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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 10 divisions engaged in contract research spanning a wide range of technologies.

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COVER

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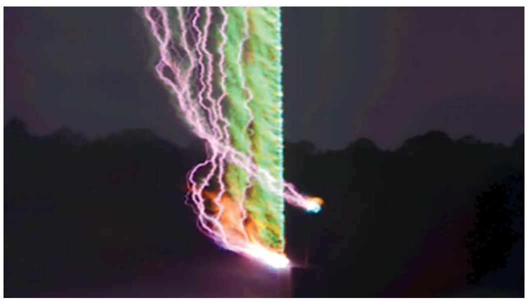
About the cover
Using an "acoustic camera" during a rocket-triggered lightning event, SwRI scientists have produced the first images of thunder. An array of microphones captured this image profile of the sound produced by the lightning discharge channel, allowing scientists to take a closer look at thunder to better understand its origin and what it discloses about the lightning process.

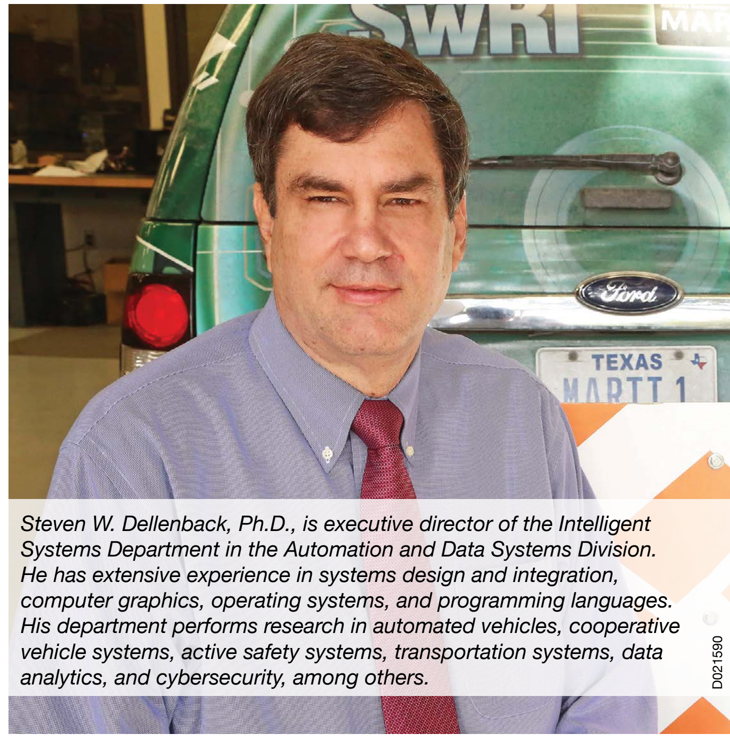
ARTICLES



Departments

UNMANNED, UNINJURED

Autonomous impact attenuator vehicles can make a hazardous work zone safer



Steven W. Dellenback, Ph.D., is executive director of the Intelligent Systems Department in the Automation and Data Systems Division. He has extensive experience in systems design and integration, computer graphics, operating systems, and programming languages. His department performs research in automated vehicles, cooperative vehicle systems, active safety systems, transportation systems, data analytics, and cybersecurity, among others.

D021590

By Steven W. Dellenback, Ph.D.

Let's face it: Roadway work zones are hazardous. Although essential to maintaining a modern highway system, road construction endangers motorists who drive through an unfamiliar array of signs, barrels, and lane changes, as well as the workers who build, repair, and maintain in-use highways. Since the turn of the century, the U.S. has improved work-zone safety through comprehensive planning and by using historical accident data to identify and understand hazards. Despite these improvements, more than 40,000 people a year are injured in automotive work zone accidents. According to the Federal Highway Administration approximately 600 people are killed in work zone accidents each year. And work zones are ubiquitous, averaging one every 100 miles in the U.S.

Because more than 30 percent of crashes in mobile or static work zones involve drivers hitting the last vehicle, work zones are often protected by "safety trucks." These trucks have crash-absorbing mechanisms attached at the rear designed to absorb the impact of a vehicle and stop it before it can hit the work crew. While these crashes are dangerous for the drivers of the safety truck and the vehicle hitting it, the situation has lower risk of catastrophe than a vehicle entering a work zone with multiple, unprotected workers on the ground.

Enhancing work zone safety with connected automation

For more than a decade, automation engineers at Southwest Research Institute (SwRI) have performed more than $50 million worth of research and development related to connected-vehicle and automated-vehicle technologies for commercial, military, and state and federal clients.

An automated truck-mounted attenuator not only removes the driver from a vulnerable position, but also helps avoid the traffic hazards a driver faces getting in and out of the cab to reposition the truck as the work convoy moves down the road.

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In a work zone application, lead vehicles could have unique fiducial markings that allow the ATMA to recognize which vehicle it should follow. The fiducial, which looks like a QR code, combined with the "bread-crumb" vehicle-following system, builds safety redundancy into the system and enhances advanced platooning behaviors, such as consistently spaced following.

SwRI is also a pioneer in Advanced Traffic Management Systems (ATMS) (see related story, page 5), which use a fusion of technologies to manage and reduce traffic congestion. By combining connected-vehicle and advanced transportation technologies with other research projects in vehicle automation, SwRI engineers demonstrated how connected automation could help reduce injuries and fatalities in road work zones.

The SwRI team demonstrated the feasibility of using automated vehicles to assume the most dangerous roles in stationary or rolling work zones. They also took advantage of connected-vehicle technology to allow maintenance vehicles to communicate with each other, the work crew, and the roadside infrastructure. Using this technology, workers and the vehicle fleet can maintain communication with advanced traffic management systems, exchanging vital information.

Automating the attenuator vehicle

Truck-mounted attenuator (TMA) vehicles positioned at the rear of a work zone serve as a buffer between highway maintenance workers and traffic entering the zone. But while the attenuator protects the workers and vehicles in the work zone, the driver of the truck is at heightened risk. On average, two attenuator trucks are hit by vehicles each week in Texas alone. That makes attenuator trucks an ideal candidate for automation.

An automated TMA (ATMA) not only removes the driver from a vulnerable position, but also helps avoid the traffic hazards a driver faces getting in and out of the cab to reposition the truck as the work convoy moves down the road. The ATMA could also serve as a key communications interface for the maintenance convoy and the traffic management center that monitors the work zone.

The SwRI engineers used a phased approach to develop and test ATMA capabilities. Initially, one of the Institute's fleet of autonomous vehicles was outfitted with a simulated impact attenuator to collect the data needed to develop and test the system. The prototype ATMA was outfitted with a basic drive-by-wire system and other hardware for autonomous operation. Engineers implemented and tested vehicle-following and gesture-recognition behaviors, and integrated the prototype with an ATMS to monitor and interact with the vehicle. (SwRI can retrofit standard vehicles with autonomous drive-by-wire steering as well as gas and brake controls.) Finally, the SwRI team also integrated a reliable vehicle interface for transmission, signal control, lights, and other vehicle systems, as well as a data analysis and visualization system.

SwRI integrated three key technology areas— connected vehicle, vehicle platooning, and hand-gesture control — for a project to demonstrate a prototype ATMA for the Texas Department of Transportation.

Connected vehicles

Beyond automating specific vehicles for enhanced work zone safety, future connected vehicle networks have the potential to transform transportation, creating a safe, interoperable wireless communications network that includes all cars, buses, trucks, trains, traffic signals, cell phones, and other devices. SwRI has played a key role in developing connected vehicle technology, including the standards for a 5.9 GHz communications network set aside for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, collectively known as vehicle-to-everything or V2x. The Institute maintains a fleet of vehicles outfitted with connected vehicle technology and has extensive facilities to support this research, including a 5.9 GHz DSRC

SwRI developed an application to allow work crews to use hand gestures to control an ATMA. The gesture-recognition application allows workers to move the automated attenuator vehicle without having to get in and out of it, saving time and improving worker safety.

antenna test field, a test track, and dedicated intelligent vehicle laboratories.

For this demonstration, SwRI engineers also used V2x technology to provide a virtual "bread crumb" trail allowing the automated attenuator truck to meticulously follow a lead vehicle. The control commands can be entered using a tablet interface in the lead truck or by a person in the work zone, transmitted using the connected vehicle network.

V2I communication allows a traffic management center to monitor and interact with the work zone, monitor traffic and predict problems, and use dynamic message signs to provide motorists up-to-date information about the work zone.

For mobile work zones — including vehicles spraying weeds, sweeping streets, or striping lanes — the SwRI-designed ATMA can be programmed to follow a maintenance vehicle in front of it or lane stripes on the pavement passing beneath it. The route does not have to be mapped before the ATMA can be used. The ATMA also can autonomously communicate the maintenance convoy's position and speed to the traffic management system control room, which in turn can communicate an alert to approaching vehicles about the work zone.

Vehicle platooning

In 2009, SwRI developed its first automated vehicle platooning application. SwRI engineers first demonstrated the technology on the streets of Washington, D.C., highlighting commercial applications before hitting the "Robotics Rodeo" circuit, demonstrating military applications at several U.S. Army bases. The SwRI-designed platooning algorithm integrates data from many vehicles into a control strategy that can direct how each vehicle paces and places itself in a platoon. Because this control strategy was already implemented in SwRI's automated vehicle platforms, the ATMA performed automated driving functions based on the positions of the other vehicles in the work convoy.

For the ATMA project, the SwRI team also used a reference marker, called a "fiducial," on the lead vehicle. The fiducial looks like a QR code and allows an ATMA to refine its position and orientation behind the lead vehicle. In a work zone application, lead vehicles could have unique tags with fiducial markings that allow the ATMA to recognize which vehicle it should follow. This system, combined with the "bread-crumb" vehicle-following system, builds safety redundancy into the system and enhances advanced platooning behaviors, such as consistently spaced line following. Fiducial markings also identify the various vehicles within the maintenance fleet.

Gesture recognition

In 2012, SwRI developed its first gesture recognition system for a military unmanned ground vehicle (UGV) application. SwRI engineers developed an image-processing algorithm capable of identifying and distinguishing a dismounted soldier's arm gestures. This technology allowed more natural interaction between the warfighter and the automated vehicle, effectively allowing a UGV to function as a member of the squad.

SwRI developed similar applications to allow work crews to use hand gestures to control an ATMA. With this application, workers needing to re-position the vehicle do not have to expose themselves to oncoming traffic by walking to and mounting the TMA. The gestures allowed commands — such as follow-me, offset to the left, offset to the right, or stop — to be captured by a vision system on the ATMA. The gesture recognition technique allows workers to move the automated attenuator vehicle without having to get in and out of it, saving time and improving worker safety.

Next-generation ATMA

As automated and connected vehicle technologies advance, SwRI is poised to deploy them in a next-generation ATMA. For instance, RANGER is an SwRI-designed, patented approach to automating localization through precise positioning and orientation. RANGER, which won a 2015 R&D 100 Award, uses localization algorithms as well as a ground-facing camera to image and store the unique "fingerprint" of a road surface. The vehicle re-orients itself precisely in relation to that stored image. RANGER allows automated driving within 1 to 2 centimeters of a target path, far more precisely than the highest-accuracy GPS systems. RANGER also can operate in areas or environments where GPS has poor performance or fails completely. This is important for instances when the ATMA is used in a tunnel, around tall buildings, among trees, or in a large interchange construction project.

In test deployments on vehicles ranging from compact cars to commercial trucks, RANGER has performed successfully in city and highway driving, in all illumination conditions, and in common adverse weather conditions. Although other sensor-based localization approaches are becoming common, none can match RANGER's precision. SwRI's plan is to dynamically collect RANGER data on the lead vehicle and share the maps with the ATMA so that it will follow the lead vehicle's path precisely.

As connected vehicle technologies proliferate, an ATMA could monitor approaching traffic and predict potential collisions, possibly giving work crews vital advance warning. These V2V systems also can alert approaching travelers if their vehicles are equipped with connected vehicle technology.

Conclusion and future directions

In the past 10 years, SwRI has developed a number of technologies that can be applied quickly and cost-effectively to work zone safety. Using multiple positioning mechanisms, a cooperative convoy control system could monitor the status of the vehicles, control the order of the work platoon, and also control the lateral and longitudinal offset for the automated crash-cushion vehicle that follows.

Because work zone injuries and fatalities remain a significant problem, existing vehicle automation and connected vehicle technologies from SwRI are relevant to enhancing work-zone safety. Deploying these technologies into "crash cushion" maintenance vehicles is relatively straightforward as a first step to improving the safety of many work zone projects, such as corridor reconstruction projects and mobile and stationary maintenance projects.

Questions about this article? Contact Dellenback at (210) 522-3914 or steven.dellenback@swri.org.

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To prototype an automated truck-mounted attenuator, SwRI mounted a simulated apparatus to the rear of one of its automated vehicles. Engineers demonstrated vehicle-following and gesture-recognition behaviors, and integrated the prototype with an automated traffic management system to monitor and interact with the vehicle.

Advanced Traffic Management Systems

Advanced traffic management systems (ATMS), such as San Antonio's Trans-Guide system, have been deployed in most major cities. These systems have been shown to reduce secondary collisions, mitigate congestion, and, most importantly, save lives. SwRI has been a pioneer in intelligent transportation systems, designing and developing ATMS for more than 20 years. Comprehensive, coordinated ATMS provide real-time, up-to-the-minute information on road conditions and help police and fire departments and highway crews respond more quickly to traffic accidents and weather conditions.

SwRI has developed state-of-the-art ATMS software called ActiveITS, which has been integrated into Florida's SunGuide®, Texas' Lonestar®, and New England's Compass traffic management systems. This technology can be shared with other agencies across the U.S.

Using ActiveITS, SwRI has integrated multiple large-scale, statewide ATMS that support 60 protocols, including dynamic message signs, incident management, camera monitoring and control, and center-to-center integration. SwRI supports more than 40 systems in five states covering more than 10,000 lane miles of highway in seven of the 20 largest U.S. cities.

~~Hearing~~ Seeing Thunder

SwRI scientists have captured the first images of thunder created by rocket-triggered lightning

By Maher A. Dayeh, Ph.D.

Lightning and the thunder that accompanies it are among the most spectacular yet familiar visual and auditory displays in nature. Describing a thunderstorm's terrifying booms, blinding flashes, and deadly electrical discharges invites superlatives, and not without reason. Lightning strikes the Earth millions of times each day, all over the world.

In the U.S. alone, it kills about 100 people each year and injures 1,000 more. It can cause power outages, fires, and plane crashes, amounting to tens of millions of dollars in damages annually. It even happens in space. Lightning has been observed on Jupiter, Venus, Saturn, and Titan. For a multitude of reasons, it's important for an increasingly technology-driven world to understand exactly what makes lightning happen — and where, and when.

For all the dazzle and danger of a thunderstorm, lightning and thunder remain poorly understood by scientists. Notwithstanding Benjamin Franklin's legendary (and lucky) kite-flying experiment, studying lightning in nature is complicated and dangerous. Also, because individual lightning strikes are unpredictable, it is impractical to build an instrument array big and close enough to observe and measure the exact conditions that trigger lightning in a cloud, or the path by which it propagates through the air.

In the past two decades, advances in instrumentation and remote sensing — and, importantly, the ability to artificially trigger lightning — have significantly enhanced scientific understanding of lightning physics. Scientists now know lightning is associated with high-energy processes that span vast scales and can be observed in different forms, including

D021596

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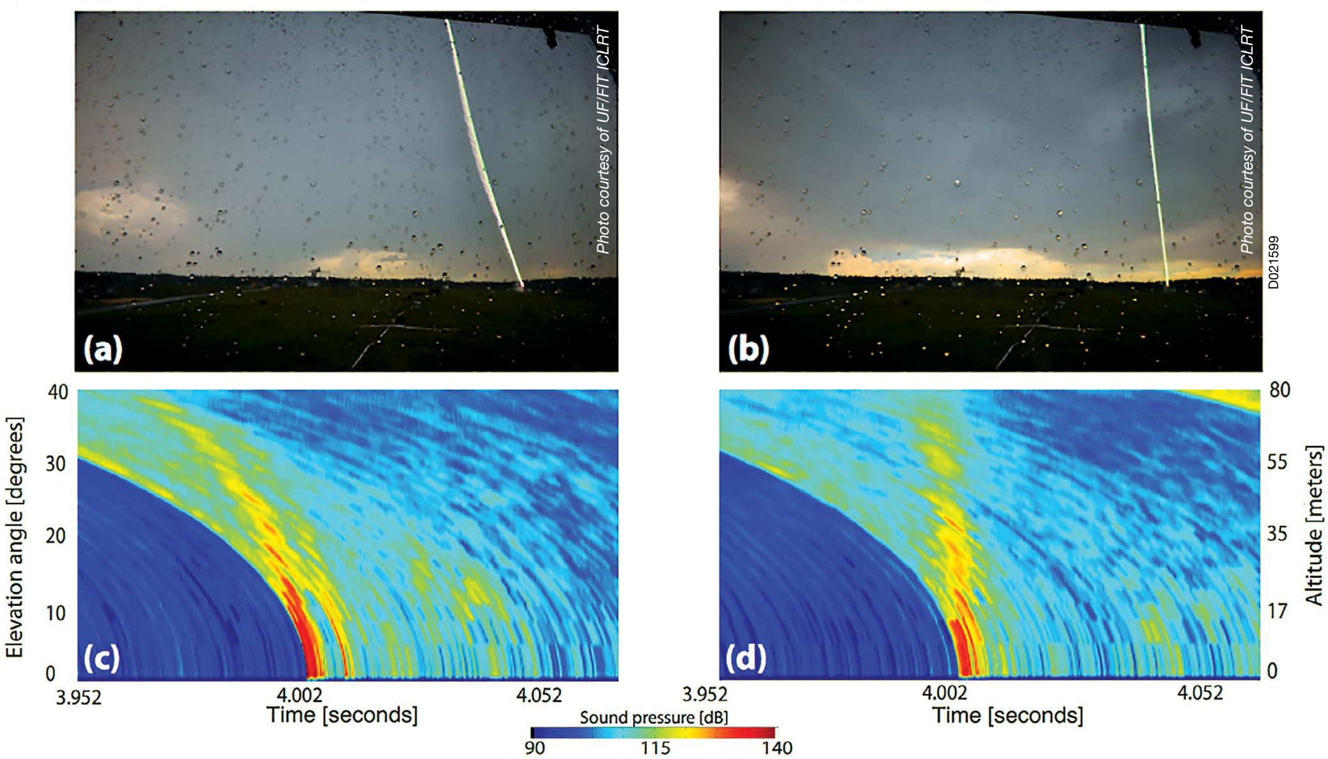
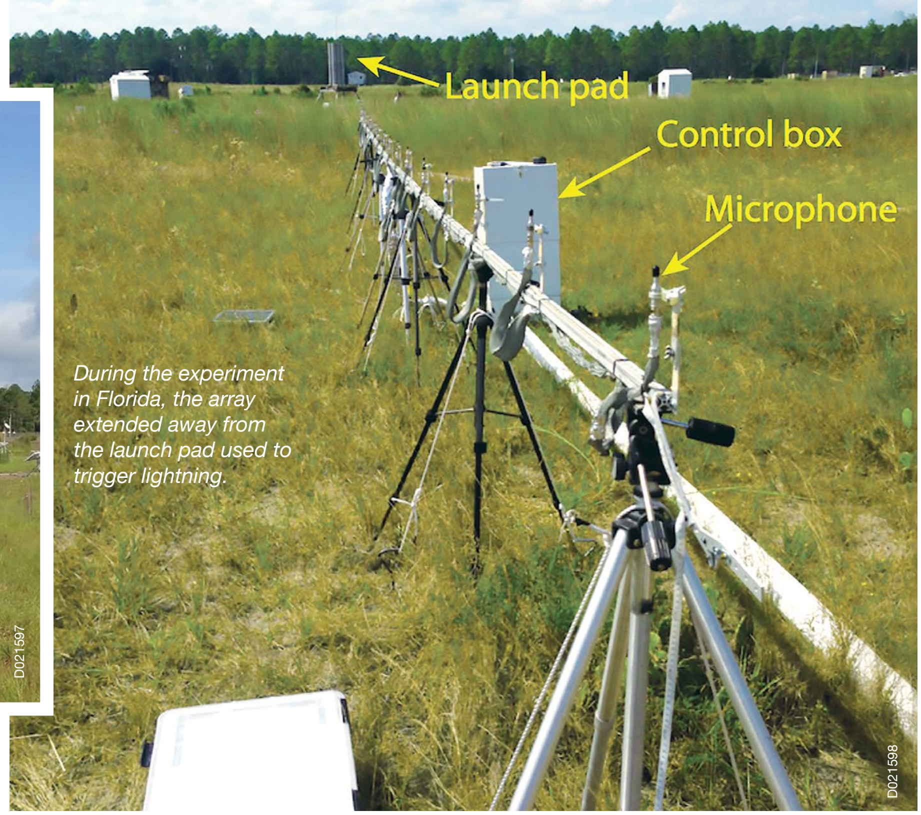


SwRI scientists compared long-exposure optical photographs of two different triggered lightning events (top) with acoustically imaged profiles of the discharge channel (below), corrected for sound speed propagation and atmospheric absorption effects. The apparent tilt of the lightning bolt in the left photo is also seen in the acoustic image.

Scientists shot a wire-grounded model rocket from this launch pad into thunderclouds to trigger artificial lightning.



During the experiment in Florida, the array extended away from the launch pad used to trigger lightning.

X-ray emissions on the ground, sprites and jets above thunderclouds in the upper atmosphere, and terrestrial gamma ray flashes observed by satellites from space as well as by instruments on the ground.

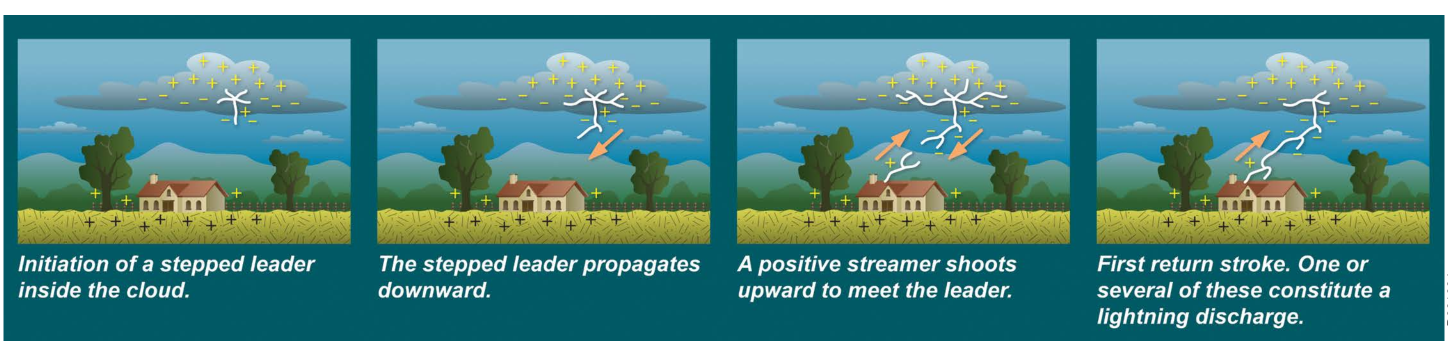
Thunder and lightning

Despite those advances, examining the physics of lightning via its acoustic signature (i.e., thunder) has been limited in part because of the old adage that lighting never strikes the same place twice. While the adage is not scientifically accurate, the random nature of lightning strikes means that thunder typically must be measured from a distance. Sound is slow compared to light, so by the time an acoustic signature reaches the instrument, the lightning bolt that caused it is long gone. Also, the measured signals will have been altered by numerous propagation and atmospheric effects. Nevertheless, a team of scientists and engineers from Southwest Research Institute (SwRI) decided to take a closer look at thunder in an attempt to understand its origin and what it discloses about the lightning process.

Lightning is a transient, high-current electric discharge. Its path is random, with the length of the path often measured in miles (or kilometers). Lightning usually occurs in dynamic atmospheric environments where electric charges produce fields strong enough to turn the surrounding air into a conductor. Scientists classify lightning strikes by how they propagate. The most common forms are ground-to-cloud, cloud-to-cloud, intra-cloud, and cloud-to-ground discharges.

Cloud-to-ground is the best understood form of lightning. These bolts start as a complex brew of electrostatic charges churning in storm clouds. Under prevailing conditions, these charges trigger "stepped leaders," or veins of electricity branching downward. After a series of successive spurts, electrons pool at their tips and trigger new leaders in a branching pattern. These stepped leaders propagate downward in a discontinuous fashion with immensely intense electric fields at their tips. Meanwhile, tall objects on the ground, such as trees or houses, can send streams of positively charged channels upward. With several stepped leaders propagating down and somewhat fewer of these streamers reaching up, a pair eventually meet. The resulting attachment process opens a discharge channel. An initial bolt travels down the path, exciting almost instantaneous return strokes that follow. This flickering flash is lightning as we know it.

Thunder happens when lightning suddenly heats the air to temperatures as high as 30,000 degrees Kelvin — five times hotter than the surface of the Sun. This sudden spike of temperature and pressure causes the surrounding air to expand rapidly outward, then collapse inward as it cools, creating a shock wave. Early in a return stroke, the pressure inside the channel is several times the atmospheric



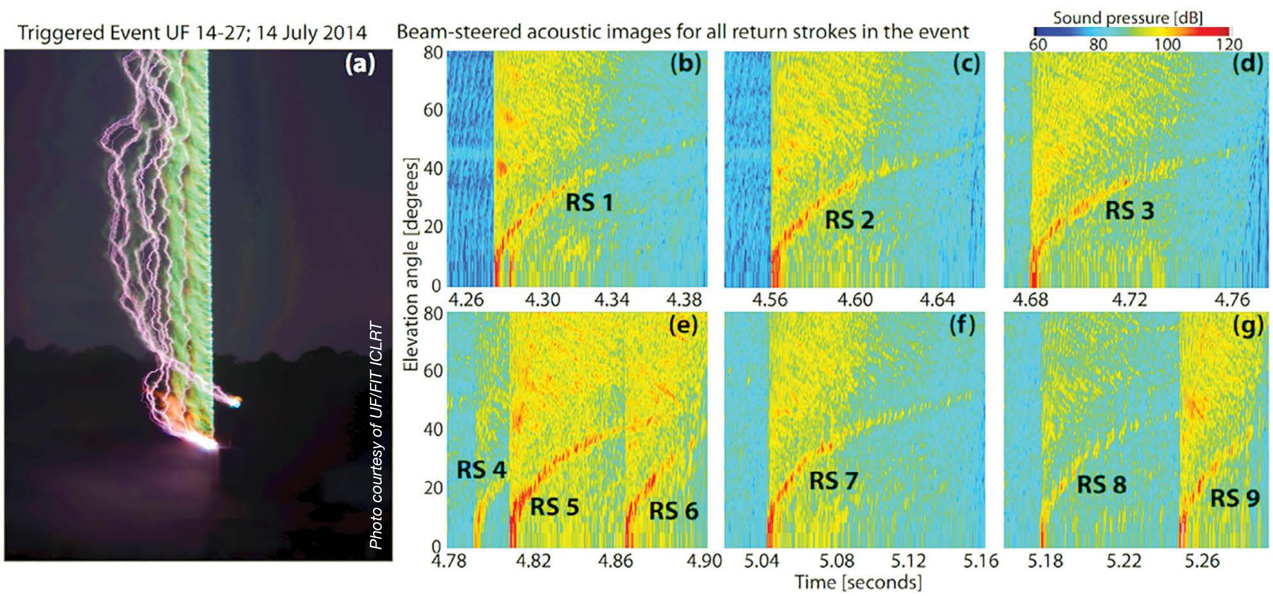
This schematic illustrates the initiation, propagation, and attachment processes that open a conductive channel or path for the primary stroke in a cloud-to-ground lightning strike. The lightning bolt often has several return strokes, which usually follow the path of the first one.

Dayeh and Engineer James J. Ramaekers calibrate an "acoustic camera," an array of 15 microphones set 1 meter apart and mounted on tripods 1.2 meters above the ground.

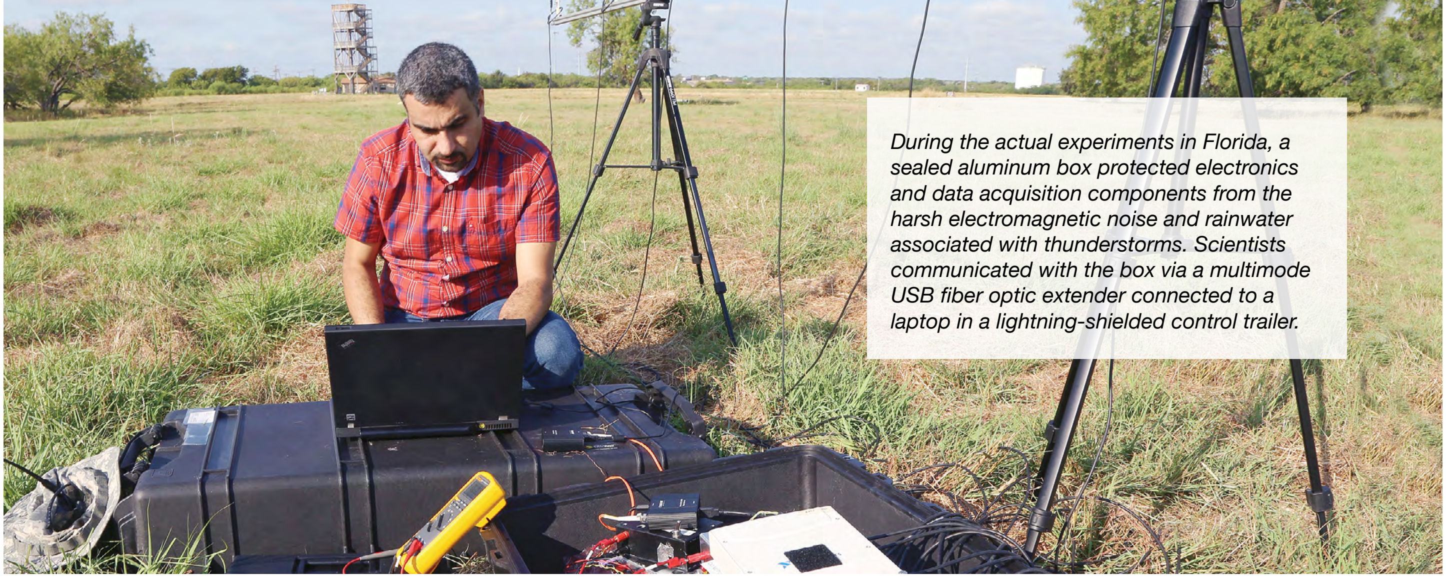
pressure. In a few tens of microseconds, the shock wave expands outward a few meters and then decays into a sound wave. The way we hear thunder largely depends on how far we are from the lightning bolt. If we are nearby, thunder sounds sharp and loud, like claps and cracks. From farther away, the sound has lost most of its high-frequency components and we only hear the longer-lasting, low-frequency rumbles. Thunder audibility is also influenced by echoes created by terrain and atmospheric effects such as humidity, wind velocity, or temperature inversions.

To date, lightning studies using acoustic signatures have focused mostly on the thunder sound spectrum's infrasound portion — less than 20 Hz, not audible to humans. Previous audible thunder research used spatially distributed microphones to map the sound sources, using triangulation and signal processing to "reconstruct" the shape of the lightning channel. This research was useful, particularly for bolts within clouds that cannot be seen, but the microphones' distance from the channel severely limited the measurements.

The high-frequency components of thunder dissipate rapidly. To get the full acoustic picture and capture a complete image of thunder, instruments must be very close to the lightning strike. To make this close-up picture, the SwRI team collaborated with scientists at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, Florida. Operated by the University of Florida and the Florida Institute of Technology, this world-renowned lightning research center specializes in producing "artificial lightning." Taking advantage of Florida's claim of receiving the most lightning strikes per year in the U.S., ICLRT offers large outdoor facilities equipped with sensors, imagers, and instrumentation. To trigger lightning, a small model rocket trailing a grounded copper wire is launched into a thundercloud during favorable electrical conditions. The copper wire provides a conductive



This long-exposure photograph (a) shows a triggered lightning event. The initial copper wire burn glows green, while nine subsequent return strokes are more purplish. Southwest Research Institute scientists plotted acoustic data (b-g) measured at the array that clearly show the unique signatures of the nine return strokes (RS) associated with the triggered lightning event. The "curved" appearance of the RS signatures is associated with sound speed propagation effects. A secondary acoustic signature after the first RS (b) is the result of an electric current pulse associated with this return stroke.



During the actual experiments in Florida, a sealed aluminum box protected electronics and data acquisition components from the harsh electromagnetic noise and rainwater associated with thunderstorms. Scientists communicated with the box via a multimode USB fiber optic extender connected to a laptop in a lightning-shielded control trailer.

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channel and creates a predictable path for lightning, allowing scientists to precisely focus instruments and perform repeatable experiments close to the discharge channel. Electricity travels down the wire, vaporizing it in the first artificial strike and triggering return strokes through the air.

Array of microphones

The SwRI team's "acoustic camera" comprised an array of 15 microphones set 1 meter apart and mounted on tripods 1.2 meters above the ground. The array faced the rocket launch pad where the copper wire was grounded and the triggered lightning would strike. A sealed aluminum box protected electronics and data acquisition components from the harsh electromagnetic noise and rain water associated with thunderstorms. Scientists communicated with the box via a multimode USB fiber optic extender connected to a laptop in a lightning-shielded control trailer. Rubber caps protected the microphones from water, wind, and excessive acoustic pressure. Scientists characterized the background noise and then collected digital signals from the microphones at 50 kHz for 10 seconds.

The team used a well-established signal processing technique known as "beamforming" to image the vertical profile of the channel. This technique allows scientists to shift recorded signals sequentially in time, based on the speed of sound and the spacing between the microphones. The technique then steers the net response of all the microphones in a specific direction, allowing directional amplification of the signal. The processed data is plotted on an x-y graph where the horizontal axis represents elapsed time and the vertical axis represents the measured acoustic response as a function of elevation along the lightning channel.

On July 14, 2014, a rocket was launched during a thunderstorm, producing triggered lightning. Electricity traveled down the wire, vaporizing the copper in a green bolt of lightning, followed by nine return strokes. Scientists processed the recorded sound signatures and created high-frequency, beam-steered images, which would have been impossible to do from afar.

Insights into lightning

The results were stunning. For the first time, the team imaged the sound waves that originate along different portions of a lightning channel. Besides the dramatic images, there are also important research implications. In natural lightning, the channel is a string of tortuous branches tens of meters long with each branch being a power source that generates a shockwave. Scientists could measure the different radiated outputs of various branches along the channel, estimating the energy that goes into each segment. These insights into lightning energetics could advance our understanding of its processes, such as how the stepped leaders advance and the air breaks down early in the discharge channel formation process.

By measuring the sounds emitted at different points along the channel and accounting for sound propagation and atmospheric effects, the SwRI scientists could trace the measured sound signals from the array back to their origin within the lightning channel. The result was the first acoustic image of thunder. Not only could the radiated sound be seen, but the projected shape of the lightning strike was apparent in the two-dimensional acoustic image.

What next?

For the first time, SwRI scientists designed and developed a large acoustic camera that literally captures the "loudness of sound" radiated along the lightning channel. After accounting for propagation and atmospheric absorption effects, the SwRI team inferred a realistic acoustic profile of thunder very close to the channel, thus constructing a visualization of thunder that depicts how thunder would look if our ears could "see" it.

This successful proof of concept introduces a new method for imaging lightning. As with every new way of measuring something, it opens the door to conduct further measurements targeting specific questions. The team looks forward to expanding the capabilities of the thunder imager and using it to answer fundamental questions about the lightning process.

Questions about this article? Contact Dayeh at (210) 522-6851 or maldayeh@swri.org.

View a short movie about Seeing Thunder

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Eyes on Europa

A pair of SwRI-developed instruments may reveal whether Jupiter's icy moon could host life

By Kurt Retherford, Ph.D., and J. Hunter Waite Jr., Ph.D.

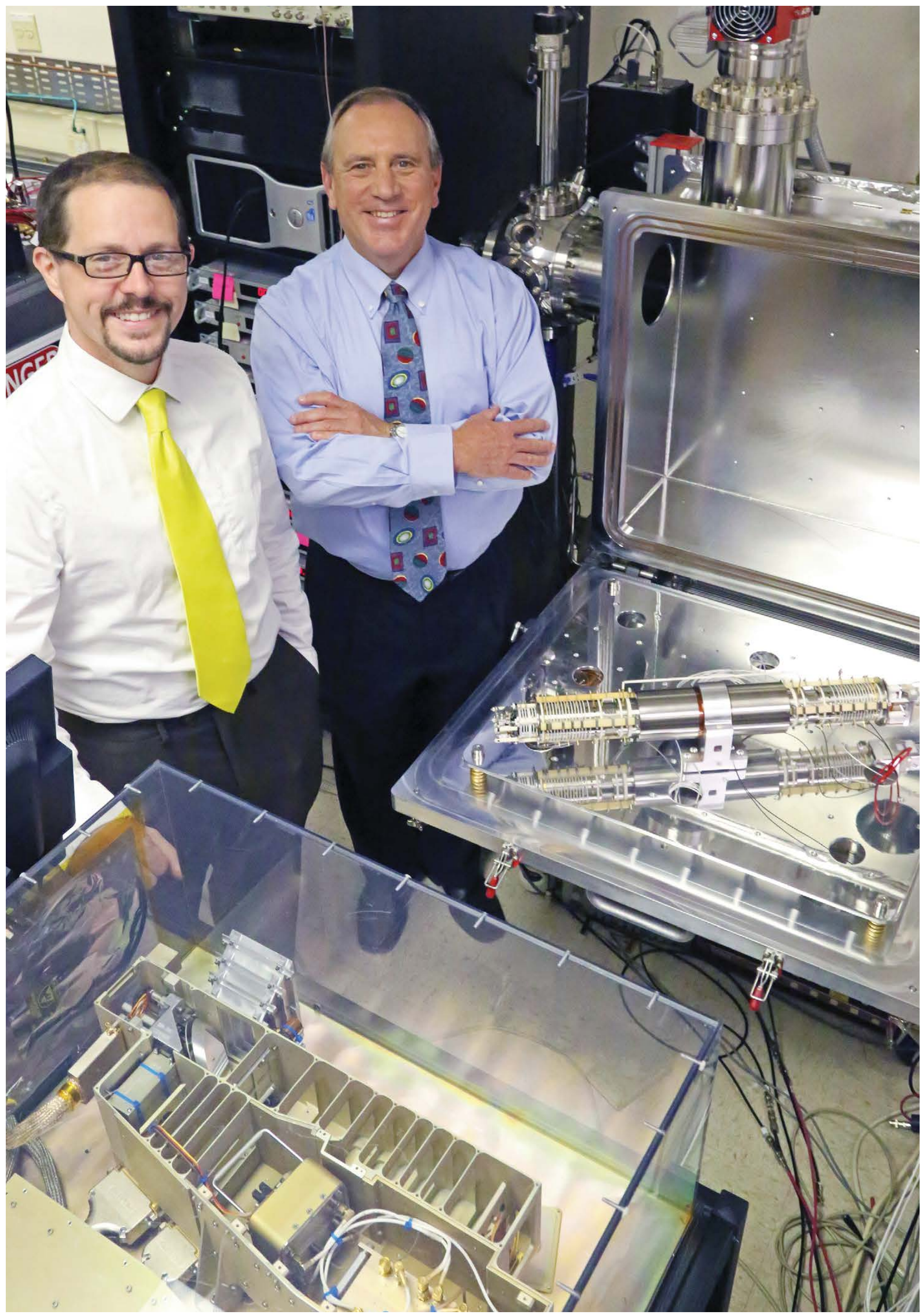
The search for life beyond Earth in our own solar system, much less elsewhere throughout the galaxy, has intrigued scientists for decades. However, processes that we would recognize as indicating life are difficult to detect. For one thing, those signs are subtle. For a spacecraft to sniff out the telltale chemicals that predict a habitable planet or moon while flying past at an altitude of hundreds or even thousands of miles, its sensors must be exceedingly sensitive. In fact, launching a suite of remote-sensing instruments capable of accurately measuring life's necessary components has been technically impossible. *Until now*.

Two instruments designed and developed by scientists at Southwest Research Institute (SwRI) have been chosen to fly aboard a future NASA spacecraft that will explore Europa, the smallest of Jupiter's four Galilean moons. Europa is about the same size as Earth's Moon and is considered a leading candidate to possibly host life in our solar system. The multi-flyby mission, scheduled to launch in the 2020s, will provide a diversity of data certain to enrich our understanding of the potential habitability of this intriguing ocean world.

Instruments to work in tandem

SwRI's MAss Spectrometer for Planetary EXploration (MASPEX) and the Ultraviolet Spectrograph (UVS) are among nine science instruments selected for the as-yet-unnamed spacecraft. The two SwRI-designed instruments will work in tandem to search for certain chemical compounds in Europa's atmosphere and then sample them to sniff out signs to determine if the icy moon could host life.

In our solar system, Europa has been considered one of the most promising portals for life since the 1990s-era Galileo mission to Jupiter discovered evidence of a liquid saltwater ocean beneath its icy crust. If an ocean truly exists there,



Kurt Retherford, Ph.D. (left), principal investigator of the Europa mission's Ultraviolet Spectrograph (UVS), is a principal scientist in the Space Science and Engineering Division. J. Hunter Waite, Ph.D., principal investigator of the MAss Spectrometer for Planetary EXploration (MASPEX), is a program director in the Space Science and Engineering Division.

An artist's concept shows how a plume of water vapor ejected from the icy surface of the Jovian moon Europa might look. SwRI's ultraviolet spectrograph will remotely search for and sense such plumes, and MASPEX will determine the detailed composition of plume gases as the spaceship flies through them.

Europa could contain twice the water of Earth. Prospects for Europan life grew even more promising after subsequent data gathered by the Hubble Space Telescope revealed evidence for plumes of water vapors emanating from the surface. These geysers, if confirmed, would provide a means to study potential subsurface water environments connected to the surface by cryo-volcanic activity.

Conditions for life

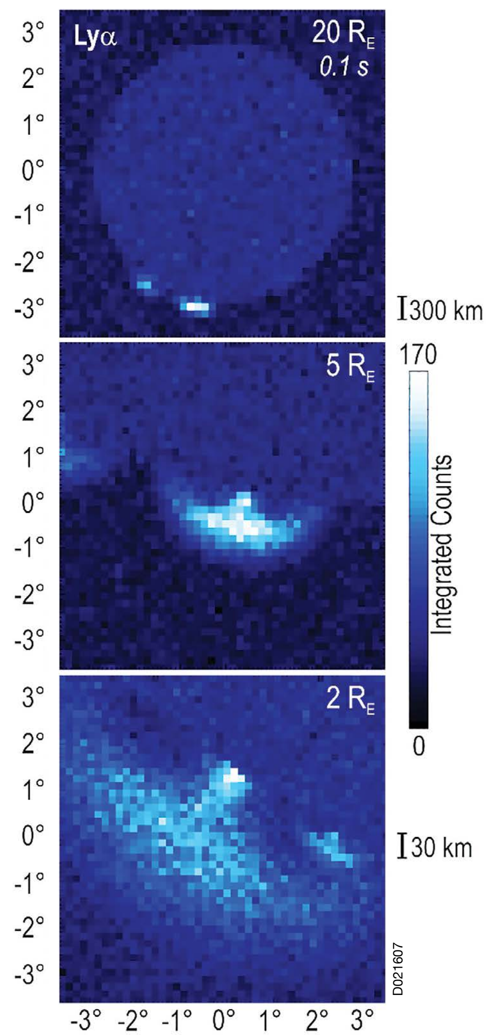
During the proposed spacecraft's multiple flybys of Europa, the UVS instrument will measure ultraviolet light emissions to determine the chemistry and composition of the moon's atmosphere as well as its source, structure, and variability. Examining the atmosphere from equator to pole, UVS will search for plumes spewing from surface cracks looking for clues about the nature of subsurface water reservoirs. UVS data will help scientists characterize potential plumes, along with its global atmosphere, in terms of distribution, structure, composition, and variability. It will examine the composition of Europa's surface using reflected UV sunlight to help understand the reddish brown colorations of linea features (stripes) that are ubiquitous on Europa. These data may also provide clues to the composition of a subsurface ocean. Finally, it will investigate how energy and mass flow in the Europan atmosphere and interact with Jupiter's strong magnetic field to affect the broader Jupiter system.

If plumes are confirmed on Europa and pinpointed by UVS, the spacecraft will fly through them allowing MASPEX to sample the volatile atmospheric gases and measure the composition. Measuring the molecular and isotopic composition will offer insights into the oxidation state and pH of the moon's subsurface ocean, as well as any potential metabolic energy sources. By a large margin, MASPEX has the highest sensitivity and highest mass resolution of any mass spectrometer ever flown in space to sample, identify, and measure gases. Its precise measurements will reveal whether the conditions for life — liquid water, certain chemical building blocks, and an energy source — exist beneath Europa's icy surface.

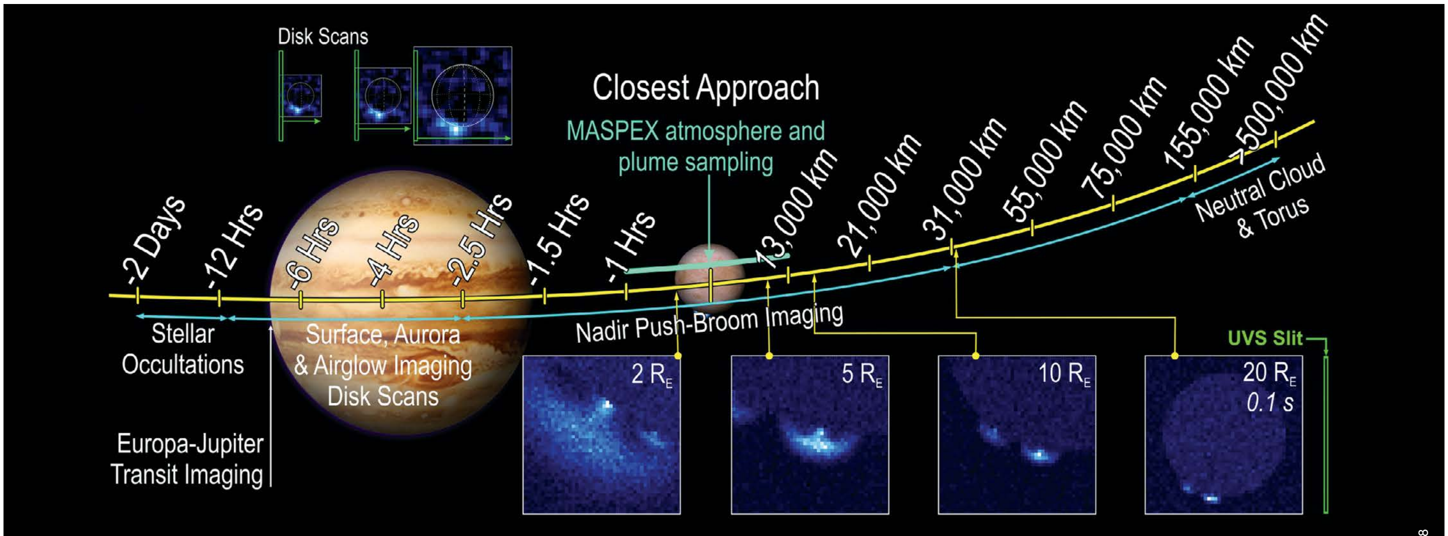
Europa-UVS

As the first blow in the one-two punch to characterize the atmosphere of Europa, UVS will examine the composition from a distance. This UV spectrograph is the type of tool astronomers use to split light into its various colors. By examining their light spectrum, scientists can then identify the chemical composition of gases based on the quantized energy levels of atoms and molecules.

Europa-UVS is the sixth in a series of SwRI-developed UV spectrographs, based on earlier instruments from the UVS/Alice "family." Earlier iterations are aboard the European Space Agency's (ESA) Rosetta comet mission, NASA's New Horizons mission that flew past Pluto in the heart of the Kuiper Belt this summer, the Lunar Reconnaissance Orbiter mission in orbit around the Moon, and the Juno mission now on its way to Jupiter. Another example of this newest UVS version will be part of the ESA's future JUpiter ICy moons Explorer (JUICE) mission, which will get close-up flyby views of Europa as well as Callisto, although its primary target is Ganymede. These two latter missions will likely overlap, so having two UVS instruments making measurements in the Jupiter system at roughly the same time will offer exciting complementary science possibilities.



SwRI's UVS and MASPEX instruments offer scientists an extraordinary opportunity to sample elements contained in the plumes spewing from the southern pole of Europa. (UVS simulated views)

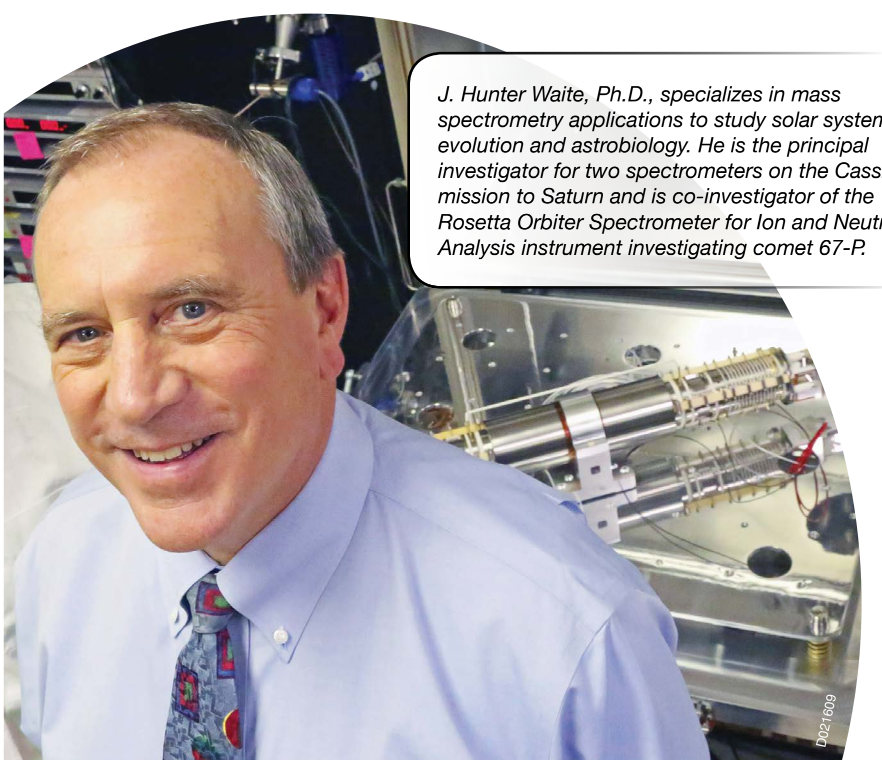


Europa-UVS conducts observations of different types starting from a large distance away from Europa. Image quality improves with proximity as shown, enabling great views of auroral features and potential plumes.

The Europa-UVS will observe photons in the 55-210 nanometer (nm) wavelength range, at moderate spectral and spatial resolution. It has three apertures of different sizes, each of which can send light to a telescope mirror feeding the spectrograph. The main entrance, or "airglow" port, is used for most observations, such as airglow, aurora, and surface mapping. The airglow port also allows stellar occultation measurements when Europa passes in front of a star and blocks its light. Scientists can study the thickness and composition of the object's atmosphere by analyzing the absorption of light from the star as it passes behind the object and emerges on the other side. Similar light absorption analyses will be studied when Europa transits in front of Jupiter, when its atmosphere can be viewed in silhouette. The "high-spatial-resolution port" is a small aperture in a separate door used for detailed observations of brighter targets such as surface features. A third aperture, called the "solar port," provides offset views of solar occultations, where again, light absorption by different molecules in the atmosphere and/or plumes is well measured (with the bright sunlight enabling high data quality).

Like its counterparts on the Juno and JUICE missions, Europa-UVS must be ruggedized to withstand the harsh radiation environment in the Jupiter system. To protect the instrument's electronic parts, UVS uses shielding and radiation-hardened parts. To protect the quality of its data, UVS filters signal pulse-height amplitudes and manages its high-voltage settings.

The UVS instrument team includes scientists from SwRI, Johns Hopkins University, the Royal Institute of Technology in Sweden, and the University of Cologne in Germany.



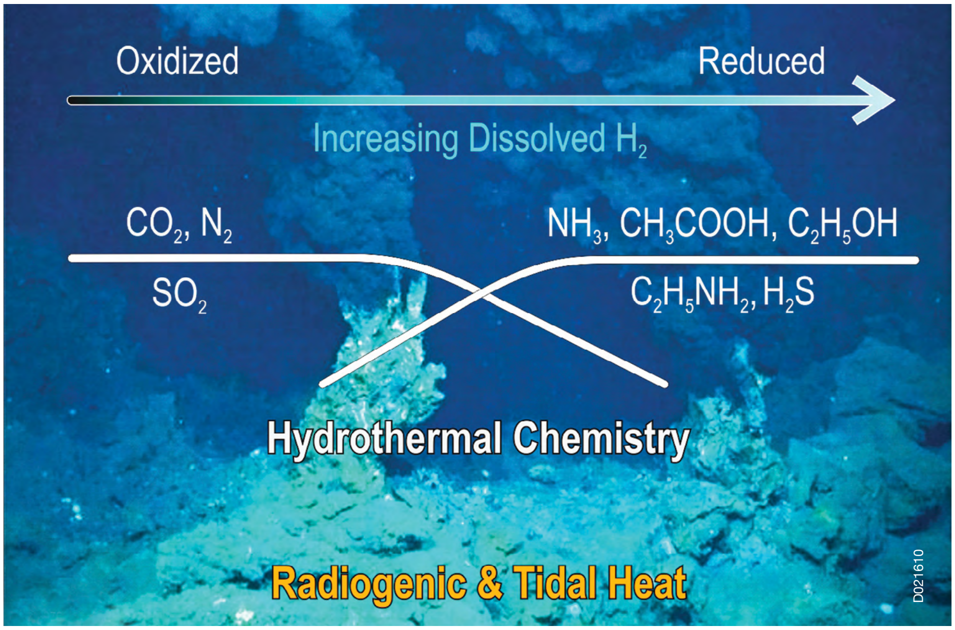
J. Hunter Waite, Ph.D., specializes in mass spectrometry applications to study solar system evolution and astrobiology. He is the principal investigator for two spectrometers on the Cassini mission to Saturn and is co-investigator of the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis instrument investigating comet 67-P.

MASPEX

MASPEX will provide the second scientific punch, precisely sampling the ambient Europan atmosphere to understand the complex interactions among the moon's interior, surface, and atmosphere. A particularly tantalizing aspect of the MASPEX experiments is the possibility of flying through and sampling material released from plumes and surface cracks. Scientists can use these measurements to infer the composition of Europa's interior, and by extension, its presumed internal ocean. The concentration ratios of common volatiles such as carbon dioxide, carbon monoxide, water, nitrogen, hydrogen, methane, and simple organic compounds provide hints about habitability. If fractures allow liquid water to escape into space, some kind of heating process is likely occurring beneath the icy surface.

MASPEX will analyze the pH and oxidation states of any plumes. In this case, scientists are specifically looking for similarities to deep sea vents on Earth, where life on our planet may have first formed. These hydrothermal vents in sea floors serve as hothouses for marine life that thrive in the dark with just the energy the vents provide.

SwRI scientists and engineers developed MASPEX through a combination of internal SwRI and NASA funding to create a time-of-flight mass spectrometer with



Typical hydrothermal systems on Earth operating at moderate temperatures favor the synthesis of organic compounds. Evidence that Europa might have a liquid saltwater ocean under an icy crust was first observed during the Galileo mission to Jupiter in the 1990s. The MASPEX molecular and isotopic composition study will offer insights into the oxidation state of the subsurface ocean and potential metabolic energy sources. Those precise measurements will reveal whether the conditions for life exist beneath Europa's icy surface.

a resolution, sensitivity, and dynamic range unparalleled in spacecraft-borne instruments of this type. MASPEX uses a beam of electrons to bombard incoming gas molecules, converting them to ions, which are then extracted into the electrostatic field of the instrument's optics for analysis. The sample to be analyzed will consist of a mixture of different chemical compounds, many with similar molecular masses. A time-of-flight mass spectrometer separates these molecules by speed to determine their composition because lighter ions travel faster than others. The longer the flight path the ions must cover, the more their different velocities will separate them and the greater the instrument's resolution.

U-shaped roller coaster

MASPEX uses novel "folded-ion optics" that provide a variable length flight path for the ions within a compact instrument. To do this, SwRI scientists installed paired electronic devices called reflectrons, which create an electrostatic field that acts like a U-shaped roller coaster. The reflectron effectively makes incoming ions run "uphill" against an increasingly strong field until they become stationary, and then slide back "downhill," regaining their original energy but traveling in the opposite direction. Two opposing reflectrons enable the ions to be "bounced" back and forth until the desired flight path has been reached, then one of the mirrors is shut off and the ions travel to the detector. Flight paths of more than 50 meters are readily achievable, even though MASPEX is less than a half-meter long.

MASPEX also has excellent sensitivity due to an ion source that stores 200,000 ions every half-millisecond before the ions are released into the ion optical path. Even with its great sensitivity, however, MASPEX has difficulty collecting enough gas to see the rarest molecules. For that, SwRI engineers incorporated a cryotrap into the instrument. This device freezes and concentrates gas samples, boosting the instrument's sensitivity by a factor of 10,000. On every flyby, MASPEX will both directly sample the atmosphere and concentrate a sample of the atmosphere, using a frigid surface to trap the gas. After the flyby, this cryotrap releases the sample into MASPEX's detectors, providing a concentrated sample of Europa's atmosphere and effectively increasing the instrument's sensitivity.

Solar-powered spacecraft

The Europa mission, planned for launch sometime in the 2020s, is now officially in its formulation phase, with a $30 million allocation in NASA's fiscal year 2016 budget request. The mission would send a solar-powered spacecraft into a long, looping orbit around the gas giant to repeatedly fly past the moon. Over three years, the spacecraft would perform about 45 flybys of Europa at altitudes ranging from 16 miles to 1,700 miles (25 kilometers to 2,700 kilometers).

NASA's Science Mission Directorate, which will be responsible for planning and operating this mission, conducts a wide variety of research and scientific exploration programs for Earth studies, space weather, the solar system, and the universe.

Questions about this article? Contact Retherford at (210) 522-3809 or kurt.retherford@swri.org, or Waite at (210) 522-2034 or hunter.waite@swri.org.

View a short movie about Eyes on Europa

Kurt Retherford, Ph.D., specializes in using space-based ultraviolet observations to study planetary atmospheres and surfaces. He is the principal investigator of the Lunar Reconnaissance Orbiter's Lyman Alpha Mapping Project (LAMP) and deputy principal investigator of the JUpiter ICy moons Explorer (JUICE) ultraviolet spectrograph.

Adam Hamilton Reflects on First Year

It's been just over a year since you became president of SwRI. What is the greatest adjustment you've had to make?

I think it's managing the demands on my time. The Institute is such a well-recognized and admired organization that people from across the city, state, and, in fact, the nation are interested in the Institute. In my position, I get numerous requests to speak at functions, participate on boards, and attend other events — much more than I can possibly accommodate. In my first year, however, the biggest demand on my time has been learning about the Institute. I really admire (Executive Vice President) Walt Downing, because he has an almost encyclopedic knowledge of what the Institute has done and is currently doing. While I'm not sure I'll ever be that well informed, every day I learn as much as I can, and I try to help define where we're headed in the future.

Adam L. Hamilton, P.E., has served since September 2014 as SwRI's fourth president in its 68-year history. Prior to his appointment, he was president and CEO of Signature Science LLC, a for-profit subsidiary of SwRI specializing in national security, biotechnology, chemistry, environmental science, and engineering. His multidisciplinary technical expertise includes engineering, biological sciences, chemical sciences, space sciences, mathematics, modeling, quality assurance, software development, and risk assessment.

How do you compare being the CEO of a for-profit firm like Signature Science to managing a diversified, nonprofit R&D facility of 10 divisions?

My time as CEO of Signature Science was all under the tutelage of Southwest Research Institute. Signature Science is a subsidiary of the Institute and is a for-profit company. However, net income is not less important to the Institute than it is for a company like Signature Science. There is a saying here that "SwRI is not for profit, but we're not for loss, either." Our net income allows us to re-invest and innovate, and to continue contributing to the scientific and technical communities.

How have national and international trends in research and development changed in the past few years, and in what direction are they headed?

We have all witnessed the virtualization of research. Some of the research and analysis that we do can also be done by organizations that don't have the infrastructure we have. So we must continue to try to find research and technology applications that make use of our current and future infrastructure. In addition to our staff, our facilities and infrastructure separate us from other research and technology organizations and allow us to offer unique value to our clients. For example, information technology is a field we must continually evaluate for investment and development purposes. The challenge is that most of our competitors in this field have limited physical infrastructure, so it's more efficient for them, and more challenging for us, to compete in that marketplace.

"This organization has people who really care about where we live and the people who live here with us."

The second thing I see is the speed with which developments occur now. Scientific and technical advancements are happening so quickly, it's difficult to develop and maintain intellectual property that is not perishable. However, we also benefit from the more rapid advances; our staff members are agile and constantly seek new ways to solve our clients' scientific and technical problems. So, the virtualization of technology applications, and the acceleration of scientific development and application are two trends that are of greatest interest.

Tell us what you consider some highlights of your first year on the job at SwRI.

I continue to be surprised by the technical accomplishments that this organization has made over the past 68 years. It seems as if success is inculcated in our culture with the expectation to continue, and I am proud to be a part of this Institute. I'm also excited about what this organization is going to be doing in the next five, 10, 15, and 20 years, because I believe we have not only a tremendous history but an exciting future. The other thing that's been fun to discover is the flavor of the culture here. You can see from the outside that the Institute is a tight-knit group, with a lot of loyalty and longevity. But from the inside, you can really see how closely connected the employees are to the organization, to each other, and — what's really remarkable — to the community. This organization has people who really care about where we live and the people who live here with us. And they show that every day.

"It seems as if success is inculcated in our culture with the expectation to continue ... I believe we have not only a tremendous history but an exciting future."

Do you recall what you were doing when the New Horizons spacecraft made its flyby of Pluto and Charon last July?

I was fortunate enough to be invited to Johns Hopkins University Applied Physics Laboratory for the flyby. I had the privilege of visiting with the son and daughter of Clyde Tombaugh, the scientist who first discovered Pluto. I was sitting on the front row next to them as Dr. Alan Stern led the countdown to the flyby. We all celebrated the event, basically a tick of the clock, when the New Horizons spacecraft flew by Pluto at its point of closest approach. That was something I'll never forget. The second important event occurred hours later, when the spacecraft successfully communicated that it had survived beyond the point of closest approach, before we saw the first images. Once we received the initial telemetry indicating that all systems were operational, we knew the spacecraft was healthy and there would be lots of data to fuel our scientific discoveries. I'd been able to attend launches in the past, and the flyby was similar to a launch. Everybody is waiting for that one event, and when it happens, there's shared joy and excitement.

How does being a research engineer compare to managing a lot of research engineers, where you don't get to do hands-on research – or do you?

I miss the hands-on scientific and technical work. I try to maintain technical competencies by listening to our researchers and touring our laboratories. But I do miss focusing on a technical problem and developing a solution that clients appreciate. You get a real sense of accomplishment when you have a technical breakthrough or make something work where others have had difficulties. However, like the Pluto flyby, I get to share in many of those breakthrough moments. I also try to keep my technical skills current by frequently reviewing scientific and technical literature. I read (although not in entirety) about 15 journals and periodicals to at least stay involved and cognizant of the developments in several technical fields. I like to share that information with our staff when I can. But I do miss the hands-on work. My indulgence now is building my own PowerPoint presentations and spreadsheets.

What's been your favorite discovery at SwRI?

Frito Pie in the cafeteria on Friday (laughs). But seriously, I am likely to continue learning about the Institute's accomplishments for years to come. The rich history of our organization has been awe-inspiring. If you look back on some of the greatest contributions that we've made, you can see the impact that our work has had on everyday life. We have contributed to science and technology in so many different ways while maintaining our mission to serve mankind through science and technology. I enjoy visiting our library and seeing some of the historic texts, listening to a lecture on a historic textbook, or reading in our newsletter about a program that we conducted 50 years ago. To me this organization has an amazing history. It's fun to be a part of it and to know that what we're doing today, right now, is going to be viewed similarly in the future.

"We all celebrated the event, basically a tick of the clock, when the New Horizons spacecraft flew by Pluto at its point of closest approach. That was something I'll never forget."

What is a typical day on the job at SwRI?

This is not a job, and neither was Signature Science. Signature Science was very much like my first child. It's all grown up now, but I still care about it and think about it. Now, the Institute is really at the forefront of my thoughts, from the time I wake up until the time I go to bed. In the morning I have to think about what engagements I have that day, who I'm meeting with. On the way to work, I'm thinking about the things I need to get done — what are my highest priority tasks and what should I probably let go? A typical day is about half-scheduled. That is, about half of my time is scheduled with appointments and meetings. But I have to leave about half of my time for the unforeseen things that happen every day that need my attention and time. In addition to administrative and fiduciary functions, I also spend a lot of my time with the staff and our clients. I enjoy developing relationships with our employees and key partners here in San Antonio, like The University of Texas at San Antonio, the UT Health Science Center at San Antonio, and Texas Biomedical Research Institute. Also, I enjoy participating in organizations that give back to the community, such as the United Way, where I'm honored to participate as a board member. Much of my time is also spent at meetings disguised as meals. This last year, I set a new record, a personal best: Three breakfasts in one morning, all organized by different entities. Many lunches are occupied with meetings of boards, and evening and weekend functions are work-related as well. So it's really more than a job. It's a lifestyle, and a lifestyle I'm quite honored to have.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What do you think are the top three challenges SwRI faces in the short term?

All organizations face some issues or impediments to what we want to do, which is to continue to grow. Right now, I think the principal impediments to SwRI's growth are related to politics and government spending. Sometimes, the need to invest in the science and technology that we can provide is overshadowed by politics. That's a shame, and it makes it difficult for us. But we've made some strides in that area and have done very well. The next problem is currently related to oil prices, because we do a lot of work for clients in oil and gas and energy. With abundant supply and low prices, some of the motivation to invest in the research and development that we are really good at has waned. Not all — some people have the foresight to continue to invest, and when they do, they invest in the best. So, we haven't been hit too hard by the declining oil prices, but, the longer that trend continues, the more likely we'll see some setbacks. Lastly, regulations, policies, procedures, and bureaucracy can impede our success. However, we have a way of satisfying all of these requirements and still being successful. Specifically related to taxes, we anticipate that our health benefits for employees may be heavily taxed starting in 2018, so we are trying to develop adjustment and coping strategies. And government auditing and oversight has become very costly — not because of anything the Institute has done — but because other organizations have had issues and problems. The level of oversight is definitely burdensome. So we are always trying to satisfy new requirements and to improve transparency and accountability with the way we manage the Institute's finances.

"Now, the Institute is really at the forefront of my thoughts, from the time I wake up until the time I go to bed."

Having had only four presidents in 68 years, Southwest Research Institute obviously takes a long-term view when it comes to planning. What is your main long-term goal for the Institute?

Sustainability. That's the minimum — to sustain the research in science and technology applications that we provide here at the Institute. And closely associated with that is growth. We need to continue to grow, because that provides the best environment for our staff. Our staff members are incredibly talented, and with talented people you always have to make sure they have a satisfying career and development path. That path includes growth as they become more involved in overseeing larger programs, managing people, and being leaders. You have to have more and bigger programs to satisfy those needs and to bring in new staff, and to provide opportunities for those new staff members as well. So, that's the mission. We'll do what we need to do in science and technology, consistent with our mission statement, and seek out ways to grow revenue. That will allow us to continue our history of growth and provide rich opportunities for our staff so that they can have long, successful careers. ♦

SwRI scientists think "planetary pebbles" were building blocks for the largest planets

Researchers at Southwest Research Institute (SwRI) and Queen's University in Canada have unraveled the mystery of how Jupiter and Saturn likely formed. This discovery, which changes our view of how all planets might have formed, was published in the Aug. 20 issue of *Nature*.

The largest planets in the solar system likely formed first. Jupiter and Saturn, which are mostly hydrogen and helium, presumably accumulated their gasses before the solar nebula dispersed. Observations of young star systems show that the gas disks that form planets usually have lifetimes of only 1 million to 10 million years, which means the gas giant planets in our solar system probably formed within this time frame. In contrast, the Earth probably took at least 30 million years to form, and may have taken as long as 100 million years. So how could Jupiter and Saturn have formed so quickly?

The most widely accepted theory for gas giant formation is the so-called core accretion model. In this model, a planet-sized core of ice and rock forms first. Then, an inflow of interstellar gas and dust attaches itself to the growing planet. However, this model has an Achilles heel; specifically, the very first step in the process. To accumulate a massive atmosphere requires a solid core roughly 10 times the mass of Earth. Yet these large objects, which are akin to Uranus and Neptune, had to have formed in only a few million years.

In the standard model of planet formation, rocky cores grow as similarly sized objects accumulate and assimilate through a process called accretion. Rocks incorporate other rocks, creating mountains; then mountains merge with other mountains, leading to city-sized objects, and so on. However, this model is unable to produce planetary cores large enough, in a short enough period of time, to explain Saturn and Jupiter.

"The timescale problem has been sticking in our throats for some time," said Dr. Hal Levison, an Institute scientist in the SwRI Planetary Science Directorate and lead author of the paper. Titled "Growing the Gas Giant Planets by the Gradual Accumulation of Pebbles," the paper is co-authored by SwRI Research Scientist Dr. Katherine Kretke and Dr. Martin Duncan, a professor at Queen's University in Kingston, Ontario.

"It wasn't clear how objects like Jupiter and Saturn could exist at all," continued Levison. New calculations by the team show that the cores of Jupiter and Saturn could form well within the 10-million-year time frame if they grew by gradually accumulating a population of planetary pebbles — icy objects about a foot in diameter. Recent research has shown that gas can play a vital role in increasing the efficiency of accretion. So, pebbles entering orbit can spiral onto the protoplanet and assimilate, assisted by a gaseous headwind.

In their article, Levison, Kretke, and Duncan show that pebble accretion can produce the observed structure of the solar system as long as the pebbles formed slowly enough that the growing planets have time to gravitationally interact with one another.

"If the pebbles form too quickly, pebble accretion would lead to the formation of hundreds of icy Earths," said Kretke. "The growing cores need some time to fling their competitors away from the pebbles, effectively starving them. This is why only a couple of gas giants formed."

"As far as I know, this is the first model to reproduce the structure of the outer solar system, with two gas giants, two ice giants (Uranus and Neptune), and a pristine Kuiper Belt," said Levison.

"After many years of performing computer simulations of the standard model without success, it is a relief to find a new model that is so successful," added Duncan.

Levison is the principal investigator of the research, funded through a National Science Foundation Astronomy and Astrophysics Research Grant.

Contact Levison at (303)546-9670 or hal@boulder.swri.edu.

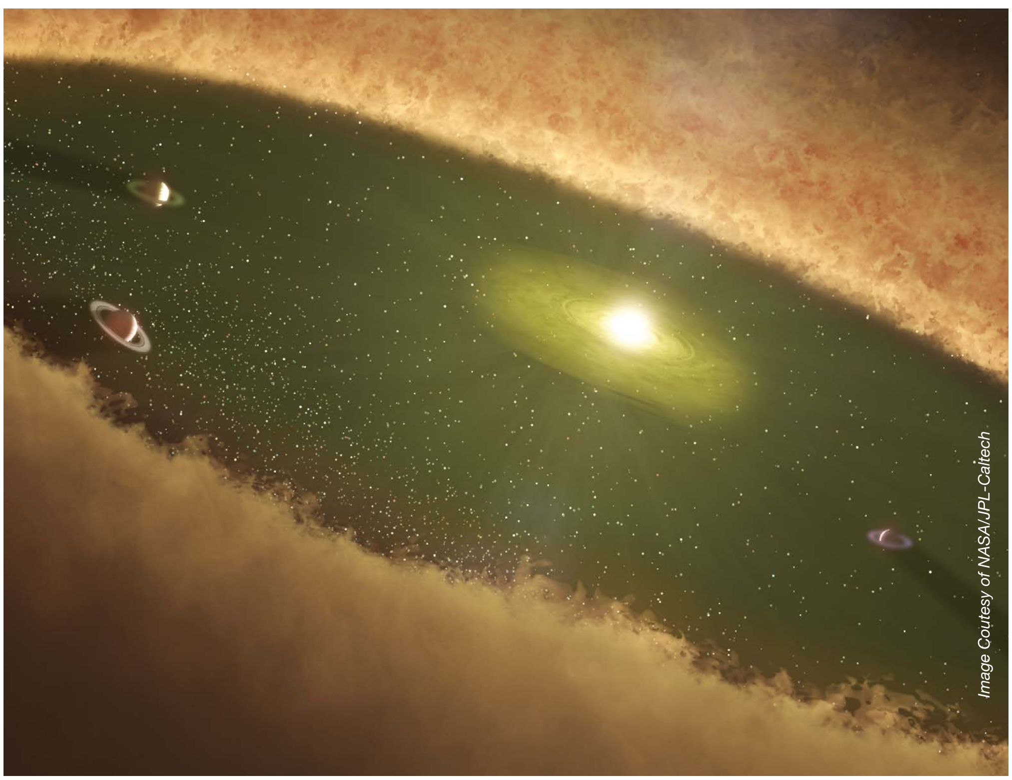

Image Courtesy of NASA/JPL-Caltech

SwRI's Durda awarded Sagan Medal

The Division for Planetary Sciences (DPS) of the American Astronomical Society has awarded its 2015 Carl Sagan Medal to Dr. Daniel D. Durda, a principal scientist at Southwest Research Institute (SwRI).

The Sagan Medal recognizes outstanding scientific communication to the general public by an active planetary scientist. Durda was selected in honor of his numerous promotional activities, such as providing television commentaries, writing for popular science journals, and other projects involving education and public outreach. He is a well-known space artist and has internationally exhibited his art, often providing his work to illustrate books and news items in science magazines and web articles.

The DPS award commemorates the late astronomer Carl Sagan, who was known for exploring the grandeur of the universe in lectures, books, and on television as host of the science series "Cosmos."

"Considering that I am in this field because of Carl Sagan and "Cosmos," this means more to me than I can find the words for," said Durda. "The planetary science community operates on the frontier of science and exploration. Being able to share my knowledge and help to popularize the amazing research results of my colleagues in the field is a great privilege."

At SwRI, Durda studies the collisional and dynamical evolution of asteroids, the effects of cratering impacts on planets and asteroids, and the geologic properties and processes on their surfaces. Asteroid 6141 Durda is named in his honor. He is an active pilot and has served as flight astronomer for airborne astronomical imaging systems flown aboard NASA and military high-altitude aircraft.

Durda enjoys sharing his personal interests and expertise with the public. He holds multiple scuba and cave diving certifications, including full cave and cave recovery specialist, and has served as the Colorado and Arizona regional coordinator for the International Underwater Cave Rescue and Recovery team. He is an avid hiker, birder, and amateur naturalist.

DPS presented the Sagan Medal and a cash award at its 47th Annual Meeting in National Harbor, Md., in November.

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D021615

New pollution abatement system significantly reduces emissions at SwRI

Southwest Research Institute (SwRI) has added a custom-designed, state-of-the-art pollution abatement system to its Steiner tunnel fire test facility, a 25-foot vented tunnel for testing construction materials, reducing the amount of hazardous waste emitted by nearly 90 percent. The $900,000 system removes acid gases, volatile organics, metal vapor, and particulate matter that may occur as an aftereffect from fire research.

This system is the first of several SwRI Fire Technology Department renovations and upgrades, which includes the development and installation of a $2.5 million custom pollution abatement system to handle emissions for furnace fire, jet fire, and car burn facilities. SwRI recently received a $500,000 grant from the Texas Commission on Environmental Quality to help defray the cost of installing this technology. The new system was fully operational in October 2015.

"ASTM E84 can be an extremely challenging test, and most Steiner tunnels do not have pollution abatement systems," said Dr. Matt Blais, director of the SwRI Fire Technology Department. "Our new system for the Steiner tunnel/ASTM E84 test increases reliability by 50 percent and reduces hazardous waste by 90 percent while removing odors, acid gas, and particulate with greater efficiency. The end result is a more reliable test that produces less waste and is more environmentally friendly."

Using ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials, SwRI subjects construction materials, such as wall coverings, foam insulation, and more, to a controlled burn to measure smoke and flame development indexes. Annually, SwRI conducts more than 500 of these evaluations in its Steiner tunnel facility along with custom fire research.

SwRI receives $3.2 million contract from U.S. Energy Department for solar power research

Southwest Research Institute (SwRI) has been awarded a $3.2 million contract by the U.S. Department of Energy SunShot Initiative. The contract is part of an $8.8 million effort to design, manufacture, and test an ultra-high-efficiency supercritical carbon dioxide (sCO_2) compressor-expander for power generation at concentrating solar power (CSP) plants. CSP plants use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines that create electricity.

SwRI turbomachinery engineers will collaborate with Samsung Techwin America (STA) to develop an integrally geared compressor-expander, or "compander," for use in an sCO_2 plant. The compander is a turbine through which a high-pressure gas is expanded to drive a multi-stage gear compressor. This integrally geared compander (IGC) has the potential to improve efficiency, modularity, and process control. The technology provides a critical step toward making sCO_2 CSP power plants commercially viable.

"This project is one of 11 sCO_2 power cycle projects SwRI is conducting for the Energy Department. The goal of these projects is to develop the critical technology building blocks needed to make sCO_2 power cycles technically feasible and commercially viable," said Dr. Klaus Brun, a program director in SwRI's Mechanical Engineering Division.

IGCs increase overall machinery efficiency, and are widely used in both air separation and process gas industries. Because all of the turbomachinery elements are integrated into a single machine, the design optimally lends itself to a modular power block, making it suitable for waste heat recovery, fossil fuel power plants, and especially CSP applications.

"STA is pleased to collaborate with SwRI on the design of an IG compressor-expander and believes that this technology will provide viable solutions to many of the practical challenges associated with sCO_2 power cycles," said Dr. Karl Wygant, vice president for the STA Turbomachinery Design and Development Center in Houston.

The compander design project also includes development of an sCO_2 compressor impeller that incorporates novel flow path designs for maximizing compressor efficiency and mechanical reliability under a wide range of inlet conditions. These novel flow path designs are enabled through direct metal laser sintering, an additive manufacturing process that increases design flexibility and produces high-strength parts.

The project, which will be conducted in three phases, began in October 2015 and will continue through September 2018 pending awards for subsequent phases. SwRI project managers for the newly funded contract are Group Leader Dr. Tim Allison and Research Engineer Dr. Jason Wilkes, both of SwRI's Mechanical Engineering Division. For more information about SwRI's Machinery Program, visit *machinery.swri.org*.

Contact Brun at (210) 522-5449 or klaus.brun@swri.org.

The new system provides controlled air flow to allow faster heating and cooling of the tunnel, improving overall operational efficiency to help meet client demands.

Last year, SwRI installed a $2 million baghouse air pollution control device to reduce particulate emissions from its diesel engine labs, reducing the Institute's overall particulate emissions by more than 50 percent.

Combined, SwRI has invested approximately $5 million in pollution abatement equipment in the last few years.

Contact Blais at (210) 522-3524 or matthew.blais@swri.org.

Technical Staff Activities

Publications

Allegrini, F., P. Bedworth, **R.W. Ebert**, **S.A. Fuselier**, G. Nicolaou and S. Sinton. "Energy Loss and Straggling of 1-50 keV H, He, C, N, and O Ions Passing Through Few Layer Graphene." *Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms*, Vol. 358 (2015): pp. 223-228, doi: 10.1016/j.nimb.2015.06.028.

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Bayless, A.J., W. Even, L.H. Frey, C.L. Fryer, **P.W.A. Roming** and P.A. Young. "The Effects on Supernova Shock Breakout and Swift Light Curves Due to the Mass of the Hydrogen-rich Envelope." *The Astrophysical Journal*, Vol. 805:98, No. 2 (2015): pp. 1-12, doi: 10.1088/0004-637X/805/2/98.

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Dayeh, M.A., N.D. Evans, **S.A. Fuselier**, **J. Trevino**, **J. Ramaekers**, J.R. Dwyer, R. Lucia, H.K. Rassoul, D. Kotovsky, D.M. Jordan and M.A. Uman. "First Images of Thunder: Acoustic Imaging of Triggered Lightning." *Geophysical Research Letters*, Vol. 42, No. 14 (2015): pp. 6051-6057, doi: 10.1002/2015GL064451.

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Hoag, K.L. and B. Dondlinger. "Vehicular Engine Design." Second Edition, *Springer-Verlag, GmbH*, Vienna (2015) ISBN 978-3-7091-1858-0.

Hunter, B., J. Cox, **M. Miller**, R. Hunter, L. Van Bastian, P. Harrison and W. Walters. "Differential Excitation Spectroscopy for Detection of Common Explosives: Ammonium Nitrate and Urea Nitrate." *SPIE Proceedings* Vol. 9454: *Detection and Sensing of Mines, Explosive Objectives, and Obscured Targets XX*, No. 945407 (2015): pp. 1-27, doi: 10.1117/12.2177708.

Johnson, G.R., **S.R. Beissel** and **C.A. Gerlach**. "A 3D Combined Particle-element Model for Intense Impulsive Loading Computations Involving Severe Distortions." *International Journal of Impact Engineering*, Vol. 84 (2015): pp. 171-180, doi: 10.1016/j.ijimpeng.2015.06.006.

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Simons, S.B., **E.L. Broerman** and **K. Brun**. "Vortex-shedding Pulsation Testing for Piping Systems (Part 2): Development of a Predictive Method for Quantifying Vortex-shedding Pulsation Amplitude Points to Eliminate Unnecessary Piping Changes." *COMPRESSORtech2*, (July 2015): pp. 22-27.

Yoshii, T., J.S. Nyman, M. Yuasa, J.M. Esparza, A. Okawa and **G.E. Gutierrez**. "Local Application of a Proteasome Inhibitor Enhances Fracture Healing in Adult Rat." *Journal of Orthopaedic Research*, Vol. 33, No. 8 (2015): pp. 1197-1204, doi: 10.1002/jor.22849.

Technical Staff Activities

Presentations

Allison, T.C. and **K. Brun**. "Testing and Modeling of an Acoustic Instability in Pilot-operated Pressure Relief Valves." Presented at the American Society of Mechanical Engineers (ASME) Turbo Expo 2015, Montreal, June 2015.

Allison, T.C., **J.C. Wilkes** and M. Pinelli. "Tutorial: Turbomachinery Instrumentation Components, Practices, and Uncertainty." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Andrew, D., **L. Smith**, **J. Feiger** and R. Pilarczyk. "Influence of 'A' Crack Tip Material Properties on Corner Crack Shape and Aspect Ratio." Presented at the 2015 Air Force Grow (AFGROW) User's Workshop, Layton, Utah, September 2015.

Bartley, G. J. "Low Temperature Limiters to Catalyst Light-off." Presented as a Contributed Talk at the 2015 Department of Energy (DOE)-Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Workshop in Dearborn, Mich., April 2015.

Beck, G.C. "Cavitating Venturi Model Using Standard Element and Options in Commercially Available Lumped-parameter Software." Presented at the 51st American Institute of Aeronautics and Astronautics/Society of Automotive Engineers/American Society of Engineering Education (AIAA/SAE/ASEE) Joint Propulsion Conference, Orlando, Fla., July 2015.

Beissel, S.R. "A Survey of Errors in Finite-Element Computations of Wave Propagation." Presented at the USNCCM13, San Diego, July 2015.

Beissel, S.R. and **G.R. Johnson**. "Evaluation of Computational Approaches of Structural Responses of Fuzes Subjected to High-frequency Environments." Presented at the 58th Annual National Defense Industrial Association (NDIA) Fuze Conference, Baltimore, July 2015.

Beissel, S.R. and **G.R. Johnson**. "Mitigation of Zero-energy Modes in Co-located Particle Methods." Presented at the 13th U.S. National Congress on Computational Mechanics (USNCCM13), San Diego, July 2015.

Bennett, J.A., **S.B. Coogan** and K. Lane. "Case Study: Dynamic Analysis of a Novel Vertical Axis Wind Turbine." Proceedings of the ASME Turbo Expo 2015, Montreal, June 2015.

Brun, K., C. Meyenberg and J. Thorp. "Hydrodynamic Torque Converters for Oil & Gas Compression and Pumping Applications: Basic Principles, Performance Characteristics and Applications." Proceedings of the ASME Turbo Expo 2015, Montreal, June 2015 and at the 2014 Gas Machinery Conference (GMRC), Nashville, Tenn., October 2014.

Bullock, M., S. Schwenzer, J. Bridges, C. Chavez, J. Fillberto, S. Kelley, **M. Miller**, J. Moore, H. Smith, T. Swindle and A. Treiman. "Noble Gas Fractionation During Low Temperature Alteration—An Experimental Approach." Presented at the 46th Lunar and Planetary Science Conference (LPSC), The Woodlands, Texas, March 2015.

Carlson, S., **D. Andrew**, R. Pilarczyk and M. Thomsen. "The Nuts and Bolts: Should They Stay or Should They Go Now?" Presented at the Materials Science & Technology (MS&T15) 2015 Conference, Columbus, Ohio, October 2015.

Carlson, S. and **R. Heller**. "Design of Full-strength, Damage Tolerant Repairs for Metallic Aircraft Structure—The Art Behind the Science." Presented at the 2015 United States Air Force Aircraft Structural Integrity Program (USAF ASIP) Conference, San Antonio, September 2015.

Carlson, S., R. Pilarczyk, **D. Andrew** and J. Hodges. "Development of Fatigue Crack Growth Methods in the Presence of Deep Residual Stress Field—Utilization of Measurement Prediction and Validation within the USAF's Damage Tolerance Paradigm." Presented at the MS&T15 Conference, Columbus, Ohio, October 2015.

Cheng, X.G., R.J Christy, M.P. Gentil and N. Edwards. "In Vivo Analysis of Tissue Engineered Collagen Constructs for Tendon Healing in an Achilles Tendon Gap Defect Model." Presented at the 2015 Military Health System Research Symposium (MHSRS), Fort Lauderdale, Fla., August 2015.

Cheng, X.G., R.J Christy, R.L. Williams, M.R. Davis and N. Edwards. "Preclinical Evaluation of Biomask Materials Toward Facial Skin Regeneration." Presented at the 2015 MHSRS, Fort Lauderdale, Fla., August 2015.

Cobb, A.C. and **J.L. Fisher**. "Defect Depth Sizing Using Guided Waves." Presented at the 42nd Quantitative Nondestructive Evaluation (QNDE) Annual Review of Progress in Quantitative Nondestructive Evaluation, Minneapolis, July 2015.

Codell, R., **S. Mohanty**, **S. Stothoff**, G. Mathieu, M. Bourgeois and D. Pellegrini. "Sensitivity Studies with a Probabilistic Radionuclide Transport Model for Geological Disposal in Meuse/Haute-Marne, France." Proceedings of the 15th International High-Level Radioactive Waste Management (IHLRWM) Conference, Charleston, S.C., April 2015.

Coogan, J.S., **T.D. Eliason**, M. Wong and **D.P. Nicolella**. "The Effect of Anatomical Variability of Temporomandibular Joint Mechanics." Presented at the 2015 Summer Biomechanics, Bioengineering and Biotransport Conference (SB3C2015), Snowbird, Utah, June 2015.

Coogan, S.B. "Potential Benefits of Pressure Gain Combustion in Liquid Rocket Engine Pre-burners." Presented at the 51st AIAA/SAE/ASEE Joint Propulsion Conference, Orlando, Fla., July 2015.

Cunningham, C.S., **D.L. Ransom**, **J.C. Wilkes**, J. Bishop and **B.A. White**. "Mechanical Design Features of a Small Gas Turbine for Power Generation in Unmanned Aerial Vehicles." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Davis, M.W., **G.R. Gladstone**, **T.K. Greathouse**, **K.D. Retherford** and **C. Grava**. "Solar Glint Suppression in Compact Planetary Ultraviolet Spectrographs." Presented at the 2015 Society of Photo-optical Instrumentation Engineers (SPIE) Optics + Photonics Conference, San Diego, August 2015.

Technical Staff Activities

Dayeh, M.A., "Implications of Thunder Imaging on the Microphysics of Lightning." Invited talk at the Chinese Academy of Sciences, Beijing, June 2015.

Dayeh, M.A., **M.I. Desai**, **R.W. Ebert** and G.M. Mason. "Properties of the Suprathermal Particle Population Near 1 Astronomical Unit (AU) During Solar Cycles 23 and 24." Presented at the Fourteenth International Solar Wind Conference (Solar Wind 14), Weihai, China, June 2015.

Dayeh, M.A., **D.J. McComas**, **M.I. Desai** and **E. Zirnstein**. "Energetic Neutral Atom (ENA) Flux Variations in Upwind and Downwind Directions." Presented at the 19th Interstellar Boundary Explorer (IBEX) Science Team Meeting, Boulder, Colo., August 2015.

Dayeh, M.A., **K. Ogasawara**, **S.A. Fuselier**, **D.J. McComas** and **P. Valek**. "Magnetospheric ENA Response to a Solar Wind Pressure Pulse." Presented at the 19th IBEX Science Team Meeting, Boulder, Colo., August 2015.

Delgado-Garibay, H. "Gas Turbine Root Cause Failure Analysis: Blade Failures." Presented at the 2015 Eastern Gas Compression Roundtable (EGCR), Pittsburgh, May 2015.

Desai, M.I. "Origin and Acceleration of Suprathermal Ions." Presented at the Solar Wind 14 Conference, Weihei, China, June 2015

Desai, M.I., **M.A. Dayeh**, **R.W. Ebert**, **D.J. McComas**, G. Li, C.M.S. Cohen, R.A. Mewaldt, N.A. Schwadron and C.W. Smith. "Spectral Properties of Large Gradual Solar Energetic Particle Events." Presented at the Solar, Heliospheric and Interplanetary (SHINE) Conference, Stowe, Vt., July 2015.

Desai, M.I., G.M. Mason, **M.A. Dayeh**, **R.W. Ebert**, **D.J. McComas**, G. Li, C.M.S. Cohen, R.A. Mewaldt, N.A. Schwadron and C.W. Smith. "Spectral Properties of Large Gradual Solar Energetic Particle Events." Presented at the SHINE Conference, Stowe, Vt., July 2015.

Desai, M.I., G.M. Mason, **M.A. Dayeh**, **R.W. Ebert**, **D.J. McComas**, G. Li, C.M.S. Cohen, R.A. Mewaldt, N.A. Schwadron and C.W. Smith. "Systematic Behavior of Heavy Ion Spectra in Large Gradual Solar Eneregtic Particle Events." Presented at the 34th International Cosmic Ray Conference (ICRC), South Holland, Netherlands, July 2015.

Eberle, D. "Uses of Radioactive Tracers at Southwest Research Institute (SwRI)." Presented at the 59th International Atomic Energy Agency (IAEA) General Conference, Vienna, June 2015.

Evans, P.T. "Current and Future Trends in Robotics and Automation, Including Operating Robotics in Dynamic Environments for High-mix Low-volume Production." Presented at the Austin Regional Manufacturers Association (ARMA) Speaker Luncheon, Austin, Texas, August 2015.

Garcia, R. "Deployment of Advanced Technologies in Maritime Security: Effective use of Unmanned Aerial Surveillance Systems." Presented at the Maritime Security 2015 East Conference, Jacksonville, Fla., March 2015.

Genestreti, K.J., **S.A. Fuselier** and **J. Goldstein**. "3-D Aspects of Magnetotail Reconnection and First Data from Magnetospheric Multiscale Mission-Hot Plasma Composition Analyzer (MMS-HPCA)." Presented at the University of Michigan, Ann Arbor, Mich., July 2015.

Genestreti, K.J., **J. Goldstein**, R.M. Skoug, B.M. Larsen, L.M. Kistler, C. Mouikis, H.E. Spence, N.E. Turner, G.D. Corley, W. Farner and C. Ramnarace. "Helium Oxygen Proton Electron Telescope (HOPEful) Attempts at Calculating the Plasmaspheric Temperature." Presented at the Geospace Environment Modeling (GEM) 2015 Summer Workshop, Snowmass, Colo., June 2015.

Genestreti, K.J., **S.A. Fuselier**, **J. Goldstein**, T. Nagai and J.P. Eastwood. "Dawn-dusk Asymmetries in the Near-Earth Reconnecting Magnetotail." Presented at the GEM 2015 Summer Workshop, Snowmass, Colo., June 2015.

Grava, C., N.M. Schneider, F. Leblanc, J.P. Morgenthaler, V. Mangano and **K.D. Retherford**. "Spatial and Spectral Asymmetries of Exospheric Sodium in the Wake of Io's Plasma Interaction." Presented at the Magnetospheres of Outer Planets (MOP) 2015 Conference, Atlanta, June 2015.

Gutierrez, **G.E.**, **N.L. Cantú**, **L. Cabell**, **A.P-Z. Clark**, **J. McDonough**, J. Johnson and B. Roche. "Intranasal Delivery of Stabilized Isoamyl Nitrite Reverses Acute Cyanide Lethality." Presented at the 2015 MHSRS, Fort Lauderdale, Fla., August 2015.

Hansen, G. and **P.M. Lee**. "Developing a High Pressure HFRR for Lubricity of Volatile Fluids." Presented at the 70th Annual Meeting and Exhibition of Society of Tribologists and Lubrication Engineers (STLE 2015), Dallas, May 2015.

Hansen, G., **P.M. Lee**, **S.Westbrook** and **G.Wilson**. "Correlation of Pump Test and High Frequency Reciprocating Rig (HFRR) Results by Modification of HFRR Contact Geometry and Parameters." Presented at the 70th Annual Meeting and Exhibition STLE 2015, Dallas, May 2015.

Heller, R. "Cybersecurity and Connected Vehicle." Presented at the 2nd Annual Florida Transportation Data Symposium, Orlando, Fla., August 2015.

Hendrix, A.R., **T.K. Greathouse**, **K.D. Retherford**, **K.E. Mandt**, **G.R. Gladstone**, **D.E. Kaufmann**, D.M. Hurley, P.D. Feldman, W.R. Pryor, **M.A. Bullock** and **S.A. Stern**. "Regional Variations in UV Lunar Signatures." Presented at the Second Annual National Aeronautics and Space Administration (NASA) Solar System Exploration Research Virtual Institute (SSERVI) Exploration Science Forum (ESF), Mountain View, Calif., July 2015.

Hoopes, K.M., **J.J. Moore**, **S.D. Cich** and C. Kalra. "Design of an Air Dynamometer for Direct Connection to the SunShot SCO2 Turbine Expander Shaft." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Hunter, B., J. Cox, **M. Miller**, P. Harrison and W. Walters. "Differential Excitation Spectroscopy for Detection of Chemical Threats: Dimethyl Methylphosphorate (DMMP) and Thiodiglycol." Presented at the 2015 SPIE Detection and Sensing of Mines, Explosive Objects, and Obstructed Targets XX Conference, Baltimore, April 2015.

Technical Staff Activities

Hurley, D.M., M. Benna, **J.C. Cook**, J. Halekas, **C. Grava**, **K.D. Retherford**, P.D. Feldman, P. Mahaffy, D. Hodges and R. Elphic. "Variability and Sources of Helium in the Lunar Exosphere." Presented at the Second Annual SSERVI-ESF, Mountain View, Calif., July 2015.

Jensema, R. and **M.I. Desai**. "Origin and Acceleration of Suprathermal Ions in Corotating Interaction Regions," Presented at the SHINE Conference, Stowe, Vt., July 2015.

Kamps, T.J., J.C. Walker, R.J. Wood, **P.M. Lee** and A.G. Plint. "The Measurement of Disorderly Friction and its use in the Detection of Scuffing." Presented at the 70th Annual Meeting and Exhibition STLE 2015, Dallas, May 2015.

Lee, P.M., **C. Wall**, **C. Wileman** and **G. Bailey**. "Detecting Ring Instability/Scuffing in a Fired Engine." Presented at the 70th Annual Meeting and Exhibition STLE 2015, Dallas, May 2015.

Liu, Y., **K.D. Retherford** and **G.R. Gladstone**. "Lunar Reconnaissance Orbiter (LRO)-Lyman Alpha Mapping Project (LAMP) Far-UV Maps of the Lunar Poles." Presented at the Sixth Annual Lunar and Small Bodies Graduate Conference (LunGradCon 2015), Mountain View, Calif., July 2015.

Llera, K., **J. Goldstein**, **D.J. McComas** and **P.W. Valek**. "Characteristics of Low-altitude Energetic Neutral Atoms: Multiple Charge Changing Interactions and Energy Loss." Presented at the American Geophysical Union (AGU) Chapman Conference on Magnetospheric Dynamics, Fairbanks, Alaska, September 2015.

Llera, K., **J. Goldstein**, **D.J. McComas** and **P.W. Valek**. "Low-altitude Emission of Energetic Neutral Atoms: Multiple Charge Changing Interactions and Energy Loss." Presented at the GEM 2015 Summer Workshop, Snowmass, Colo., June 2015.

McComas, D.J. "The IBEX: Exploring the Local Interstellar Medium and the Sun's Interaction With It." Presented at Imperial College, London, June 2015.

Medrano, M.R., **E. Flores** and **H.Y. Lai**. "Evaluation of Technology Development for Direct Replacement Biofuels Using Thermochemical Processes." Presented at the 2015 American Institute of Chemical Engineers (15 AIChE) Spring Meeting and 11th Global Congress on Process Safety, Austin, Texas, April 2015.

Moore, J.J., **K. Brun**, N. Evans and C. Kalra. "Development of 1 MwE Supercritical CO2 Test Loop." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Moore, M. and **T. Thompson**. "Honey I Shrunk the Network: From ARPANET to Personal Area Networks." Presented at NASA, Houston, July 2015.

Musgrove, G.O., **A.M. Rimpel** and **J.C. Wilkes**. "Tutorial: Applications of Supercritical CO_2 Power Cycles: Fundamentals and Design Considerations." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Neely, G., **R. Coppersmith, C**. **Ng**, **Reinhart, T.** and A. Combi. "Fuel Compensation Solution for a Multi-fuel Capable Diesel Engine." Presented at the 2015 NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS) Power & Mobility (P&M) Technical Session, Novi, Mich., August (2015).

Noonan, P. and **A. Whittington**. "Automatic Generation of XForms-based User Interfaces." Presented at the European Test and Telemetry Conference (ETTC), Toulouse, France, June 2015.

Ogasawara, K., **S. Livi**, **M.I. Desai**, **F. Allegrini**, **D.J. McComas**, **J.-M. Jahn** and **R.W. Ebert**. "Calibration Study of the Double-cusp Type Electrostatic Analyzer for Solar Wind Suprathermal Ions." Presented at the 12th Annual Meeting of the Asia Oceania Geosciences Society (AOGS) 2015, Singapore, August 2015.

Oxley, J. "Encapsulation via Annular Jet Process." Presented at the Encapsulation & Controlled Release (EncapCR) Fest, Edison, N.J., August 2015.

Oxley, J. "Encapsulation via Emulsion and Other Chemical Processes." Presented at the EncapCR Fest, Edison, N.J., August 2015.

Randolph, L. "TxDOT Variable Speed Limits Using Weather, Construction, and Traffic Data." Presented at the 2015 National Rural ITS Conference (NRITS), Snowbird, Utah, August 2015.

Randolph, L. and **J. Johnson**. "Active Traffic Management: Texas Variable Speed Limit Pilot Project." Presented at the 2015 Intelligent Transportation Society (ITS) of America 25th Annual Meeting & Expo, Pittsburgh, June 2015.

Retherford, K.D. and the Europa-Ultraviolet Spectography (UVS) Science Team. "Europa-UVS Instrument Overview." Presented at the 2015 NASA Outer Planets Assessment Group (OPAG) Meeting, Laurel, Md., August 2015.

Rimpel, A.M. and **J.C. Wilkes**. "Tutorial: Rotordynamics 101." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Roming, P. "Swallowed by a Black Hole." Presented at the Shapley Lecture, University of South Dakota, Vermillion, S.D., April 2015.

Siebenaler, S.P., *et al*. "Evaluation of Distributed Acoustic Sensing Leak Detection Technology for Offshore Pipelines." Presented at the 25th International Ocena and Polar Engineering (ISOPE 2015) Conference, Kona, Hawaii, June 2015.

Soltero, C.G. "Characteristics of a Relevant Lean Measure, Why the Right Performance Measures are Important, and the Linkages between Strategic Goals, KPIs, Value Stream Measures, and Cell Measures." Presented at the ARMA Lean Leadership Training, Austin, Texas, April 2015.

Stoker, L. and **S. Carlson**. "Finite Element Analysis of Bonded Repairs and Analysis Methods for the ASIP Engineer." Presented at the 2015 USAF ASIP Conference, San Antonio, September 2015.

Technical Staff Activities

Thacker, B.H. "Uncertainties in the Comparison of Observed and Predicted Crack Growth Through a Residual Stress Field." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Towler, J. and B. Gerkey. "Robotic Operating System—Military: Concept Overview." Briefing to the National Advanced Mobility Consortium (NAMC), Novi, Mich., August 2015.

Warnock, S.T., **E. Flores** and **H.Y. Lai**. "Commissioning Lab Scale Circulating Fluidized Bed for Evaluating Commercial Scale Fluid Catalytic Cracking (FCC) Catalyst, Additives, and Operating Conditions to Support Ever-changing Feedstocks." Presented at the 15 AIChE Spring Meeting & 11th Global Congress on Process Safety, Austin, Texas, April 2015.

Westbrook, S.R. "Types of Diesel Fuel Contaminants." Presented at the American Society for Testing and Materials (ASTM) Diesel Cleanliness Workshop, Fort Lauderdale, Fla., June 2015.

Wileman, C. and **P.M. Lee**. "Investigation into Engine Wear Map Development Using Radioactive Tracer Testing." Presented at the 70th Annual Meeting and Exhibition STLE 2015, Dallas, May 2015.

Wilkes, J.C. and **T.C. Allison**. "A General Model for Two-point Contact Dry-friction Whip and Whirl—Further Advancements and Experimental Test Results." Presented at the ASME Turbo Expo 2015, Montreal, June 2015.

Yoshii, T., J.S. Nyman, M. Yuasa, J.M. Esparza, A. Okawa and **G.E. Gutierrez**. "Local Application of a Proteasome Inhibitor Enhances Fracture Healing in Adult Rat." Presented at the 55th Annual Meeting of the Orthopaedic Research Society, Las Vegas, March 2015.

Internal Research

Funded July 1, 2015

Anderson, B. "Low-cost Lighter-than-air Flight Control System."

Avery, P., A. Van Horn, **M. Brooks** and **M. Brown**. "Subtle Anomaly Detection in the Global Dynamics of Connected Vehicle Systems."

Ayling, D., **K. Saylor** and **M. Moore**. "Bump in the Connector Victory Adapter."

Beissel, S., **C. Gerlach**, **S. Chocron**, **G. Johnson**, **W. Couvillion** and **J. Walker**. "Improving the Efficiency of Computations Involving the Ballistic Impact of Full-scale Structures of Composite Materials."

Caspi, A. "Demonstration Flight of New Technology for Solar Hard X-ray Spectroscopy for Future CubeSat Missions."

Caspi, A. "Laboratory Calibration and Environmental Testing of New Hard X-ray Spectrometer for Future CubeSat Missions."

Kilpatrick, S. and **B. Abbott**. "Select Super-optimization of Finite Element Analysis Tools."

Kroll, S., **S. Eakle**, **A. Yau** and **J. Gomez**. "A New Method for Quantifying Urea and Urea Thermal Decomposition Byproducts."

Lamb, D., **C. DeForest** and **T. Howard**. "Augmenting a Novel Magnetohydrodynamics Code for Studying Astrophysical Plasmas and Space Weather."

Ling, J. "Method for Stem Cell Expansion."

Liu, E., **K. McCubbin** and **S. Mitchem**. "Validating Using Laser Scan Micrometry to Measure Surface Changes on Non-concave Surfaces."

Morgan, P., **P. Lobato**, **K. Brunner** and **R. Legg**. "Octane Index Effects on Fuel Economy."

Music, W. "GLRT (Generalized Likelihood Ratio Test) Signal Detection and Beamforming of N-channel Array."

Nance, B. and **J. Polendo**. "Airborne High Frequency Direction Finding Enhancements."

Roming, P., **M. Epperly** and **M. Koets**. "Radiation Hard ASICs (Application-Specific Integrated Circuits) for Space Imaging."

Tapia, R., **S. Mann**, **B. Chancellor** and **W. Couvillion**. "Construction Equipment Operator Training Simulators Technology Update."

Untermeyer, T. and **J. Huczek**. "RF (Radio Frequency) Detection of Fire Source."

Walls, M., **C. Chadwell** and **T. Alger**. "State-of-the-art D-EGR (Dedicated Exhaust Gas Recirculation)."

Whitaker, T. and **S. Anderson**. "Developing SwRI Capabilities for Detection of Isotopes of Lead."

Patents

Amann, M. and **T.F. Alger II**. "Method and Related System of Using Crankcase Pressure To Detect Pre-Ignition in Spark Ignition Engine." U.S. Patent No. 9,080,521. July 2015.

Benke, R.V., **R.Hill Jr.**, **R.T. Pabalan**, **J.A. Moryl** and **J.R. Pruitt**. "Methods for Vaporization and Remediation of Radioactive Contamination." U.S. Patent No. 9,105,363. August 2015.

Furman, B.R., **S.T. Wellinghoff** and **C.K. Baker**. "Electrophoretic Formation of Nanostructured Composites." U.S. Patent No. 9,103,046. August 2015.

Koci, C.P., **V.L.C. Ulmet**, **S. Simescu**, **M.K. Khair** and **G.D. Neely.** "Diesel Engine Operation for Fast Transient Response and Low Emissions." U.S. Patent No. 9,062,577. June 2015.

Miller, **M.A.**, **R. Wei** and **G. Hatton**. "Superhydrophobic Compositions and Coating Process for the Internal Surface of Tubular Structures." U.S. Patent No. 9,121,540. September 2015.

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