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Since its founding in 1947, Southwest Research Institute (SwRI) has contributed to the advancement of science and technology by working with clients in industry and government. Performing research for the benefit of humankind is a long-held tradition. The Institute comprises 11 divisions engaged in contract research spanning a wide range of technologies.

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COVER

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About the cover
A portable solar cell atop a rotating fixture has a "moth-eye" light-absorbing coating applied inside a vacuum deposition chamber.

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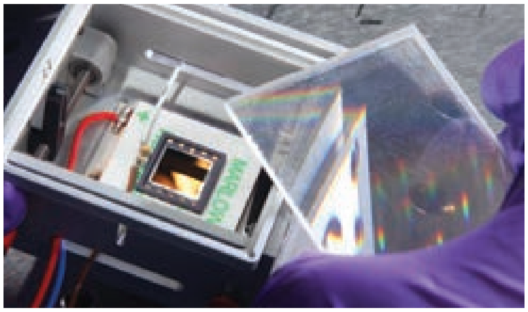

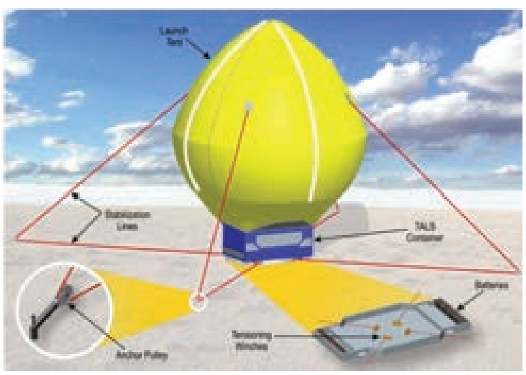

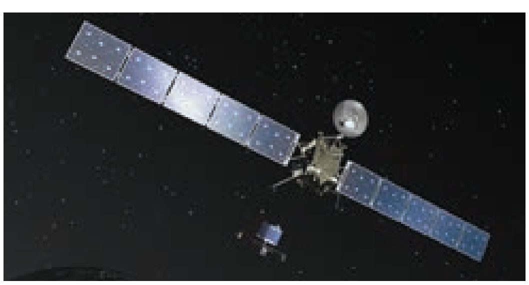

Departments

Portable Power from the Sun

An SwRI-developed solar module for warfighters could reduce weight and expense

By Jeffrey L. Boehme

Advances in telecommunications and electronics have given warfighters better effectiveness and situational awareness in the field, but those improvements tend to come with added weight and expense. Batteries make up 20 percent of the weight a warfighter must carry in-theater and rank second behind munitions in annual infantry battalion expenditures, according to a 2011 U.S. Army study.

Both weight and money could be saved by using secondary batteries that can be recharged through energy harvesting techniques. Solar energy panels known as thin-film photovoltaics are portable and easily deployable, and can be rolled up or folded for storage; thus they are often the preferred system for energy harvesting. However, their energy per unit of volume or weight is limited unless their exposure to sunlight is optimized through the use of concentration optics or solar-tracking mechanisms.

A team of engineers from Southwest Research Institute (SwRI) has begun to develop a portable yet rugged solar module system based on state-of-the-art photovoltaics (PV) research. Its approach focuses on treating the solar module as a system of discrete components combined in a way that maximizes conversion efficiency and

Photo By: Sgt. Keonaona C. Paulo

minimizes weight, volume and operating cost. SwRI's solar module system contains a dispersion/concentration PV system, a solar tracking module, a secondary harvesting system and some biologically inspired, anti-reflective coatings.

Dispersion/concentration photovoltaic system

The SwRI-designed system's primary energy-harvesting unit is a concentrator photovoltaic system (CPVS), which addresses two major factors affecting PV efficiency. The first major factor is the number of photons striking the PV surface. Increasing the number of photons that strike a PV surface is relatively straightforward using light-concentrating optics, such as Fresnel lenses or parabolic mirrors.

The second factor, the band-gap, or zone of sensitivity of the semiconductor material in the device, is more complex. Photons with energy less than the band-gap of the PV material are not absorbed by the cell, and those whose energy exceeds the band-gap are re-emitted as heat or light. When only one semiconductor material is used, a significant portion of the solar spectrum's energy does not get converted into electricity. Therefore, it is desirable to include multiple semiconductor materials in a PV system, either through vertical stacking or lateral splitting. In vertical stacking, layers of semiconductor materials are grown atop one another such that photons with different wavelengths are selectively absorbed or transmitted by the materials in the vertical stack.

The selective absorption of photons within a specific wavelength region allows each photon-sensing junction within the multi-junction PV cell to convert energy very efficiently. For example, according to the National Renewable Energy Laboratory (NREL), the efficiency of four-junction PV cells has reached 37.8 percent, compared to 28.8 percent for the best single-junction PV cell. Although vertically stacked, multi-junction PV cells are highly efficient, they are typically more expensive than single-junction cells because of the multi-step processes required to deposit multiple materials, plus the complex deposition procedures required to match inter-layer lattice constants and currents. Their higher cost per kilowatt-hour often precludes their widespread use for civilian as well as military applications.

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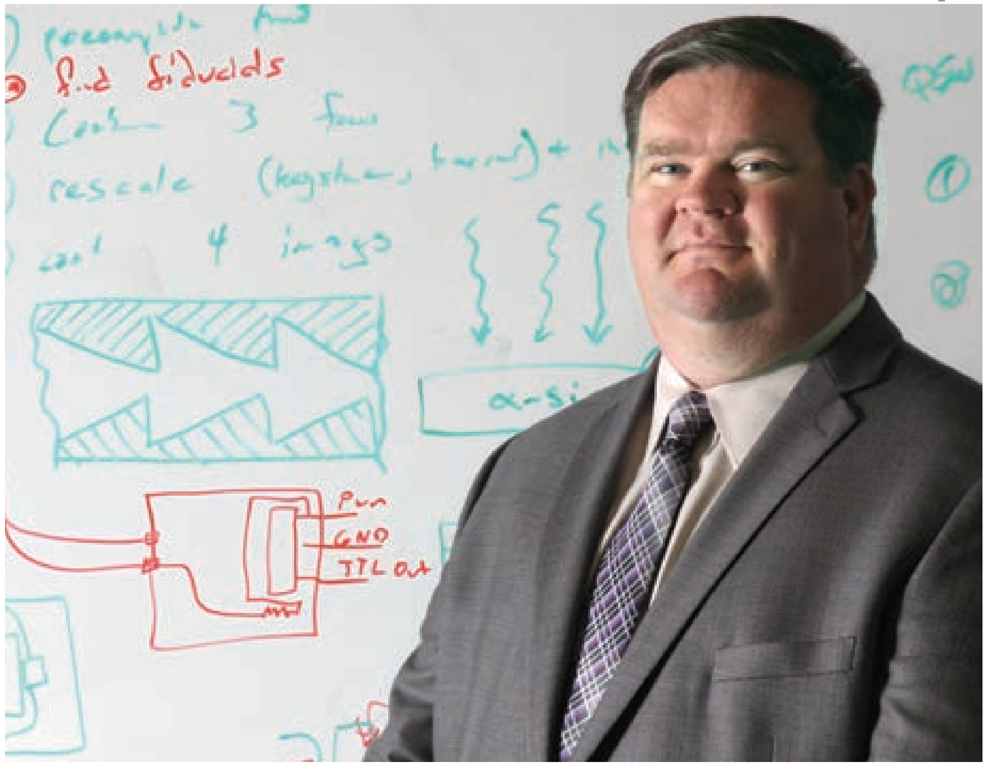
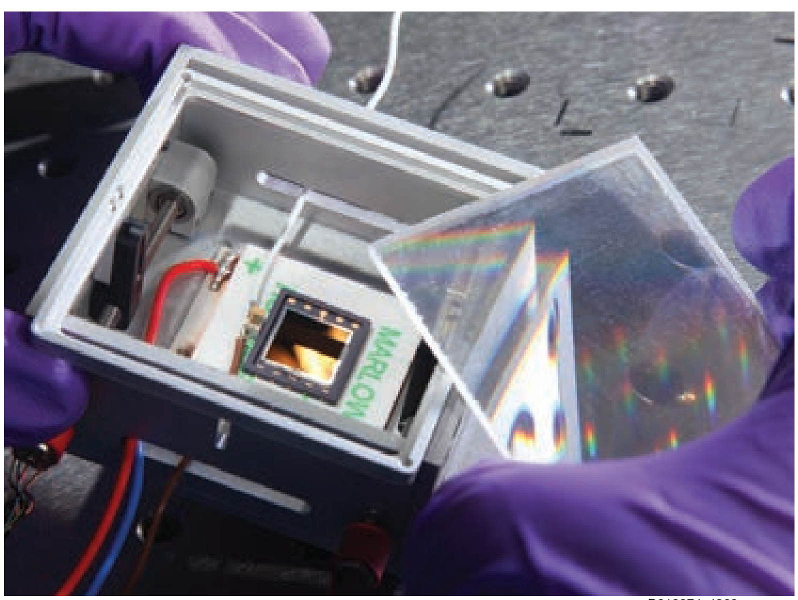


Dr. Jeffrey L. Boehme is a staff scientist in the Applied Physics Division, with a background in tailoring the color of electrochromic polymers and devices. His work at SwRI has included developing low-cost techniques for fabricating organic light-emitting devices and photo detectors without the use of vacuum. He was principal investigator on an internally funded research product to develop active thermal control devices using electrochromic materials, and is currently program manager of a program to investigate the survivability of nanoparticles in harsh environments.

Lateral splitting, on the other hand, exploits the efficiency gains associated with narrow-band illumination by using optical components to split the solar spectrum into multiple narrow-band beams that impinge upon single-junction PV cells manufactured from different semiconductor materials. Because single-junction PV cells are easier to manufacture, a variety of low-cost, off-the-shelf PV cells is available for use in lateral solar cell architecture. The difficulty, and therefore the expense, of those systems often lies in their spectrum dispersion optics.

Researchers have used curved microprism arrays, holographic optical elements and



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Three layers of semiconductor materials that selectively gather photons of different wavelengths, below a light-concentrating Fresnel lens (at right), are superimposed atop a scavenger photovoltaic cell module (interior).

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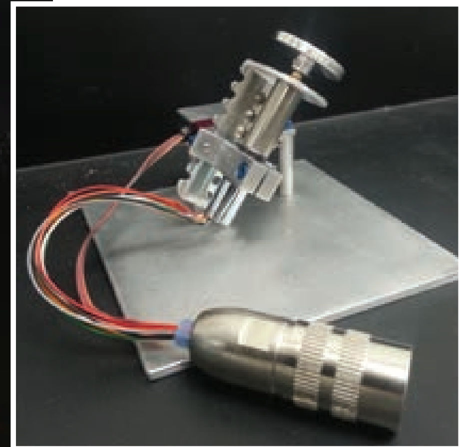

An engineer inspects the photovoltaic cell atop a portable solar module onto which a "moth-eye" light-absorbing coating has been applied using a rotating fixture (top inset) and a vacuum-deposition chamber (bottom inset).

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dichroic surfaces to split the solar spectrum into two or more narrow-band beam components, with varying degrees of success. Because many of these optical elements can be difficult and expensive to mass-produce, the SwRI team selected a spectrum dispersion system that lends itself to easier manufacturing. This system is based on flat sheets of molded linear microprism arrays.

Although it is more desirable to divide the solar spectrum into three or more wavelength bands, the team chose to disperse the solar spectrum onto two PV cells in the prototype design to reduce complexity.

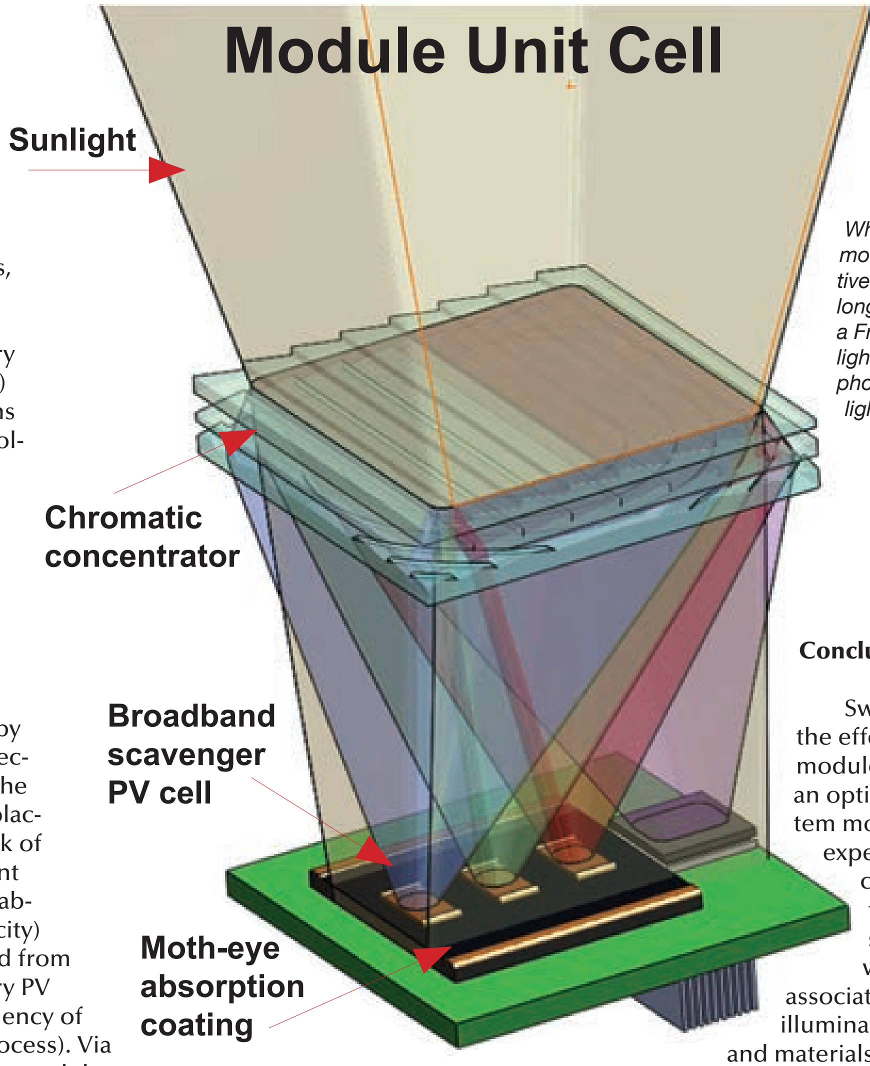
In addition to the spectrum dispersion optics, the team added a Fresnel lens as an optical concentrator to further increase module-level efficiency. Parabolic mirrors often have larger acceptance angles than Fresnel lenses, but they are larger, heavier, and often require an inverted PV mounting system. Minimizing weight and volume while maximizing ruggedness was considered more important for defense applications.

Solar tracking mechanism

The SwRI team also added a solar tracking mechanism to improve sun-catching efficiency. While high-precision, multi-axis mechanisms are the norm for conventional concentrator photovoltaic systems, they are far from ideal. They are often placed on a pedestal and rotated about one or two axes throughout the day. They are typically large, heavy and expensive, primarily because the mechanism must support the weight of the concentrator photovoltaic system as well as wind-induced loads, which can be substantial. Again, weight and volume are critical for mobile Department of Defense (DoD) applications where the human and physical costs of transport are significant. With that in mind, the SwRI team implemented a modified, compact solar tracking mechanism that fits within the enclosed solar module unit.

Secondary energy harvesting system

Solar tracking errors, actuator limitations and optical effects such as reflection or scattering reduce the amount of light striking the primary PV cells and result in efficiency losses. The SwRI-designed system contains a number of secondary, broadband PV cells that can harvest stray photons that do not strike the primary PV cells. The secondary PV cells are located on the periphery of the spectrally tuned primary PV cells to scavenge weakly concentrated light from the Fresnel lens concentrator as well as highly concentrated, spectrally separated light that does not strike the primary PV cells.



When sunlight strikes the solar module, three unit-cells collectively absorb short, medium and longer wavelength photons and a Fresnel lens focuses remaining light on a broadband scavenger photovoltaic cell with "moth-eye" light absorption coating applied.

PV cells operate better at shorter wavelengths, and in most multi-junction PV systems (including SwRI's two-cell primary energy harvesting system) the lowest-energy photons in the spectrum are not collected. As much as 7 percent of the solar energy resides in the short- to mid-wavelength infrared (IR) region (1,400 nm – 8,000 nm). Because the solar spectrum is laterally split in the SwRI solar module, some of the IR energy can be harvested by incorporating a thermoelectric generator (TEG) into the solar module design. By placing a heat sink on the back of the unit, a thermal gradient across the TEG will be established (generating electricity) and heat will be dissipated from the primary and secondary PV cells (enhancing the efficiency of the energy conversion process). Via these two routes, the solar module system can generate additional energy.

"Moth-eye" anti-reflective coatings

To maximize the efficiency of the energy harvesting system, it is necessary to maximize the amount of light absorbed by the PV cell. Because of the high refractive index of most PV cells, reflectance at the surface is estimated at upwards of 30 percent. To minimize Fresnel reflections and improve light capture, the surfaces of PV cells are often textured, creating three-dimensional structures that increase the likelihood that a reflected photon will be captured by a neighboring PV cell surface. Anti-reflective (AR) coatings also can be deposited onto PV surfaces using various methods. A key issue with AR coatings, however, is their responsivity over the entire solar spectrum and their effectiveness at a variety of incident angles. While several layers with varying refractive indices and thicknesses can be deposited, each layer increases the cost, such that the cost-effectiveness of AR coating may be brought into question.

To address the cost issue, SwRI researchers have begun to develop biologically inspired AR surfaces based on the eye structure of nocturnal moths. Nocturnal moths have excellent night vision due to regular, high-aspect-ratio, sub-wavelength photonic structures on their corneal surface that trap broadband light over a large range of incident angles. The SwRI team tried to fabricate biologically inspired AR coatings based on the glancing angle deposition technique. In this process, a substrate material is rotated around an axis perpendicular to its surface and deposition flux is applied at an oblique angle. High-aspect-ratio structures are formed by the effect of shadowing during film deposition, and the shape of the formed structures is regulated by controlling the substrate rotation parameters.

Conclusion

SwRI researchers examined the effectiveness of various solar module components to develop an optimized lateral solar system module. The theoretical and experimental results indicate that optical losses in the spectrum dispersion system must be carefully weighed against the gains associated with narrowband PV illumination. For the prism angles and materials tested, a 24-degree microprism array is an adequate compromise between Fresnel reflection losses and spectrum dispersion ability. Prism orientation and direction play a significant role in optical losses and spectrum dispersion. As a result, additional analysis is currently underway. Based on an internal review of module fabrication and assembly processes, surface roughness, prism rounding and machining debris are believed to significantly reduce the light transmitted to the primary PV cells. While optical losses are not atypical for lateral solar cell architectures, the SwRI team is currently working to minimize these losses through improving fabrication techniques and incorporating secondary energy harvesting units into the system. More research is needed before the system can harvest solar energy at the desired efficiency, but initial results are promising toward development of an optimized solar module system for defense applications.

Questions about this article? Contact Boehme at (210) 522-5979 or jeffrey.boehme@swri.org.

High Performance, Low Profile

Novel antenna arrays, combined with miniaturized processing equipment, bring direction finding capability to the tactical level

Patrick J. Siemsen is a principal engineer in SwRI's Signal Exploitation and Geolocation Division. He has been involved in the design of shipboard and land-based direction finding systems with both military requirements and rugged commercial requirements. He has led the development of low radar cross section shipboard direction finding antennas, a body-worn DF antenna vest and vehicle-mounted and human-transportable DF antennas for tactical field applications.

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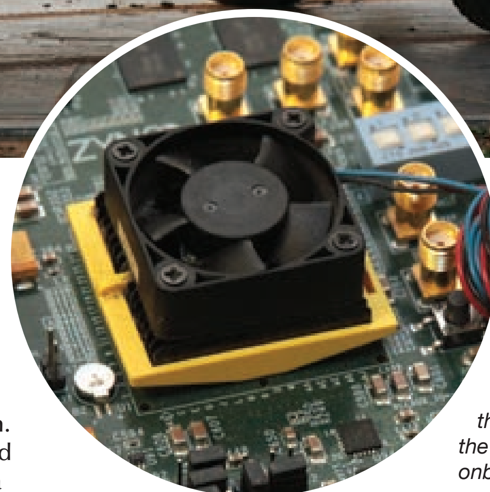


Optimal locations for mounting direction finding antennas on tactical vehicles like the Humvee (above) are complicated by signal interference from combat equipment mounted atop the vehicle, and also by the need to miniaturize its onboard electronic signal processing system (detail inset).

By Patrick Siemsen

Warfighters on the frontlines of the battlefield typically have to rely on communication with distant and remote radio direction finding (DF) assets to obtain tactical information about the location and strength of the enemy. The sheer bulk and weight of traditional direction-finding antenna arrays and their processing equipment, let alone large mast-mounted antennas that give away their location, have limited their suitability for battlefield deployment, relegating them instead to rear areas or airborne or shipborne stations, or in some cases, behind the frontlines as strategic assets.

A team of engineers from the Tactical Products Department of the Signal Exploitation and Geolocation Division at Southwest Research Institute (SwRI), using internal research funding, is designing and developing novel direction finding antenna arrays to help alleviate this problem. Significant electromagnetic numerical modeling is employed in this effort using CAD software. Two such products recently developed are the AVM-375 DF Antenna Set and the AP-460 DF “Tent” antenna. The AVM-375 consists of up to four low-profile DF sub-arrays that are distributed around the body of military vehicles, providing “on-the-move” DF capability with low visible signature. The AP-460 is a patented human-transportable direction-finding antenna array made of conductive fabric that collapses and stows into a soldier’s backpack for easy transportation. Along with new and innovative antenna arrays, SwRI engineers also develop advanced DF processing architectures and software that run on field-programmable gate arrays (FPGA) in low size, weight, and power (SWaP) configurations. Together, these advanced technologies are helping bring direction finding systems to the frontlines.

Vehicle-mounted, low-profile antenna sub-arrays

Adding traditional direction finding equipment onto military vehicles, such as the high-mobility multipurpose wheeled vehicle (HMMWV, or Humvee®), requires an antenna array on a mast that extends significantly above the vehicle to get it away from external clutter located on the vehicle’s roof. For the Humvee, one such clutter agent is a rotating turret which, because of its rotating nature, cannot be removed through calibration. Elevating the antenna severely limits vehicle mobility and also reveals its mission. SwRI’s solution was to distribute groups of linear DF antenna sub-arrays around the vehicle’s body, each consisting of miniature low-profile directional antenna elements. The arrays face outward, away from vehicle clutter. Any remaining effects from the vehicle can be remedied through calibration. A new version of SwRI’s beam-steer vector match (BSVM) DF algorithm was developed specifically for distributed arrays, removing the effects of inter-array spacing from the DF solution.

The AVM-375 DF antenna set comprises four sub-arrays, each containing three antenna elements per band, linearly aligned behind a conductive backplate. The backplate, in addition to serving as the mounting mechanism, provides an electromagnetically reflective surface to shield the array from scattering effects coming behind the array and also to give the individual antenna elements more directivity facing out from the backplate.

Portions of an SwRI-designed AVM-375 antenna system's sub-arrays are shown with their protective radomes removed, and as mounted on a vehicle, beneath light tan-colored radomes that are visible here ahead of the front door and at the right-rear corner.

The sub-arrays—with one facing front, rear and two broadside—work together to provide 360-degree coverage. Two different antenna element types are used: balanced-shielded loop antenna elements to cover VHF frequencies and tapered-slot antenna (TSA) elements for UHF. Each sub-array design was 30 inches long by 7.5 inches tall by 3.5 inches deep for this platform.

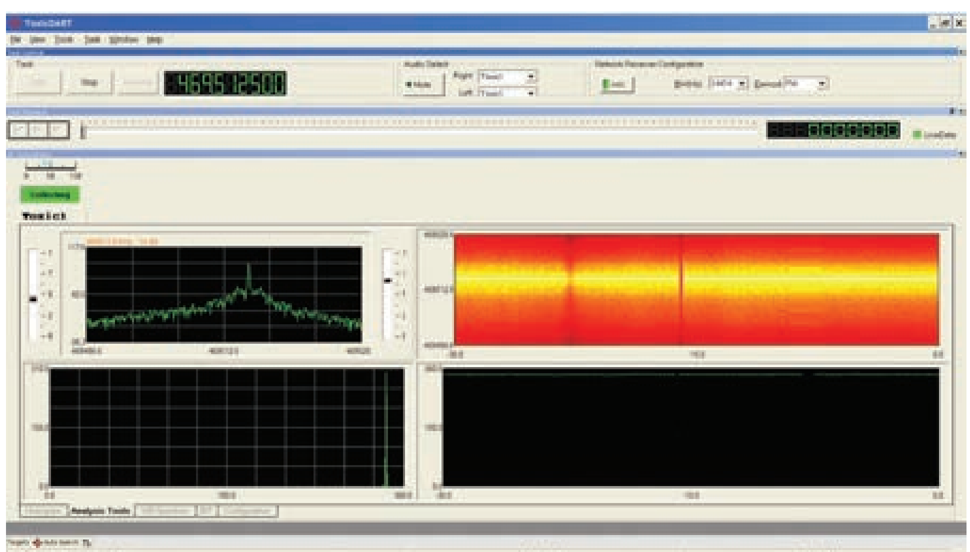
The novel approach was proven through a government-sponsored demonstration on a Humvee. Because of specific mission constraints, the front- and rear- facing arrays had to be moved to the sides of the vehicle for this installation. Two of the sub-arrays were custom-designed to fit behind the front fenders. The remaining two sub-arrays were moved closer to the rear of the vehicle but faced broadside. Although not ideal, 360-degree coverage was still provided. The sub-arrays were mounted using existing bolt holes wherever possible to facilitate ease of installation. Cables were routed underneath the fender skirts and into the vehicle's interior through existing holes in the body. Other installations on the vehicle included a reference discone antenna (so named because it comprises disc-shaped and cone-shaped elements), a wireless modem antenna and dual GPS antennas. The reference discone antenna and the wireless modem antenna were mounted on posts on the rear of the Humvee. The dual GPS antennas were mounted to the hood.

A miniaturized processor using SwRI-developed DF architecture and software was installed in the vehicle's cab and a laptop computer provided visual display of reported lines of bearing. The DF processor operated from battery power, but could also be powered through the vehicle's own power distribution. The RF cables from the antenna arrays connected directly to the processor.

Engineers calibrated the system by turning the vehicle around in circles while collecting calibration data at specific frequencies. Only a single calibration is needed for installation of a given platform type, as long as the sub-arrays are installed the same way.

Vehicle heading information was provided during the demonstration by a dual GPS antenna array mounted on the hood. The demonstration involved driving around the SwRI antenna field site while collecting DF data on a number of fixed and hand-held transmitters at the site. DF lines of bearing were collected in both a DF mapping mode and a data logging mode. For the DF mapping mode, lines of bearing were continuously displayed on a satellite map of the SwRI field site, emanating from the location of the vehicle as it was driven. For the data logging mode, continuous calculated lines of bearing and actual direction of arrival (calculated from knowing the latitude and longitude of both the transmitter and the Humvee) were logged to a data file for post-processing, from which DF error was obtained. Additional DF tests were performed on over-the-air signals and while rotating the vehicle's turret. Finally, "fox hunts" were performed, where the vehicle crew would search for a hand-held transmitter at an unknown location.

Stationary DF testing prior to the demonstration, with the vehicle sitting on a rotator, yielded an overall RMS DF



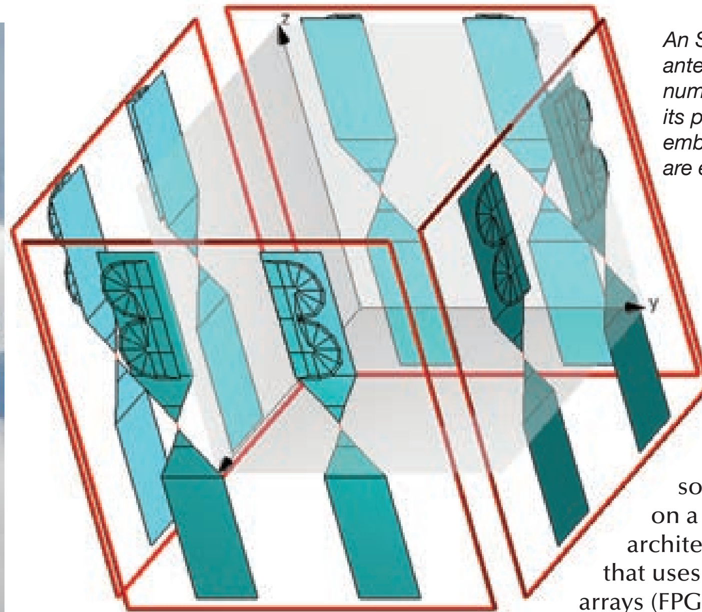
This visual display from the graphical user interface of the field programmable gate array (FPGA)-based DF processor on the Humvee shows the DF spectrogram after rotating the vehicle's turret 360 degrees in azimuth.

error across frequency of 3.8 degrees. For mobile testing, the 68th percentile (one standard deviation) of the DF error averaged between 5 and 10 degrees. DF results collected during the demonstration matched closely with those results.

Human-transportable "tent" antenna

The logistics and transportation of DF equipment to the front lines of the battlefield are rather difficult given its traditional large size and extreme weight. In addition, the setup process is painstaking. The SwRI-designed AP-460 DF "tent" antenna is a lightweight, collapsible, human-transportable DF antenna specifically designed for tactical field applications, where the operator requires quick setup and teardown time (less than 5 minutes). The antenna elements and associated cabling are fully integrated into a cube-shaped fabric structure (the "tent") that collapses and stows into a soldier's backpack. Antenna elements are made from conductive fabric and small printed circuit boards. The total weight is less than 5 pounds. The antenna is mounted on a tripod with mast that extends 20 feet above the ground. The tent portion is supported to the mast using shock-corded fiberglass poles much like those that campers use to support their tents.

The tent structure is cube-shaped, with four outward faces made of polyester mesh material supported by a flexible, flat-spring steel outer frame around each face. The top and bottom are open.



An SwRI-designed AP-460 "tent" antenna is shown alongside the numerical model used for analyzing its performance. Antenna elements embedded in the "tent" lining are evident.

The AP-460 DF antenna provides full coverage across the VHF/UHF frequency ranges in three separate but concentric antenna arrays fabricated into the single pop-up structure. Each antenna array covers a different portion of the operating frequency range. The lower frequency array covers from 20 MHz to 160 MHz and is made up of four shielded loop antennas, one on each face of the structure. The loop antennas are made from flexible RF cable routed through channels sewn around the outer edge of each face. Small circuit boards serve as the feed points and electrical gap for the shielded loops. The middle frequency array covers from 160 MHz to 650 MHz and consists of eight bow-tie type antennas, with two on each face. The bow-tie antenna elements are made using conductive cloth material sewed directly onto each face. The higher-frequency array covers from 650 MHz to 3 GHz and consists of eight tapered slot antennas, with two on each face. The tapered slot antenna elements are made out of circuit board material that fits into pockets sewn onto the faces. All circuit boards are small enough so that the structure can still collapse.

The same processing equipment used with the Humvee-mounted antenna can be used with the tent antenna. Power can be provided through solar-rechargeable military radio pack batteries. With the DF processor, the tent antenna produces exceptional DF line-of-bearing (LOB) accuracy of better than 5 degrees RMS across the operating frequency range.

Advances in FPGA processing technology

Through SwRI's internally funded research program, a joint software/firmware "system on a chip" (SOC) processing architecture has been developed that uses field-programmable gate arrays (FPGA) in a low size, weight and power (SWaP) configuration. FPGAs are integrated circuits that can be configured after manufacture. The low SWaP is a key requirement for deploying the technology on small, tactical platforms. Unlike previous designs which suffer from low-speed data transfer between the FPGA and the processor, SoC technology eliminates this bottleneck and simplifies resource allocation. Faster FPGA-based digital signal processing capabilities, combined with an expanding array of intellectual property cores and development tools for FPGAs, enable new system architectures and thus new capabilities on small tactical platforms. In addition, portable software libraries running on FPGAs have been achieved for prosecution of wideband communications signals.

Direction finding missions

These products have applications not only for the military, but also in law enforcement, border patrol and other functions. A number of government agencies have expressed interest in these products. External funding has recently been secured for application of the AVM-375 onto a helicopter platform. As with the Humvee, the DF sub-arrays are custom-fitted to the vehicle's unique mounting requirements.

The complete SIGINT/DF sensor for mobile platforms, including ground vehicles, aircraft, UAVs, and others, is made possible by these enabling technologies from SwRI: novel antenna designs and advanced signal-processor architecture.

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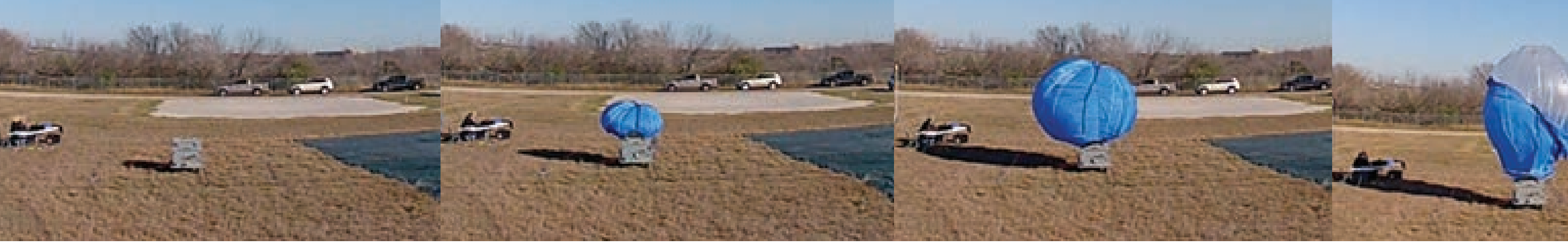
Balloon in a Box

An SwRI-developed concept allows easy transport and autonomous launch of lighter-than-air vehicles



By William D. Perry

Ever since the days of observation balloons, rigid airships and Navy blimps, inflating and launching most lighter-than-air (LTA) systems have required a large open space, specialized equipment and a well-trained launch crew. Even for non-rigid airships and balloons, unpacking and laying out the hull for inflation typically must be done inside a very large hangar, or outdoors under very low wind conditions, because the hulls can be several hundred feet in length and are made from very lightweight material.

Throughout the lengthy inflation and launch process, the hull is at risk of damage from wind gusts or contact with obstacles. Usually, large handling equipment and an experienced launch team are also needed to get the LTA system aloft without damage.

Given a choice, most military operators would prefer to deploy their LTA systems quickly from remote, unimproved sites, using minimum personnel with limited training. For this reason, a team of engineers from Southwest Research Institute (SwRI) undertook an internally funded research project that resulted in the Tactical Aerobotic Launch System (TALS) concept by which LTA systems can be launched from a self-contained, easily portable package that provides inflation, stabilization, protection and release. TALS can be operated by a small team, or by remote control or autonomous launch on command. The concept is adaptable to balloons, airships and tethered aerostats.

TALS applications

Tactical military applications for LTA vehicles require deployment under widely varied conditions, from sites that may be unimproved, and with limited space. Possible launch sites can include a jungle clearing, lake or sea surface, beach, a helipad on a naval vessel or a mobile ground vehicle. The self-contained TALS can be shipped using available military vehicles and stored, completely integrated and ready to go for rapid deployment.

Deployed LTA systems provide a platform for a variety of electronic systems used for communication relay, real-time surveillance, communications intercept and other functions.

Aerobotic launch concept

The TALS concept uses a single shipping container in which the LTA system is packed along with a supply of lifting gas (helium or hydrogen). The inflation subsystem includes batteries for power and digital electronics that control the inflation and launch processes. The container can be transported by truck or helicopter to the launch site, where a small team secures the container to the ground, vehicle or other heavy

The TALS shipping container is packed with lifting gas, batteries and launch-control electronics as well as the vehicle itself.

The Tactical Aerobotic Launch System (TALS) enables a lighter-than-air vehicle to be launched autonomously from a portable, self-contained package, in remote and unimproved environments.

structure. Once the container is secured, the LTA system can be launched immediately or left for autonomous launch at a later time using a timer or telecommand. After launch, the container can be recovered and refurbished for reuse.

At the planned launch time, the integrated control system determines whether the wind velocity and direction are acceptable. If so, the inflation and launch process begins with the top of the container opening to expose the protective tent that covers the folded LTA system. Guy lines with automated extension and tensioning, which are attached to the tent, provide stability during the inflation process. The inflation rate and total gas quantity are automatically controlled. The hull rises from the container as it is inflated inside the protective tent, and when a predetermined amount of lifting gas has been injected, gas flow ceases and the top of the tent opens, allowing the LTA vehicle to escape and ascend.

Expanding the envelope

SwRI has a long history of designing and operating autonomous LTA vehicles, such as HiSentinel, a non-rigid, electric-powered, autonomous airship that was partially inflated with helium on the ground and launched like a balloon. It assumed its aerodynamic shape as the helium expanded with increasing altitude and decreasing atmospheric pressure. By the time HiSentinel reached its operating altitude around 65,000 feet, the expanded helium had pressurized the gas envelope enough to provide rigidity and structural strength. TALS builds on that experience by addressing additional, non-flight issues such as storage, transport, inflation and launch logistics.

TALS, an SwRI disruptive technology internal research project, was conducted in two phases.

After first successfully completing the feasibility study and a full-scale TALS preliminary design, funding was provided for the

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William Perry is an Institute Engineer in the Space Systems Directorate of the Space Science and Engineering Division. He manages the Institute's lighter-than-air section, which designs and tests advanced lighter-than-air vehicles for military and science applications.

In this artist's rendition, a truck-transported container serves as the inflation and launch platform for a TALS application in an austere environment.

design, construction and testing of a functional, one-third scale TALS to demonstrate rapid automated launch of large LTA systems from remote, unimproved sites using only a small team, in windier conditions than conventional launch methods allow.

In Phase I, SwRI engineers established the performance requirements for a tactical launch system, sized for a HiSentinel 80 airship, which is 200 feet long and weighs about 1,100 pounds. The SwRI team determined the optimal size, shape and mass of the launch container and completed a preliminary design that included packing, power, control, communications, tent and lifting gas systems for launching a full-scale airship. Total weight of the full-scale TALS container and its contents was less than 6,000 pounds. At 9 feet tall, 8 feet wide and 14.6 feet long, the container would be easily transportable by aircraft, helicopter, truck or ship. Based on the results of the feasibility study, the team next designed a maller, one-third scale TALS to serve as a feasibility demonstrator.

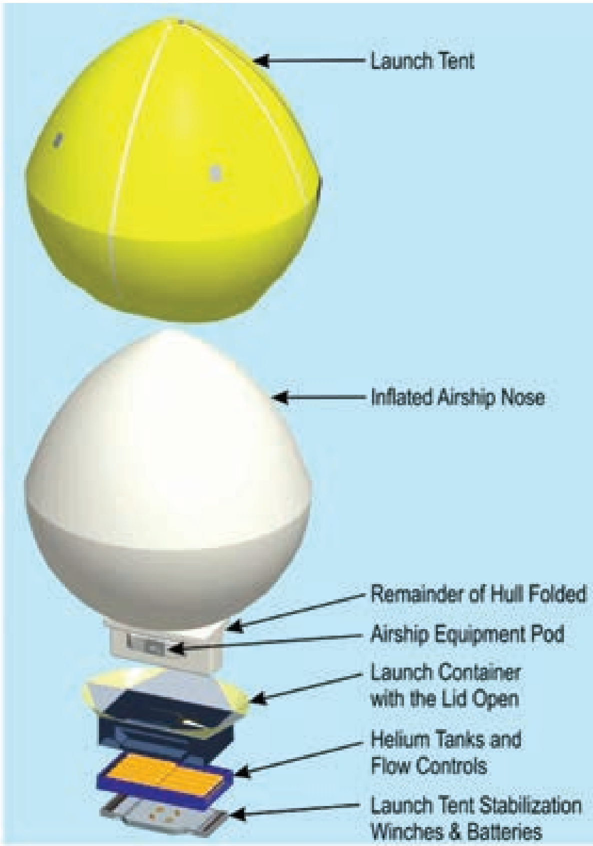
In Phase II, the TALS feasibility demonstrator was fabricated and integrated. It is fully automated, with all of the basic functions of a full-size model, except an external supply of helium is used to minimize cost. The TALS demonstrator launches a one-third scale model of a HiSentinel-80 airship. The scale airship's volume and mass are approximately 4.3 percent of those of the full-scale airship. The team fabricated and assembled the TALS demonstrator that included the container, stabilization system, inflation system and launch release. Raven Aerostar fabricated the tent and one-third scale airship test hulls to the SwRI designs. A custom trailer for transporting the TALS demonstrator and its helium supply to the field for testing was also assembled.

Testing the TALS demonstrator

In preparation for field testing, the SwRI team evaluated each subsystem independently before integration. They next performed extensive functional testing of the completed demonstrator in the laboratory under controlled conditions. The team performed two field tests under light wind conditions, resulting in a list of changes and refinements that were needed before the system would be ready for demonstration.

The TALS team spent another year modifying, refining and testing the TALS hardware and software in preparation for an on-site demonstration. Laboratory tests under ideal conditions, along with field tests over a range of wind conditions, resulted in many changes that mproved reliability and performance. The laboratory tests included more than 20 inflation and release cycles using air for safety. These tests verified the inflation and release sequence but could not test the loads produced by the lift of the helium gas and effects of wind and moisture. Only field testing using helium for lift and under real weather conditions could verify the TALS performance.

The team completed eight fully automated field launches under a range of wind and moisture conditions. Prelaunch setup times averaged five minutes once the launch container was placed in position. Inflating and launching the test airship took fewer than 10 minutes. Based on these results, a full-scale airship would take about 20 minutes to set up, inflate and launch, making the entire process



The TALS package comprises the airship, protected within a launch tent, along with all equipment required to launch it.

well within the target of less than one-half hour.

The TALS stabilization line system demonstrated that it could control the tent and keep it vertical during the inflation process. No sailing or flagging of the tent occurred, even with winds up to 12 knots (14 mph). The system has a 20-knot (23 mph) design limit, which the team hopes to verify during future field tests. Meanwhile, testing revealed that the launch process and all of the TALS elements were working well.

Balloon in a box

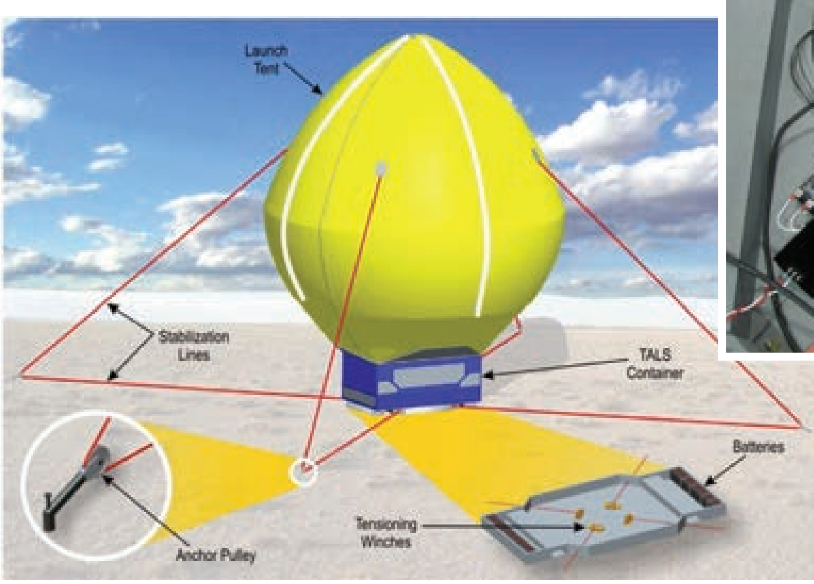
As a final step, the SwRI team would need to demonstrate the concept for representatives of the military. The team made plans for a live, on-site demonstration of the 1/3 scale TALS for representatives from the Department of Defense (DoD) encompassing the U.S. Army Space and Missile Defense Command, Defense Advanced Research Projects Agency and the Office of the Secretary of Defense. When a budget-related government shutdown prevented travel to the planned demonstration, the SwRI team conducted the TALS demonstration and sent a video of the successful automated launch demonstration to the DoD representatives. Based on the promising results of the scale-model proof-of-concept demonstration, they have requested a full-scale TALS be included as an integral part of the next generation HiSentinel Airship program.

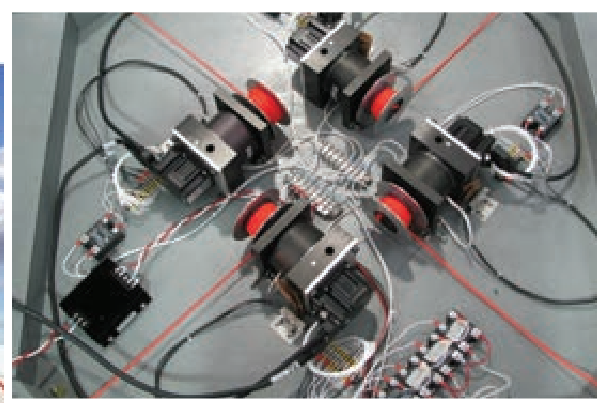
Conclusion

The SwRI LTA team's design and successful demonstration of its TALS system proved the feasibility of a fully automated launch system concept that is applicable to balloons, airships and aerostats. The self-contained TALS can launch LTA vehicles, directly from the container, under local or remote control, in less than 30 minutes, in winds as high as 12 knots, without problems.

Questions about this article? Contact Perry at (210) 522-2747 or bill.perry@swri.org.

Acknowledgments
The author thanks U.S. Army Space and Missile Defense Command/Army Forces Strategic Command and the SwRI internal research program for continued funding and technical support for the HiSentinel platform. Additional thanks go to Raven Aerostar for providing the tent and test airship hulls for the TALS system. The author acknowledges the significant contributions of Senior Program Manager Steve Smith, Senior Research Engineer David Lopez, Senior Engineering Technologist Thomas Wilson, Senior Research Engineer James Noll and Principal Engineer Michael L. Fortenberry, of SwRI's Space Science and Engineering Division, to this research.





The airship is stabilized during the critical initial inflation phase using tether lines that are adjusted using battery-powered tensioning winches (inset).

Rosetta: Long Journey to a Small Place

After 10-year voyage, the spacecraft will rendezvous with a comet in 2014

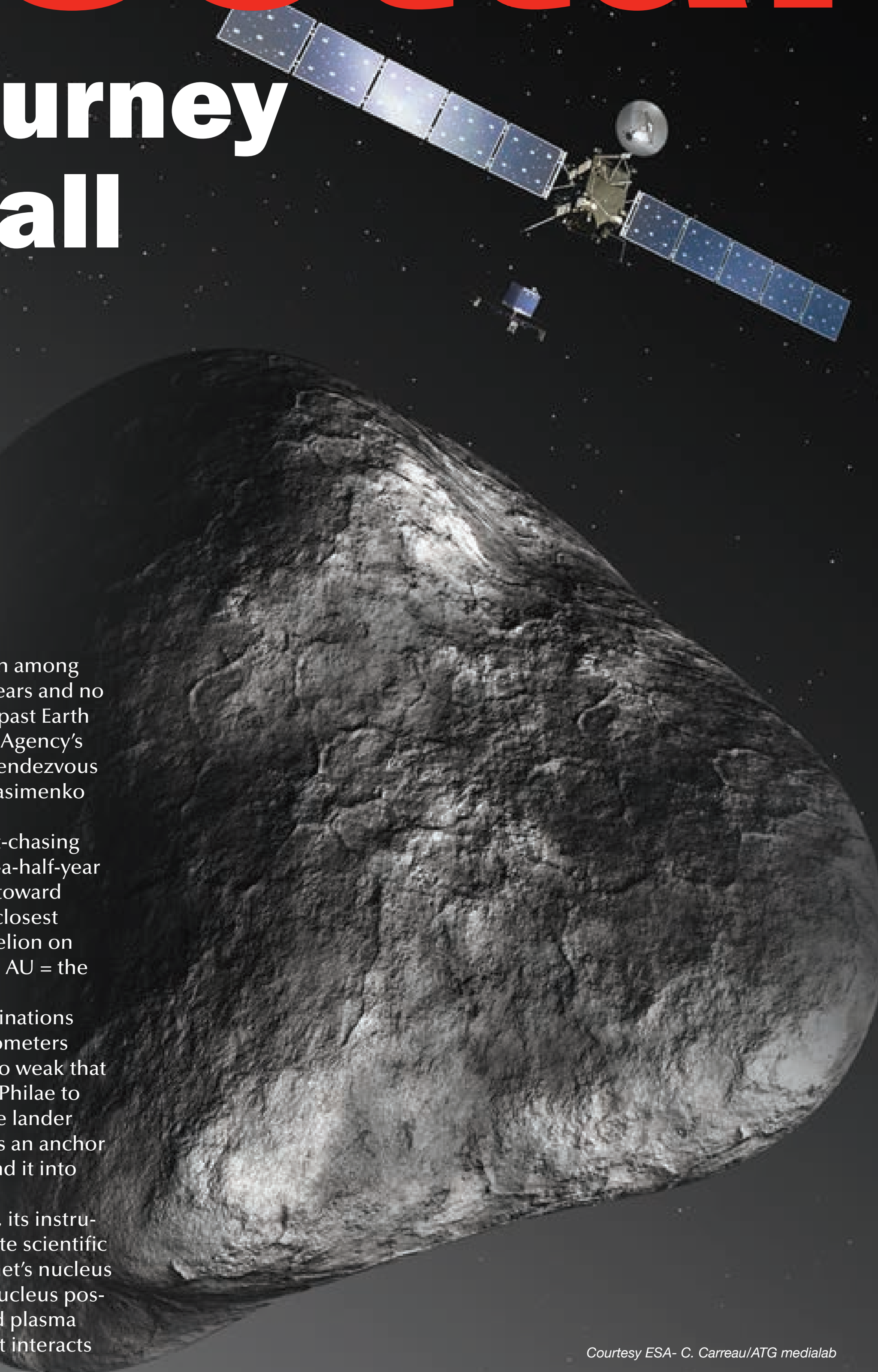
By Ray Goldstein, Ph.D.

In terms of time and distance, it's been among the longest space voyages. After 10 years and no fewer than four gravity-assist swings past Earth (3) and Mars (1), the European Space Agency's Rosetta spacecraft will pull into a gentle rendezvous orbit around Comet 67P Churyumov-Gerasimenko (C-G for short) sometime in August 2014.

At the end of January 2014, the comet-chasing spacecraft was awakened from a two-and-a-half-year hibernation and set on its final approach toward rendezvous, even as C-G itself begins its closest approach toward the Sun, reaching perihelion on August 13, 2015 at 1.24 AU from the Sun (1 AU = the distance between Earth and the Sun).

Comet CG is one of the smallest destinations ever for a spacecraft mission. At just 3 kilometers wide and 5 kilometers long, its gravity is so weak that when Rosetta dispatches a lander named Philae to the comet's surface in November 2014, the lander will fire a harpoon into the comet to act as an anchor so its spring-cushioned legs won't rebound it into space.

During Rosetta's rendezvous mission, its instrument payload will gather data to investigate scientific questions such as how and when the comet's nucleus will become active, what properties the nucleus possesses, what makes up the neutral gas and plasma that form its coma or "tail," how the comet interacts



Courtesy ESA- C. Carreau/ATG medialab

with the solar wind, and what comprises its cometary dust.

The why and what of studying comets

Scientists believe that comets were born in the outer reaches of the Solar System, more than 4 billion years ago when the planets were forming. Far away from the Sun, they formed out of icy material as well as rocky matter, which turned them into the "dirty snowballs" (or perhaps "icy dirtballs") of space. As the most primitive objects in the Solar System, comets are believed by many scientists to have kept a record of the physical and chemical processes that occurred during the early stages of the evolution of the Sun and Solar System. Cometary material, therefore, represents the closest we can get to the conditions that occurred when the Solar System was born. Like the original Rosetta Stone, which allowed 19th-century archeologists to translate ancient Egyptian hieroglyphics for the first time, the Rosetta spacecraft's instrument suite will help 21st-century scientists better understand the composition and processes that existed at the Solar System's formation.

While planets orbit the Sun in roughly circular fashion, comets' orbits are notably eccentric, taking an elliptical path that can alternate between the dark and cold of the Solar System's edge and the Sun's burning heat. For example, Comet C-G's 6.45-Earth-year orbit varies from 1.24 AU to 5.68 AU.

When a comet approaches the Sun, the fuzzy, tailed star-like body that we see in the night sky is the product of a combination of physical and electromagnetic phenomena. The nucleus of a comet – the dirty snowball part – consists of not only ice and rock, but an exterior dust coating, or mantle. As it speeds toward the Sun, the comet plows directly into the solar wind, a stream of electrically charged particles, or plasma dragging along a magnetic field, flowing outward from the Sun at a million miles an hour. A thick plasma bow-shock wave forms in front of the comet's nucleus. Meanwhile, ultraviolet solar radiation begins heating the ice in the nucleus as the comet nears the Sun, causing outgassing and ionizing water vapor, forming the "coma" and tail structure that we see and think of as a comet. Dust particles become electrically charged and levitate off the comet's surface, contributing to the "tail."

Rosetta's instruments and what they do

Rosetta and the Philae lander will approach Comet C-G with an onboard suite of instruments specializing in unlocking the interactions of the comet and the plasma environment as it reaches its nearest approach to the Sun. The spacecraft is powered by two solar panels with a combined area of 64 square meters, stretching out 32 meters tip-to-tip.

Among Rosetta's 11 science instruments are two contributed by Southwest Research Institute. SwRI space scientists are principal investigators for the Ion and Electron Spectrometer (IES) as well as ALICE, its ultraviolet imaging spectrograph. Other instruments include the Comet Nucleus Sounding, secondary ion mass analyzer, grain impact analyzer and dust accumulator, a micro-imaging analysis system, microwave instrument, imaging system, and visible and infrared mapping spectrometer.

The Philae lander carries 10 additional instruments, which include an alpha proton X-ray spectrometer, an evolved gas analyzer, a magnetometer and a plasma monitor, a sample and distribution device, a surface electric sounding and acoustic monitoring experiment, and a cometary sampling and composition experiment.

SwRI's Ion and Electron Sensor (IES), a member of the Rosetta Plasma Consortium (RPC) consisting of five particles and fields instruments, measures the flux of electrons and ions as functions of energy and direction. Its principal investigator is Dr. Jim Burch, vice president of SwRI's Space Science and Engineering Division. Along with other members of the RPC, it will investigate the solar wind's interaction with the comet nucleus and atmosphere (i.e. coma), and the processes that govern the composition, structure, and dynamics of the atmosphere. An important aspect of the measurements is observing the evolution of the density and structures in the coma as C-G moves closer to the Sun. This has never been done before. Ground-based observations of comets give only the overall appearance and composition and large-scale structure of the coma. Results of the measurements can then be compared with predictions from theoretical models. Disagreement means corrections to the models will be in order.

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Dr. Raymond Goldstein, a staff scientist in the Space Science and Engineering Division, has an extensive background in the design, testing and data analysis of laboratory as well as space instrumentation. He led the preliminary design of an ion mass spectrometer that flew by comet Halley on the European Giotto spacecraft and has been co-investigator for instruments aboard NASA and European Space Agency missions, including DS-1, Rosetta and Bepi Columbo.

The ALICE instrument from SwRI, whose principal investigator is SwRI Associate Vice President Dr. Alan Stern, is an ultra-violet (UV) imaging spectrometer, measuring the intensity of UV light emitted by or reflected from the nucleus or coma as a function of wavelength. These measurements will help determine the properties of the nucleus surface and dust grains, plus the composition and details of the chemical reactions in the emitted gases. As in the case of IES, ALICE will also follow the evolution of these characteristics of the comet as it moves along its orbit around the sun. Some of the processes that occur at a comet that both IES and ALICE will be studying also are known to occur throughout the universe.

Rosetta is a project of the European Space Agency (ESA) with contributions from several individual European countries as well as NASA.

Questions about this article? Contact Goldstein at (210) 522-6223 or raymond.goldstein@swri.org.

TECHNICS

Brief notes about the world of science and technology at Southwest Research Institute

New research finds "geologic clock" that helps determine Moon's age

An international team of planetary scientists including researchers from Southwest Research Institute determined that the Moon formed nearly 100 million years after the start of the solar system, according to a paper published April 3 in *Nature*. This conclusion is based on measurements from the interior of the Earth combined with computer simulations of the protoplanetary disk from which the Earth and other terrestrial planets formed.

The team of researchers from France, Germany and the United States simulated the growth of the terrestrial planets (Mercury, Venus, Earth and Mars) from a disk of thousands of planetary building blocks orbiting the Sun. The scientists discovered a relationship between the time the Earth was impacted by a Mars-sized object to create the Moon and the amount of material added to the Earth after that impact.

Augmenting the computer simulation with details on the mass of material added to the Earth by accretion after the formation of the Moon revealed a relationship that works much like a clock to date the Moon-forming event. This is the first "geologic clock" in early solar system history that does not rely on measurements and interpretations of the radioactive decay of atomic nuclei to determine age.

Published literature provided the estimate for the mass accreted by Earth after the Moon-forming impact. Other scientists previously demonstrated that the abundance in the Earth's mantle of highly siderophile elements, which are atomic elements that prefer to be chemically associated with iron, is directly proportional to the mass accreted by the Earth after the Moon-forming impact.

From these geochemical measurements, the newly established clock dates the Moon to 95 ±32 million years after the beginning of the solar system. This estimate for the Moon formation agrees with some interpretations of radioactive dating measurements, but not others. Because the new dating method is an independent and direct measurement of the age of the Moon, it helps to guide which radioactive dating measurements are the most useful for this longstanding problem.

"This result is exciting because in the same simulations that can successfully form Mars in only 2 to 5 million years, we can also form the Moon at 100 million years. These vastly different timescales have been very hard to capture in simulations," said author Dr. Kevin Walsh, a research scientist in SwRI's Space Science and Engineering Division.

This research was funded by the European Research Council, as well as NASA's Astrobiology Virtual Planetary Laboratory, Planetary Geology and Geophysics, Lunar Science Institute and Solar System Exploration Research Virtual Institute programs.

The paper, "Highly Siderophile elements in Earth's Mantle as a Clock for the Moon-forming Impact," by Seth Jacobson, Alessandro Morbidelli, Sean Raymond, David O'Brien, Kevin Walsh and David Rubie, was published in the April 3, 2014, issue of *Nature*.

Contact Walsh at (303) 546-9670 or kevin.walsh@swri.org.

New combustion catalyst and aftertreatment consortium

Southwest Research Institute (SwRI) is forming the Advanced Combustion Catalyst and Aftertreatment Technologies (AC^2AT) consortium.

The four-year joint-industry consortium, scheduled to kick off in June 2014, is open to original equipment manufacturers and affiliated businesses in the automotive industry and provides a collaborative approach to evaluating engine emissions and novel catalyst technologies. Annual membership is $95,000.

"As future emission regulations are proposed, it is important for engine and equipment manufacturers to understand the detailed composition of emissions from these advanced combustion concepts, evaluate what strategies can be developed to treat emissions, and identify alternative uses for catalysts that can reduce fuel consumption and harmful emissions," said Cary Henry, principal engineer in SwRI's Engine, Emissions and Vehicle Research Division.

The Institute will pursue patents for technology developed by the AC^2AT program, and participants will receive a royalty-free license to use AC^2AT-developed technology. Consortium members benefit from the combined funding, providing substantially more pre-competitive research than would be possible with funding from a single client.

As an independent applied R&D laboratory, SwRI has extensive experience managing consortia. The AC^2AT consortium will be the eighth automotive industry-related consortium currently managed by the Institute. For more information see ***ac2at.swri.org***.

Contact Henry at (210) 522-2424 or chenry@swri.org.

SwRI launches new automotive consortium focusing on fuels and lubricants

Southwest Research Institute (SwRI) has announced it is launching the Advanced Engine Fluids (AEF) consortium to better understand fuel and lubricant chemistry and its effects on engine combustion. The AEF will hold its first meeting on July 7, 2014, at Southwest Research Institute in San Antonio.

Sharing costs through a consortium gives companies access to more research than would be feasible if funded individually, according to Dr. Thomas Briggs, a manager in the Engine Systems Research and Development Section in the Engine, Emissions and Vehicle Research Division. Also, members will receive free licensing for any patents that are produced from the consortium's work.

Membership in the AEF consortium is $100,000 per year and may be renewed annually. Members receive monthly updates and meet quarterly.

"Engine technology is changing so rapidly that it has become difficult for fuel and lubricant technologies to keep up," said Briggs. "The new technologies being applied to engines are dramatically changing the demands placed on the fluids. We are also seeing more and more evidence that the chemical and physical details of the fluids significantly impacts engine performance."

The AEF consortium will research the impact of fuels and lubricants on engine combustion and the requirements needed for optimizing future engine technologies.

"Our research will focus on ways to accelerate improvements for fuels and lubricants to keep up with emerging fuel economy standards," Briggs said. "SwRI's decades-long experience in fuel and lubricant testing combined with our industry-leading research on advanced engines gives us unique insight into the challenges facing modern fuel and lubricant companies."

SwRI has managed a number of automotive consortia, including two long-running programs: the High-Efficiency, Dilute Gasoline Engine (HEDGE®) consortium, now in its third phase, which seeks to improve gasoline engine technology for heavy-duty applications, and the Clean High-Efficiency Diesel Engine VI consortium, the industry's longest-running diesel research consortium, which develops efficiency and emissions solutions for future diesel engines.

Contact Briggs at (210) 522-5153, or e-mail at thomas.briggs@swri.org.

McComas to receive 2014 COSPAR Space Science Award

The Committee on Space Research (COSPAR) has selected Dr. David J. McComas, assistant vice president of the Space Science and Engineering Division at Southwest Research Institute (SwRI), to receive a 2014 COSPAR Space Science Award during the inaugural ceremony of the 40th COSPAR Scientific Assembly, August 4, in Moscow. The award recognizes outstanding contributions to space science.

"I am incredibly honored and humbled to be receiving COSPAR's Space Science Award," McComas said. "It's really a tribute not to me, but to all of the great people that I have been privileged to work with here at SwRI and, before that, at Los Alamos National Laboratory, and all of my many other excellent colleagues and collaborators from around the world."

Since joining SwRI in 2000, McComas has helped lead SwRI's overall space science and engineering program. He is principal investigator of NASA's Interstellar Boundary Explorer (IBEX) and Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) missions. He also is principal investigator for space science instruments on numerous other NASA missions, including two instruments for the Solar Probe Plus mission, scheduled to launch in 2018.

McComas is a Fellow of the American Geophysical Union, the American Physical Society and the American Association for the Advancement of Science. He is also a member of the NASA Advisory Council (NAC), for which he chairs the NAC Science Committee.

McComas holds six patents and has authored more than 500 refereed scientific papers that have been cited approximately 18,000 times, spanning a range of research topics including coronal, solar wind, heliospheric, magnetospheric, cometary, planetary and interstellar science, as well as numerous space flight instruments and techniques.

COSPAR was established in 1958, just at the start of the space age, by what is now the International Council for Science. Worldwide membership in COSPAR has grown to include 43 member nations involved in space research. Over the past three decades there have been 25 prior recipients of COSPAR's Space Science Award worldwide, starting with its first recipient — James A. Van Allen in 1984.

Contact McComas at (210) 522-5983 or david.mccomas@swri.org

Technical Staff Activities

Publications

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Presentations

Allegrini, F., R. DeMajistre, H.O. Funsten, P.H. Janzen, D.J. McComas, D.B. Reisenfeld and N. Schwadron. "Interstellar Boundary Explorer (IBEX)–Hi Observations of Heavier Than Hydrogen Energetic Neutral Atoms." Paper presented at the American Geophysical Union (AGU) 2013 Fall Meeting, San Francisco, December 2013.

Amann, M. "Engine Parameter Optimization for Improved Engine and Drive Cycle Efficiency for Boosted, GDI Engines with Different Boosting System Architecture." Paper presented at the 2014 Society of Automotive Engineers (SAE) World Congress, Detroit, April 2014.

Bessee, G. "Energy Institute (EI) Multi-product Pipeline Protocol and Water Mapping Example." Presented at the Aviation Fuels Conference, London, March 2014.

Bichon, B.J. "Bayesian Process Control for Composite Bonding in DARPA TRUST." Paper presented at the Defense Manufacturing Conference, Orlando, Fla., December 2013.

Bramson, A.M., S. Byrne, N.E. Putzig, J.J. Plaut, S. Mattson and J.W. Holt. "Thick Subsurface Water Ice in Arcadia Planitia, Mars." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013, and at the Lunar Planetary Science XLV Meeting, The Woodlands, Texas, March 2014.

Brun, K., W. Foiles, T. Grimley and R. Kurz. "Experimental Evaluation of the Effectiveness of Online Water Washing in Gas Turbine Compressors." Paper presented at the 42nd Turbomachinery Symposium, Houston, September 2013.

Brun, K., R. Kurz and J. Thorp. "Inlet Fogging and Overspray Impact on Industrial Gas Turbine Life and Performance." Paper presented at the 20th Symposium of the Industrial Application of Gas Turbines Committee, Banff, Canada, October 2013.

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Brun, K., K. Wygant and J.C. Wilkes. "Tutorial: Centrifugal Compressor." Paper presented at the 2014 Gas Electric Partnership Conference, Houston, February 2014.

Buzulukova, N., M.-C. Fok, A. Glocer, D.G. Sibeck, D.J. McComas and P.W. Valek. "Extracting Global Precipitation Pattern from Global Modeling with Two-way Coupled BATSRUS-CRCM-RBE." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Bzowski, M., M.A. Kubiak, J.M. Sokol, E. Moebius, T. Leonard, H. Kucharek, D.J. McComas and G. Livadiotis. "New Population of Neutral Helium in the Heliosphere Discovered by IBEX." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Bzowski, M., E. Moebius, S. Fuselier, D. Heirtzler, M.A. Kubiak, H. Kucharek, M.A. Lee, D.J. McComas, J. Park, N. Schwadron, J.M. Sokol and P. Wurz. "Interstellar Neutral Gas Flow Measurements with the Interstellar Boundary Explorer (IBEX) – Implications on Heliospheric Boundary Diagnostic." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Cardinal, J.W., R.C. McClung, Y.D. Lee, Y. Guo and J. Beek. "Recent Developments and Challenges Implementing New and Improved Stress Intensity for Factor (K) Solutions in NASGRO for Damage Tolerance Analyses." Paper presented at the Aircraft Airworthiness and Sustainment Conference, Baltimore, April 2014.

Carroll, J.N., C. Caffrey and A. J. Peterson. "Fuel Effects Study with In-use Two-stroke Motorcycles and All-terrain Vehicles." Paper presented at the SAE/KSAE 2013 Powertrain, Fuels and Lubricants Meeting, Seoul, Korea, October 2013.

Carroll, J.N., A.J. Peterson and C. Caffrey. "Fuel Effects Study with Small (< 19kW) Spark-ignited Off-road Equipment Engines." Paper presented at the SAE/KSAE 2013 Powertrain, Fuels and Lubricants Meeting, Seoul, Korea, October 2013.

Cheng, X.G. "Novel Magnetic Calcium Phosphate (MCaP) Nanoparticles (NPs) for Biomedical Applications." Invited seminar presented at San Antonio Nanotechnology Forum, San Antonio, December 2013.

Cheng, X.G. and R. J. Christy. "The Key Role of the Topography of a Biomaterial and the Release of a Growth Factor on Differentiation of Adipose-derived Stem Cells." Paper presented at San Antonio Conference on Stem Cell Research and Regenerative Medicine, San Antonio, February 2014.

Cheng, X.G., D.P. Nicolella, T.L. Bredbenner and Q. Ni. "A New Generation of Bone Cement Prepared by a Magnetic Field-triggered Polymerization Process." Poster presented at 2014 Orthopaedic Research Society (ORS) Conference, New Orleans, March 2014.

Cheng, X.G., G.M. Zhong, J. McDonough and M. MacNaughton. "Synthesis of Novel Particulate Adjuvants for Vaccine and Preliminary Evaluation." Invited talk at the 2013 San Antonio Vaccine Development Symposium, San Antonio, November 2013.

Chirathadam, T.A. "Design Guidelines for the Reliability of Buried Gas Transmission Pipelines." Paper presented at the 2014 Gas Processors Association Convention, Dallas, April 2014.

Christian, E.R., H.O. Funsten, D.J. McComas and N. Schwadron. "Motions in the Ribbon of ENAs Observed by the Interstellar Boundary Explorer (IBEX)." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Conrad, A.R., W.J. Merline, A. La Camera, P. Boccacci, M. Bertero, B. Carry, J. Drummond and J.C. Christou. "Detecting Asteroid Satellites with Fizeau Interferometry." Paper presented at the 3rd Workshop on Binaries in the Solar System, the Big Island, Hawaii, June 2013.

Czechowski, A., J. Grygorczuk. R.E. Ratkiewicz and D.J. McComas. "Strong Interstellar Field: Structure of the Heliosphere and Production of the Energetic Neutral Atoms." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Dannemann, K.A., F.S. Campbell, A.J. Carpenter, T.T. Kirchdoerfer, R.P. Bigger, I.S. Chocron, J.D. Walker, U. Heisserer and H. van der Werff. "*In-situ* Testing for Monitoring Damage Development in a Single-ply Composite Material." Paper presented at the Minerals, Metals and Materials Society 2014 143rd Annual Meeting and Exhibition, San Diego, Calif., February 2014.

Dante, J.F. and E.N. Macha. "Effectiveness of Inhibitors on Aluminum and Aluminum/Steel Couples as a Function of Relative Humidity." Paper presented at the Corrosion Conference 2014, San Antonio, March 2014.

Das, K., A. Ghosh, D. Basu and L. Miller. "Soil Structure and Fluid Interaction Assessment of New Modular Reactor: Part 1–Numerical Simulation of Fluid Motion Due to Seismic Waves." Paper presented at the ASME 2014 Small Modular Reactors Symposium, Washington, D.C., April 2014.

Dayeh, M.A., R. DeMajistre, S. Fuselier, P.H. Janzen, D.J. McComas, D.G. Mitchell, K. Ogasawara, S.M. Petrinec, N. Schwadron and K.J. Trattner. "Structure and Location of the Terrestrial Plasma Sheet as Observed by the Interstellar Boundary Explorer (IBEX)." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

DeForest, C.E., T.A. Howard and W.H. Matthaeus. "Imaging the Variable Solar Wind." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

DeForest, C.E., T.A. Howard and D.J. McComas. "Imaging Solar Wind Sources at the Inner Edge of the Heliosphere." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Desai, M.I., F. Allegrini, M. Bzowski, M.A. Dayeh, H.O. Funsten, S. Fuselier, M.A.Kubiak, D.J. McComas, N.V. Pogorelov, N. Schwadron, J.M. Sokol, G.P. Zank and E.J. Zirnstein. "Energetic Neutral Atoms Measured by the Interstellar Boundary Explorer (IBEX): Evidence for Multiple Heliosheath Ion Populations." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Drummond, J.D., B. Carry, W.J. Merline, C. Dumas, H. Hammel, S. Erard, A. Conrad, P. Tamblyn and C. Chapman. "The Size and Pole of Ceres from Nine Years of Adaptive Optics Observations at Keck and the VLT." Paper presented at the American Astronomical Society, DPS meeting No. 45, Denver, October 2013.

Elliott, H.A., D.J. McComas, J. Mukherjee, P.W. Valek, G. Livadiotis, P.A. Delamere, F. Bagenal and G. Nicolaou. "New Horizons Solar Wind Around Pluto (SWAP) Solar Wind Measurements." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Enke, B.L., W.F. Bottke, D.D. Durda, W.J. Merline, K. Walsh, D.C. Richardson and E.I. Asphaug. "Evolution of Tools for the Simulation of Binary-forming Asteroid Impacts." Paper presented at the 3rd Workshop on Binaries in the Solar System, the Big Island, Hawaii, June 2013.

Evans, N.D. "Measurement of High Amplitude Relief Valve Noise During a Full-scale Blowdown Test." Paper presented at the 166th Meeting of the Acoustical Society of America, San Francisco, December 2013.

Feng, M., S. Cooks and Z. Feng. "Treatment of Flowback Water from Hydraulic Fracturing with Biochar." Paper presented at the 2014 AIChE Spring Meeting, New Orleans, April 2014.

Feng, M., C. K. Tan and D. Daruwalla. "Lignin Depolymerization in Ionic Liquids with the Presence of Hydrogen Transfer Agents." Paper presented at the 2014 AIChE Spring Meeting, New Orleans, April 2014.

Feng, M. and R. Zhan. "Oxygenated Compounds as Reducing Agent for NO_X Removal in a Selective Non-Catalytic Reduction (SNCR) System." Paper presented at the 2014 AIChE Spring Meeting, New Orleans, March 31–April 3, 2014.

Fichtner, H., K. Scherer, F. Effenberger, J. Zoennchen, N. Schwadron and D.J. McComas. "The IBEX Ribbon as a Signature of the Inhomogeneity of the Local Interstellar Medium." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Flores, E. and M. Hartmann. "Modeling Laboratory Circulating Fluid Bed Fast Pyrolysis Using Representative Compounds for Improved Product Quality and Hydrogen Retention." Paper presented at 2014 AICHE Spring Meeting and 10th Global Congress on Process Safety, New Orleans, April 2014.

Fox, N.J., S.D. Bale, R.B. Decker, R. Howard, J.C. Kasper, D.J. McComas, A. Szabo and M.M. Velli. "Solar Probe Plus: A NASA Mission to Touch the Sun." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Frahm, R.A., H.A. Elliott, J.D. Winningham, J.R. Sharber, C.E. DeForest, T.A. Howard, E.J. Kallio, S. McKenna-Lawlor, F. Duru, D.D. Morgan, A.J. Coates, D. Odstrčil, R.N. Lundin, Y. Futaana and S.V. Barabash. "Asymmetry of the Mars Ionosphere Boundary Altitude during a Solar Energetic Particle Event." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Frisch, P.C., M. Bzowski, H.O. Funsten, G. Livadiotis, D.J. McComas, E. Moebius, H.-R. Mueller, N. Schwadron and J.M. Sokol. "Spatial and Temporal Interstellar Structure: What Will IBEX Find?" Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Fritz, S. "Locomotive Biodiesel Updates." Paper presented at the 2014 National Biodiesel Conference, San Diego, April 2014.

Fritz, S. "Locomotive Exhaust Emissions Measurements for Various Blends of Biodiesel Fuel." Paper Presented at the 2014 ASME–ASCE–IEEE Joint Rail Conference and Exposition, Colorado Springs, Colo., January 2014.

Funsten, H.O., R. DeMajistre, P.C. Frisch, J. Heerikhuisen, D.M. Higdon, P.H. Janzen, B. Larsen, G. Livadiotis, D.J. McComas, E. Moebius, S. Reese, D.B. Reisenfeld, N. Schwadron and E.J. Zirnstein. "Mirror Symmetry of the IBEX Ribbon of Enhanced Neutral Atom (ENA) Flux." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

George, D.L. "CNG Sampling." Paper presented at the 2014 Natural Gas Sampling Technology Conference, New Orleans, January 2014.

Ghosh, A., K. Das, D. Basu and L. Miller. "Soil Structure and Fluid Interaction Assessment of a Small Modular Reactor Numerical Study of Soil Reactor Structure Interaction." Paper presented at the ASME 2014 Small Modular Reactors Symposium, Washington, D.C., April 2014.

Goldstein, J., P.W. Valek, D.J. McComas and J.A. Redfern. "TWINS Observations of Local Time Dependence of Precipitating Ions." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Hamilton, V.E., A.R. Vasavada and P.R. Christensen. "Coordinated MSL and Mars Odyssey Observations of Ground Temperature in Gale Crater." Paper presented at the Lunar Planetary Science XLV Meeting, The Woodlands, Texas, March 2014.

Hamilton, V.E., A.R. Vasavada, P.R. Christensen, M.A. Mischna and the MSL Science Team. "Coordinated *In Situ* and Orbital Observations of Ground Temperature by the Mars Science Laboratory Ground Temperature Sensor and Mars Odyssey Thermal Emission Imaging System: Implications for Thermal Modeling of the Martian Surface." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Hanley, J., J.B. Dalton, V. Chevrier and C. Jamieson. "Spectra of Low-Temperature Chlorine Salt Hydrates and Implications for Europa." Paper presented at the Workshop on the Habitability of Icy Worlds, Pasadena, Calif., February 2014.

Hanley, J., M. Mellon and R. Arvidson. "Mechanical Strength of Martian Analog Soils." Paper presented at the Lunar Planetary Science XLV Meeting, The Woodlands, Texas, March 2014.

Hanna, R.D. and V.E. Hamilton. "Correlating Thermal Inertia and Olivine Abundance on Mars with THEMIS." Paper presented at the Lunar Planetary Science XLV Meeting, The Woodlands, Texas, March 2014.

Hartmann, M., M. Feng and E. Flores. "Chlorine Control for Fuel and Chemicals Production from Pyrolysis of Waste Plastics." Paper presented at 2014 AICHE Spring Meeting and 10th Global Congress on Process Safety, New Orleans, March 2014.

Howard, T.A., C. DeForest, S.J. Tappin and D. Odstrčil. "Exploring Polarized Heliospheric Imaging." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Khalek, I.A. "The Role of High Efficiency Particle Filters in Emissions Reduction: Current State and a Look into the Future." Presented at the 2014 SAE World Congress, Detroit, April 2014.

Khalek, I.A., R. Mechler, V. Premnath, R. Giannelli and M. Spears. "Denuder for Particulate Matter Artifacts Removal: Development and Applications." Presented at the SAE World Congress, Detroit, April 2014.

Kirchoff, M.R. and P. Schenk. "The Resurfacing and Bombardment History of Saturn's Moon Dione from its Global Crater Database." Paper presented at the Lunar Planetary Science XLV Meeting, The Woodlands, Texas, March 2014.

Lester, M., H.J. Opgenoorth, D.J. Andrews, E. Dubinin, N.J. Edberg, M. Fraenz, T.A. Howard, W.W. Kofman, L. Lei, R.J. Lillis, M. Matta, D.D. Morgan, H. Nilsson, A. Opitz, K. Peter, J.A. Wild, P. Withers and O.G. Witasse. "Reduced Low Energy Electron Counts and Their Relationship to Crustal Magnetic Fields at Mars." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Liljedahl, A., R.P. Daanen, G. Frost, G. Grosse, N. Matveyeva, M. Necsoiu, M. Raynolds, V. Romanovsky, J. Schulla and D. Walker. "Observed Ice Wedge Degradation at Multiple Continuous Permafrost Locations and Their Simulated Effects on Watershed Scale Hydrology C52A-04." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Livadiotis, G. and D.J. McComas. "Large-scale Quantization in Space Plasmas." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Livadiotis, G. and D.J. McComas. "Understanding Kappa Distributions in Space Physics." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Llera, K., J. Goldstein, P.W. Valek and D.J. McComas. "Ion Precipitation: Loss Cone State and Low-altitude Emission Response Time to Solar Wind Pressure Pulse-driven Magnetospheric Compression." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Lu, B.T. "A Science-based Crack Growth Model for Buried Pipelines Undergoing High pH SCC (II) – Application." Paper presented at the Corrosion Conference 2014, Paper No. 2014-0003617, San Antonio, March 2014.

Mattson, S., A. Kilgallon, S. Byrne, A.S. McEwen, C. Okubo, N.E. Putzig and P. Russell. "Meter-scale Pits in Mars' North Polar Layered Deposits." Paper presented at the Lunar Planetary Science XLV Meeting, The Woodlands, Texas, March 2014.

McClung, R.C., M.P. Enright, J.M. McFarland, K.S. Chan, W-T Wu and R. Shankar. "Linking ICME to Component Life Management During Design." Paper presented at the Minerals, Metals and Materials Society 2014 143rd Annual Meeting and Exhibition, San Diego, February 2014.

McClung, R.C., M.P. Enright, J.P. Moody, Y.D. Lee and J.M. McFarland. "Integrating Fatigue Crack Growth into Reliability Analysis and Computational Materials Design." Paper presented at the 11th International Fatigue Congress (FATIGUE 2014), Melbourne, Australia, March 2014.

McComas, D.J. "IBEX: Five Years of Observing the Outer Heliosphere." Paper presented at the 13th Annual International Astrophysics Conference, Myrtle Beach, S.C., March 2014.

McComas, D.J. "The Interstellar Boundary Explorer–IBEX." Paper presented at the Department of Physics and Astronomy Graduate Research Seminar, The University of Texas at San Antonio, January 2014.

McComas, D.J., M.A. Dayeh, M. Bzowski, R. DeMajistre, H.O. Funsten, S. Fuselier, P.H. Janzen, M.A. Kubiak, G. Livadiotis, D.B. Reisenfeld, N. Schwadron and J.M. Sokol. "The Evolving Heliosphere Observed Over IBEX's First Five Years (2009–2013)." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

McGovern, P.J., M.R. Kirchoff, O.L. White and P. Schenk. "Magma Ascent Pathways Associated With Large Mountains on Io." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

Mehta, D., T. Reinhart, J. Steiber and J. Anthony. "Current and Future Greenhouse Gas Regulations for Trucks." Paper presented at the 2013 SAE High Efficiency Heavy Duty Vehicle Symposium, Rosemont, Ill., October 2013.

Moebius, E., M. Bzowski, P.C. Frisch, S. Fuselier, D. Heirtzler, M. Hlond, M.A. Kubiak, H. Kucharek, M.A. Lee, T. Leonard, D.J. McComas, N. Schwadron, J.M. Sokol and P. Wurz. "Interstellar Neutral Gas Inside and Outside the Heliosphere as Viewed from the Interstellar Boundary Explorer (IBEX)." Paper presented at the AGU 2013 Fall Meeting, San Francisco, December 2013.

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