyond low Earth orbit. To ensure the astronauts' safety, Aerojet Rocketdyne and Blue Origin completed an Escape Pad test in October 2012 using the Aerojet Rocketdyne-developed Crew Capsule Escape solid rocket motor. In addition, ATK delivered an inert launch abort motor for the Exploration Flight Test-1 for NASA's Orion Multi-Purpose Crew Vehicle, which is scheduled to fly in 2014.

In late 2012, **ATK** tested an upgraded GEM-60 motor at 30 F. Early this year, the company also tested a new CASTOR 30XL upper stage, which flew on Orbital Sciences' Antares rocket from NASA's Wallops Island facility in Virginia. Strategically, ATK and the Air Force tested the newly developed Large Class (92-in.-diam.) Stage 1 solid rocket motor in May at Promontory, Utah. The high-performance motor was developed for the Large Class Stage 1 program and uses emerging technologies from Air Force development programs.

The **Ariane 5 ES**, powered by two MPS, or Moteur Propergol Solide, solid rocket motors designed by **Herakles**, placed two satellites into orbit in July. One was Europe's largest telecommunications spacecraft, Alphasat, for Immarsat; the other, for the Indian Space Research Organisation, was India's latest meteorological satellite, INSAT-3D. The Ariane 5 ES is integrated at the French Guiana plant run by Europropulsion. This was the 70th Ariane 5 launch.

Several missile flight tests took place in late 2012 and 2013. In October 2012, the Navy supported the launch of a Royal Navy **Trident 2 D5** Fleet Ballistic Missile. This was the 143rd successful test flight for the Trident 2 D5 since its completion in 1989. This year there were two Missile Defense Agency intercept flights.

In February, the Third Stage Rocket Motor and Solid Divert Attitude Control System, both manufactured by **ATK**, were on a Standard Missile-3, or **SM-3**, **Block 1A** guided missile integrated and delivered by Raytheon, for Flight Test Mission 20. The missile was launched from the USS Lake Erie, which engaged the target over the Pacific Ocean. In May, the SM-3 Block 1B was launched from a Navy Aegis Cruiser off the coast of Kauai, Hawaii, where the missile destroyed a complex separating short-range ballistic missile target in the Flight Test Missile-19.

Building on the success of the SM-3 Block 1A, the SM-3 **Block 1B** missile incorporates an enhanced two-color infrared seeker and the Throttleable Divert and Attitude Control System. The latter system is manufactured by **Aerojet Rocketdyne**. The test marks the 23rd intercept for the SM-3 program. Aerojet Rocketdyne manufactures the Mk 72 booster and the Mk 104 dual-thrust rocket motor, providing first- and second-stage propulsion for both the SM-3 Block 1A and Block 1B missiles.

This year **Raytheon** began SM-6 deliveries from its new state-of-the-art manufacturing site, the Redstone Missile Integration Facility. In 2010, Raytheon and **Nammo** Group began development and qualification of an alternative rocket motor for the AIM-120 AMRAAM, or Advanced Medium-Range Air-to-Air Missile. Nammo, the second AMRAAM rocket motor source, based in Raufoss, Norway, was officially certified as a second source by the Nonnuclear Munitions Safety Board this year. Raytheon celebrated the 60th anniversary of the Standard Missile Family in May and achieved a production milestone in June by delivering the 5,000th AIM-X Sidewinder air-to-air missile.

Ariane 5's heavy-lift launch of Alphasat and INSAT-3D was the rocket's 70th flight from French Guiana. Credit: ESA/CNES/Arianespace.

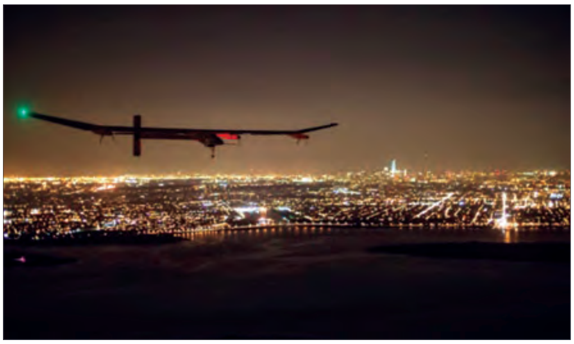
Science, engineering aid energy efforts

by Sivaram Arepalli

*The **Terrestrial Energy Systems Technical Committee** works to advance the application of engineering sciences and system engineering to the production, storage, distribution and conservation of energy for terrestrial uses.*

There have been considerable advances in terrestrial energy systems this year. These include the increasing use of solar energy in Germany, which in July went beyond 50% of the country's total energy consumption. The global investment in **renewable energies**, including solar and wind, has gone up considerably. Public interest in these technologies has increased because of the debate on global warming. Emphasis has shifted away from development of energy storage systems such as batteries and supercapacitors. According to an Energy Information Administration report, world energy consumption will rise 56% in the next three decades, driven by growth in developing countries such as China and India.

Advances in oil and gas production included focus on hydraulic fracturing, or fracking. **ARPA-E**, the Advanced Research Projects Agency-Energy, is supporting a $34-million program on biocatalyst technologies that can convert natural gas to liquid fuel for transportation. In the area of cleaner coal technologies, the Energy Innovation Center at the of **University of Wyoming** is developing new catalytic coal gasification technologies, which can produce a desired synthetic gas for producing chemicals, including ethylene glycol.



***Top**, Solar Impulse takes off from Dulles International Airport in Virginia en route to New York. **Bottom**, Solar Impulse prepares to land at John F. Kennedy International Airport to complete its Across America tour. Credit: Solar Impulse.*

According to Australian climate scientist **Barry Brook**, next-generation compact **nuclear** reactors will provide reliable, safe and economically competitive energy capable of bringing carbon dioxide emissions under control.

A low cost alternative to silicon **solar cells** is found in perovskites, or calcium titanium oxide minerals. University of Oxford researcher **Henry Snaith** claims that perovskites can provide power for as little as $0.15/W, or one-quarter the price of thin-film silicon devices. SunPower announced that it has completed the installation of a 930- kW solar system on the rooftop of the Indira Paryavaran Bhavan building in New Delhi, India's first net zero energy building. This year marked the completion of a truly historic feat for a solar plane, when **Solar Impulse** flew coast-to-coast from San Francisco to New York City. The aircraft, powered by about 11,000 solar cells, weighs roughly the same as a small car.

In May, **General Electric** announced a new line of smart wind turbines that generate 20-24% more power than the previous best turbine in this class. The improved turbine design has new smart systems and accompanying storage capacity. With both its own sensors and access to the Internet, it can adjust everything from its electronics operations to its blade positions.

A collaboration between Point Source Power and Lawrence Berkeley National Laboratory resulted in a "Biomass-powered **Fuel Cell** for Developing Countries." This metal-supported solid-oxide fuel cell is a simple, affordable technology that can operate directly on hydrocarbon fuels in a cookstove.

Next-generation **battery** technologies such as lithium-air, lithium-sulfur, and solid-state will add to the growing $20-billion Lithium-ion market. Work at Lawrence Berkeley National Laboratory focuses on a high-power redox flow battery using hydrogen and bromine. This effort seeks to develop a cost-effective electrochemical system for storing grid-scale energy. In 2012, America's electric vehicle market tripled in size, and in the first half of 2013 it more than doubled. This rapid expansion has been fueled by high consumer satisfaction and impressive reductions in electric vehicle battery costs, which have fallen more than 50% in the past four years.

Energy transmission is moving toward **direct current**. A high-voltage direct current transmission line carrying thousands of megawatts might lose 6-8% of its power over 1,000 mi., while a similar alternating current line can lose 12-25%. The direct current lines also can better manage the variable output from renewable power plants. There is increasing demand to reduce green gas emissions, and green energy is coming closer to reality by following processes that reduce environmental impacts. Progress in this direction will require continued collaboration among governments, industries and academic institutions.

There is a steep rise in global demand for energy, and this likely will increase the need for training in energy science and engineering programs in all countries.

NASA examines health effects of spaceflight

by Joe Chambliss

*The **Life Sciences and Systems Technical Committee** advances technologies required to keep people healthy and safe as they explore space.*

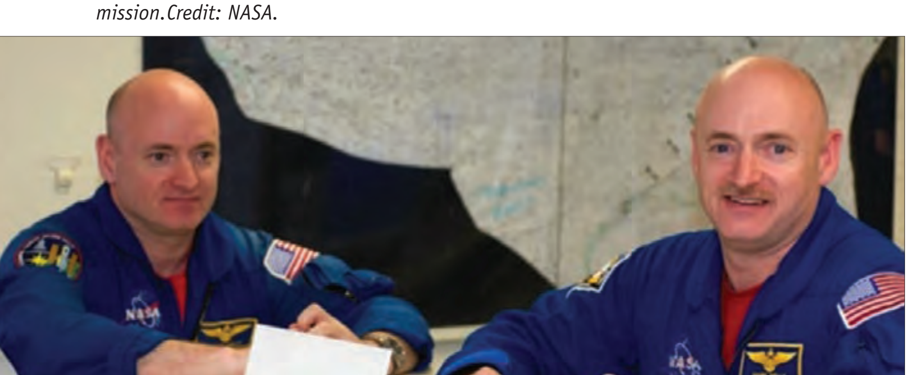
The life sciences and systems community is actively conducting aerospace-related efforts focused on enabling **human exploration** of space. Science, technology and outreach efforts have been under way at space organizations around the world to address the life science and support needs anticipated for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

In support of life sciences, the community participated in the annual AIAA congressional visits day to inform members of **Congress** of space life sciences research priorities, and to assess the current direction of Congress relative to the space program. While there has been less emphasis on this area in the past few years, all indications point to a recovery and a great future for life sciences on the **International Space Station**.

In February, the non-profit Inspiration Mars Foundation proposed taking advantage of a rare flight opportunity in 2018 to send a human crew on a **501-day flyby of Mars**. The initiative has caught the aerospace community's attention and has resulted in a Space Act Agreement between NASA and the organization to investigate the technical features of the mission. In July, Taber MacCallum, co-founder of Paragon Space Development, presented the mission concept as the keynote speech at the 2013 AIAA International Conference on Environmental Systems in Vail, Colorado.

NASA's **Flight Opportunities Program** is in its fourth year of flying competitively selected technology payloads in space-relevant environments on parabolic aircraft, high-altitude balloons, suborbital reusable launch vehicles, and other commercial craft. NASA's goals include technology advancement with potential broad application to future NASA missions, stimulation of the commercial space industry, and Earth benefits. Many innovative life sciences-related technologies have been or will soon be flown in support of areas such as grey water purification; sensorimotor adaptation; space medicine and surgery; autonomous 3D cell culture; telemetric bio-imaging; and cerebral hemodynamics monitoring.

Twin brothers Scott Kelly (left) and Mark Kelly will be monitored, one on the ISS and the other on Earth, for comparison of their physiological responses during Scott's year-long space station mission.Credit: NASA.



Russia initiated and NASA has started planning a **Mars mission simulation** on the ISS to start in 2015.

NASA is using an idea proposed by **twin brothers** Mark Kelly and Scott Kelly to perform a study that has been confined to science fiction until now. The agency will be monitoring the biological states of both brothers over the span of a year, with a twist: Scott will be aboard the ISS for the duration of that period, while Mark, a former astronaut who retired from NASA in 2011, will remain on Earth. Blood samples will be taken from Scott at regular intervals before, during and after the ISS mission. Corresponding samples will be taken from Mark, who will maintain his normal lifestyle. NASA will be seeking research proposals that focus on specific biological attributes, including the effects of space on genetic mutations in Scott, protein levels in the two men's bodies, levels of other biological molecules, and differences in astronaut psychology on Earth versus in space.

The **European Space Agency** (ESA) has partnered with NASA to start a contract for a biology experiment dubbed **NIH.1a**, to be carried out on the ISS. The experiment will test the hypothesis that the inhibition of the **immune response** in spaceflight is similar to that of aging. Also in preparation is an analysis of ESA's BICE experiment, which is short for Biomechanical quantification of bone and muscle loading to Improve the quality of 0-g Countermeasure prescriptions for resistive Exercise. BICE involves a combined use of NASA's Advanced Resistance Exercise Device and the Italian Space Agency's ELaboratore Immagini TElevisive (ELITE) S2.

In the U.S., NASA made significant progress this year in Advanced Exploration System and **Game Changing Development** projects for life sciences-related areas: the Multi-Mission Space Exploration Vehicle, extravehicular activity suit and life support, Suitport, Deep Space Habitat, analog missions, logistics reduction and repurposing, water recovery, spacecraft fire safety demonstrations, radiation protection, and atmosphere resource recovery and environmental monitoring.

NASA's continued development of technology for **CAMRAS**, the CO_2 and Moisture Removal Amine Swingbed, overcame startup and on-orbit integration problems and has now been operated in the ISS.

Surprises, new knowledge in microgravity

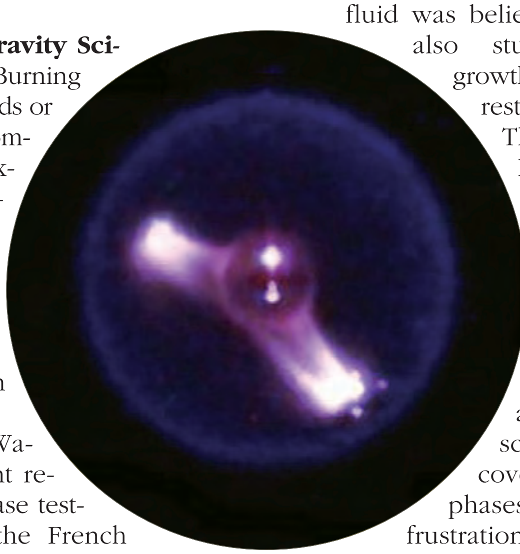
by Brian Motil, Michael Hicks, and Jeffrey Marchetta

*The **Microgravity and Space Processes Technical Committee** encourages the advancement and public awareness of low-gravity studies in physics, materials, biological sciences, and related fields.*

Aboard the International Space Station, results from the Flame Extinguishment or **FLEX** experiment using methanol droplets showed that flames are surprisingly resilient at O_2 concentrations as low as 7% when the atmosphere is blended with a mixture of N_2/Xe, nitrogen-xenon gases. This is well below the previously held limit of approximately 13%. The FLEX investigation has also provided the discovery of a "reversed" two-stage burning phenomenon where high-temperature flames transition to a steady low-temperature burning regime following the extinction of the visible high-temperature flame. Rapid flame bursts were observed that resulted from the auto-ignition of incomplete combustion products generated during the low-temperature burning regime, illustrating the unique hazards associated with microgravity fires. FLEX-2 significantly extends the scientific scope of FLEX, looking at fundamental combustion phenomena such as sooting processes, condensed phase processes, surrogate fuel development, and interactions between fuel droplets.

In the ISS **Microgravity Science Glovebox**, the Burning and Suppression of Solids or BASS experiment completed tests and is expected to begin operating in early 2014. It is designed to study the burning and extinguishment characteristics of a wide variety of flammable materials in microgravity.

The Supercritical Water Mixture experiment recently started a six-phase testing program inside the French space agency CNES' mini-laboratory, called **DECLIC**, which stands for Dispositif d'Etude de la Croissance et des LIquides Critiques. Review milestones were successfully completed for the following: the Burning Rate Emulator experiment, designed to investigate material flammability using a gaseous fuel; the Solids Flammability Ignition and Extinguishment experiment, or SoFIE, which looks at a range of flammability and extinguishment phenomena using solid fuels; and the AES-funded Spacecraft Fire Experiment, or Saffire, designed to replicate large scale fire phenomena using an expendable cargo vehicle as a test bed after undocking from the ISS.



A burning droplet of heptane observed during the FLEX experiment aboard the space station. Credit: NASA.

In the area of microgravity fluid physics, several ISS experiments were operated, with exciting results. The Capillary Channel Flow and Capillary Flow Experiment-2, both studying various aspects of capillary flows, focused on investigating techniques to passively separate gas bubbles in water. Both experiments demonstrate an effective and reliable means of passively separating bubbles in microgravity. The **Constrained Vapor Bubble** experiment has also achieved ground-breaking results including the first-ever controlled visualizations of explosive boiling in a constant-volume, confined system in microgravity. Additional accomplishments include developing a model to predict the minimum film thickness needed to nucleate a bubble in a thin liquid film, and the minimum film thickness required for boiling to occur rather than evaporation within a wickless heat pipe.

In colloid science, the Binary Colloidal Alloy Test or **BCAT** demonstrated the first experimental observations of phase separation well beyond where a model critical fluid was believed to separate. BCAT also studied seeded crystal growth, and crystal growth arrested by phase separation. The Advanced Colloids Experiment, **ACE-1**, observed unexpected particle size dependence when assembling stabilizers based on depletion attraction. ACE-1 is the first in a series of studies aimed at solving a number of fundamental scientific questions: discovery of new ordered phases; frozen configurations; frustration and glasses; and the process of self-organization itself.

Investigating the Structure of Paramagnetic Aggregates from Colloidal Emulsions-3, or **InSPACE-3**, continued operating aboard the ISS. The InSPACE-3 vial samples contain paramagnetic particles that form column-like structures that move throughout the sample and coalesce to reduce the magnetic interaction energy. Visual observations of microscopic, aggregate structures will yield a better understanding of the interplay of forces between structures in magneto-rheological suspensions. Applications of this work include improved brake systems, seat suspensions, robotics, airplane landing gear, and seismic dampers.

Missiles score more intercepts

by James D. Walker

*The **Weapon System Effectiveness Technical Committee** advances the science and technology of predicting, measuring, evaluating, and improving the lethality of weapon systems.*

A multiple-targets missile defense test led by the Missile Defense Agency in September tested a layered defense architecture. Called Flight Test Operational-01, the test began with the launch of two medium-range ballistic missile targets on operationally realistic trajectories toward a defended area near the Army Kwajalein Atoll/Reagan Test Site. Space and ground systems provided launch alerts. Sailors aboard the USS Decatur with its **Aegis** weapon system detected and tracked the first target with the onboard AN/SPY-1 radar, developed a fire control solution, launched a Standard Missile-3, or SM-3, Block 1A missile and intercepted the first target.

To demonstrate layered defense, a second AN/TPY-2 radar in terminal mode, located with the **THAAD** or Terminal High-Altitude Area Defense weapon system, acquired and tracked the target missiles. Soldiers used THAAD to develop a fire control solution, launched a THAAD missile, and intercepted the second target. Also to demonstrate layered defense, a second THAAD interceptor was launched at the target that had been destroyed by the Decatur, as a contingency in the event the SM-3 did not achieve an intercept.

A Standard Missile-3 Block 1A interceptor is launched from the USS Decatur during an intercept test on September 10. Credit: Missile Defense Agency.

SM-3 missiles made three additional intercepts this year. During a February 12 test called Flight Test Standard Missile-20, sailors aboard the USS Lake Erie intercepted a medium-range ballistic missile target over the Pacific Ocean using an SM-3 Block 1A guided missile. MDA's two Space Tracking and Surveillance System-Demonstrator satellites detected and tracked the target, then forwarded track data to the Lake Erie for use in the fire control solution. After launch and separation, the SM-3's kinetic warhead acquired the target reentry vehicle, diverted into its path, and destroyed the target via a **kinetic impact**.

The first of two THAAD interceptors is launched during a test conducted by the Missile Defense Agency. Credit: Missile Defense Agency.

The use of space-based systems in the intercept extends the battlespace beyond the Aegis's radars, enabling **longer range intercepts** and defense of larger areas.

The next SM-3 test, called Flight Test Standard Missile-21, took place on September 18. A complex, separating short-range ballistic missile target was launched from the Pacific Missile Range Facility on Kauai, Hawaii. The Lake Erie then detected and tracked the missile with its onboard AN/SPY-1 radar. The ship, equipped with the second-generation Aegis ballistic missile defense weapon system, developed a fire control solution and launched two SM-3 Block 1B guided missiles to engage the target. The first SM-3 intercepted the target warhead. This was the first salvo mission of two SM-3 Block IB guided missiles launched against a **single separating target**. The test was also operationally realistic, in that the target's launch time and bearing were not known in advance, and the complex target was said to be the most difficult engaged to date.

In Flight Test Standard Missile-22 on October 3, sailors aboard the Lake Erie engaged a medium-range ballistic missile target launched from Kauai. The Lake Erie detected and tracked it, developed a fire control solution and launched the SM-3 Block IB guided missile to engage the target. The SM-3 delivered the **kinetic kill** vehicle, which destroyed the target through direct impact.

This was the **28th intercept** in 34 flight test attempts for the Aegis Ballistic Missile Defense program since flight testing began in 2002.

A ground-based midcourse defense interceptor test on January 26 of this year was the first since a failed attempt in December 2010. The January test examined the performance of the **exo-atmospheric kill vehicle** through two divert sequences. Although the test flyout manaeuvers went as expected, the subsequent integrated exercise and flight test on July 5 was a disappointment. A primary objective, the intercept of a long-range ballistic missile target launched from Kwajalein, was not achieved. The interceptor missile was launched from Vandenberg Air Force Base, Calif. Initial information pointed to a stage separation failure in the upper stages as the cause of the failure.

Across all Ballistic Missile Defense System programs, from 2001 through 2013, there have been 64 hit-to-kill intercepts in 80 flight test attempts

Mining, habitats lead space architecture work

by David Nixon

*The **Space Architecture Technical Committee** focuses on the architectural design of the environments where humans will live and work in space, including facilities, habitats, and vehicles.*

NASA's current focus on an asteroid rendezvous mission as human space exploration's next big goal has begun to stimulate ideas from the space community at large. One of these, called the **Robotic Asteroid Prospector**, takes a path different from NASA's. The plan proposes the gradual buildup of a space mining infrastructure paced to coincide with the emergence of a commercial space resources market. A team from Astrotecture, V Infinity Research, and Honeybee Electronics developed the idea under a NASA Innovative and Advanced Concept Grant.

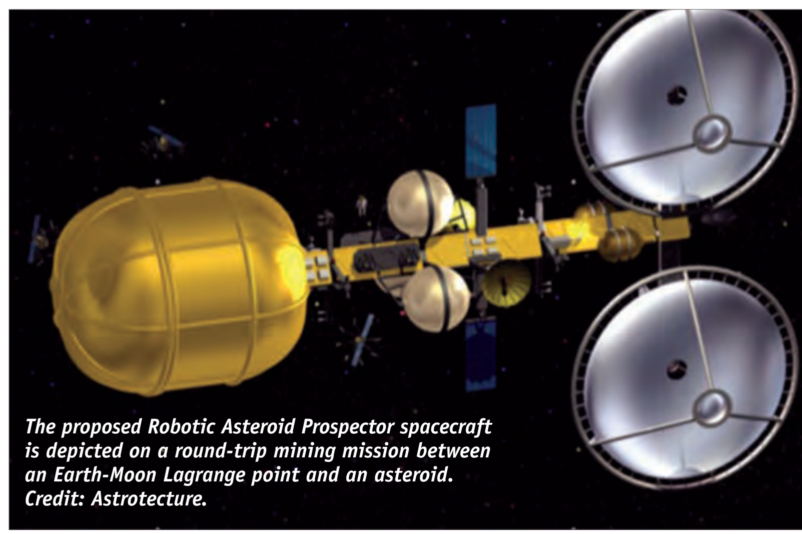
Examples of near-term resources with commercial appeal are **water** and **platinum**. A fleet of mining spacecraft would be staged from an Earth-Moon Lagrange point and returned there from asteroids on a cyclical basis, much like bulk cargo ships on round-trip ocean voyages between distant ports.

The Robotic Asteroid Prospector spacecraft's key design feature is a **solar thermal propulsion** system that would provide propulsive thrust, electricity, and heat for mining and mineral processing. The preferred propellant is liquid oxygen and hydrogen from water. This would allow the spacecraft to refuel at a water-rich asteroid for its return voyage to cislunar space, thus shaving off the mass that must be staged out of the Lagrange point. The spacecraft would rendezvous with an asteroid at its pole, match its rotation rate, and grapple with it to begin mining operations. The Astrotecture team carried out an experiment in extracting and distilling water from frozen regolith simulant as a first step in testing the mission concept's viability.

Architects and engineers who design space habitats are beginning to forge links with those who design air-tight habitats for post-disaster survival on Earth. Through these links, space design and engineering know-how can flow down and help to support design for human survival in extreme conditions including floods, fires, earthquakes, and eruptions. This is a field where space spin-off technology can have real humanitarian benefits.

For example, a consortium is at work in Europe on **Self-deployable Habitats for Extreme Environments** (SHEE), funded under the European Union's Seventh Framework Program. Consortium members are the International Space University, Liquifer Systems Group, Space Applications Services, and the University of Tartu–Institute of Technology, Sobriety, Comex and Space Innovations.

SHEE would comprise a deployable envelope, measuring 5 m in diameter, that encloses a 1.5–2.5-m-diam. rigid core structure. Deliverable by land, sea, or air, SHEE habitats would be particularly useful at bringing support and protection to communities that have been exposed to **natural disasters**. Each habitat would be up to 4 m tall and would include robotically deployed subsystems and an external power generation system. A habitat prototype will be tested as a temporary living module for two people.



The proposed Robotic Asteroid Prospector spacecraft is depicted on a round-trip mining mission between an Earth-Moon Lagrange point and an asteroid. Credit: Astrotecture.

Self-deployable Habitats for Extreme Environments would enable research on the Moon or Mars and shelter people on Earth after natural disasters. Credit: SHEE Consortium.

The use of **robotics** in building construction is a technology at a primitive level of readiness and, despite rhetoric about sustainability, most buildings still rely on traditional infrastructure for consumable utilities supply and waste disposal. SHEE and projects like it can help to show the way out of this dependency. They can reinvigorate architecture's primordial mission to provide safe and secure refuges from the hazards of an uncertain world, while using state-of-the-art technology in an ecologically friendly way.

Advancing robotics

by Kate Stambaugh, Gregory P. Scott, and David Spangler

*The **Space Automation and Robotics Technical Committee** works to advance the development of these technologies and their application to space programs.*

Teleoperation—meaning remote control of a robot by a human—saw significant progress in 2013.

Robonaut 2, performing a task onboard the space station, can be controlled by teleoperators on the ground. Credit: NASA.

The **NASA Robotic Refueling Mission**, or RRM, which is attached externally to the Dextre robotic arm on the International Space Station, conducted orbital refueling technology demonstrations. With **Dextre** teleoperated from the ground, the RRM accomplished fluid transfer tasks, cut thermal blankets, and removed fasteners and caps. A new hardware box was delivered to the station in August so that RRM can begin a new phase of even more complex servicing tasks.

Inside the ISS, **Robonaut 2** is mastering the art of working alongside humans in orbit. Earth-based control teams can now teleoperate this humanoid robot to wipe handrails, make airflow monitoring checks, and perform other cleaning duties, freeing ISS crewmembers to focus on the onboard science experiments. Robonaut 2 is also providing technology spinoffs that are now available for licensing across a variety of industries. Also onboard the ISS is **Kirobo**, a small Japanese humanoid talking robot. JAXA, the Japan Aerospace Exploration Agency, launched Kirobo to study human-robot interactions during long-duration space missions.

Someday astronauts will need to teleoperate robots on the surface of a planetary body from the safety of their orbiting spacecraft or habitat. To demonstrate this ability, NASA sent hardware to the ISS so that astronauts onboard could operate a robot located on Earth. In separate activities during June and July, three astronauts on the station each **drove a robot** on the ground and manipulated it to perform several tasks. These were the first demonstrations of a robot on Earth being controlled from space.

In the area of planetary surface robotics, the Mars Exploration Rover **Opportunity** celebrated the 10-year anniversary of its Mars landing on August 6. Opportunity also broke the record for the longest distance traveled by a NASA rover, surpassing the Apollo 17 lunar rover's mark. The Mars Science Laboratory's Curiosity rover spent its first year successfully driving and drilling on the Martian surface. Curiosity also began using autonomous navigation in August to avoid hazards while driving.

Japan's Kirobo, now onboard the ISS, is a small talking humanoid robot. Credit: Kibo Robot Project.

There are also many space robotics initiatives currently in development. This year DARPA's satellite servicing program, **Phoenix**, completed Phase 1. NASA's **Asteroid Redirect Mission** is in its early planning stages and will need a variety of space automation and robotics capabilities to be successful. Also in development are several international planetary rovers destined for the Moon, Mars, and asteroids.

Early work toward colonization

by Anita Gale, Ron Kohl, and Mike Snyder

*The **Space Colonization Technical Committee** promotes the development of advanced concepts, science, and technology to enable and enhance permanent human presence in space.*

Although recent years have not brought development or even unified planning of integrated infrastructure components to enable future **space settlement**, 2013 has seen small steps toward that goal. The most visable aspect of expanding the human economy throughout the Earth-moon system, known as cislunar space, is the continuing commercialization of space services.

The International Space Station is currently the primary focus of commercialization. **SpaceX** and **Orbital Sciences Corp.** delivered **cargo** to the station through their Commercial Cargo contracts. Most importantly, SpaceX's Dragon also returned equipment to Earth. A relative abundance of vehicles has been bringing supplies and experiment hardware to the station, but no return capability had been available since the space shuttle's final flight in 2011. Dragon has begun to relieve the backlog of experiment results waiting for return to Earthbound researchers. Orbital Sciences' Cygnus spacecraft, after delivering cargo to the ISS, was loaded with items no longer needed by the station's astronauts. They then used a robotic arm to detach the craft for its destructive reentry, which took place as planned in late October.

Progress toward on-site manufacturing in space is scheduled to begin in 2014 with NASA and space manufacturing company Made in Space planning to send a **3D printer** to the ISS. The 3D Printing in **ZeroG** Experiment will have astronauts printing test samples to demonstrate the potential of additive manufacturing in a zero-gravity environment. Use of this technology in space would start with the construction of parts, tools and small **CubeSats**, but in a longer timeline could allow the creation of larger structures, spacecraft, and habitable bases. The ability to manufacture in zero gravity, using raw materials found on space missions, would circumvent the cost issues and launch requirements inherent in creating similar items on Earth.

Commercial **crew services** to ISS are also in development, with contracts awarded to Boeing for its CST-100 spacecraft and to SpaceX for a human-rated version of Dragon, with a smaller contract to Sierra Nevada for its Dream Chaser spaceplane. The current contracts continue development into mid-2014; NASA is soliciting proposals for the next phase of the program, which may involve a downselect to one or two contractors through initial flights. An indication of the importance of moving supplies to and from ISS is the requirement that commercial crew craft also carry cargo.

The ISS itself is also commercializing its services. CASIS, the Center for the Advancement of Science in Space, was established to manage ISS as a U.S. national laboratory and bring **non-traditional users** to the station. Already established or in the works are partnerships with Merck, Novartis, Cobra Puma, Baylor College of Medicine, M.D. Anderson Cancer Center, and the Boston Museum of Science. CASIS offers seed money to help fund promising research projects and assistance with payload development, system integration, and access to launch providers. The organization's emphasis on looking to space for innovative technologies has potential for finding an economic imperative that may eventually lead to large-scale industry in space.

Large structures for space settlements might be printed and assembled in space. Credit: Made in Space.

An initiative more clearly associated with future space settlement was announced by **A.P.J. Abdul Kalam**, **former president of India**, at the National Space Society International Space Development Conference in May: He is encouraging the U.S., India, the U.K. and Japan to form a partnership for development of solar power satellite technologies. A focus is on the environmental benefits of **solar power from space**. Early activity associated with the concept primarily involves a series of international conferences. One goal is to eventually involve the G8 and G20 nations, the world's top eight and top 20 leading economies, respectively.

Film and **literary** works also helped to maintain public awareness of space colonization. Late summer saw release of the movie ***Elysium***, whose plotline included a major space settlement. The 2012 book *The Visioneers* by W. Patrick McCray described the development of early space settlement concepts by Gerard O'Neill and others during the 1970s.

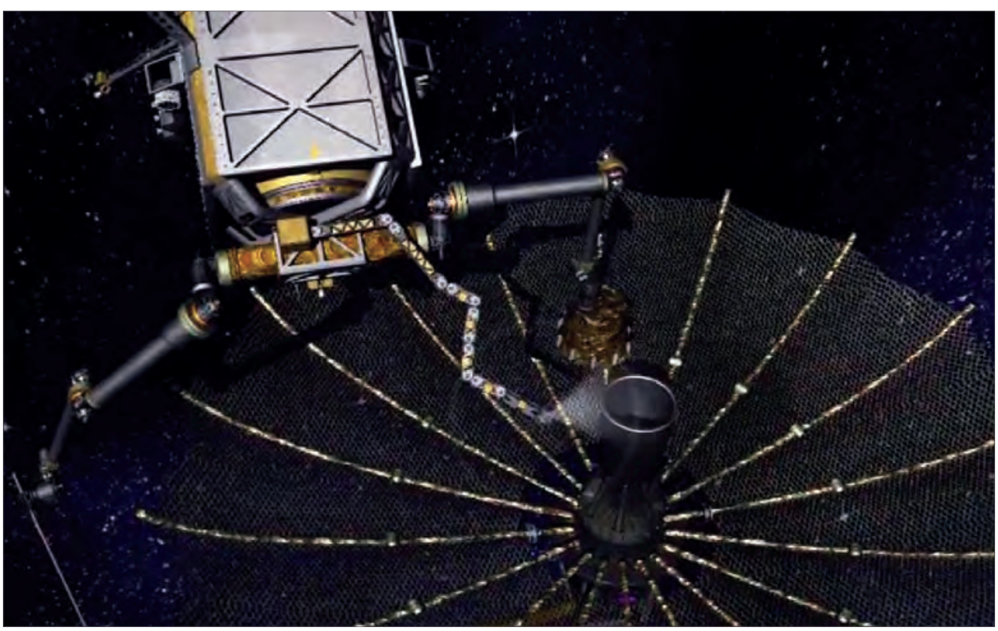
Logistics plans look beyond LEO

by Tovey Bachman

*The **Space Logistics Technical Committee** fosters development of integrated space logistics capabilities that enable safe, affordable and routine spacefaring operations.*

NASA is studying ways to support and maintain human exploration spacecraft for missions beyond low Earth orbit. Proposed strategies focus not only on reducing the number of failures, but also on improving maintainability and reducing the total mass and volume needed for spacecraft spare parts. Strategies include redundancy, reliability, commonality, asset repurposing, in-space manufacturing, lower levels of repair, and repair during assembly.

There are three manned spaceflight programs—the Space Launch System, the Multi-Purpose Crew Vehicle, and the Ground Systems Development and Operations programs—under NASA's Exploration Systems Development enterprise. A **Logistics Integration Team** is leading development of integrated products to ensure consistent integrated logistics support and maximize supportability, commonality, and affordability. The team developed a baseline Cross Program Logistics Integration Plan and mapped out logistics responsibilities for programs at the NASA Kennedy launch site. The team also is working on a commonality approach.



DARPA's Phoenix program proposes to harvest and reuse components from retired satellites. Credit: DARPA.

Over the years, sophisticated analytical and simulation models have been developed to trade off spares investment vs. system availability for spacecraft such as the International Space Station, the space shuttle, and proposed deep-space craft. **Ground systems**, although vital to space launches, have received relatively little attention in terms of their logistical support. NASA's Ground Systems Development and Operations Program has been establishing an approach to spares prioritization and budgeting, using RBS, or **readiness-based sparing**, to improve on the previous item-oriented approach. RBS takes an operating scenario, together with item characteristics such as cost, procurement and repair lead times, and parts demand patterns, then produces a tradeoff curve for system availability vs. cost.

This approach gives NASA logisticians a pragmatic and independent "analytical sandbox," enabling them to better quantify the trade space surrounding their logistical support and inventory management policies. The output from RBS provides a well-documented, repeatable analytical process for answering basic inventory management questions regarding the depth, range, placement and balance of spare parts. The approach is projected to provide significantly greater system uptime for any available budget.

Commercial spaceflight continues to develop its logistics capability to deliver payloads to the ISS and put satellites in orbit. SpaceX delivered supplies to ISS in March using its Dragon capsule, which also carried home used equipment. The next Dragon mission was planned for December. Orbital Sciences Corp. carried supplies to the station in September aboard its Cygnus capsule, a demonstration mission that the company expects to be followed by more flights.

MIT, in research on space supply chain network optimization, has developed a new version of its **network flow model**. This version can automate optimal network generation rather than using a static network. The new model will include treatment of in-situ resource utilization and resource depots, as well as network design capability.

DARPA's **Phoenix** program completed Phase 1 of its plan to develop a sustainable ecosystem of hardware delivery, capture, and transport using an on-orbit servicer/tender. A goal is to demonstrate the first on-orbit space assembly by harvesting retired satellite antennas to create new space systems.

Going beyond mission limits

by Michael Squire

The ***Space Operations and Support Technical Committee*** *focuses on operations and relevant technology developments for manned and unmanned missions in Earth orbital and planetary operations.*

Mission termination is an inevitable phase of space operations. Often, however, when a primary mission ends, a new one can follow. This is the hope for the **Kepler Space Telescope**. In 2013, after a remarkable four years discovering planets beyond the solar system, that phase of Kepler's career came to an end. The telescope's ability to home in on target stars with the required precision was lost when the second of four reaction wheels failed in May; three are needed. Efforts have now turned to finding new scientific missions that use hybrid attitude control, which would employ the two remaining wheels in concert with the spacecraft's thrusters.

Space operations farther out in the solar system focused on **Mars**. The Mars Science Laboratory rover Curiosity marked its first year of surface operations in August after driving about 1.6 km and sending back more than 190 gigabits of data, including 36,700 full images. The rover also performed the first drill sampling on another planet; the results hint at evidence of a past Martian environment that could have supported life. The Mars Exploration Rover Opportunity, not to be outdone by its younger cousin, became NASA's leader in beyond-Earth driving, passing the 37 km traveled on the lunar surface by the Apollo 17 Lunar Roving Vehicle in 1973. Opportunity is now behind only the Soviet Lunokhod 2 rover; analysis this year of NASA Lunar Reconnaissance Orbiter images showing the rover's tracks calculated that the Soviet rover traveled over 42 km in 1973.

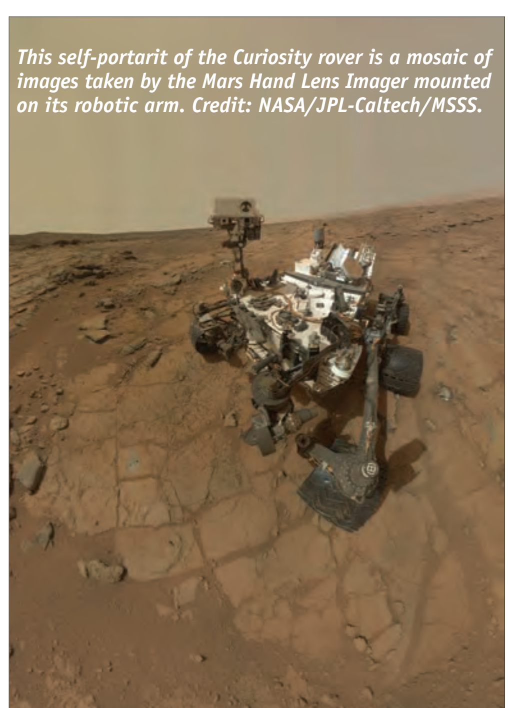
The **Voyager 1** spacecraft reached an even more historic milestone: In September, scientists analyzing data from the craft determined that it has officially left the solar system and crossed into interstellar space. Extrapolating the results backward in time showed that the transition actually occurred in August 2012.

Other space **science** activities in 2013 included launches of IRIS, or Interface Region Imaging Spectrograph, which is studying the Sun's lower atmosphere; and LADEE, or Lunar Atmosphere and Dust Environment Explorer, which is preparing to gather data on the Moon's atmosphere and the region near the lunar surface. GRAIL, the Gravity Recovery and Interior Laboratory mission, ended in December 2012 when controllers directed the two lunar orbiters, Ebb and Flow, to an impact with the Moon's surface.

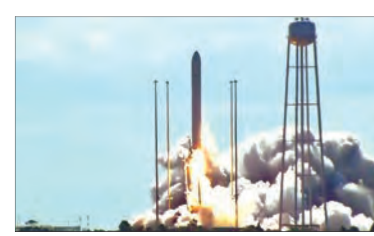
NASA's **commercial** partners made progress in 2013. Orbital Sciences' Antares launch vehicle delivered a mass simulator to orbit in April, setting the stage for the September launch of their Cygnus cargo craft, which delivered supplies to the International Space Station. Cygnus is expected to join SpaceX's Dragon in the fleet of commercial spacecraft supporting ISS.

The **time** needed for a crew to reach ISS was dramatically reduced this year. The Russian Soyuz TMA-08M, launched in March, docked with ISS less than 6 hr after liftoff, instead of the two days it used to take, using a new expedited rendezvous procedure for the first time for a crewed vehicle. One of the studies performed on board ISS this year advanced on-orbit satellite servicing with the first robotic fluid transfer, tested as part of the Robotic Refueling Mission. The **Chinese** continued development of their own space laboratory, Tiangong-1, with the Shenzhou-10 mission launched in June. This three-person flight included the second female Chinese astronaut and set a new Chinese duration record of 15 days.

The number of **countries** operating satellites grew by four this year, with Azerbaijan (Azersat), Austria (TUGSAT-1/UniBRITE), Ecuador (NEE-01 Pegaso), and North Korea (ESTCube-1) all sending up first satellites. North Korea and South Korea also executed their first successful orbital launches.



This self-portarit of the Curiosity rover is a mosaic of images taken by the Mars Hand Lens Imager mounted on its robotic arm. Credit: NASA/JPL-Caltech/MSSS.



An Orbital Sciences Antares rocket takes off from NASA's Wallops launch site in Virginia. Credit: NASA TV.

Private investors eye space resources

by Kurt Sacksteder

*The **Space Resources Technical Committee** works to enable the identification, recovery, processing and use of space resources on the Moon, Mars, and elsewhere in space to support automated and crewed missions.*

In the space resources community there is broad agreement that affordable, sustainable human space exploration will require the use of non-terrestrial natural resources to supply propulsion, power, life-support consumables and manufacturing materials. Along with lunar, planetary and asteroid scientists, space resource advocates are conceiving new exploration approaches in which science helps to identify resources, and resources enable scientific exploration.

At government agencies, visionary programs have nurtured space resource utilization. This year, however, some of the most significant developments came from the private sector, with the establishment of new companies and private funding of investments and achievements.

Planetary Resources, or PRI, has been developing its plans for prospecting and mining near-Earth asteroids. The company secured additional investors and key industrial partners including Bechtel and 3D Systems. Raising $1.5 million via **Kickstarter**, a crowd-sourced fundraising web site, PRI also provided resources for its Arkyd-100 Space Telescope program. In addition, the company partnered with Zooniverse to create the **Asteroid Zoo** citizen science project. PRI also supports and secures R&D contracts with NASA, DARPA, and other entities. The company's first technology demonstration spacecraft, the A3, is scheduled for launch from the International Space Station in the second quarter of 2014.

NORCAT, the Northern Centre for Advanced Technology, spun off its Innovation and Prototype Department to create **Deltion Innovations**. The new company brings terrestrial mining expertise to bear on development of mining technologies for harvesting space resources. Deltion supports robotics and will facilitate opportunities for transferring technology between the terrestrial and space technology sectors. The company also will seek opportunities to commercialize space-derived technology in partnership with the mining industry and other resource sector interests. In addition Deltion will host the annual Planetary and Terrestrial Mining Science Symposium.

In May, Honeybee Robotics' 1-m drill and Carnegie Mellon University's Zoe rover were deployed in the Chilean **Atacama Desert**. The 10-kg drill autonomously acquired samples from various depths and delivered them for Raman spectrometer analysis onboard the rover.

At the University of Texas at El Paso, where the NASA-sponsored Center for Space Exploration Technology Research is studying combustion of lunar regolith simulants and magnesium, researchers extended the project to include **Martian regolith** simulants. Thermite processing could produce structural materials on the Moon and Mars. In July, a team of students at the university investigated processing onboard the NASA-sponsored reduced-gravity aircraft.

Missouri University of Science and Technology offered the first course in asteroid mining. The class explored the aerospace and mining aspects of responsibly exploiting near-Earth objects and Main Belt asteroids. The most innovative approach proposed was mining platinum group elements while moving the **near-Earth asteroid** to an orbit known as an **Aldrin Cycler**.

NASA Glenn conducted lunar thermal/vacuum/soil environmental testing of an **auger** provided by the Canadian Space Agency and a **spectrometer** provided by NASA Ames. The auger drilled into water-doped, cryogenically frozen lunar soil simulant matching lunar polar conditions. The spectrometer measured water signatures from the auger cutting pile. These tests comprise the first environmental readiness hardware demonstration for NASA's planned lunar prospecting initiative.


In Chile's Atacama Desert, Carnegie Mellon University's Zoë rover analyzed soil samples acquired by Honeybee robotics' 10-kg drill. Credit: Carnegie Mellon Robotics Institute.

Constellations gain new satellites

by Daniel Kwon

*The **Space Systems Technical Committee** fosters the development, application and operation of space systems and addresses emerging issues in the area.*

While budget sequestration and a cyclical lull in commercial communication satellite procurements were an early theme of 2013, the year marked the growth of several existing satellite constellations and several new missions.

In February, the Landsat program added **Landsat 8**—formerly called the Landsat Data Continuity Mission—to its series of Earth observing satellites. Built by **Orbital Sciences**, the spacecraft was launched in early February by an Atlas 5 401. After checkout and verification by NASA, it was handed over to the U.S. Geological Survey in May. Thousands of users rely on Landsat imagery for insights from land resource monitoring to urban planning to education. Not to be outdone by Landsat's newest member, Landsat 5 set the new Guinness World Record for "Longest-operating Earth observing satellite" in February by delivering data for 28 years and 10 months, far longer than its original three-year design life.

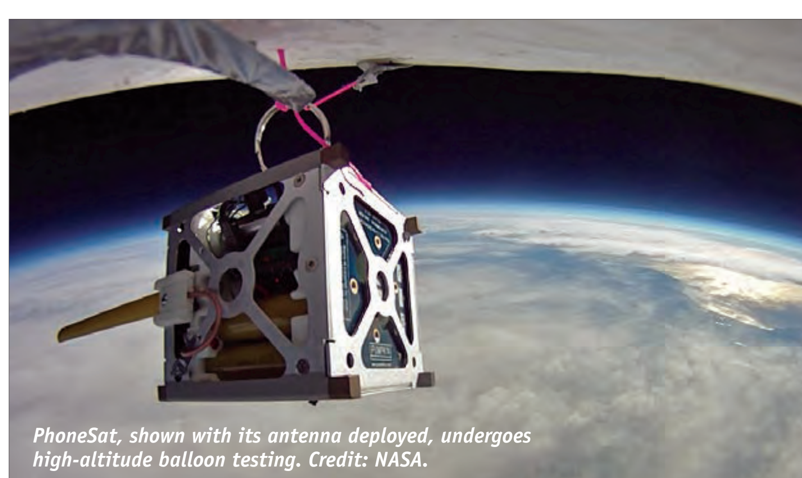
MILSATCOM, or U.S. military satellite communications, had a busy year augmenting several satellite systems. The third AEHF, **Advanced Extremely High Frequency**, satellite was launched in September. On-orbit testing of AEHF-2 was completed in late 2012. AEHF will replace the Milstar system to provide highly secure, protected communications under even the harshest environments, such as a nuclear event. AEHF operates in the EHF (30–300 GHz) and SHF (3–30 GHz) bands. Within the SHF band, the Air Force's WGS, or **Wideband Global SATCOM**, added WGS-5 in May and WGS-6 in August. WGS operates in X-band (8–12 GHz) and Ka-band (20–30 GHz) to provide high-capacity communications. Each WGS satellite can route several Gbps providing over 10 times the communications capacity of the previous Defense Satellite Communications System. Finally, in the UHF band (300 MHz–3 GHz), the Navy's Mobile User Objective System added **MUOS-2** in July. MUOS is designed to provide cellphone-like communications to mobile users using a third-generation Wideband Code Division Multiple Access waveform. Final operational capability is planned for 2015 with four satellites plus an on-orbit spare and four ground stations. In addition to U.S. MILSATCOM augmentations, the Air Force Space Based Infrared System added the GEO-2 infrared mission detection satellite in March.

In June, NASA's IRIS, the **Interface Region Imaging Spectrograph**, was placed into a Sun synchronous orbit by Orbital Sciences using its air launched Pegasus XL rocket. Images from IRIS have shown unprecedented detail into the layers of the Sun, and observations throughout the next two years will reveal more about how solar emissions impact the near-Earth space environment and Earth's climate.

NASA's **Commercial Crew and Cargo** programs had a busy year starting in March with SpaceX's second Commercial Resupply Services mission to the ISS. CRS-2 was the first flight of the Dragon's unpressurized trunk for cargo. In April, the maiden flight of the two-stage Antares rocket from the Mid-Atlantic Regional Spaceport in Wallops Island, Virginia, lofted a Cygnus mass simulator along with the 3U, or three-unit, Dove-1 CubeSat and three 1U PhoneSat CubeSats called Alexander, Graham and Bell. PhoneSat was a NASA technology demonstration experiment to examine application of consumer electronics as the basis of an extremely low-cost satellite bus. Graham and Bell were based on the HTC Nexus One phones, while Alexander was based on a Samsung Nexus-S phone. All three run the Android 2.3.3 Gingerbread operating system.

In February, Landsat 8 was launched in Orbital Sciences' Gilbert, Arizona, manufacturing facility. Credit: Orbital Sciences.

2014 will be another busy year for NASA, with additional CRS flights for **SpaceX** and **Orbital**. Also expected are major design, development and test milestones for the companies involved in NASA's CCiCap, or commercial crew integrated capability, and CCtCap-commercial crew transportation capability-development programs. ⩓



PhoneSat, shown with its antenna deployed, undergoes high-altitude balloon testing. Credit: NASA.

Space tether concepts gain momentum

by Sven G. Bilén

*The **Space Tethers Technical Committee** focuses on the development and use of tether-based technologies for space systems.*

This year's developments in the space tethers community focused on new technologies, applications, and flight missions.

DragEN, the deployment mechanism on Saber Astronautics' picosatellite tether system, was validated on parabolic flights in fall 2013 via NASA's Flight Opportunities Program. The company is now preparing for the system's first launch onboard a CubeSat developed by Manipal Institute of Technology. The launch is slated for spring 2014.

Seeking to lower the cost of maintaining the International Space Station's orbit, Tethers Unlimited collaborated with NASA Marshall, Northrop Grumman, Millennium Space Systems, Penn State, and the University of Michigan to develop a detailed conceptual design for an electrodynamic tether tug. Called the **PROPEL-Tug**, it could be validated using an ISS cargo craft such as the H-2 Transfer Vehicle as a launch platform and a multiton payload for demonstrating orbit-raising and deorbit maneuvers.

Tethers Unlimited looked at the feasibility of enabling nanosatellites to be launched as secondary payloads on geostationary satellite missions and then tossing them into an Earth-escape trajectory using a small momentum-exchange tether system called **NanoTHOR**. The effort, conducted under a Phase-1 grant from NASA's Innovative Advanced Concepts Program, found that a relatively simple winching maneuver could scavenge the hundreds of megajoules of orbital energy required.

In the PROPEL-Tug concept, Japan's H-2 Transfer Vehicle and a multiton payload could be used to demonstrate electrodynamic tether propulsion. Credit: Tethers Unlimited.

Under a separate grant from the same NASA program, in work led by the University of Washington, Tethers Unlimited studied the feasibility of using a high-strength tether to deliver a **planetary sampler** payload to the surface of moons and minor planets and then retrieve the sampler. Currently, the company is working with the Jet Propulsion Laboratory to develop a tether SpinCASTER mechanism and control methods that would enable deployment and retrieval of the lab's Double Asteroid Redirection Test asteroid sampling system. This team is working under a Phase-1 Small Business Innovation Research contract.

Star Technology and Research is working with subcontractors Tether Applications, the Naval Research Laboratory, and Boeing to design and develop hardware for their ElectroDynamic Delivery Express spacecraft. The craft would enable **propellantless** orbit changes and delivery of micro- and nanosatellite payloads to multiple orbits on a single launch vehicle. A design review presented by the team to NASA in August included novel emitter and solar array designs, communications systems, and space tether tracking and orbit determination. This work is part of NASA's Game-Changing Development Program.

Researchers at York University received three grants from the Natural Science and Engineering Research Council of Canada for theoretical and experimental investigations of the dynamics and control of electrodyamic tether spacecraft. This work will develop a **multiphysics model** of an electrodynamic tether system and optimal control algorithms for efficient end-of-mission deorbit.

In studies of using electrodynamic tethers for propulsion of very small satellites, in the pico- and femtosatellite size range, the University of Michigan studied very short tethers for drag makeup and repositioning. For example, a 10-m-long electrodynamic tether may be appropriate for smartphone-sized spacecraft using less than 1 W of power. Students at the university are developing a 1U, or single-unit, CubeSat mission called the Miniature Tether Electrodynamics Experiment to investigate the dynamics of this concept.

The three-year European Commission-financed **Bare Electrodynamic Tethers** project is wrapping up its research on the universal design of these tether systems for deorbiting satellites at end of life. The group completed design, manufacturing, and ground testing of a deployer, a hollow cathode, a power control module, and tape-tether subsystems suitable for a representative deorbit mission. The project also tested deployer hardware via parabolic flights. The consortium that conducted the project included three universities: Politecnica de Madrid, Padova, and Colorado State; three research institutes: ONERA-Toulouse, DLR-Bremen, and Fundacion Tecnalia), and the small company, **emxys**.

A busy year for launch providers

by Jim Knauf and the AIAA Space Transportation Technical Committee

*The **Space Transportation Technical Committee** works to foster continuous improvements to civil, commercial, and military launch vehicles.*

In 2013, the U.S. debated private sector rocket development versus NASA's Space Launch System, while Europe deliberated about Ariane's follow-on. Budgets challenged everyone, and there were some launch failures. Yet new private and public launch systems gained traction.

NASA completed the **Space Launch System** preliminary design review and made progress on manufacturing tooling and engine testing enroute to a 2017 uncrewed circumlunar flight. Orbital Sciences demonstrated its **Antares** rocket in an April launch, and in September the company launched supplies to the International Space Station using its Cygnus cargo spacecraft for the first time under a Commercial Resupply Services Contract with NASA. SpaceX launched its first **Falcon 9 v1.1** rocket, powered by the new Merlin 1D engine.

The **Air Force** and **SpaceX** signed an agreement governing Falcon 9's certification and eventual eligibility to compete for military launches. Similar agreements are pending for the Falcon Heavy and Antares. Boeing's CST-100 capsule and Sierra Nevada's Dream Chaser lifting body, both planned for Atlas launches, and the SpaceX Dragon capsule/Falcon 9 progressed toward achieving capability mid-decade under NASA's commercial crew program. NASA issued a draft request for proposals for construction and flight test leading to certification. ULA, the United Launch Alliance, made progress with Atlas 5 upgrades and pad crew access development to accommodate human spaceflight by 2016. Stratolaunch enlisted Orbital Sciences and ATK to build the air-launched **Magna rocket**, and opened an assembly/test hangar in Mojave, California.

ULA conducted 11 launches, eight using Atlas launchers and three using Deltas. The launches included a Delta 4 Heavy from Vandenberg AFB; the heaviest Atlas payload to date, a Navy-managed **Mobile User Objective System** satellite; and the first Atlas Global Positioning System launch since 1985. SpaceX completed a second operational cargo delivery to the ISS with the fifth and final Falcon 9 v1.0. Orbital Sciences launched a Minotaur 1 and Pegasus XL, the last currently on the manifest.

Twelve Russian Soyuz flights included four **Progress** cargo deliveries and four ISS crew deliveries. One of these made the first direct crew ascent, docking in hours versus two days. After four Proton successes, a government Proton-M carrying three navigation satellites failed. Earlier, a Rockot-Briz rocket left three satellites in the wrong orbit. Rockot resumed flight in September and Proton was scheduled to do so later in the year. But the string of **failures** since 2010 in the usually reliable Russian fleet prompted calls for Russian space industry reform.

After four consecutive successes since emerging from bankruptcy in 2011, Sea Launch lost a Zenit 3SL rocket because of a first-stage hydraulic pump manufacturing issue. Flights resume in 2014. A Space International Services Land Launch Zenit-3SLB flew in August. The Zenit and Proton failures and the delayed availability of Falcon 9 v1.1 caused **uncertainty** in the commercial market launch vehicle supply.

Europe flew four Arianespace Soyuz, the second Vega rocket, and four Ariane 5s, which included the fourth Automated Transfer Vehicle to the ISS. European space ministers reached consensus on a baseline configuration for the future Ariane 6.

Chinese launches included a Long March 2F with China's fifth human spaceflight to the Tiangong lab. New rocket development includes work on the Long March 5 heavy lifter to support space station and exploration programs.

Japan's pair of H-2As and an H-2B included the fourth H-2 cargo transfer vehicle to the ISS. The new Epsilon small launcher was to orbit a small space telescope in September.

The launch of KSLV-1, the **Korean** Space Launch Vehicle, marked South Korea's first orbital launch success. This was the third attempt.

On its third 2013 flight, **India's** Polar Satellite Launch Vehicle was scheduled to loft the country's first Mars orbiter by year's end. A Geosynchronous Launch Vehicle with domestic cryogenic third stage also was slated for late this year.

Virgin Galactic's Spaceship 2 achieved supersonic flight, with **suborbital** tests to take place by year's end. The company is also developing several other suborbital manned systems.

Orbital Sciences demonstrated its Antares rocket in an April launch. Credit: NASA.

The Falcon 9 Dragon awaits launch on a mission to the space station. Credit: SpaceX.

25 Years Ago, December 1988

Dec. 21 The Antonov An-225 Mriya, the heaviest airplane ever made, flies for the first time. Built for the Soviet Union's space program to accommodate a complete Buran space shuttle, the Mriya has a maximum takeoff weight of 1,322,750 lb. Powered by six 51,590-lbf Lotarev D18T turbofans, the plane is 275 ft 7 in. long with a span of 290 ft. The giant U.S. Hughes H-4 wooden flying boat known as the Spruce Goose, flown only once in a taxiing test in 1947, was longer, at 320 ft 6 in. *Air International*, March 1989, pp. 146-147.

50 Years Ago, December 1963

Dec. 2 Air Force Lt. Gen. George H. Brett, military aviation pioneer and deputy commander of the Allied Forces in the Southwest Pacific campaign during WW II, dies in Orlando, Fla., at age 77. *Aviation Week*, Dec. 9, 1963, p. 37.

Dec. 3 Air Force Col. Charles "Chuck" Yeager, the pilot who broke the sound barrier in 1947 in the Bell X-1, flies the M2-F1 experimental wingless glider, or Lifting Body, at Edwards AFB, Calif. This is the second flight of the M2-F1, which was first flown on Aug. 16, 1963, by NASA research pilot Milton Thompson. For Yeager's flight, the craft is towed up to 9,000 ft and then released from the carrier plane. Yeager glides the M2-F1 down to 4,000 ft/min, then tilts its nose up to reduce the speed for landing. The glider is one of several lifting bodies that contributed to aerodynamics research for the space shuttle. *Washington Post*, Dec. 4, 1963; M2-F1 file, NASM.

Dec. 4 The Navy reveals its new Submarine Rocket antisubmarine missile, known as Subroc. This solid-propellant submarine-launched rocket-propelled depth bomb, although never used in combat, is in service from 1965 to 1989. Once the missile rises from the water, its booster is automatically separated and the depth bomb payload continues on a ballistic trajectory toward its target. The range of the inertially guided missile is about 35 mi. Dept. of Defense Release 1536-63; *Aviation Week*, Dec. 9, 1963, pp. 33-35.

Dec. 9 The University of Tokyo opens Japan's Kagoshima Space Center on the tip of the island of Kyushu. Later renamed the Uchinoura Space Center, the site is used for launching the country's first large-scale rockets and all of its scientific satellites. The solid-propellant Lambda 2 sounding rocket is the first craft launched from the center, on Dec. 12. D. Baker, *Spaceflight and Rocketry*, pp. 159-160.

Dec. 10 Secretary of Defense Robert S. McNamara announces the cancellation of the Air Force Dyna-Soar X-20 manned aerospacecraft program. Designed by

Boeing with Air Force, NASA, and Boeing sponsorship, the ambitious Dyna-Soar was to be a piloted, maneuverable hypersonic spaceplane for gathering data on aerodynamics and reentry from orbital flights, mainly for military purposes. The full-scale craft is never completed, however. In the same announcement, McNamara gives a green light to the Air Force's Manned Orbiting Laboratory program. *Space Business Daily*, Dec. 12, 1963, p. 386; J. Miller, *The X-Planes*, p. 146-151; *Flight International*, Dec. 19, 1963, p. 1009.

Dec. 14 French aviatrix Marie Marvingt, who flew across the English Channel in a balloon in 1909 and was the first French woman to hold a pilot's license, dies at 88 in Nancy, France. She participated in many early air shows and held women's flight records for distance and endurance. *New York Times*, Dec. 16, 1963, p. 35.

Dec. 19 A solid-propellant Scout rocket launches Explorer 19, NASA's second air density balloon satellite, at Vandenberg AFB, Calif. The small, 17.8-lb spacecraft is designed to take atmospheric measurements. *Flight International*, Jan. 2, 1964, p. 34; NASA press release 63-271.

Dec. 19 It is announced that the 4,000 residents of Cape Canaveral, Fla., have decided to retain the town's original name even though its launch site was renamed the Kennedy Space Center

Past

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

in honor of the recently assassinated President John F. Kennedy. *Washington Post*, Dec. 20, 1963.

Dec. 21 From the newly renamed Kennedy Space Center, a Thor-Delta booster launches the Tiros VIII meteorological satellite. Among its advances over early weather spacecraft is the first automatic picture transmission system. This provides real-time local weather information to any area of the world having a simple, low-cost ground station. NASA press release 63-269.

75 Years Ago, December 1938

Dec. 5 A new system of radio communication for Great Britain and Northern Ireland begins operation. The system provides four types of radio services: traffic, for routine ground station communications; aircraft, including ground-to-air, air-to-air, and direction finding; meteorological; and radio beacon, for navigation. *Interavia*, Dec. 14, 1938, p. 6.

Dec. 6 A Douglas DC-3 of the Dutch airline KLM makes a special flight from Amsterdam to Pretoria, South Africa, to mark the centenary of the Boers' victory over the Kafir tribe. This flight is also an effort by KLM to take part in the air traffic to Africa. The plane carries several high Dutch government officials as well as 23,000 letters. *Interavia*, Dec. 9, 1938, p. 7.

Dec. 15 The Dept. of Labor establishes the minimum wage of 50 cents an hour for aircraft industry workers, or $20 a week for a 40-hr week. W. Shrader, *Fifty Years of Flight*, p. 66.

Dec. 17 During celebrations marking the 35th anniversary of the Wright brothers' first flight, Hugh L. Dryden of the National Bureau of Standards delivers the second Wright Brothers Lecture at Columbia University. His topic is "Turbulence and the Boundary Layer." Twenty years later, Dryden will become NASA's first deputy administrator. W. Shrader, *Fifty Years of Flight*, p. 66.

Dec. 17 The Rear Adm. William A. Moffett Memorial Trophy is awarded to the Aviation Unit of the USS Northampton for safety in flying. The silver trophy is named after the Navy Bureau of Aeronautics' chief, who died in the crash of the USS Akron airship. *Aero Digest*, February 1938, p. 28; *Aviation Year Book*, 1939, p. 469.

Dec. 28 The National Aeronautic Association names Howard Hughes the most outstanding U.S. aviator of 1938. W. Shrader, *Fifty Years of Flight*, p. 66.

Dec. 30 Italy's Angelo Tondi and Giovanni Pontonutti set two world speed records of 251.8 mph and 250.9 mph in a Savoia S.79 carrying 5,000-kg payloads for 1,000 km and 2,000 km, respectively. *Aircraft Year Book, 1939*, p. 469.

And During December 1938

—For the first time in professional hockey's history, an entire major league team is transported by air when the Detroit Red Wings fly from New York to Chicago on a United Airlines Mainliner. *Aero Digest*, January 1939, p. 35.

100 Years Ago, December 1913

Dec. 11 Sikorsky's second big airplane, the Ilya Muromets, makes its first flight, near St. Petersburg, Russia. Underpowered and difficult to handle, the plane crashes. However, its performance improves after its four 100-hp Mercedes engines are replaced with more powerful engines. On Feb. 11, 1914, the plane flies with 16 people aboard, then the largest number ever flown. In June it achieves a record day and night flight from St. Petersburg to Kiev, a distance of 1,590 mi. On the same flight, the first full in-flight meal is served. C. Gibbs-Smith, *Aviation*, p. 170; H. Nowarra and G. Duval, *Russian Civil and Military Aircraft 1884-1969*, pp. 26-27.

Dec. 17 Spain, whose Army is using airplanes in its war against Morocco, drops bombs with effect near Tetouan. *Flight*, January 1914, p. 22.

Subjects

SPACE AND ATMOSPHERIC SCIENCE

SPACE STATION

SPACE TRANSPORTATION

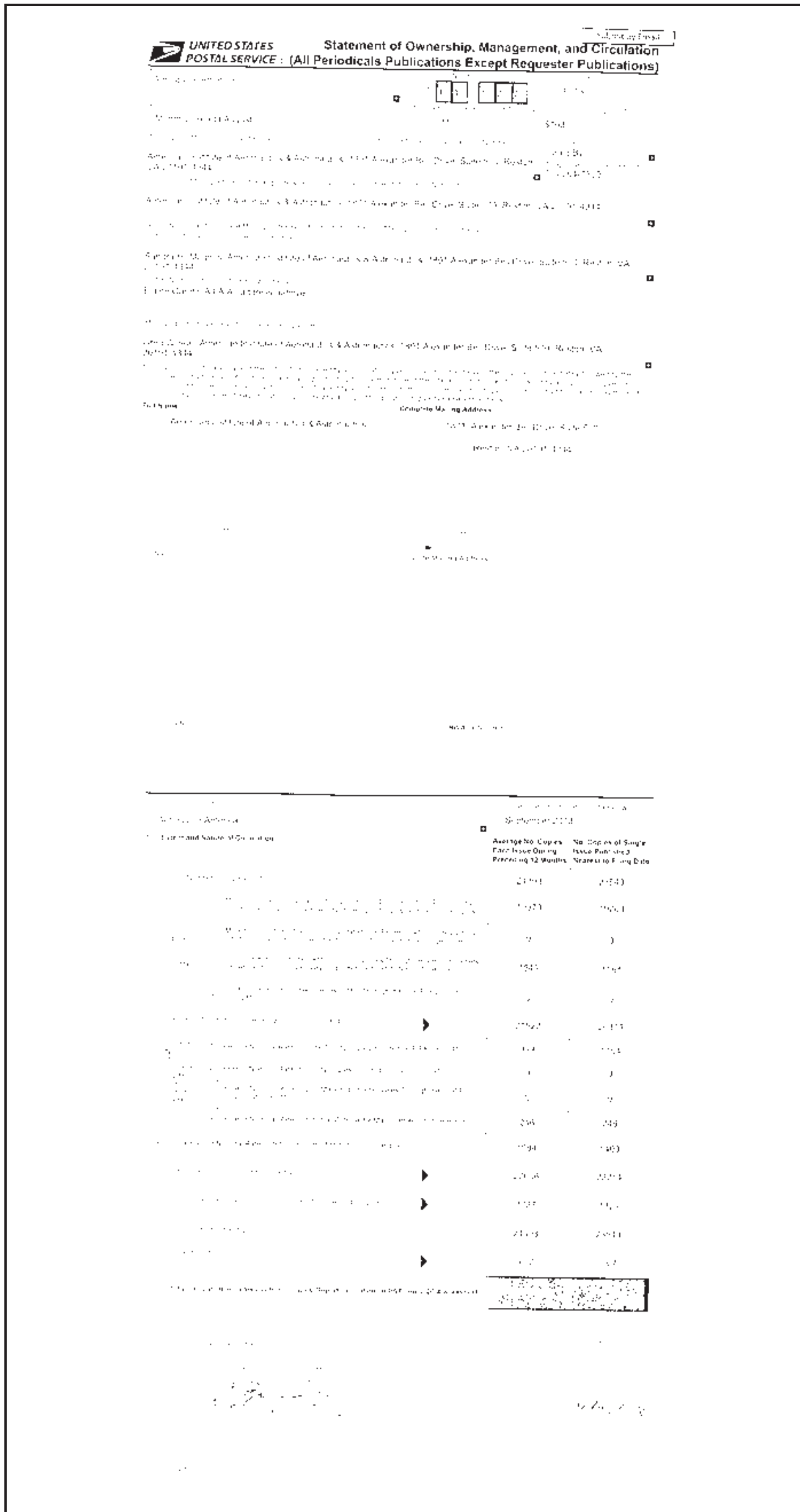
SPACECRAFT

INTERVIEWS

Authors

A

B



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TENURE-TRACK FACULTY POSITIONS AVAILABLE

The Department of Mechanical and Aerospace Engineering (MAE) at the University of Central Florida (UCF) invites applications for tenure-track Assistant Professor positions in multiple areas of Mechanical or Aerospace Engineering. Outstanding candidates with established research programs and appropriate experience may be considered for appointment at a higher level. We expect the selected applicant to establish a vibrant research program and contribute to UCF's mission of providing pre-eminent educational programs. Of particular interest are applicants with broad research and teaching interests in aerodynamics, gas dynamics and manufacturing. Preference will be given to applicants with both experimental and computational expertise. A doctoral degree from an accredited institution in a relevant Engineering field is required.

The MAE department offers B.S., M.S. and Ph.D. programs. Both BSAE and BSME programs are ABET accredited. UCF is located in Orlando, in close proximity to NASA Kennedy Space Center (KSC) and many companies. UCF is part of the Florida Center for Advanced AeroPropulsion (FCAAP), and receives benefits from the Florida HighTech Corridor matching program.

Successful candidates will also have an excellent opportunity to build collaborative partnerships with nearby industry including Lockheed Martin, Siemens, Boeing, Mitsubishi, Harris, Embraer, and Alstom as well as KSC and FCAAP. The Central Florida Research Park is located adjacent to the UCF campus and is home to the nation's largest cluster of government agencies and industries specialized in training and simulation R&D. For more details regarding the department, visit www.mae.ucf.edu or contact Jay Kapat, Chair of MAE Search Committee, maefacsearch@ucf.edu.

Applications should be submitted through www.jobswithucf.com (Search Jobs > Keyword: 36266). Review of applications will begin on December 15, 2013 and will continue until the positions are filled. Along with the application, candidates should submit a: a) cover letter, b) curriculum vitae, c) brief research plan, d) one page statement of your teaching philosophy, and e) list of names and contact information of at least four references.

EEO/AA Policy: The University of Central Florida is an equal opportunity/ affirmative action 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
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Suite 500
Reston, VA 20191-4344

AIAA

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING-DEPARTMENT CHAIR

UNIVERSITY OF CENTRAL FLORIDA

The College of Engineering and Computer Science at the University of Central Florida (UCF) solicits applications and nominations for the position of Chair of the Department of Mechanical and Aerospace Engineering (MAE). A doctorate in an appropriate engineering discipline or a closely related field is required, as is a distinguished record of scholarship, teaching, research funding, and professional visibility. Administrative experience is highly desirable. UCF is located on a beautiful, modern campus in a suburban setting just outside Orlando. Enrollment is approximately 60,000 at the 2rd largest university in the U.S. The MAE Department is home to 26 full-time faculty, several lecturers and adjuncts, and a Center for Advanced Turbines and Energy Research (CATER). The reputation of the department is continually growing with numerous faculty achievements including NSF CAREER awards, an ONR Young Investigator award, and fellowships in professional societies. The annual research expenditures of the department are nearly $6 million with funding from both industries and government agencies. Areas of strength include energy, turbomachinery, biofluids, nanomaterials and composites, manufacturing, and mechanical systems and control (www.cecs.ucf.edu/mae). Opportunities abound for multidisciplinary research with other academic and research units at UCF, including the new College of Medicine and several research centers at UCF. Opportunities for collaboration and industry partnership exist with Alstom, Harris, Lockheed Martin, Pratt and Whitney, Progress Energy, SAIC, Siemens, and over 100 high-tech companies in a research park near the UCF campus.

The MAE Chair will provide leadership and vision that builds on the strengths of the department; identifies promising new programs and initiatives; and encourages innovation, creativity, collaboration, and professional growth for the faculty, staff, and students. Under the Chair's direction, the department is expected to participate in cutting-edge, multidisciplinary research and to contribute substantially to the growing reputation of the College of Engineering and Computer Science (CECS) for excellence in research, education, and professional service. Applications must be submitted electronically at: www.jobswithucf.com (Search Jobs > Keyword: 33396) and should include a cover letter; a complete CV; and a one-page vision statement. Nominations may be sent to: Dr. Ranganathan Kumar (Ranganathan.Kumar@ucf.edu), Associate Dean for Research, College of Engineering & Computer Science, University of Central Florida. P.O. Box 162993, Orlando, Florida 32816-2993. Screening of applications will begin December 1, 2013. The position is expected to be filled by August 2014. UCF is an Equal Opportunity/Affirmative Action employer.

THE UNIVERSITY OF ALABAMA

DEPARTMENT OF AEROSPACE ENGINEERING AND MECHANICS

Seeks applications for three tenure-track faculty positions

The Department of Aerospace Engineering and Mechanics at The University of Alabama invites applications for three tenure track faculty positions. While all applications will be considered, highest priority will be given to candidates with expertise in a) astronautics, b) composite and multifunctional materials, or c) computational modeling and simulation of phenomena relevant to flight vehicles. It is anticipated that successful candidates will join the faculty at the rank of tenure-track Assistant Professor, although exceptional candidates may be considered for higher rank depending upon experience and qualifications.

With 14 tenured and tenure-track faculty members, the AEM department enrolls 200+ undergraduate students in the ABET-accredited BSAE program and 50+ graduate students in the MS and PhD programs. The AEM department is currently experiencing an era of unprecedented growth and expansion. The AEM department benefits from the University's rapid expansion in terms of facilities, including the recent construction of the $300 million Engineering and Science Quad. This four building complex provides over 900,000 square feet of state-of-the-art research and instructional space, the majority of which is devoted to the College of Engineering.

The University of Alabama is located on a beautiful 1,168 acre residential campus in Tuscaloosa, a dynamic and resilient community of over 150,000. The Tuscaloosa community provides rich cultural, educational, and athletic activities for a broad range of lifestyles. With technology-oriented government/industrial research centers (including the U.S. Army's Redstone Arsenal and the NASA Marshall Space Flight Center) in north Alabama and a growing aviation industrial sector (including Airbus aircraft manufacturing and engineering centers) in south Alabama, The University of Alabama is centrally located in Alabama's north-south aerospace corridor.

Applicants must have an earned doctorate degree in aerospace engineering or a closely related field. Applicants are to submit: a letter of application, a detailed CV, statement of teaching and research interests, and contact information for at least three professional references. Successful applicants are expected to: develop a strong externally funded research program, demonstrate a commitment to excellence in teaching and mentoring of students, and provide service to the profession, university, college and AEM department. All application materials must be submitted via The University of Alabama's employment website (http://facultyjobs.ua.edu/postings/34373). Review of applications will begin immediately and continue until the positions are filled. Inquiries should be addressed to Dr. Semih Olcmen, Department of Aerospace Engineering and Mechanics, Box 870280, The University of Alabama, Tuscaloosa, Alabama 35487-0280 or sent by e-mail to solcmen@eng.ua.edu.

Qualified women and minorities are encouraged to apply. The University of Alabama is an equal opportunity, affirmative action, Title IX, Section 504, ADA employer. Salary will be competitive and commensurate with experience level.

ASSISTANT PROFESSOR
Control of Human-Robot Collaborative Systems

THE DEPARTMENT OF AEROSPACE ENGINEERING & ENGINEERING MECHANICS AT THE UNIVERSITY OF TEXAS AT AUSTIN is seeking highly qualified candidates for a tenure-track faculty position with emphasis on control and estimation theory for aerospace human-robot collaborative systems. Particular focus will be placed on qualified candidates working in the areas of human decision modeling, dynamics of knowledge acquisition, machine learning, opportunistic/probabilistic perception, human-machine interface, cognitive science, and computational neuroscience, with controls applications to semi-autonomous aerospace vehicles and robotic agents.

This position has a September 2014 target start date. The successful candidate for this position is expected to supervise graduate student research, teach undergraduate and graduate level courses in the guidance, navigation and controls areas, develop and maintain a strong and active sponsored research program, collaborate with other faculty, and be involved in service to the department, university, and the engineering profession. Applicants for this position should have received, or expect to receive a doctoral degree in engineering, or a related discipline, prior to September 2014. Applications received by **January 15, 2014** are assured full consideration, but the search will continue until the position is filled. This position has been designated as security-sensitive, and a criminal background check will be conducted on the applicants selected.

To apply, submit an application online at
http://www.ae.utexas.edu/faculty/faculty-openings.
Only complete applications will be considered.

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.

DIRECTOR
CENTER FOR SPACE RESEARCH

The Department of Aerospace Engineering and Engineering Mechanics at The University of Texas at Austin seeks applicants to fill an endowed chair position. This senior leadership position requires recognized expertise in areas such as satellite geodesy, precision orbit determination, astrodynamics, multispectral remote sensing and related multi-disciplinary fields. He/she will serve as Director of the Center for Space Research, which is a major research center with a staff of approximately 100 members. The Director will be responsible for establishing the Center goals and leading efforts to ensure continuation of the multi-decadal research efforts, and grow new areas of center expertise. He/she should have extensive experience with contemporary large-scale research programs, modern space missions, and/or comprehensive analysis of satellite data. The chair holder is expected to teach graduate and undergraduate courses, maintain an internationally recognized sponsored research program, supervise graduate students, collaborate with other faculty in and beyond UT, and be involved in service to the university and the profession.

Applications received by **January 15, 2014** 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 a doctoral degree in aerospace engineering or a related discipline.

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 Positions

Department of Aerospace Engineering
Dwight Look College of Engineering
Texas A&M University

The Department of Aerospace Engineering in the Dwight Look College of Engineering is continuing to strategically increase in size and strength. This trend supports the University's program to increase access for qualified students to pursue engineering education at Texas A&M University (http://engineering.tamu.edu/25by25). This year, the Department invites applications for **two open-rank tenure-track positions** at the assistant professor, associate professor, or professor levels from exceptional individuals who have demonstrated expertise in one of the following aerospace disciplines:

1. Aerothermal sciences with applications to aerospace systems.

2. Autonomous aerospace systems, rotorcraft systems, or sensing systems.

3. Aerospace structures and advanced multifunctional or extreme-environment materials.

Applicants who apply a balanced approach among theory, computation, and experiment, or who bridge the above disciplines are especially encouraged to apply. The successful candidate will have the opportunity to collaborate with renowned colleagues whose research thrust areas include transition and turbulence, combustion and propulsion, multifunctional or extreme-environment materials, advanced computations and diagnostics, autonomous systems, space systems and satellites, and high-speed vehicle systems.

Applicants must have earned a doctorate in aerospace engineering or a closely related field. The successful candidate will be expected to teach at the undergraduate and graduate levels; develop and sustain an independent, externally-funded research program; mentor graduate students; and provide service to the university and professional community.

Information on the University, the Dwight Look College of Engineering, and the Department of Aerospace Engineering can be found at tamu.edu (university), engineering.tamu.edu (college) and aero.tamu.edu (department). Applicants should submit a cover letter, a detailed resume, a statement of their research and teaching interests, and the names and contact information of five references to Dr. John Hurtado, Chair of the Search Committee, Department of Aerospace Engineering, Texas A&M University, 3141 TAMU, College Station, TX 77843-3141; jehurtado@tamu.edu. Full consideration will be given to applications received by December 15, 2013. Applications received after this date may be considered until positions are filled. Appointments are anticipated to be filled for the Fall 2014 semester.

The members of Texas A&M Engineering are all Affirmative Action/Equal Employment Opportunity Employers. It is the policy of these members in all aspects of operations each person shall be considered solely on the basis of qualifications, without regard to race, color, sex, religion, national origin, age, disabilities or veteran status.

UNIVERSITY OF CALIFORNIA IRVINE

The Mechanical and Aerospace Engineering Department invites applications for a tenure-track, assistant professor position in Flight Systems. We seek candidates with (i) expertise in dynamics, control, and optimization, (ii) research directed at a flight system, combining experiments with theory and modeling, (iii) high potential for world-class research and attracting students and funding, and (iv) commitment and capability to contribute to the educational mission of the Department. A doctoral degree in aerospace engineering or a closely related engineering field is required.

To ensure full consideration for the first round of interviews, applications should be received by February 1, 2014. The search will continue until the position is filled. Completed applications containing a cover letter, curriculum vitae, three to five letters of recommendation, and copies of three principal publications should be uploaded electronically.

Please refer to the following website for instructions:

https://recruit.ap.uci.edu/apply/JPF02170

Information about the department can be found at:

http://mae.eng.uci.edu.

UCI is an equal opportunity employer committed to excellence through diversity and strongly encourages applications from all qualified applicants, including women, minorities and other under-represented groups. UCI is a recipient of an NSF ADVANCE award for gender equity; responsive to the needs of dual career couples; and committed to work-life balance through an array of family-friendly policies.

UNIVERSITY OF MARYLAND 1856

INSTITUTE FOR SYSTEMS RESEARCH
A. JAMES CLARK SCHOOL OF ENGINEERING

FACULTY POSITION IN MODEL-BASED SYSTEMS ENGINEERING

The Institute for Systems Research (ISR) and the A. James Clark School of Engineering at the University of Maryland, College Park, invite applications for a tenure-track assistant professor position in Model-Based Systems Engineering (MBSE). We seek applicants with a doctoral degree who have research expertise in MBSE, formal approaches to engineering design and validation, requirements engineering, and multi-objective optimization and trade-off analysis, with appropriate connections to an engineering and/or biological domain.

This position is tenure track in a Clark School department (Aerospace, Electrical and Computer, Fire Protection, Mechanical, Civil and Environmental, Chemical and Biomolecular, Materials Science and Engineering, or Bioengineering) with a joint appointment to the ISR. The tenure home for this appointment will be in the department, and the ISR and its Director will also review the candidate's dossier.

The position holder will contribute to teaching systems engineering, advise systems engineering students for their theses, and develop new systems engineering courses. With regard to research responsibilities, the position holder will propose and conduct MBSE methodology and tools research that improves the ability to conceive, design and analyze complex multi-domain systems and will collaborate with other ISR faculty researchers to incorporate MBSE methods into ISR multi-disciplinary research.

The Clark School's (**www.eng.umd.edu**) graduate programs collectively rank 19th nationally (11th among public universities) in U.S. News & World Report's "America's Best Graduate Schools 2014." In 2013 the Academic Ranking of World Universities ranked the Clark School programs 16th in the world. ISR (**www.isr.umd.edu**), an original NSF ERC, celebrates 27 years of multi-disciplinary research in cooperation with universities, government, and industry. With annual expenditures exceeding $20M, it conducts interdisciplinary research and provides education in systems engineering and sciences; and devises basic solution methodologies and tools for systems problems in disparate application domains. ISR has 38 joint appointment faculty; 27 affiliate faculty; and eight research scientists from four colleges and 14 units across the University of Maryland.

Prospective candidates should demonstrate the required expertise and apply with:

1) A cover letter; 2) Curriculum vitae; 3) Teaching and research statements; 4) Three relevant scientific papers; 5) List of references

TO APPLY: Please visit (**ejobs.umd.edu**) and find posting #105839. For best consideration, submit applications by January 31, 2014; the position remains open until filled. The University of Maryland is an EEO/AA employer. We strongly encourage women and minorities to apply.

TENURE-TRACK FACULTY POSITION OPENING

The William E. Boeing Department of Aeronautics & Astronautics at the University of Washington invites applications for a full-time tenure-track faculty position. We are primarily focused on hires at the Assistant or Associate professorial ranks, although individuals at senior ranks with exceptional credentials may be considered. Particular areas of interest in the aeronautics and astronautics fields include guidance, navigation, and control systems, fluid mechanics, propulsion, structures, and space systems. The area of plasma physics is of interest as well. Candidates with research interests in other, emerging areas related to aerospace engineering are also encouraged to apply. Applicants must have earned a PhD or foreign equivalent in an appropriate engineering or related discipline by the date of appointment.

The Department is committed to excellence in research and teaching, with the expectation that all University of Washington faculty engage in teaching, research and service. The successful candidate will be expected to develop a vigorous and innovative externally-funded research program, provide high-quality teaching that integrates research with instruction at both the undergraduate and graduate levels, and participate in service activities. He/she will complement our existing research strengths, interact with various research groups within the Department, and provide a bridge between Aeronautics & Astronautics and other disciplines.

Applications should include a letter of application, a CV with a list of publications, concise statements of research and teaching interests and program-development goals, and the names and contact information of five professional references. 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:

www.engr.washington.edu/facsearch/apply.phtml?pos_id=141

The position will be open until filled, but we expect interviews to begin in February 2014. For any administrative issues related to this search, please contact the A&A Department Search Committee, at search@aa.washington.edu.

The William E. Boeing Department of Aeronautics & Astronautics is one of the original aerospace engineering departments in the nation, and the only one of its type in the Pacific Northwest, a region whose extensive aerospace industry continues to be a major contributor to the technological development, economic vitality, and security of the United States. Under its strategic plan the department has been building strength in the multidisciplinary areas of aircraft systems, space systems, and energy systems, while continuing to pursue basic research in areas of fundamental importance to aeronautics and astronautics. For information about the department, please visit http://www.aa.washington.edu.

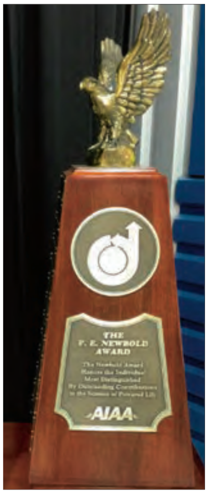
The University of Washington is an affirmative action, equal opportunity employer. The University is building a culturally diverse faculty and staff and strongly encourages applications from women, minorities, individuals with disabilities, and covered veterans. The University is the recipient of a 2006 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.

AIAA Bulletin

Above: William (Bill) Lewis, right, receives a replica of the F.E. Newbold Award from David Eames, AIAA representation and Rolls-Royce Indianapolis employee.

The AIAA 2013 F.E. Newbold V/STOL Award was presented to retired Rolls-Royce Bristol employee, William J. (Bill) Lewis in recognition of over 30 years of leadership and advocacy of supersonic V/STOL aircraft within Rolls-Royce and throughout the US/UK aerospace industry.

The AIAA F.E. Newbold Award trophy (pictured on right) is now on display in The Rolls-Royce Heritage Trust (RRHT) museum in Indianapolis, IN. Information about the RRHT-Indianapolis can be found at http://www.rolls-royce.com/about/heritage/heritage_trust/branches/indianapolis_branch.jsp



DECEMBER 2013

AIAA Directory

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www.aiaa.org

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* 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.

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
	11th AIAA/ASME Joint Thermophysics and Heat Transfer Conference **21st AIAA Lighter-Than-Air Systems Technology Conference** **15th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference** **AIAA Modeling and Simulation Technologies Conference** **45th AIAA Plasmadynamics and Lasers Conference** **7th AIAA Theoretical Fluid Mechanics Conference**		
22–27 Jun†	**12th International Probabilistic Safety Assessment and Management Conference**	Honolulu, HI (Contact: Todd Paulos, 949.809.8283, secretariat@psam12.org, www.psam12.org)	
13–17 Jul†	**International Conference on Environmental Systems**	Tucson, AZ (Contact: Andrew Jackson, 806.742.2801 x230, Andrew.jackson@ttu.edu, http://www.depts.ttu.edu/ceweb/ices/)	
15–18 Jul†	**ICNPAA 2014 – Mathematical Problems in Engineering, Aerospace and Sciences**	Narvik University, Norway (Contact: Seenith Sivasundaram, 386.761.9829, seenithi@aol.com, www.icnpaa.com)	
28–30 Jul	**Propulsion and Energy 2014** **(AIAA Propulsion and Energy Forum and Exposition)** **Featuring:** **50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference** **12th International Energy Conversion Engineering Conference**	Cleveland, OH	**14 Jan 14**
2–10 Aug†	**40th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events**	Moscow, Russia http://www.cospar-assembly.org	
5–7 Aug	**SPACE 2014** **(AIAA Space and Astronautics Forum and Exposition)** **Featuring:** **AIAA/AAS Astrodynamics Specialist Conference** **AIAA Complex Aerospace Systems Exchange** **32nd AIAA International Communications Satellite Systems Conference** **AIAA SPACE Conference**	San Diego, CA	**21 Jan 14**
7–12 Sept†	**29th Congress of the International Council of the Aeronautical Sciences (ICAS)**	St. Petersburg, Russia (Contact: www.icas2014.com)	**15 Jul 13**
29 Sep–3 Oct†	**65th International Astronautical Congress**	Toronto, Canada (Contact: http://www.iac2014.org/)	
2015			
5–9 Jan	**AIAA SciTech 2015** **(AIAA Science and Technology Forum and Exposition 2015)** **Featuring:** **23rd AIAA/ASME/AHS Adaptive Structures Conference** **53rd AIAA Aerospace Sciences Meeting** **AIAA Atmospheric Flight Mechanics Conference** **AIAA Spacecraft Structures Conference (formerly the AIAA Gossamer Systems Forum)** **AIAA Guidance, Navigation, and Control Conference** **AIAA Modeling and Simulation Technologies Conference** **11th AIAA Multidisciplinary Design Optimization Specialist Conference** **17th AIAA Non-Deterministic Approaches Conference** **56th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference** **8th Symposium on Space Resource Utilization** **33rd ASME Wind Energy Symposium**	Kissimmee, FL	

For more information on meetings listed above, visit our website at www.aiaa.org/calendar or call 800.639.AIAA or 703.264.7500 (outside U.S.).

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

AIAA Continuing Education courses.

Event & Course Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
2014			
11 Jan	**1st AIAA Sonic Boom Prediction Workshop**	National Harbor, MD	
11 Jan	**Low Reynolds Number Workshop**	National Harbor, MD	
11–12 Jan	**Decision Analysis**	National Harbor, MD	
12 Jan	**Introduction to Integrated Computational Materials Engineering**	National Harbor, MD	
13–17 Jan	**AIAA SciTech 2014** **(AIAA Science and Technology Forum and Exposition 2014)** **Featuring:** **22nd AIAA/ASME/AHS Adaptive Structures Conference** **52nd AIAA Aerospace Sciences Meeting** **AIAA Atmospheric Flight Mechanics Conference** **AIAA Guidance, Navigation, and Control Conference** **AIAA Modeling and Simulation Technologies Conference** **10th AIAA Multidisciplinary Design Optimization Specialist Conference** **16th AIAA Non-Deterministic Approaches Conference** **AIAA Spacecraft Structures Conference (formerly the AIAA Gossamer Systems Forum)** **55th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference** **7th Symposium on Space Resource Utilization** **32nd ASME Wind Energy Symposium**	National Harbor, MD	**5 Jun 13**
26–30 Jan†	**24th AAS/AIAA Space Flight Mechanics Meeting**	Santa Fe, NM Contact: http://www.space-flight.org/docs/2014_winter/2014_winter.html	**2 Oct 13**
27–30 Jan†	**Annual Reliability and Maintainability Symposium (RAMS) 2014**	Colorado Springs, CO (Contact: Jan Swider, 818.586.1412, jan.swider@pwr.utc.com)	
Feb–June	**Advanced Computational Fluid Dynamics**	Home Study	
Feb–June	**Computational Fluid Turbulence**	Home Study	
Feb–June	**Introduction to Computational Fluid Dynamics**	Home Study	
Feb–June	**Missile Design and System Engineering**	Home Study	
Feb–June	**Spacecraft Design and Systems Engineering**	Home Study	
2–6 Feb†	**American Meteorological Society Annual Meeting**	Atlanta, GA (Contact: Claudia Gorski, 617.226.3967, cgorski@ametsoc.org, http://annual.ametsoc.org/2014/)	
1–8 Mar†	**2014 IEEE Aerospace Conference**	Big Sky, MT (Contact: Erik Nilsen, 818.354.4441, erik.n.nilsen@jpl.nasa.gov, www.aeroconf.org)	
24–26 Mar†	**49th International Symposium of Applied Aerodynamics**	Lille, France (Contact: Anne Venables, 33 1 56 64 12 30, secr.exec@aaaf.asso.fr, www.3af-aerodynamics2014.com)	
30 Apr	**2014 Aerospace Spotlight Awards Gala**	Washington, DC	
5–9 May	**SpaceOps 2014: 13th International Conference on Space Operations**	Pasadena, CA	**5 Aug 13**
26–28 May	**21st 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)	
5 Jun	**Aerospace Today ... and Tomorrow: An Executive Symposium**	Williamsburg, VA	
16–20 Jun	**AVIATION 2014** **(AIAA Aviation and Aeronautics Forum and Exposition)** **Featuring:** **20th AIAA/CEAS Aeroacoustics Conference** **30th AIAA Aerodynamic Measurement Technology and Ground Testing Conference** **AIAA/3AF Aircraft Noise and Emissions Reduction Symposium** **32nd AIAA Applied Aerodynamics Conference** **AIAA Atmospheric Flight Mechanics Conference** **6th AIAA Atmospheric and Space Environments Conference** **14th AIAA Aviation Technology, Integration, and Operations Conference** **AIAA Balloon Systems Conference** **AIAA Flight Testing Conference** **7th AIAA Flow Control Conference** **44th AIAA Fluid Dynamics Conference** **20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference**	Atlanta, GA	**14 Nov 13**

From the Corner Office

THE NEED FOR AN R&D INVESTMENT STRATEGY

JIm Albaugh, AIAA President-Elect

It is with great anticipation that I prepare to serve you as the President of AIAA, coming at what I believe is an important period for our nation and industry. In the coming years I will use this column to explore issues impacting AIAA and U.S. aerospace leadership. Of foremost concern currently is the issue of R&D spending, the defense industrial base (DIB), and the impact on not only the nation, but also the global community.

We are all fortunate to work in this great industry. While creating over 56 million jobs worldwide, aerospace connects and protects the world, brings people together to collaborate on national and global challenges, and ultimately promotes a greater understanding of different cultures and points of view. Today the United States is the global leader in aerospace. We build the world's most capable and efficient airplanes, spacecraft, and weapons—systems that are second to none. As current AIAA President Mike Griffin and Executive Director Sandy Magnus have shared in this column and other publications, despite this leadership position, U.S. aerospace preeminence is threatened, and with it our public security, our still recovering economy, and our profession and industry's future. There is surprisingly little public dialogue on what is at stake or even a sense of commitment to maintaining a leadership role.

While other countries are investing aggressively in aerospace and defense, the United States is doing the opposite. Our politicians are focused on what to cut, not how to grow. As an example, Department of Defense budget reductions are staggering by any measure, estimated to be half a trillion dollars over the next 10 years with over $30 billion in R&D cuts over the next half decade alone. In the area of defense systems, there is clearly a national impact. But equally important is the resulting effect on the global economy and other technical capabilities that depend on multinational collaboration and civilian applications of technical advancements. When extrapolated across all government-funded R&D, this grossly reduced level of R&D spending will delay or eliminate many potential breakthroughs in other areas such as Earth observation, global navigation, and reduction in terrorism—in effect shackling innovation and dampening inspiration nationally and worldwide.

Although the funding outlook is uncertain, looking at the current state of our industry there are still many positives. In an area near and dear to me, there is a strong and growing commercial aviation market with a demand for over 35,000 new passenger airplanes and freighters worth almost $5 trillion in sales over the next 20 years. This added global capacity will enable the transportation of people, goods, and services that will benefit humanity worldwide. And it's not just in commercial aviation, one only need look to the recent successes of commercial space ventures to show that there is still much that can and will be accomplished with the dedication of investments and resources.

Our proud national legacy as a leader in aerospace and our current success, however, do not guarantee our preeminence tomorrow. For example, the traditional duopoly between Boeing and Airbus in the passenger aircraft market is being challenged by competition from China, Canada, Russia, Japan, and Brazil. While not all entrants into this market will be commercially successful, some of them certainly will. To maintain a leadership position in this area the answer is very simple: continue to build the world's most capable aerospace systems through technical leadership. Maintaining that capability in a competitive environment is beneficial to all customers and users because it strengthens and improves the products of all manufacturers. If the United States stops innovating while others continue, we here in the United States lose in the near term and, really, everyone loses in the long run.

The lack of a long-term investment mindset in R&D, exacerbated by the absence of political fortitude to underpin R&D imperatives for aerospace is a formidable obstacle that impedes our profession's skills from being applied to the world's most vexing challenges. As given voice by Sandy in her 21 October 2013 *Space News* opinion "Ransoming Our Future," the failure of U.S. leaders to "focus on the future and implement a long-term vision" for aerospace and defense R&D is letting our industrial base atrophy, pushing R&D overseas, allowing our infrastructure to decay, and losing critical capabilities. All this comes at our own national peril but also has a lasting global impact. There is little recognition of the fragile nature of the our DIB, which enabled the United States and its allies to prevail over 20th-century tyrants, put a man on the moon, and established worldwide leadership in aviation and space It also provided additional benefits to global security and commercial applications to universal advancements in global communications, weather monitoring, and disaster relief.

Many believe that just because defense products are being manufactured that the DIB is healthy. On the contrary, to have a strong DIB one must have a contractor base that understands how to conduct R&D effectively, how to take that R&D and move it efficiently into detailed design, how to transition those designs into production, and, ultimately, how to manage a supply chain and deliver products, not just manufacture products.

A strong industrial base is not a given. It is the product of the right policies, robust long-term investments, a well-defined set of priorities, and, of course, time. With reduced R&D spending in aerospace and defense and very few new program starts, our industry is jeopardizing its development capabilities as well as its ability to transition design into manufacturing and ultra-reliable products. Once this comprehensive development capability is gone, it will be difficult to rebuild.

Most every nation that is serious about sustaining and strengthening its aerospace industry has established a broad DIB policy. In the United States our policy is one of market forces, driven increasingly by budget considerations. While a policy should not define specific outputs and production, it needs to define and underpin the long-term viability of our defense industrial base, including the ability to preserve the development of critical technologies, capabilities, and skills.

A debate among government, industry, and academia facilitated by technical societies like AIAA would be a good place to start. Starting that debate itself is a challenge because of continued government travel restrictions, technical conference participation limitations, and the fiscal hesitancy for all parties to participate. Getting this right will require a bold commitment by all parties. It is critical to both our nation's long-term economic and national security and to maintain the leadership of global enterprises addressing challenges too large and complex for any single entity to address.

These and other issues such as ensuring a level playing field for global competition, the role of government in supporting critical technologies, workforce development and retention, support for critical infrastructure, and the environment must also be discussed, debated, and addressed by the government and our technical community. This column will continue to provide a window into these debates. Likewise the upcoming AIAA SciTech 2014 with its fundamental focus on R&D, but also all of AIAA's new forums going forward, will focus and shape the debate on innovation and a future aerospace profession we should all continue to feel fortunate to call our own.

CALL FOR PAPERS FOR *JOURNAL OF AEROSPACE INFORMATION SYSTEMS*

Special Issue on "Aerospace Human–Automation Interaction"

The *Journal of Aerospace Information Systems* is devoted to the applied science and engineering of aerospace computing, information, and communication. Original archival research papers are sought that include significant scientific and technical knowledge and concepts. In particular, articles are sought that demonstrate the application of recent research in human–automation interaction to a wide range of practical aerospace problems in the analysis and design of vehicles, on-board avionics, ground-based processing and control systems, flight simulation, and air transportation systems.

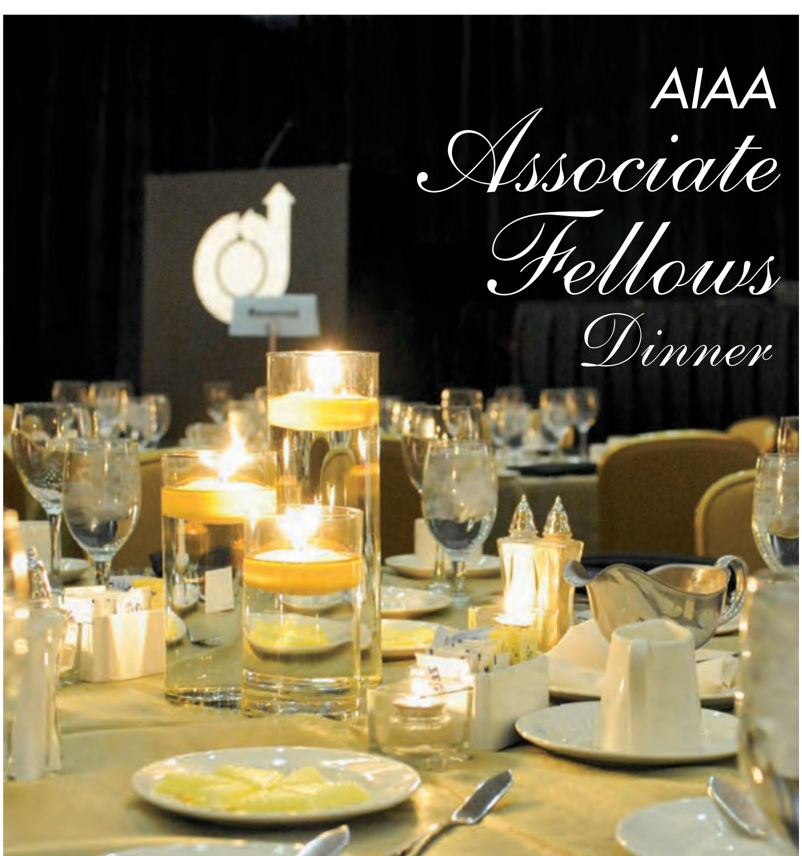
Information about the organizers of this special issue as well as guidelines for preparing your manuscript can be found in the full Call of Papers under Featured Content in Aerospace Research Central; arc.aiaa.org. The journal website is **http://arc.aia.org/loi/jais**.

Key research areas included in the special issue are:

- *Metrics and Measures*, including real-time measures or techniques to measure mission effectiveness, function allocation, observability, mental models, and situation awareness.
- *Personification issues of advanced automation*. Should intelligent systems behave as agents with a personality and autonomy, or should advanced automation be built and used as a tool?
- *Novel analysis techniques for verification of automation, human, vehicle/device, and environment interaction*: including formal modeling, simulation, and the use of virtual environments. Certification of systems with human operators and advanced intelligent automation.
- *Design Methods*, including methods for the inclusion of etiquette into automation design, automation awareness of its own boundaries and limitations, and interfaces for static and adaptive automation
- *Human interaction aspects of future developments in automation for ATC and aircraft*, including monitoring systems, delegation of authority, and certification issues with advanced and adaptive automation.
- *Roles and effects of automation in all aspects of training*, including on skill development, college curricula, and certification of designers and engineers working on human–automation interaction as well as certification of operators and personnel working with advanced automation.
- *Joint Cognitive Systems*, collaboration and joint decisions taken by humans and automation, compatibility of automation, and human decisions and actions.

These areas are only indicative. Also, the special issue is open to manuscripts that are relevant to the applied science and engineering of aerospace computing, information, and communication in systems with human–machine interaction but do not fit neatly into any of the above areas. We do envisage, however, that successful manuscripts will include experimental results, sophisticated simulations of aerospace systems, or (in the case of a paper in the areas of education or policy) well-researched and thorough arguments for policies and their implementations.

Deadline: Submissions are due by **15 May 2014**.
Anticipated Publication Date: **September 2014**.
Contact Email: Karen Feigh, Karen.feigh@gatech.edu or René van Paassen M.M.vanPaassen@TUDelft.nl



165 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 hours, Monday, 13 January 2014, at the Gaylord National Hotel and Convention Center, National Harbor, Maryland.

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 2014 Associate Fellows. Tickets to this celebrated event are available on a first-come, first-served basis and can be purchased for $100 via the AIAA SCITECH 2014 registration form or onsite based on availability. Business attire is requested.

AIAA
The World's Forum for Aerospace Leadership

14-106

Dr. Sandra Magnus' Visit to St. Louis

Karen Copper

On 10 October, Boeing hosted Dr. Magnus on a tour of the Boeing St. Louis facility, visiting the F-15 Eagle and F/A-18 Super Hornet assembly areas. It was a personal homecoming as the tour also included the Compact Range Test Facility in which Dr. Magnus worked for McDonnell Douglas Aircraft Company as a stealth engineer, working on internal research and development and later the Navy's A-12 Attack Aircraft program. Dr. Magnus commented that being in the facility again and seeing everyone brought back many great memories.

Sandy and current Boeing employees with whom she worked in the Near Field Test Facility, L-R Paul Pericich, Tom Mroczkowski, Melba Pulaski, Tom Burbridge, Jeff Ackerman, Larry Brase, Sandy Magnus, Dave Betterly, Wayne Crouch

Sandy also met with Chair Frank Youkhana's AIAA St. Louis Section Council during a working lunch. Her message focused on the current state of the aerospace industry and the role

Dr. Sandra Magnus at head of table, CW from Sandy: Larry Brase, Trent Duff, John Donigan, Daniel Caraway, Rudy Yurkovich, Frank Youkhana, Ryan Rudy, Brad Sexton, David Riley

that AIAA must fill to ensure a strong and vibrant future for the industry. The Section was encouraged to engage members and their technical managers in understanding the vital role they play in AIAA conferences in communicating their industry needs to members of the academia and government.

Later in the day, the Boeing St. Louis auditorium filled to capacity as over 200 AIAA members, guests, and students listened to former astronaut Dr. Sandra Magnus share her perspectives on space. Dr. Magnus' NASA career included 159 days in space traveling more than 60-million miles orbiting the Earth more than 2660 times. She performed critical functions in Missions STS-112, STS-126, and STS-135/ULF7.

Dr. Magnus during presentation.

After Dr. Magnus' talk, she spoke with AIAA members and students.

New Lectureship in Aerospace Engineering Seeks Nominees!

The Yvonne C. Brill Lectureship in Aerospace Engineering has been established in the memory of Yvonne Brill, pioneering rocket scientist, AIAA Honorary Fellow, and NAE member. Nominations are now being solicited for the inaugural lectureship in September 2014. The ideal nominee should have a distinguished career involving significant contributions in aerospace research and/or engineering and will be selected based on technical expertise, originality, and influence on other important aerospace issues such as ensuring a diverse and robust engineering community. NAE or AIAA members are eligible to place a nomination. Contact carols@aiaa.org to request the nomination form. Nominations are due to AIAA on or before **15 December 2013**.

SPACE 2014

5–7 AUGUST 2014

SAN DIEGO, CALIFORNIA

FEATURING

AIAA/AAS ASTRODYNAMICS SPECIALIST CONFERENCE

AIAA COMPLEX AEROSPACE SYSTEMS EXCHANGE

32ND AIAA INTERNATIONAL COMMUNICATIONS SATELLITE SYSTEMS CONFERENCE

IMPORTANT DATES

Abstract Manuscript Deadline
21 January 2014

Author Notification
26 March 2014

Final Manuscript Deadline
14 July 2014

CONFERENCE OVERVIEW

The AIAA Space and Astronautics Forum and Exposition is AIAA's premier event on space technology, policy, programs, management, and education. At this three-day event, attendees can expect lively discussions with government and industry leadership in plenary panel and keynote sessions; interactive exhibits, demonstrations, presentations, and poster sessions in the exposition hall; and networking activities for all participants, including students and young professionals.

SPONSORSHIP AND EXHIBIT OPPORTUNITIES

Contact: Merrie Scott
Phone: +1.703.264.7530
Email: merries@aiaa.org

TECHNICAL TOPICS

Submit your abstract or draft manuscript today at **www.aiaa-space.org**. Submission deadline is **21 January 2014.**

- Commercial Space
- Communications Systems
- Astrodynamics
- National Security Space
- Space and Earth Science
- Space Exploration
- Space Operations & Logistics
- Space Colonization, Resources, and Tethers
- Space History, Society, and Policy
- Space Systems
- Space Transportation and Launch
- Space Robotics and Space Architecture
- Space Systems Engineering and Economics

PROPOSALS FOR SPECIAL SESSIONS

Individuals who wish to organize special sessions within the technical program (e.g., invited oral presentations, panels, or demonstrations) should submit a short proposal describing the nature of the session as it relates to a specified technical track. Be sure to include the names of the organizers and proposed participants. Please email your proposal by 21 January 2014 to Tony Williams, SPACE Forum 2014 Technical Program Chair, at **antony.williams@jacobs.com**

ABOUT SAN DIEGO

California's second largest city, San Diego, boasts a citywide population of nearly 1.3 million residents and more than 3 million residents countywide. San Diego is renowned for its idyllic climate, 70 miles of pristine beaches, and an array of world-class attractions. Popular attractions include the world-famous San Diego Zoo, Old Town San Diego, and the Gaslamp Quarter.

AIAA

The World's Forum for Aerospace Leadership

14-108

TWO HISTORIC SITES DESIGNATED

Emily Springer

The AIAA Historic Sites Committee ended the Historic Aerospace Sites Program with two aviation-related sites. **Lunken Field**, in Cincinnati, OH, was the largest municipal airport in the world when it was built in the 1920s. Sivaram Gogeneni, AIAA Director of Region III, designated Lunken Field as an AIAA Historic Site at a ceremony in September.

Lunken Field is still home to the oldest standing control tower. Here, the Aeronautical Corporation of America (Aeronca) built the economical but efficient C-2 airplane, helping to shape the future of general aviation. The Metal Aircraft Corporation of Cincinnati built another airplane here, the Flamingo, which is best known for being the first aircraft to fly over what is now Angel Falls, Venezuela.

In 1926, the Embry-Riddle Company, which already had passenger and mail service out of Lunken, established the first government-approved flight school in the nation here. In 1929, Embry-Riddle merged with the Aviation Corporation of Delaware (AVCO), renamed American Airways shortly thereafter. Their earliest flights included ferrying passengers to Chicago. The Sky Galley restaurant, still operating at Lunken, was the first to serve meals on airplanes.

In late September, AIAA Region I Director Ferd Grosveld dedicated the **Igor I. Sikorsky Memorial Airport** in Bridgeport and Stratford, CT, as an AIAA Historic Site. This airport was the site of much of Igor Sikorsky's work, particularly on the VS-300, the first practical helicopter flown in the United States and the basis for the majority of helicopters constructed since then. Sikorsky also developed the F4U Corsair airplane here, used by the Navy in World War II. Originally called Bridgeport Municipal Airport, it was renamed in 1972 after Sikorsky's death.

The American Helicopter Society (AHS) International was a cosponsor of the designation of Sikorsky Airport as a Historic Site, and AHS International is now creating their own historic site program. AIAA and AHS were privileged to have Nikolai Sikorsky, one of Igor Sikorsky's sons, speak on his behalf at the designation ceremony.

Due to budget constraints, the Historic Sites Program has, unfortunately, been cancelled. It's been a good run—AIAA designated 60 sites; our program led to the creation of two other Historic Sites programs (by AHS International, mentioned above, and the Royal Aeronautical Society) and involved thousands of AIAA members, company employees, and historians. The AIAA Historic Sites Program can count millions of media "hits" through its 13 years of ceremonies. Tony Springer, the chair of the Historic Sites Committee, would like to thank former Executive Director Cort Durocher and former AIAA President Sheila Widnall for helping to kick off the program initially; former AIAA President the late John Swihart for his cheerful willingness to fly anywhere in the world to help out with ceremony; and many, many thanks to all the section and TC members who participated over the years so enthusiastically in nominations and celebrations.

From left to right: Ferd Grosveld, AIAA Region I Director; Mark Hammond, Sikorsky Aircraft Corporation; Mike Hirschberg, AHS International Executive Director (and AIAA Associate Fellow); Dan Libertino, President, Igor Sikorsky Archives; Nikolai Sikorsky; and Stephen Ford, Sikorsky Airport Manager.

Region III Director Sivaram Gogeneni designating Lunken Field, Ohio, as an AIAA Historic Aerospace Site in September.

The Lunken Field designation (from left to right): Lunken Field manager Fred Anderton; Dayton/Concinati section chair Oliver Leembruggen; Dayton/Cincinnati section historian Marc Polanka, and Region III Director Sivaram Gogeneni. They are standing with the plaque presented by AIAA to the airport.

HAWAII BRANCH ENJOYS TALK GIVEN BY GENE AUSTIN

On 7 October, the Hawaii branch of the AIAA San Fernando Pacific Section was privileged to hear Gene Austin speak at Club 14 at the United States Coast Guard Base Honolulu. Attendees of all ages—from school children to AIAA members to the XO of the base—were on hand to hear Mr. Austin recount his 40-year career with NASA, including his supervision of the X-33 program, over lunch.

Mr. Austin discussed reusable and non-reusable launch vehicles, and the shift from government-led to commercial space. With launch costs coming down, the view he expressed of the future was highly optimistic.

Mr. Austin was fortunate to be at the center of the space sector from the time of Wernher von Braun (whom he knew), through the heyday of the Lockheed Martin Skunk Works, up to the time of the X-33. He provided some fascinating insights not only into the technology and the history, but also into the contract bidding of those eras.

The Coast Guard generously helped with its club facility and active-duty Coast Guard from Sand Island and Barbers Point Air Station were in attendance for an enjoyable education in space transportation technologies. The Hawaii branch hopes to offer a series of events in coming months, with interesting speakers and an opportunity for space enthusiasts to "talk space" and socialize.

AIAA ALBUQUERQUE SECTION TEAMS WITH THE NATIONAL MUSEUM OF NUCLEAR SCIENCE AND HISTORY FOR A FLIGHT SIMULATOR

Don Nash, AIAA Albuquerque Section Corp Officer

The AIAA Albuquerque Section recently partnered with the National Museum of Nuclear Science and History (NMNSH) on the acquisition and integration of a fixed based/motion Flight Simulator (**http://www.mydreamflyer.com**). The simulator replicates an aircraft motion in pitch and roll.

During the 2012 School-to-World gathering for Mid-School students in Albuquerque, our AIAA section had our small aircraft wind tunnel and our laptop with a control stick and Micro Soft Flight Simulation software running to show students how to control an aircraft. Intel Corp was there with their two racecars that students could sit in and "drive the racecar via a monitor"—it was a big hit. Our AIAA members thought that a similar motion-based flight simulator would be a hit and provide a STEM experience; especially if students could actually sit in and obtain an orientation of real flight.

Shortly after the School-to-World gathering one of our AIAA members was attending a briefing by the NMNSH and they were looking for ideas for their upcoming "Dynamics of Flight" exhibit running from June 2013 through December 2013.

Our member started sorting out reasonability cost fixed based motion simulators and through contacts at the Greater St. Louis Air & Space Museum a potential simulator was found that met our above requirements. This was the "My Dream Flyer™." Information on the simulator was presented to the NMNSH and they agreed to a partnering agreement. Our AIAA section contributed ~23% of the costs from our Section and Cat II funds. We agreed that our members would assemble and integrate the simulator and load the Micro Soft Flight Software and bring it to an operational state. A big "thank you" to the AIAA volunteers—the NMNSH has indicated that the simulator has been a big hit with museum visitors.

Information on the Simulator

"The Dreamflyer™ is a personal virtual-reality flight motion simulator designed to enhance the flight simulation experience. The pilot-lead and pilot-induced roll and pitch oscillation is interpreted by the brain to perceive the feeling of flight."

"Dreamflyer™ captures the motion based on simple gravitational movements of the chair initiated by the user in response to the views on the screen. By using gravitational force to generate motions, the Dreamflyer™ has eliminated the need for hydraulics and motors, and associated costly maintenance."

As described the President of Flight Motion Simulators Inc. (FMS): "To your computer the Dreamflyer™ looks like a Saitek x-52 joystick, throttle and rudder pedals. FMS modified the joystick so the base is under the seat and moves with the seat but the handle end is mounted to a joystick metal rod. The seat moves as the joystick handle is moved. It seems very realistic for smaller planes."

The simulator being demonstrated.

Roll: +/- 15 degrees
Pitch: +/- 15 degrees
User/Pilot max weight: 250 lbs.
A Dell computer and 21 inch monitor is installed to display aircraft attitude and terrain

The partnering agreement states the simulator will remain at the NMNSH during their Dynamics of Flight Exhibit that runs until December 31, 2013, but after January 1, 2014 our AIAA Section will have access to it to take to various STEM activities within our Section. We will be looking at making the simulator more mobile so it can be transported to other localities. If you have any questions please contact: denash1616@aol.com.

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.

OBITUARIES

Chief Exploration Scientist for NASA's Human Exploration and Operations Mission Died in August

Michael J. Wargo died on 4 August. He was 61 years old.

Dr. Wargo was an important contributor to NASA's human lunar and planetary exploration program, having worked on the Lunar Reconnaissance Orbiter and the LCROSS satellite among other projects. He helped map resources for human missions to the moon and participated in the discovery of ice in the shadows of lunar craters. As part of the team planning the next robotic Mars mission in 2020, Dr. Wargo gathered crucial scientific information needed to send humans to the moon and Mars, as well as near-Earth asteroids. His work helped develop a plan for human and robotic space exploration for the next two decades.

Dr. Wargo graduated from MIT with a B.S. in Earth and Planetary Science and received a Doctorate in Materials Science in 1982. At MIT he was honored with the John Wulff Award for Excellence in Teaching and the Hugh Hampton Young Memorial Fund Prize for exhibiting leadership and creativity while maintaining exceptionally broad and interdisciplinary interests.

He began his nearly two-decade career at NASA working in the microgravity research division. Because of his ability to explain complex scientific findings in understandable terms, NASA also used him as a spokesman at press conferences.

Dr. Wargo received numerous awards, including NASA's Exceptional Service Medal and seven group achievement awards. On 9 October, NASA honored Dr. Wargo by having the moon-orbiting LADEE spacecraft broadcast a recording of his voice—the first human voice to be heard from lunar orbit since the Apollo 17 mission. NASA also has asked the International Astronomical Union to name a crater on the moon in his honor.

AIAA Senior Member Haynes Died in September

Ray M. Haynes died on 22 September 2013. He was 69 years old.

Dr. Haynes earned his B.S. in Aerospace Engineering at the University of Arizona in 1967 and his MBA in 1969. He also earned degrees in Systems Engineering (M.S.) in 1971 from RCA Computer Institute (Princeton) and in Operation Research Management (Ph.D.) at Arizona State University in 1988.

Dr. Haynes had a varied professional career, working in both the public and private sectors of education and business. He worked with AiResearch, RCA, and TRW-Fujitsu before his arrival at the California Polytechnic State University in 1988 as an adjunct Professor in the College of Business. He was a co-founder/director of the Engineering Management program (EMP) at Cal Poly and later became a tenured full professor and associate dean before he officially retired in 2000. He published more than 100 articles and case studies. Over his distinguished career, Haynes also lectured at the University of Arizona, Arizona State University, California Institute of Technology, University of California-Riverside, the University of Central Florida, Loyola Marymount University, Massachusetts Institute of Technology, Purdue University, and Stanford University.

Dr. Haynes worked at TRW/Northrop Grumman as Director of the University Strategic Technical Alliances offices of Northrup Grumman until his retirement in 2009. At the time of his death, he was serving as Director of STEM Integration at DaVinci Schools in California and Project lead Consultant for the Northrop Grumman STEM Innovation Campus in Arizona. He also participated in a National Academy of Engineering project, Infusing Real-world Experiences in Engineering Education, which issued a report early this year. He was a member of AIAA, ABET and ASEE.

CALL FOR AWARD NOMINATIONS

Recognize the achievements of your colleagues by nominating them for an award! 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 nomination on a daily basis and applies to the appropriate year. Any AIAA member in good standing may serve as a nominator and are urged to read award guidelines to view nominee eligibility, page limits, letters of endorsement. All nominations must comply with the limit of 7 pages for the nomination package; see details on the webpage (**https://www.aiaa.org/secondary.aspx?id=230**).

Aerospace Communications Award is presented for an outstanding contribution in the field of aerospace communications.

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.

Air Breathing Propulsion Award is presented for meritorious accomplishment in the science of air breathing propulsion, including turbomachinery or any other technical approach dependent on atmospheric air to develop thrust, or other aerodynamic forces for propulsion, or other purposes for aircraft or other vehicles in the atmosphere or on land or sea.

The industry-renowned **Daniel Guggenheim Medal** was established in 1929 for the purpose of honoring persons who make notable achievements in the advancement of aeronautics. AIAA, ASME, SAE, and AHS sponsor the award.

Energy Systems is presented for 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.

George M. Low Space Transportation Award honors the achievements in space transportation by Dr. George M. Low, who played a leading role in planning and executing all of the Apollo missions, and originated the plans for the first manned lunar orbital flight, Apollo 8. (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)

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 ASEE by **14 January**.

Jeffries Aerospace Medicine & Life Sciences Research Award is presented for outstanding research accomplishments in aerospace medicine and space life sciences.

Missile Systems Award—Technical Award is presented for a significant accomplishment in developing or using technology that is required for missile systems.

Missile Systems Award—Management Award is presented for a significant accomplishment in the management of missile systems programs.

Propellants and Combustion Award is presented for outstanding technical contributions to aeronautical or astronautical combustion engineering.

Space Automation and Robotics Award is given for 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 Processing Award is presented for significant contributions in space processing or in furthering the use of microgravity for space processing. (Presented odd years)

Space Systems Award recognizes outstanding achievements in the architecture, analysis, design, and implementation of space systems.

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

Theodor W. Knacke Aerodynamic Decelerator Systems Award recognizes significant contributions to the effectiveness and/or safety of aeronautical or aerospace systems through development or application of the art and science of aerodynamic decelerator technology. (Presented odd years)

The **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.

Wyld Propulsion Award is presented for outstanding achievement in the development or application of rocket propulsion systems.

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

Upcoming AIAA Continuing Education Courses

Courses at AIAA Science and Technology Forum and Exposition 2014 (AIAA SciTech 2014)
www.aiaa.org/scitech2014courses

Saturday–Sunday, 11–12 January 2014

Decision Analysis

Instructor: John C Hsu

Decision analysis supports system life cycle development throughout all phases and system hierarchical levels. The course presents the trade study process as part of the systems engineering process, and introduces various decision analysis methods, including the traditional trade study methods, trade space for Cost as Independent Variable (CAIV), Analytic Hierarchy Process (AHV) as a part of the Analytic Network Process (ANP), Potentially All Pairwise Rankings of All Possible Alternatives (PAPRIKA), and Decision Analysis with Uncertain Information/Data.

Sunday, 12 January 2014

Introduction to Integrated Computational Materials Engineering

Instructor: David Furrer and Jason Sebastian

Designed to provide an overview of integrated computational materials engineering (ICME), this course offers a primer on the various types of models and simulation methods involved in ICME. It is aimed at providing a general understanding of the critical issues relative to ICME, with the goal of increasing participants' knowledge of materials and process modeling capabilities and limitations. The important aspects of linking materials models with process models and subsequently to component design and behavior analysis models will be reviewed.

Saturday, 11 January 2014
Workshops at AIAA Science and Technology Forum and Exposition 2014 (AIAA SciTech 2014)
www.aiaa.org/scitech2014courses

1st AIAA Sonic Boom Prediction Workshop

Sponsored by the Applied Aerodynamics Technical Committee

The objective of the First Sonic Boom Prediction Workshop is to assess the state of the art for predicting near field signatures needed for sonic boom propagation. Comparisons will be made between participant solutions on workshop-provided grids. Participants are requested to apply their best practices for computing solutions on the provided geometries. There is particular interest in exploring refinement techniques including grid adaptation and alignment with flow characteristics. Impartial comparisons will be made between different solution schemes as well as with wind tunnel validation data for assessing the state of the art and identifying areas requiring additional research and further development. For more information, please visit the Sonic Boom Prediction Workshop website (**http://lbpw.larc.nasa.gov**).

Low Reynolds Number Workshop

Organized by Ming Chang, Lockheed Martin Aeronautics, and Michael OI, US Air Force Research Lab

Micro Air Vehicles (MAVs) are flight articles resembling natural flyers (birds, bats, insects) in size and functionality. While of extensive defense interest since at least the 1990s, scientific and engineering progress has been episodic, with principal advances more from trial and error than first-principles science. Pacing issues include the aerosciences as well as payloads/energy/materials. We aim to explore the state of the art in both the sciences and applications, examining research directions and interest for academia, industry, and government.

The workshop aims to gather industry, academia, and government to assess new research directions and connection between the sciences and the applications. By the end of the day, we intend to assemble a credible sight-picture of who is pursuing what research, and what might be the beginning of a business case. Outcomes aim to include an understanding of where the MAV community stands in 2014 relative to where we've been throughout the past 20 years, and how to begin bridging scientific/academic advances with the needs of industry and the user community. For questions, please contact Ming Change at 661.572.6228 or ming.chang@lmco.com, or Michael V. OL at 937.713.6650 or michael.ol@wpafb.af.mil.

To register for a course or workshop at AIAA SciTech 2014, visit www.aiaa.org/scitech2014 and select "Register Now".

February–June 2014
Home Study Courses
www.aiaa.org/homestudy

Introduction to Computational Fluid Dynamics

Instructor: Klaus Hoffmann

This introductory course is the first of the three-part series of courses that will prepare you for a career in the rapidly expanding field of computational fluid dynamics. Completion of these three courses will give you the equivalent of one semester of undergraduate and two semesters of graduate work. The courses are supported extensively with textbooks, computer programs, and user manuals.

Key Topics

- Classification of partial differential equations (PDEs)
- Finite-difference equations

• Parabolic equations
• Stability analysis
• Elliptic partial differential equations
• Hyperbolic partial differential equations
• Scalar representation of the Navier-Stokes equations
• Incompressible Navier-Stokes equations

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. Completion of these three courses will give you the equivalent of one semester of undergraduate and two semesters of graduate work. The courses are supported extensively with textbooks, computer programs, and user manuals.

Key Topics
• Grid-generation-structured grids
• Transformation of the equations of fluid motion from physical space to computational space
• Euler equations
• Parabolized Navier-Stokes equations
• Navier-Stokes equations
• Grid-generation-unstructured grids incompressible Navier-Stokes equations
• Finite volume schemes

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. The courses are supported extensively with textbooks, computer programs, and user manuals.

Key Topics
• Introduction to turbulence and turbulent flows
• Reynolds average Navier-Stokes equations
• Parabolic equations
• Turbulence models
• Compact finite difference formulations
• Boundary conditions
• Large eddy simulation
• Direct numerical simulation

Missile Design and System Engineering

Instructor: Gene Fleeman

This course provides the fundamentals of missile design, development, and system engineering. A system-level, integrated method is provided for missile configuration design and analysis. It addresses the broad range of alternatives in satisfying missile performance, cost, and risk requirements.

Key Topics
• Key drivers in the missile design process
• Critical trade-offs, methods, and technologies in aerodynamic, propulsion, structure, seeker, warhead, and subsystems sizing to meet flight performance and other requirements
• Launch platform-missile integration
• Robustness, lethality, guidance, navigation & control, accuracy, observables, survivability, reliability, and cost considerations
• Missile sizing examples for missile systems and missile technologies
• Missile system and technology development process

Spacecraft Design and Systems Engineering

Instructor: Don Edberg

This course presents an overview of factors that affect spacecraft design and operation.

Key Topics
• History
• Design drivers
• Orbital mechanics and trajectories
• Systems engineering
• Design considerations
• Estimation, testing, and failure prevention

To register for any of these Home Study courses, visit www.aiaa.org/homestudy and select "Register Now".