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About the Institute

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

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COVER



About the cover

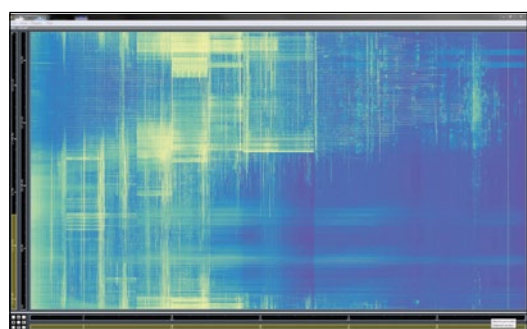
Exposed rock strata can reveal folds, faults and other deformation features that also exist deep underground in the same formation and may have significance for the performance of oil and gas reservoirs.

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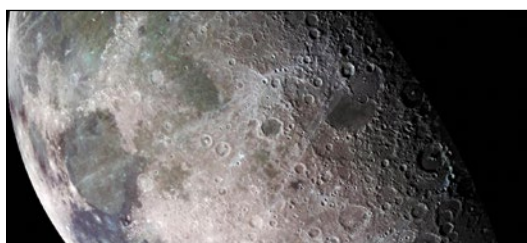
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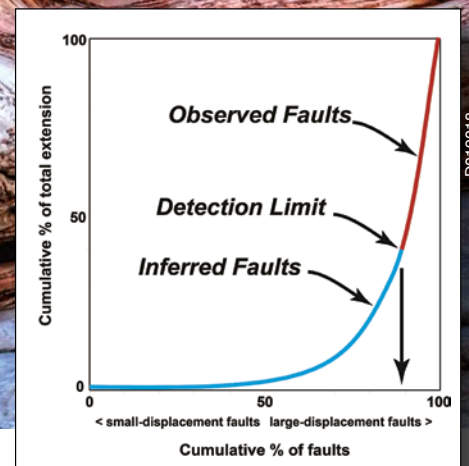
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Stress Management

Structural geology and geomechanics are applied to energy exploration and production

Rock strata often are non-uniform and may contain folds, faults and other deformation. Faults too small to observe using traditional seismic technology, such as those marked in red in the bottom inset photo, nevertheless may be important to the formation and performance of oil and gas reservoirs. A significant percentage of total faulting may be below the detection limit, as shown in the graph in the top inset.



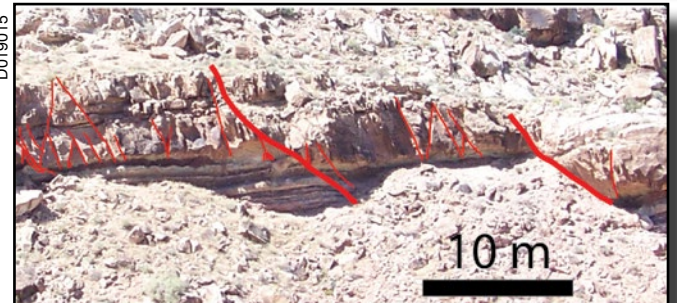
By David A. Ferrill, Ph.D., Alan P. Morris, Ph.D., Kevin J. Smart, Ph.D. and Ronald N. McGinnis

After more than 150 years of oil and gas production following the first successful oil well in Pennsylvania in 1859, most of the easy-to-produce oil and gas reservoirs have already been found. New hydrocarbon discoveries tend to be more structurally complex and located in tighter rock, at greater depths or in deeper water. Finding these harder-to-reach resources, and then producing from them, calls for ever-increasing expertise in characterizing and understanding the influences of geologic structures on the deposition and deformation of reservoir, seal, and source strata.

Over the years, new and more sensitive seismic technologies have been developed to reveal formerly unrecognized subsurface geologic structures. In many cases, however, the products of geologic deformation which occur as faults, folds and fractures are still below the detection limits of 3-D seismic reflection data, thus requiring a geologist to predict or infer subseismic-scale

deformation. To be successful in these increasingly challenging exploration and production environments, petroleum geologists need higher resolution tools, but perhaps more important, they need sophisticated training to aid interpreters as they analyze the data generated by the improved hardware and software tools. A team of geologists from Southwest Research Institute (SwRI) has developed approaches to aid oil and gas exploration and improve the prospects for successful production from unconventional reservoirs.

The process involves collecting data to characterize the natural deformation, rock mechanical properties and stress environments; studying outcrops to characterize reservoir rocks or their analogs; analyzing stress fields, both past and present, and



predicting stress changes resulting from production activities such as hydraulic fracturing and pressure declines; and performing geomechanical analyses using physical analog and numerical modeling techniques.

Stress and geomechanical analyses allow geologists to leverage limited static data and thus track dynamic stress and deformation over time. The time scales range from geologically instantaneous seismic deformation caused by earthquakes or induced hydraulic fracturing, to longer-term production



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(field lifetime) scales, and ultimately to geologic time scales.

The basics of reservoir analysis

Geologic structure, stress and fluid pressure conditions, and geomechanical behavior of rock are key elements in determining trap, reservoir and charge in hydrocarbon systems. Conventional hydrocarbon traps are commonly formed by geologic structures such as domes, anticlines, and sealing faults. Fracture and fault systems can also compromise trap integrity and may be difficult or impossible to detect. So-called unconventional resource plays, where the source and reservoir rock are the same, are becoming increasingly important in hydrocarbon exploration and production. These unconventional plays are typically dependent on induced fracturing ("fracking") for their economic viability, and therefore the presence or absence of natural faults and fractures, the ambient stress state, and the mechanical characteristics of the reservoir rocks are critical factors in planning effective production strategies.

Reservoir quality, especially in tight (low porosity) reservoir rock, is often enhanced by open natural fractures. In contrast, small-displacement sealing faults can significantly reduce reservoir quality and compartmentalize hydrocarbon reservoirs. Increasing fluid pressure to stimulate hydraulic fracturing in unconventional shale or tight sand

reservoirs takes advantage of *in situ* stress and fluid pressure conditions to reactivate natural fractures and induce new fractures to create or enhance fracture permeability. In contrast, declining fluid pressures over a reservoir's productive lifetime can cause naturally permeable faults and fractures to close or lose their permeability, thus reducing overall reservoir permeability or compartmentalizing the reservoir.

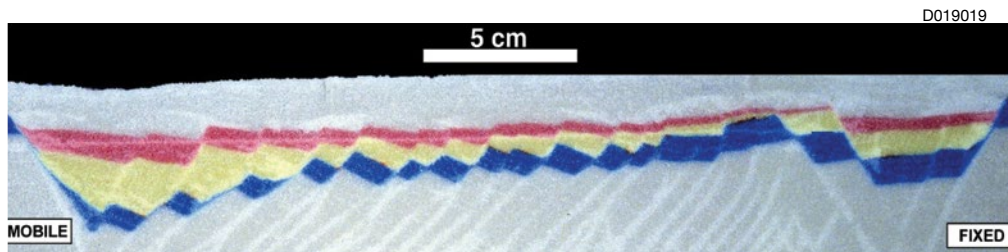
In many cases, hydrocarbon generation and migration into a reservoir depends on stress conditions, geomechanical properties of rock, deformation processes, and geologic structure. These conditions commonly combine to provide pathways for migration of hydrocarbons from the site of source rock maturation, sometimes called the "kitchen." In unconventional reservoirs, the kitchen is also the reservoir, and conditions that are favorable for migration are detrimental to the richness of the reservoir because they allow some hydrocarbons to escape.

Although, with virtually no significant exceptions, oil and gas reservoirs are

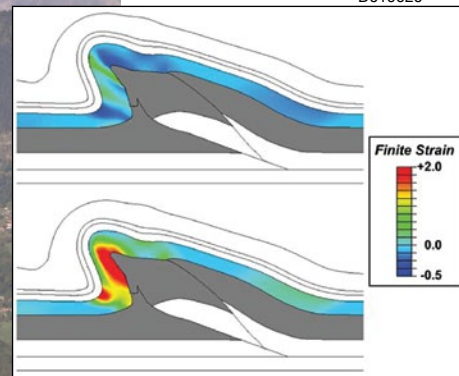
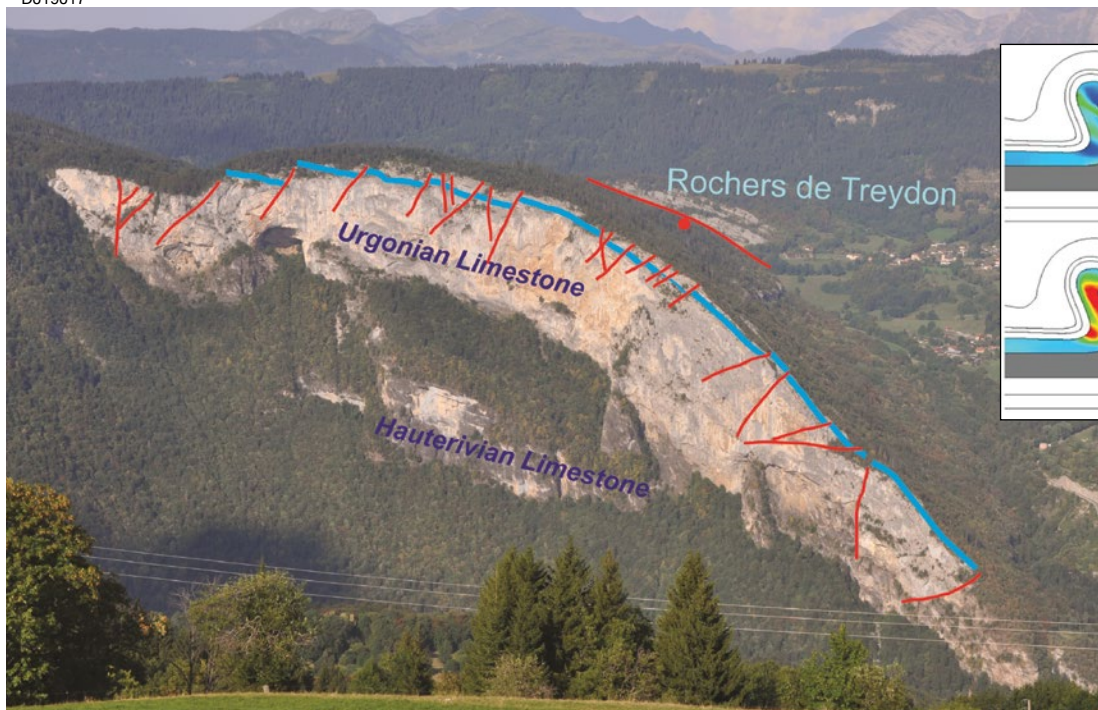
buried beneath the earth's surface, direct analogs of the rock types and structural features (folds, faults and fractures) can be observed first-hand somewhere at the earth's surface. In the spirit of H.H. Read's observation that the best geologists are the ones who have seen the most rocks, it is essential to develop an understanding of reservoir behavior by observing and analyzing rocks in the field. To this end, geologists inform their models by studying the closest field analogs to the reservoir rocks they wish to understand.

Modeling applications

Geomechanics is the application of mechanical (or rock mechanical) principles to geologic problems. Although geomechanical modeling often invokes the idea of computer-based analysis, the structural geology community has a well-established record of using physical analog as well as numerical modeling techniques to understand structural geology and geomechanics problems.



This photograph shows a vertical slice through a model of extensional faulting that uses unconsolidated sand to simulate brittle rock. Physical analog modeling is useful for simulating fault systems.



Red lines show faults on a field photograph from an SwRI study of the plunging Barge anticline in Haute Savoie, France. The inset shows 2-D finite element simulation of the Barge anticline with contours of minimum (upper diagram) and maximum (lower diagram) principal strain magnitudes (red=extension, blue=contraction).

Therefore, these two approaches should be thought of as complementary.

Physical analog models typically employ a model material or materials whose behavior in the lab is analogous to some material in nature. Among the most commonly used materials for studying geologic phenomena are dry sand, wet clay and silicone putty. Physical analog models have the advantage of allowing very large strains to develop and failure (fault rupture) to occur. They are especially well-suited to the study of complex three-dimensional structures as they form, and they can provide powerful conceptual insights. The primary disadvantages are the difficulty in building multiple near-identical models, which makes parametric study challenging, and the limitations on extractable information. For example, the geometry and developmental history of a structure are available, but quantitative stress values are not.

Numerical models also have a long history of use in understanding structural geology and geomechanics problems. Numerical models offer the advantage of providing detailed information such as stress, strain, temperature and pore pressure throughout the entire evolution of the structure, both temporally and spatially. In general they are

well-suited to parametric studies where one or more components are systematically varied; for example, material properties and loading conditions. Even with recent advances in computer power, however, complex three-dimensional numerical models are still difficult to construct and may take days or even weeks to run.

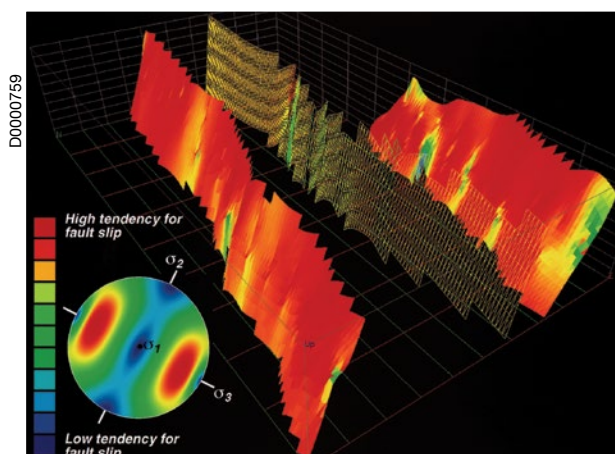
Finite element modeling is particularly powerful for oil industry problems because it allows modeling of systems across all scales and time frames, simulating large displacements and strains,

implementing diverse material model (viscous, elastic, plastic, viscoelastic or elastic-plastic) behavior, simulating permanent deformation and tracking realistic stress, strain and fluid pressure.

Major strides have been made in recent years in simulating oilfield-scale structures, calibrating models against quantitative measures of geometry, deformation, or stress and fluid pressure information and testing the influence of variables such as rock strength and the role of bedding plane slip. These results have demonstrated that finite element forward models can replicate large-scale geometries and patterns of smaller-scale deformation within layers. Results have also highlighted the key role that mechanical layering and bedding plane slip can have on deformation, and the importance of factoring this into numerical simulations. New results are demonstrating the utility of finite element modeling to simulate induced hydraulic fracturing in mechanically layered rocks, including the generation of tensile and shear failure.

Summary

Structural geology, stress and geomechanical analysis are important components of oil and gas industry exploration and production. This is especially true as the industry enters increasingly complex and



Slip tendency analysis of three fault surfaces illustrates that minor fluctuations in fault orientation result in significant changes in slip tendency within a homogeneous stress state. Slip tendency can correlate with fault zone permeability and serve as an indicator of fault leakage, migration pathways or areas at high risk for loss of circulation during drilling.

SwRI program illuminates Eagle Ford geology for oil and gas producers

Before risking millions to drill a new well, oil company geologists might wish they could peer through thousands of feet of solid rock to better understand what lies below.

Through a program managed by Southwest Research Institute's (SwRI) Geosciences and Engineering Division, geologists are studying the deeply buried South Texas formation known as the Eagle Ford Shale by visiting the places where it is exposed at the ground surface.

The Eagle Ford Formation is a highly productive oil and gas reservoir. In the industry, it's a type known as "unconventional," which generally means that the source rock for the hydrocarbons is also the reservoir, a situation sometimes called self-sourced. Variability in mineralogy, natural fracturing, and ambient stress state influence the industry's ability to hydraulically fracture the reservoir, therefore making it a challenge to develop an optimal drilling strategy.

Geologists want to know how pre-existing 'natural' fractures might influence hydraulic fracturing and well performance, what types of fractures are likely to be produced, how far they will extend and what volume of rock a well may be able to produce from. The answers to these questions are crucial to drilling strategy.

To help answer such questions and understand the fundamental relationships between stratigraphy, natural fracturing, and stress conditions, SwRI in 2011 organized a joint industry project for producers in the Eagle Ford and associated formations.

Midway through its first two-year phase, the Eagle Ford Joint Industry Project includes eight member oil companies. It offers geologists a chance to view outcrops of the Eagle Ford and associated formations at locations in West and South Central Texas.



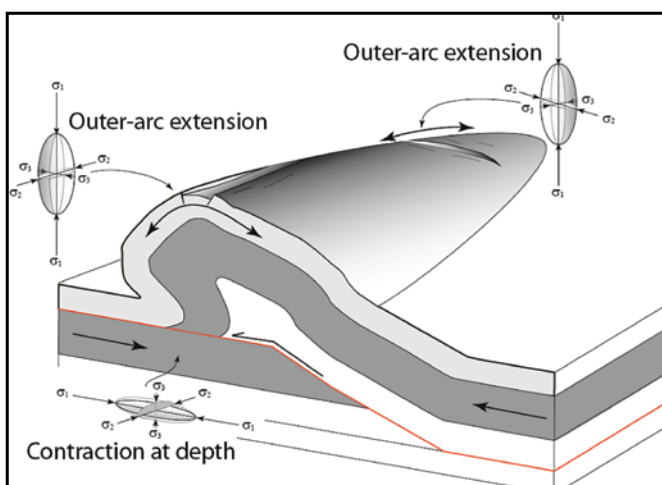
Petroleum-bearing strata can be better understood by viewing locations where they outcrop, such as this exposure of the Boquillas Formation, also known as the Eagle Ford, in a road cut near Del Rio, Texas.

From studies of those outcrops, investigators analyze the stratigraphy and mechanical behavior of the strata and natural deformation including faulting, folding, and fracturing, as well as past and present stress conditions. The analyses help producers understand the pre-existing natural deformation, as well as the important role that mechanical stratigraphy plays in controlling distribution and style of faulting, fracturing and related deformation.

In addition to outcrop-based analyses, the project includes geomechanical simulation of natural and induced fracturing to better understand the behavior of the Eagle Ford and other mechanically layered or heterogeneous self-sourced (unconventional) reservoirs. These results are transforming how companies understand and plan development in the Eagle Ford.

Membership fee for the consortium is \$75,000 for each two-year phase.

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This conceptual model of a plunging fold shows opposing geologic forces at work, such as extension at the outer arc compared to contraction at deeper locations.

geologic and geomechanical investigations are often warranted to address exploration and production challenges, and the selection of the approach(es) depends on the problem, setting and available data. Mapping is often the first order of business, and many problems can be preempted by

pressure conditions, and perturbations to structural geologic and geomechanical conditions that will occur due to injection and extraction processes. Efforts to understand these factors should start simple, start early in the project and be updated using additional data as they become available.

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challenging geologic environments both conventional and unconventional. Sound understanding of structural geology and geomechanics concepts can be developed through classroom and outcrop studies. Site-specific structural

careful interpretation, consideration of multiple working hypotheses for areas of poor data, and better mapping. It is never too early in a project to start thinking about subseismic scale structure, mechanical stratigraphy, stress and fluid

Acknowledgments

We appreciate the thoughtful review by Dr. Gary Walter. Portions of this work were supported by several Southwest Research Institute Internal Research and Development projects.

A Good Scouttm



An SwRI-developed tool enables signal analysts to scan an area's radio spectrum and locate signal sources.

By James H. Nixon

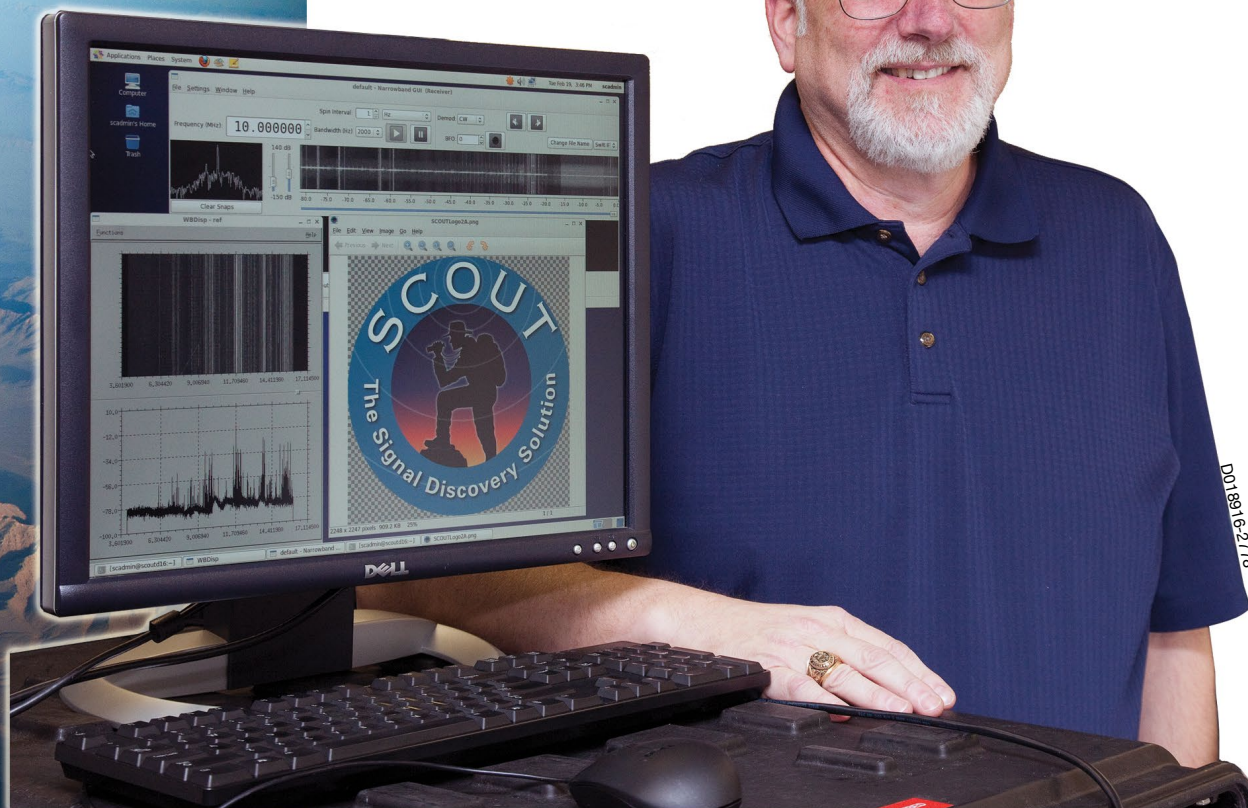
Tourists who find themselves in an exotic locale typically spend some time taking in the local sights and sounds to get a better sense of the place and its people. Likewise, before military specialists can operate safely in some remote and potentially hostile part of the world, they also need a sense of the local environment's electronic sights and sounds.

An almost universal facet of modern communications is the unseen and silent chatter of wireless communications, both friendly and hostile. Unlike normal broadcast radio or TV stations, the

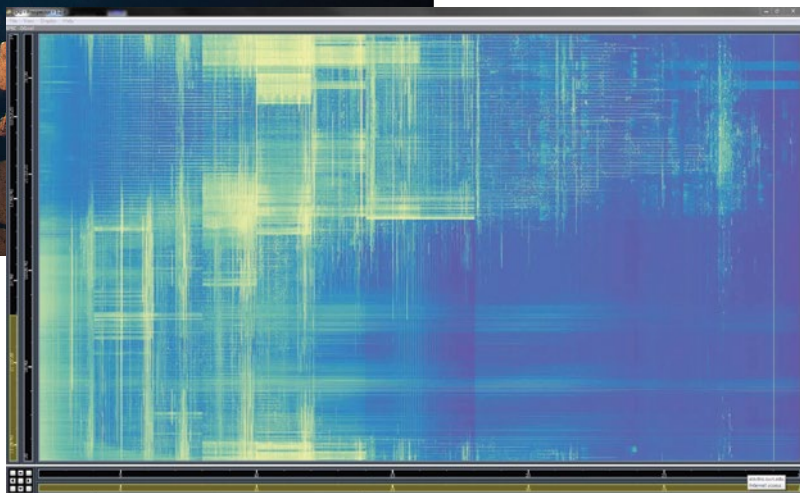
sources of this chatter don't advertise their broadcast frequencies. It is up to signal intelligence, or SIGINT, specialists to detect the signals, locate their source and interpret their significance to the mission at hand. Engineers at Southwest Research Institute (SwRI) have been conducting research in antennas and geolocation for more than 60 years. A newly developed system — dubbed Scout — is a portable, yet highly capable system for supporting radio frequency (RF) survey teams deploying to uncharted geographic regions.

Reading the signals

Scout comprises a family of wideband radio frequency survey and direction-finding systems that operate in the high, very high and ultra-high (HF, VHF and UHF) frequency ranges. It provides a view into the types of communications transmissions employed in the geographic region of interest. If a network of Scouts is deployed, the locations of these transmitters can be determined using direction finding and radiolocation techniques. Such surveys are an important first step in



James H. Nixon is director of the SIGINT Solutions Department in SwRI's Signal Exploitation and Geolocation Division. He leads the design, development and deployment of modern radio communications intelligence solutions. His expertise includes wideband and narrowband signal acquisition and direction-finding systems.



One aspect of the Scout system is an SwRI-developed function known as "Prospector," whose user interface allows the operator to select from a stored display of radio frequency activity over the past 24 hours.

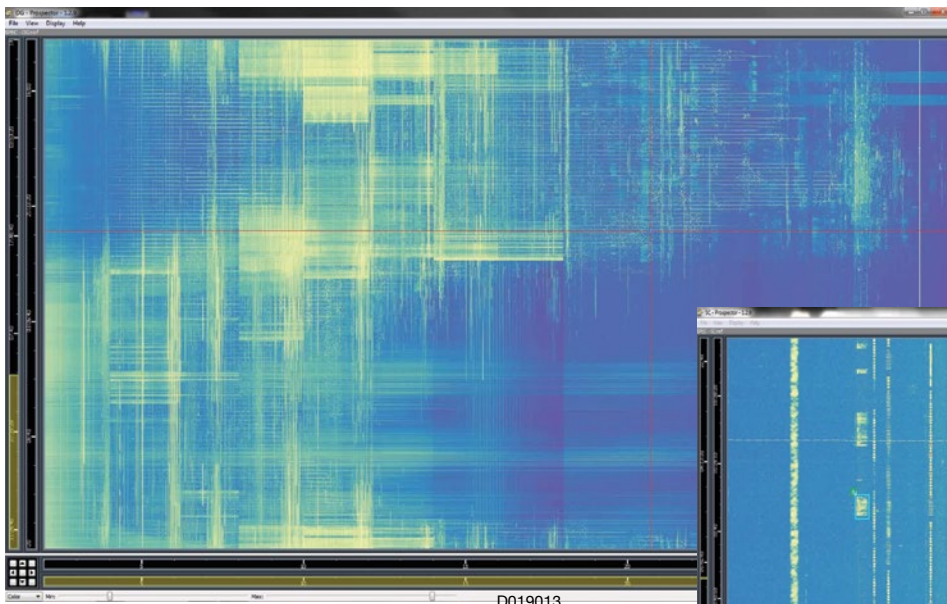
understanding an adversary's modes of communication and preparing military and intelligence sources for the electronic battlefield.

SIGINT is derived from electronic signals and systems used by adversaries for communications systems, radars

and weapons systems. It provides a vital window into the capabilities, actions and intentions of adversaries. A category of SIGINT called communications intelligence, or COMINT, focuses on exploiting an adversary's communications signals. These types of signals include voice,

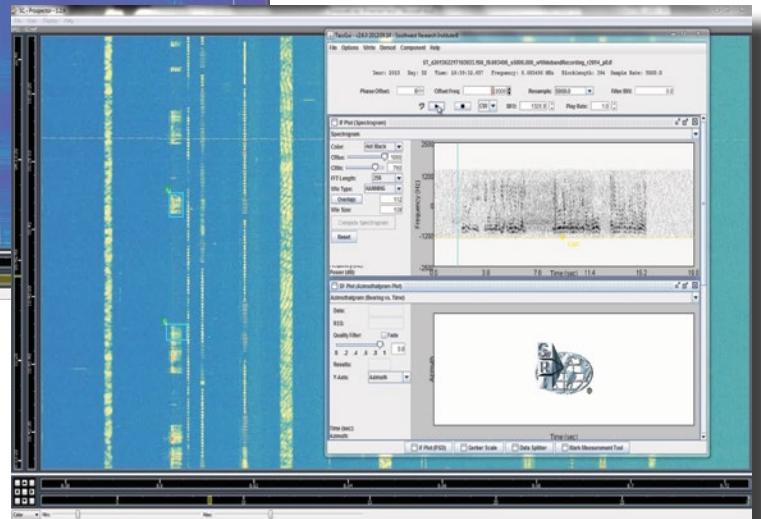
Morse code and many digitally coded signals, such as those used by cell phones and data modems.

Scout includes a radio antenna, special radio signal tuners and a number of high-performance servers similar to those used by information technology



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An operator can select a single RF signal (left top photo) for analysis by Scout software (right bottom photo).



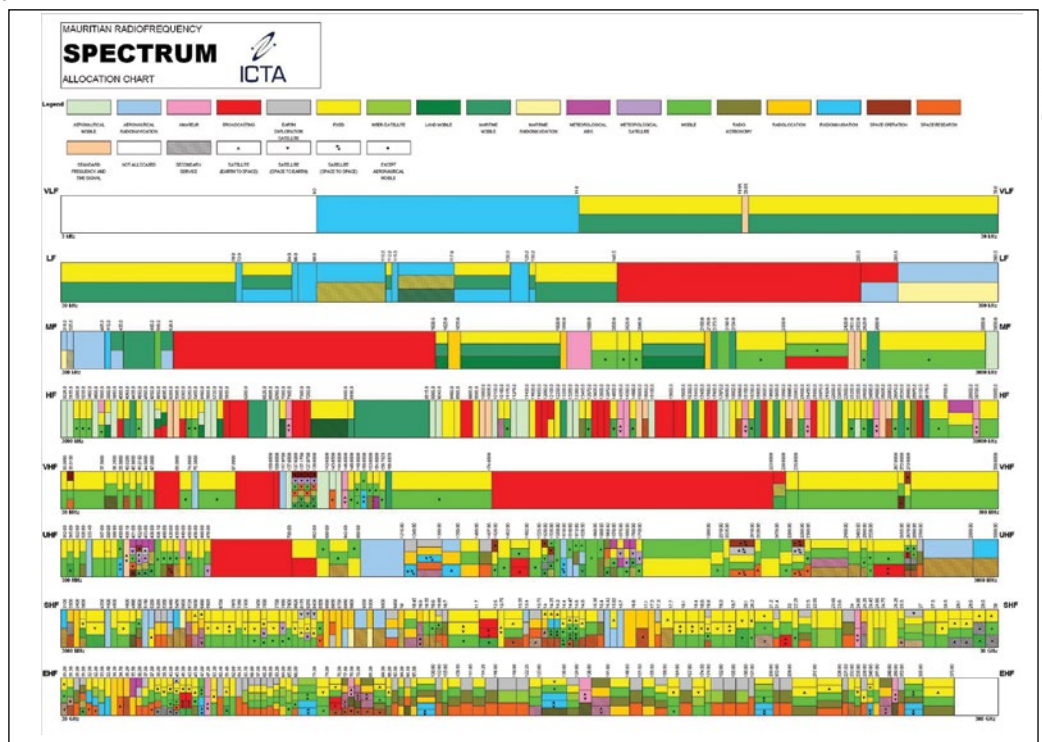
data centers and for scientific research. Once the radio spectrum is digitally converted to ones and zeros by the special wide-bandwidth radio receiver hardware, the digitized radio spectrum is transferred over a high-capacity local area network to an array of computer servers. SwRI-developed software running on these servers performs a number of signal processing steps needed to take the raw RF environment and transform it to useful information. The first step in this process is to automatically detect signal events occurring anywhere within the frequency coverage of the system. Once such energy has been detected, the system builds a software radio receiver that filters and isolates the new energy into a narrow-band channel.

Adding a sense of direction

The Scout system can construct hundreds of these channels simultaneously. Once the new energy has been channelized, it is routed to one of many mission prosecutor software services. Within these mission

prosecutors, the channel is automatically analyzed by SwRI-developed modulation recognition software to determine the general type of modulation employed and ascertain whether the energy comes from a voice, Morse code or digital modem signal, and what kinds of digital modulation techniques are

being employed. Additional processing is applied to digitally modulated signals to further refine the identification process, ultimately resulting in a determination of the specific type of modem employed, and in some cases, the underlying data protocols in use.



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Scout operates across the RF spectrum, as shown in this usage allocation chart.

If the digital signal is recognized by the system, it is then demodulated and decoded to extract the underlying data being communicated. Even signals that are not part of the Scout signal-of-interest library are catalogued. This information can help the user discover new signals of interest. If the unit is equipped with the radio direction-finding option, a line of bearing is computed from the Scout's location to the radio transmitter. Moreover, a number of Scouts can be networked together and the various lines of bearing can be triangulated so that the radio transmitter's estimated location can be computed. The final results are stored in a database. Web browser-based tools are provided with the system to allow any authorized user on the Scout network access to the collection results.

Record now, playback later

Scout also supports manual search and user-driven signal discovery operations. The automatic RF environment cataloging operation requires that the user already know many details about the signals of interest. In many cases the types of signals are known, and the automatic search capability will confirm that they exist in the geographic region of interest. However, if an adversary deploys a newly invented signal waveform, the automatic system may not identify those emissions or characterize them in enough detail to assist the user. For these situations, the SwRI team developed a graphical user interface (GUI) tool, called Prospector, which is deployed with Scout to enable the operator to visualize the RF environment and search for interesting and unique signal activity. This is accomplished by storing the last 24 hours of RF spectrum on Scout's internal hard drive. An operator who sees an interesting signal event can simply draw a box around the signal and Scout constructs a software radio on the spot that channelizes the signal and presents the waveform in another SwRI-developed tool called Tass. Tass provides a multitude of signal analysis tools that enable the breakdown of signal structures, including demodulation of fundamental modulation schemes. Scout's ability to store the



An SwRI engineer prepares a Scout system for operation. The unit is much more compact than earlier systems.

entire radio-frequency environment on disk and channelize any part of the spectrum at will is akin to having "TiVo® on steroids" — except that instead of storing only your favorite channels, Scout stores everything on the RF spectrum, enabling the operator to reconstruct any kind of signal event after the fact.

Combining capabilities of earlier systems

Originally developed to replace a now-retired system, Scout not only exceeds its predecessor's capabilities in automatic detection of known signals of interest, but also has a fully integrated direction-finding capability. The way signals are described in Scout is compatible with U.S. Department of Defense formats, enabling Scout to leverage new signals as they are developed by others. Additionally, 24 hours of RF environment storage and a GUI enable the user to manually scour the last 24 hours of RF activity and reconstruct and locate a signal event. This capability was previously performed by other systems that were separate from Scout's predecessor.

Scout does a job that previously required a number of systems from multiple vendors. By combining automatic search and signal identification functions with a manual search tool, Scout reduces the hardware resources required to support RF survey missions and also reduces the cost.

Scout is based on commercially available, high-performance servers widely used in

data centers across the globe. All of the signal processing required to support the operating modes consists of software rather than expensive special-purpose processing components such as those developed for the aerospace industry. This combination of commodity hardware and a software-defined framework gives Scout an unprecedented level of scalability and expandability. Leveraging the commercial computer market allows the use of the latest computer technology with minimal risk of obsolescence and keeps costs economical, while taking advantage of the latest breakthroughs in the globally driven computer market.

Although Scout's primary application is in support of U.S. and allied military, law enforcement and intelligence communities, potential commercial applications could include surveying other types of radio spectrum signals, such as electromagnetic interference emissions from industrial and power distribution sources.

Questions about this article? Contact Nixon at (210) 522-2619 or jim.nixon@swri.org.

A Dazzling Development in Security

An SwRI-developed technology fends off intruders using an eye-safe laser

By Joseph N. Mitchell

Imagine that you are captain of a small naval vessel off the coast of an unfriendly nation where other ships have been subject to harassment or attacks. It's dusk, and it is difficult to see clearly. Suddenly, your crew spots a small fishing boat off the port side about a mile away and closing fast. You try to signal the boat, but it continues to approach. You have seen many fishermen in these waters, and now you have a decision to make: Is this just another fisherman who simply doesn't see you, or is this an attack? A wrong decision could cost the lives of your crew, or it could create an international incident and kill innocent civilians.

A team of engineers from Southwest Research Institute (SwRI) is working on a program with the U.S. Navy to develop a technology to assess, slow and even thwart these potential threats, without harming people. The Long Range Ocular Interrupter, known informally as the "laser dazzler," uses a high-intensity but eye-safe visible laser source to deliver a dazzling, brilliant beam to targets more than a mile away. It is used to help determine the intent of an unknown person or vessel



D018966-7001

The dazzler was tested outdoors at distances greater than a mile.

Joseph N. Mitchell is a senior research engineer in the Applied Physics Division. He specializes in developing electro-optical, laser, infrared and remote sensing systems. He has worked on a variety of programs including biometrics acquisition, industrial inspection and measurement, standoff imaging, spectroscopy, novel optical materials and in development of miniature and MEMS-based opto-mechanical devices.

and a more aggressive response can be initiated.

Using light for nonlethal deterrent

by their response to it. It operates at multiple levels of effect, ranging from a low-intensity alert level to a glare level that would cause most people to turn away and leave the area.

If the intent of the approaching vessel appears hostile, the level of effect can be further increased to slow or even suppress an individual's ability to take action. If the individual or vessel continues to approach, then the hostile intent is clear

The "dazzling" effect inherent in bright flashing illumination has been studied for several decades. The critical parameter is optical intensity (also referred to as power density). An "eye-safe" laser is one that has an intensity below a threshold known as the maximum permissible exposure (MPE). This level varies depending on the exposure duration and the wavelength of the light. At bright intensities below the MPE permanent damage does not occur, but



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temporary impairment, such as glare or flash-blindness, can degrade the ability to perform visually oriented tasks. With flash-blindness, an individual exposed to sudden changes in illumination experiences a temporary state during which nothing can be seen except an afterimage. The eye is protected from this to some degree by the natural blink-aversion response, but bright or flashing lights actually can attract the eye.

Flashing lights or images can induce further neurologic effects that may

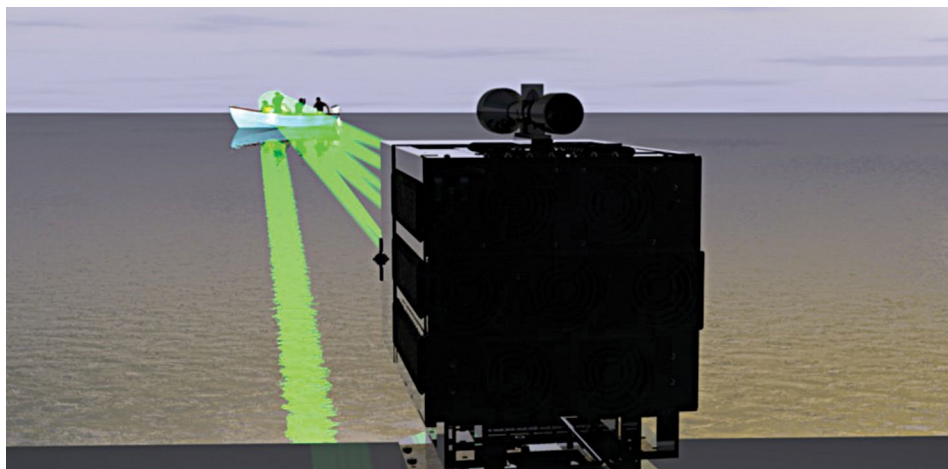
stun, or make an individual experience dizziness or be unable to act. Because the human eye is most sensitive to green light, illumination in this wavelength range produces the most “bang for the buck” and also results in the longest re-adaptation time after the illumination is removed.

Laser applications

The laser dazzler can be used in a wide range of operations. It can help reduce civilian casualties and keep

warfighters out of harm’s way by allowing them to engage at a safe distance. Besides maritime applications, the system also can be used at roadside checkpoints, embassies and military base access points, and for crowd dispersal in riot situations to reduce injuries and property damage.

The development program for the laser dazzler has been a rapid undertaking, going from an initial study of several possible design concepts to a prototype for field evaluations in just eight months. From initial evaluations, the SwRI team developed a system design that uses an array of laser sources of low to moderate power. This has the advantages of redundancy in the event of loss or partial failure of any of the lasers, reduced cost per watt of



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A concept illustration shows the laser dazzler in operation as it tracks an unknown vessel.



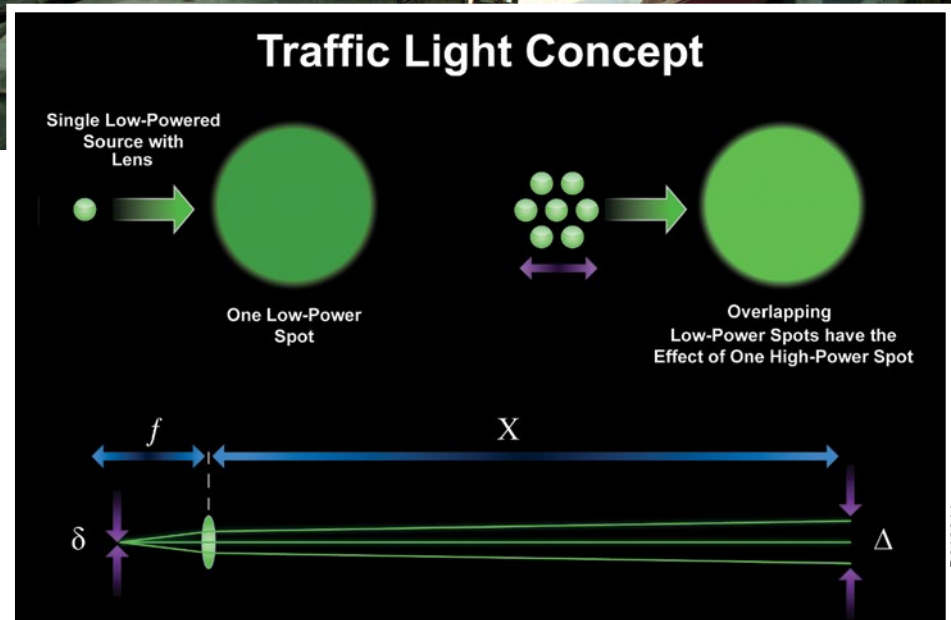
The dazzler could be used to safely disperse crowds in riot situations to reduce the risk of civilian injuries or property damage.

D019018

optical power and a more distributed heat load to improve cooling. Although some early concepts involved combining the beams into a single large-output beam within the dazzler, the selected design keeps the beams separate and relies on a small amount of divergence that allows the beams to overlap at long range. The beams are aligned so that by the time they reach a certain distance, they have expanded to the desired size and are essentially fully overlapped. Keeping the beams separate enables the use of small, lightweight, low-cost optical components and provides for scalability should more lasers be required. In addition, alignment of the beams is simplified and can even be electronically controlled through small manipulations of the lenses rather than movement of the entire laser modules.

Building a dazzler

Once the general system design was developed, SwRI engineers fabricated a prototype system intended for field evaluations to prove both the feasibility of the design and determine its effectiveness. Although considerably larger and heavier than the production model,



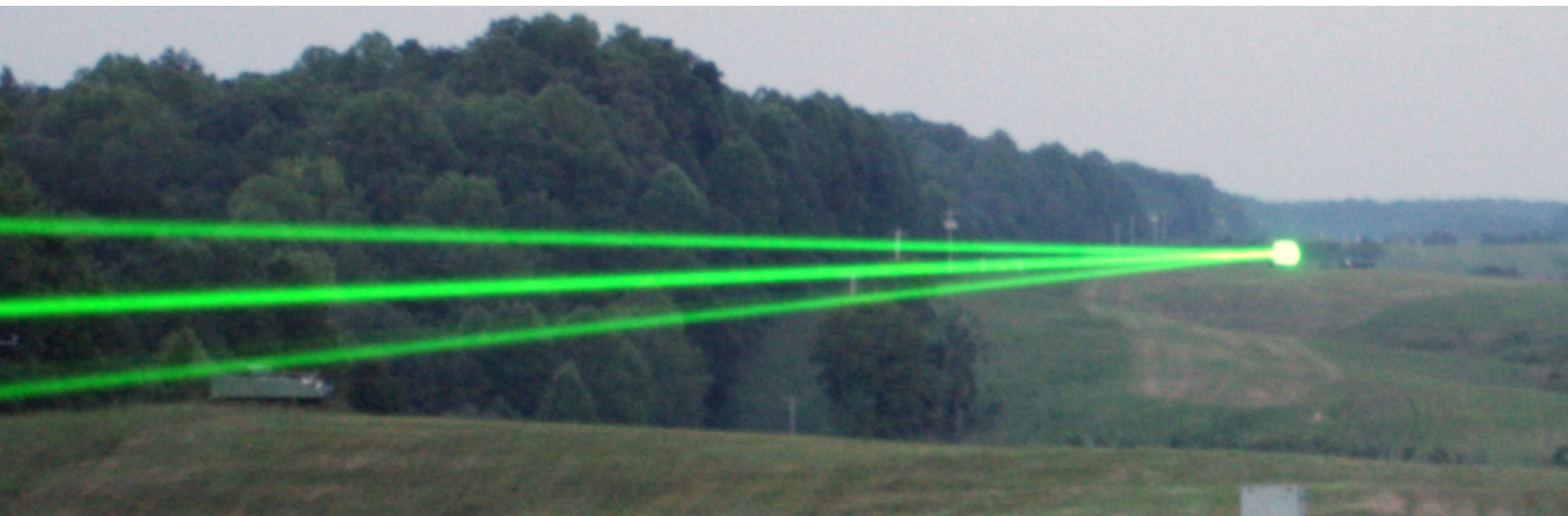
The dazzler uses an array of moderate power sources whose beams are designed to expand and merge into a single large beam at the system's operating range. Spot size at the operating range is a function of distance, source divergence and lens focal length.

the prototype model was built to allow for quick assembly and easy troubleshooting. It was made from commercial off-the-shelf components wherever possible, allowing the SwRI team to design and assemble the prototype in less than four months. The prototype contained an active cooling system for the lasers, including thermoelectric coolers and forced air, individually adjustable lenses, a focusing mechanism for the entire lens assembly, an alignment scope and electronics to monitor and control the laser

power and temperature, safety interlocks, power supplies, and strobe controls.

Characterizing the system's performance was a significant part of the effort, using parameters such as optical power density, spot uniformity and the effects of atmospheric turbulence, among others. In addition, the team wanted to characterize the system's performance under a range of environmental conditions. SwRI engineers conducted a series of indoor and outdoor tests at several sites, including SwRI's headquarters in

D019011



The dazzler was tested under daylight conditions at Fort A.P. Hill.

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San Antonio, a three-mile range at Fort A.P. Hill in Virginia and a 1.5-mile over-water range at Dahlgren, Va. The SwRI team was able to evaluate performance in both day and night conditions in the summer heat of South Texas, during the blowing wind and dust of an approaching thunderstorm and during rain, mist and fog conditions. Although these conditions resulted in different effects on the laser beams, the dazzling effect remained effective regardless of atmospheric conditions.

Future development

With the successful demonstration of the concept, SwRI engineers have begun work on the next phase of the program: developing a production-grade system, then building several laser dazzler units for expeditionary deployment. Custom lasers are being manufactured for SwRI by a subcontractor. These will be more robust in a wide range of ambient conditions and will be able to maintain power levels even under relatively high ambient temperatures without active cooling.

SwRI will integrate these lasers into a military-grade, ruggedized package that will include control electronics, a power supply and the user controls. The dazzler system will include a number of features designed to simplify and automate its use, including a pointing and tracking system, a day/night imaging system, automatic range detection to ensure eye safety and maintain optical power levels



The laser dazzler prototype is shown in operation.

D019025

appropriate for different targets, and dynamic control of the laser beam's divergence and spot pattern.

Now, imagine once again you are the naval captain envisioned at the beginning. You order the laser dazzler to be deployed. Your ship's crew points it toward the approaching boat and fires the laser at warning level. The boat continues to approach and swerves to evade the beam, but the dazzler adjusts its alignment to follow the boat's motion. Your crew increases the laser's intensity and activates the strobe effect.

The boat slows, then turns sharply and starts heading away, eventually disappearing in the distance.

You may never find out who was in the other boat, but your own crew and vessel are safe and you didn't have to deploy lethal force. In a few years, the use of lasers in situations such as this could be a reality as an alternative to conventional weaponry.

Questions about this article? Contact Mitchell at (210) 522-5799 or joe.mitchell@swri.org.

A Moon-shot in the Dark



An SwRI-developed instrument observes mercury, other chemicals in the plumes of intentional lunar impacts by two spacecraft.

When NASA's twin GRAIL spacecraft made their final descent for impact onto the Moon's surface in December 2012, the Lunar Reconnaissance Orbiter's (LRO) sophisticated payload was in position to observe the effects. As plumes of gas rose from the impacts, the Lyman Alpha Mapping Project (LAMP) aboard LRO detected the presence of mercury and hydrogen and measured their time evolution as the gas rapidly expanded into the vacuum of space at near-escape velocities.

NASA intentionally crashed the GRAIL twins onto the Moon on Dec. 17, 2012, following successful prime and extended science missions. Both spacecraft hit a mountain near the lunar north pole, which was in shadow at the time. Developed by Southwest Research Institute (SwRI), LAMP uses a novel method to peer into the darkness of the Moon's permanently shadowed regions, making it ideal for observations of the Moon's night-side and its tenuous atmospheric constituents.

"While our results are still very new, our thinking is that the hydrogen detected from the GRAIL site might be related to an

enhancement at the poles caused by hydrogen species migrating toward the colder polar regions," said Dr. Kurt Retherford, LAMP principal investigator and a principal scientist at SwRI.

In October 2009, LAMP observed the impact on the Moon of NASA's Lunar Crater Remote Observation and Sensing Satellite (LCROSS), making the first confirmation of the presence of atomic mercury, molecular hydrogen and carbon monoxide, along with smaller amounts of calcium and magnesium. Based on the analysis of lunar samples from the Apollo missions, G.W. Reed, a chemist at the Argonne National Laboratory, predicted an enhancement of mercury near the poles and its permanently shaded regions as far back as 1999. However, the prediction went unnoticed until it was cited by the LAMP team in the scientific literature. The new mercury measurements are being used to study the migration process behind this enhancement.

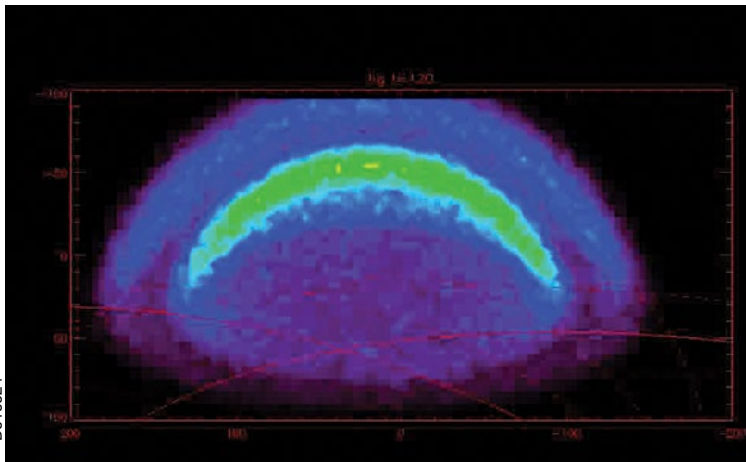
"Combining GRAIL results with LCROSS results could tell us more about hydrogen and water near the poles," said Dr. Thomas Greathouse, a LAMP team member and SwRI senior research scientist. "We have begun to understand that the amount of water ice near the polar regions is higher than was previously thought, but we don't fully understand how it gets there."

LAMP usually observes the night-side lunar surface using light from nearby space (and stars), which bathes all bodies in space in a soft glow. This Lyman-alpha glow is invisible to human eyes but visible to LAMP as it reflects off the Moon. However, the new detection of Lyman-alpha emissions from native lunar atomic hydrogen gas released by the impact is a first for LAMP, and for any previous instrument.

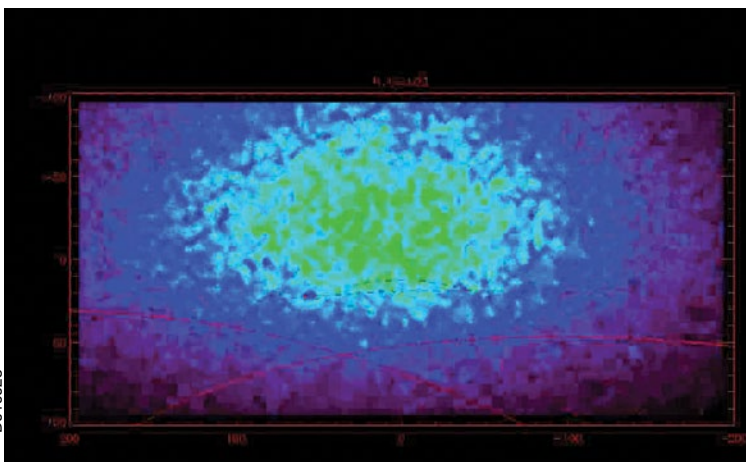
The NASA Goddard Space Flight Center in Greenbelt, Md., developed and manages the LRO mission. LRO's current Science Mission is implemented for NASA's Science Mission Directorate. NASA's Exploration Systems Mission Directorate sponsored LRO's initial one-year Exploration Mission that concluded in September 2010.

Contact Retherford at (210) 522-3809 or kurt.retherford@swri.org.

Animation models show the time evolution for mercury (top) and hydrogen (bottom) as plumes of gas rapidly expand into the vacuum of space following the planned impact of the GRAIL twins onto the lunar surface.



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DOI19023

SwRI, University of New Hampshire collaborate on new Space Science Department

Southwest Research Institute (SwRI) and the University of New Hampshire have signed a research collaboration agreement enabling the organizations to augment their areas of expertise and seek opportunities in astrophysics, Earth and ocean science, and larger and more complex space science missions. The agreement took effect March 11, 2013.

Dr. Jim Burch, vice president of SwRI's Space Science and Engineering Division, and Harlan Spence, director of UNH's Institute for the Study of Earth, Oceans, and Space (EOS), will oversee the collaboration for their respective organizations.

"The collaboration benefits both institutions because it allows SwRI access to a much wider range of science disciplines and allows UNH to benefit from SwRI's extensive science mission management expertise," said Burch.

The five-year agreement calls for SwRI to open a new department — the SwRI Earth, Oceans and Space (SwRI-EOS) Department — at UNH's Durham, N.H., campus. The agreement also allows SwRI and UNH to team up on proposals to NASA, the National Oceanic and Atmospheric Association and the National Science Foundation.



Contact Burch at (210) 522-2526 or jim.burch@swri.org.

TECHNICS

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

SwRI receives NACE International Distinguished Organization Award

Southwest Research Institute (SwRI) received the prestigious NACE International Distinguished Organization Award, given by the leading professional society for the corrosion control industry, in recognition of outstanding contributions by an organization to the field of corrosion science or engineering.

The award recognizes organizations that have, over a sustained period of time, made outstanding contributions in the field of corrosion science or engineering, or have provided major technological contributions to either field. The Institute was recognized for its sustained contributions to both industry and government organizations in fundamental and applied aspects of corrosion science, corrosion life prediction, corrosion sensing and monitoring, corrosion testing and development of corrosion-resistant coatings.

SwRI has been actively engaged in the corrosion field for more than 40 years, supporting the oil and gas, petrochemical, pipeline, nuclear and aerospace industries, as well as civilian and defense agencies of the U.S. government and various foreign commercial and government organizations.

SwRI launches third high-efficiency gasoline engine consortium

Southwest Research Institute (SwRI) has launched its third cooperative research program aimed at developing a high-efficiency gasoline engine for the light-duty automotive and medium-duty engine markets. This four-year effort will expand on earlier efforts to improve gasoline engine technology for future emissions and fuel economy requirements.

The HEDGE[®]-III (High-Efficiency Dilute Gasoline Engine) consortium incorporates new and more aggressive efficiency, performance and emissions goals that are in line with existing and potential future regulations and expectations. The overall goal is to develop the most cost-effective solutions for future gasoline engine applications. In addition to focusing on high levels of exhaust gas recirculation (EGR) and supporting technologies such as high-energy ignition and advanced boosting systems to develop strategies for high efficiency, the consortium will examine topics

outside of cooled EGR that contribute to high-efficiency engine operation as well as develop tools for developing high-efficiency engines.

HEDGE-III will target the Low Emission Vehicle III (LEV III) standards and, for the first time, extensively investigate cold-start technologies and monitor particle mass/particle number (PM/PN) emissions on a regular basis. Efficiency goals include a "best efficiency" of 43 percent and part-load efficiency goals that target diesel-like fuel consumption, with the target of "best in class" cycle emissions. In addition, the consortium will impose transient performance targets to make sure the high-efficiency engines are capable of providing high customer satisfaction.

"During HEDGE-II, we built a 2-liter prototype dedicated-EGR gasoline engine that is the most efficient multi-cylinder



spark ignition engine I've seen," said

Dr. Terry Alger, assistant director in SwRI's Engine, Emissions and Vehicle Research Division.

"The port-fuel-injected engine achieved 207 grams/kilowatt-hour, which compares very favorably to a similarly sized U.S. diesel engine in terms of fuel consumption.

With a combination of its fuel injection system and stoichiometric combustion (correct amount of air and fuel mixture to burn all the fuel), it has potential for ultra-low hydrocarbon emissions with no particulates."

HEDGE-III is a four-year, annual renewal cooperative research program with an annual fee of \$125,000 for original equipment manufacturers and \$70,000 for suppliers.

Contact Alger at (210) 522-5505, or talger@swri.org.

SwRI's Alger elected Fellow of the Society of Automotive Engineers

Dr. Terry Alger, assistant director of the Engine and Vehicle Research and Development Department in the Engine, Emissions and Vehicle Research Division at Southwest Research Institute (SwRI), has been elected a Fellow of the Society of Automotive Engineers (SAE).



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Fellow is the highest grade of membership in the SAE and recognizes long-term members who have made a significant impact on the society's mobility technology through leadership, research and innovation. The distinction is bestowed on about 20 recipients each year. Alger is recognized for his "work on advanced SI (spark ignition) engine technology in which he has repeatedly demonstrated the rare combination of technical and business leadership that results in research that breaks through to production." He received the award, as well as the SAE Lloyd L. Withrow Distinguished Speaker Award that is conferred upon those speakers at SAE meetings who have received the Oral Presentation Award more than twice over the

past years, during the SAE World Congress in Detroit April 16–18. Alger has authored more than 40 published papers and holds 10 U.S. patents.

Contact Alger at (210) 522-5505 or talger@swri.org.



SwRI to manage Numerical Propulsion System Simulation Consortium

Southwest Research Institute (SwRI) has been awarded a contract to become the manager of the Numerical Propulsion System Simulation (NPSS) consortium. NPSS is an advanced object-oriented, non-linear thermodynamic modeling environment used by the aerospace industry for modeling turbomachinery, rocket engines, environmental control systems, ducting, vapor cycles and other equipment and phenomena. SwRI will assume responsibility for the consortium May 1.

NPSS originated in the 1990s as a NASA Glenn Research Center project with a focus on developing a rapid simulation capability for engine design.

"As industry adopted the software tool, it became more important to aerospace companies because it allowed for collaboration and model sharing for integration with other vehicle system models," said David Ransom, manager of the Machinery Structural Dynamics Section in SwRI's Mechanical Engineering Division. "The NPSS Consortium was formed, and NASA licensed the software to the consortium so industry partners could continue developing it for their needs."

As consortium manager, SwRI will provide overall project management and engineering support for maintenance and development activities as directed by the member companies. NPSS can be obtained by either the purchase of a commercial license or through consortium membership. See npssconsortium.org.

Contact Ransom at (210) 522-5281 or dransom@swri.org.

Particle sensor consortium enters its second year

After a successful first year in which it demonstrated the potential of operating real-time particle sensors in engine exhaust systems, the Particle Sensor Performance and Durability (PSPD) consortium will focus its second year of research on improving the sensors' durability and reliability.

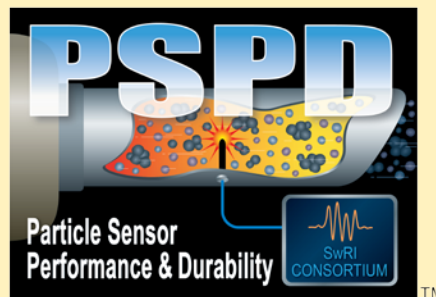
First-year research focused on investigating the performance of the spark-plug-sized exhaust particle sensors at different levels of engine exhaust velocity, temperature, particle concentration, electric charge and size distribution.

"The consortium's goal is to develop particulate matter sensors for production engine emission systems that will provide value similar to that being provided by NO_x sensors," said consortium Principal Investigator Dr. Imad Khalek, a senior program manager in the Engine, Emissions and Vehicle Research Division at Southwest Research Institute. Twelve sensors were mounted in engine exhaust systems and used simultaneously during the first year.

"This opens up the possibility of using real-time, onboard particle sensing for numerous engine and instrument applications such as onboard diagnostics for exhaust particle filters, retrofit technology, engine control, inspection and maintenance, portable emissions, smoke meter replacement and others," Khalek said. "The applications of a real-time particle sensor are limitless."

Research goals in the second year will include both improved sensor performance and durability. The start date for Year 2 is June 1, 2013. The annual membership fee is \$55,000. For more information see pspd.swri.org.

Contact Khalek at (210) 522-2536 or ikhalek@swri.org.



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Anderson, C.A., I.S. Chocron, K.A. Dannemann, A.E. Nicholls and N.L. Scott. "Testing Boron Carbide Under Triaxial Compression." Paper presented at the 37th International Conference and Exposition on Advanced Ceramics and Composites, Daytona Beach, Fla., January 2013.

Bell, J., J.H. Waite Jr., K.E. Mandt and B.A. Magee. "Updated Results from the Titan Global Ionosphere-Thermosphere Model." Paper presented at the 2012 AGU Fall Meeting, San Francisco, December 2012.

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Bonfond, B. "Dynamics of the Main/Rotation Aurora." Paper presented at the International Space Science Institute (ISSI) Workshop on Giant Planet Magnetodiscs and Aurorae, Bern, Switzerland, November 2012.

Bonfond, B. "Main Oval Expansion and Spectacular Outer Emission in Jupiter's Aurora: Is Io Responsible?" Paper presented at the Europlanet Workshop: Aurora and Magnetospheres of Giant Planets, Kamari, Greece, May 2012.

Bonfond, B. and R. Gladstone. "Understanding the 3D Morphology of the Jovian Aurora Using Juno-UVS Observations: Simulations and Tomographic Reconstruction." Paper presented at the 2012 AGU Fall Meeting, San Francisco, December 2012.

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Klar, R., S. Miller, M. Brysch and A. Bertrand. "Performance of the Magnetospheric Multiscale Central Instrument Data Handling." Paper presented at the IEEE Aerospace Conference 2013, Big Sky, Mont., March 2013.

Koets, M., J. Alvarez, M. Tapley, B.D. Moore, J. Pruitt and W. Toczynski. "Enabling Fractionated Spacecraft Communications Using F6WICS." Paper presented at MILCOM 2012, Orlando, Fla., November 2012.

Koets, M.A., J. Alvarez, M. Tapley and B. Walls. "Communications Infrastructure for Fractionated Spacecraft." Paper presented at Workshop on Spacecraft Flight Software, San Antonio, November 2012.

Lamb, D.A., S. Saar and C. DeForest. "Evolution of Coronal Bright Points and Photospheric Magnetic Fields." Paper presented at the 2012 AGU Fall Meeting, San Francisco, December 2012.

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Martinez, J. "ITS Florida: A Brief History." Paper presented at the ITS Nevada Chapter Meeting, Las Vegas, November 2012.

Martinez, J. "Leveraging ITS for Environmental Gains." Paper presented at the 2012 Transpo Conference, Bonita Springs, Fla., October 2012.

Martinez, J. "SunGuide Version 6.0 and Beyond." Paper presented at the Institute of Transportation Engineers (ITE) Student Chapter Meeting at Florida International University (FIU), Miami, October 2012.

Martinez, J. "Visual Analytics for Improved Transportation Operations." Paper presented at the 2012 Transpo Conference, Bonita Springs, Fla., October 2012.

McClung, R.C., M.P. Enright, W. Wu and R. Shankar. "Integrating Computational Materials Engineering into Probabilistic Damage Tolerance Analysis for Component Design." Paper presented at the 2013 Annual Meeting of the Minerals, Metals and Materials Society (TMS), San Antonio, February 2013.

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Mitchem, S. "Discussion on the Aggregation of Electric Vehicles for G2V and V2G Applications." Paper presented at the IEEE Computer Society San Antonio Chapter Meeting, San Antonio, February 2013.

Moebius, E., P.A. Bochsler, M. Bzowski, P.C. Frisch, S.A. Fuselier, H. Kucharek, T. Leonard, D.J. McComas, L. Petersen, L.A. Saul, N.A. Schwadron and P. Wurz. "Diagnostics of the Interstellar Gas with IBEX Neutral Atom Observations in the Inner Heliosphere." Paper presented at the 2012 AGU Fall Meeting, San Francisco, December 2012.

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Osidele, O. and R. Green. "Time Series Modeling of Environmental Impacts in Gulf of Mexico Coastal Basins." Paper presented at the Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, January 2013.

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Rimpel, A.M. and J.C. Wilkes. "Tutorial: Applications of Supercritical CO2 Power Cycle: Fundamentals and Design Considerations." Presented at the sCO2 Power Cycle Technology Roadmapping Workshop, San Antonio, February 2013.

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Saur, J., S. Duling, L. Roth, P.D. Feldman, D.F. Strobel, K.D. Retherford, M.A. McGrath, F. Musacchio and A. Wennmacher. "Ganymede's Magnetic Field Environment from Hubble Space Telescope Observations and Modeling." Paper presented at the 2012 AGU Fall Meeting, San Francisco, December 2012.

Saur, J., S. Duling, L. Roth, P.D. Feldman, D.F. Strobel, K.D. Retherford, M.A. McGrath, F. Musacchio and A. Wennmacher. "Hubble Space Telescope Observations of Ganymede's Time-variable Auroral Ovals." Paper presented at the 2012 AGU Fall Meeting, San Francisco, December 2012.

Saur, J., S. Duling, L. Roth, P.D. Feldman, D.F. Strobel, K.D. Retherford, M.A. McGrath, F. Musacchio and A. Wennmacher. "Mapping Ganymede's Time-Variable Aurora in the Search for a Subsurface Ocean." Paper presented at the German Physical Society (DPG) Meeting, Jena, Germany, February 2013.

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Schwamb, M.E., C.J. Lintott, D. Fischer, J.M. Brewer, M.J. Giguere, S. Lynn, M. Parrish, K. Schawinski, R. Simpson, A.M. Smith, J.A. Orosz, J.A. Carter, A. Howard, G. Torres, J.R. Crepp, W.C. Keel, W.F. Welsh, N.A. Kaib, D. Terrell, R. Gagliano and K.J. Jek. "Planet Hunters in the Kepler Extended Mission." Paper presented at the 221st American Astronomical Society (AAS) Meeting, Long Beach, Calif., January 2013.

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Siebenaler, S.P. "Continuous Leak Detection for Offshore Pipelines." Paper presented at the 4th Subsea and Arctic Leak Detection Symposium, Houston, December 2012.

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Stillman, D.E., R.E. Grimm, T.I. Michaels and K.P. Harrison. "Formation of Recurrent Slope Lineae (RSL) by Freshwater Discharge of Melted Cold Traps." Paper presented at The Present-day Habitability of Mars Meeting, Los Angeles, February 2013.

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Internal Research

Funded January 1, 2013

Andrews, J., D. Rose, M. Vincent and J. Peterson. "Mission Operations Center Capability Development."

Bailey, G. and M. Jones. "Development of Advanced Analysis of Aluminum Cylinder Heads."

Blackstone, L. "Feasibility Study for Embedded Software Control of Flexible RF Filters."

Boehme, K., A. Burmeister and B. Davis. "Wideband Wireless Capability on Small Tactical Platforms."

Buie, M. "NEO Survey Simulator."

Callahan, T. and J. Chiu. "Diesel and Natural Gas Dual Fuel Engine Operating Envelope."

Fisher, B. and R. Logan. "High-Fidelity Physics-Based Simulation of Construction Equipment."

Gutierrez, G. and G. Rossini. "Applied CNS Formulations for Treatment of Chemical Warfare Threats and Traumatic Brain Injury."

Hicks, F. and J. Pruitt. "Alternative Advanced Electronic Countermeasure Techniques."

Lu, B. and S. Hudak. "Crack-Size Effect in Corrosion-Fatigue Crack Growth."

Michell, R. and M. Samara. "Fostering International Collaborations for Auroral Imaging at the European Incoherent Scatter Radar Facilities."

Mohanty, S. "Chemical-Based Tertiary Oil Recovery from Carbonate Rocks."

Ogasawara, K., S. Livi and K. Coulter. "Fabrication and Characterization of a Single Crystal Diamond Detector for <300 keV Particles."

Pruitt, J. and A. Fleischmann. "Practical Metamaterial Phase Shifter."

Rivera, M., R. Garcia, J. Mitchell, G. Roach and J. Boehme. "Development of a Wireless Power Transfer Technique for Quick-Charging Inaccessible Electronic Devices."

Schindhelm, E. "Design Study for a UV/Optical/IR Telescope on the International Space Station."

Shoffner, B., S. Kouame, C. Ellis-Terrell, K. Coulter and T. Alger. "Investigation of an Oleophobic Coating Effect on Gasoline Direct-Injection (GDI) Engine Components to Reduce Carbon Deposits."

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Sturgeon, P. and R. Garcia. "Dynamic Real-time Lane Modeling."

Young, E. "Pre-Fight Demonstration of a Solid-State Motion Compensation Camera."

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Allsup, C., C. Gomez and J. Nicho. "Robotic Handling of Unstructured Materials: Semi-Random Component Pick and Place for Assembly."

Barth, E. "Capability Development for a Titan Microphysics Model: Particle Shape and Cloud Composition."

Bessee, G. "Investigation of the Rheology and Tribology Properties of Mono-Oleate as an Additive for SAE J1488-10 Emulsified Fuel-Water Separation Test Method."

Cheng, X., Q. Ni, T. Bredbenner and D. Nicoletta. "A New Generation of Bone Cements/Grafts Based on Magnetic Calcium Phosphate Nanoparticles (MCaP NPs) Using a Magnetic Field-Triggered Polymerization Process."

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Cox, P.A., J. Mathis, M. Grimm and C. Weiss. "Design, Analysis and Instrumentation of a Full-Scale Reusable Landmine Test Rig."

De Los Santos, A., D. Guerrero and M. Freeman. "Development of High Voltage Optocoupler for Space Applications."

Dennis, G. "Characterization of a Low-Cost Radar/Radiometer as a Close-Range Blast Detection Sensor."

Feng, M., C.K. Tan and D. Daruwalla. "High Octane Number Gasoline Production from Lignin."

Fisher, J. "EDAS-MS Upgrade and Demonstration Preparation."

Grimm, R. and D. Stillman. "Field Tests for the Geophysical Detection of Subsurface Ice."

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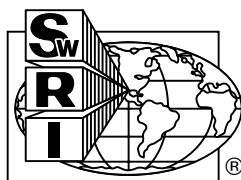
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