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About the cover
A new, titanium personnel sphere designed by SwRI helps the Alvin *science submersible increase its deep-diving capability.*

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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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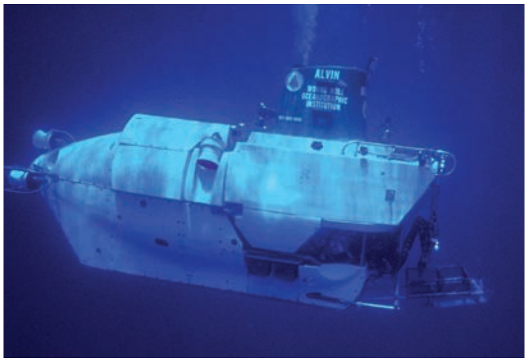
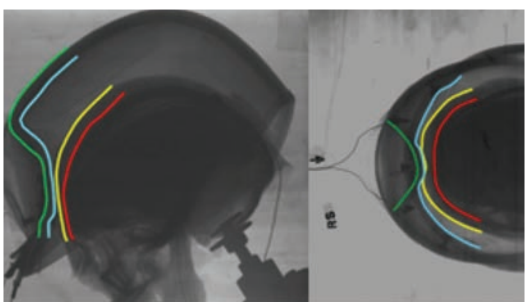




Departments

Photo courtesy Woods Hole Oceanographic Institution

Southwest Research Institute & *Alvin*: A 50-Year Relationship

SwRI plays a major role in the history of a deep-water research submersible

By Jerry Henkener

Photo courtesy Woods Hole Oceanographic Institution

Alvin *was commissioned in June 1964.*

Alvin is a three-person, deep-diving science submersible owned by the U.S. Navy and operated by Woods Hole Oceanographic Institution (WHOI) for almost 50 years. During that span, it has made more than 4,000 dives. Over the last half-century it has assisted in locating an H-bomb, photographically documented the wreckage of the *Titanic*, and evaluated deep-sea life in the Gulf of Mexico following the Deepwater Horizon oil spill. Southwest Research Institute (SwRI) has been part of its rich history, both before its initial launch in 1964 and most recently for a major redesign of the submersible.

The story of *Alvin* is interesting not only because of the technology employed in its initial construction, but because it is a particularly interesting saga of SwRI engineers overcoming the challenges associated with a "life-extending" technology update of a legacy program.

An *Alvin* replacement concept

Alvin, named after Allyn Vine, a physicist and oceanographer who envisioned the concept of the submersible, was initially commissioned June 5, 1964, with an HY-100 steel personnel sphere and an operating depth of 2,440 meters (8,010 feet). A year earlier, *Alvin's* personnel sphere had been hydrostatically tested in a 90-inch test chamber at SwRI, marking the beginning of a 50-year relationship between SwRI and the submersible.

In 1973, *Alvin* was retrofitted with a new personnel sphere made from titanium alloy 6211 and was initially certified by the U.S. Navy for an operating depth of 4,000 meters. In 1994, after an arduous series of calculations by the Naval Sea Systems Command (NAVSEA) structures branch of the U.S. Navy, *Alvin's* operating depth was increased from 4,000 meters to 4,500 meters, allowing scientists to view 68 percent of the ocean floor.

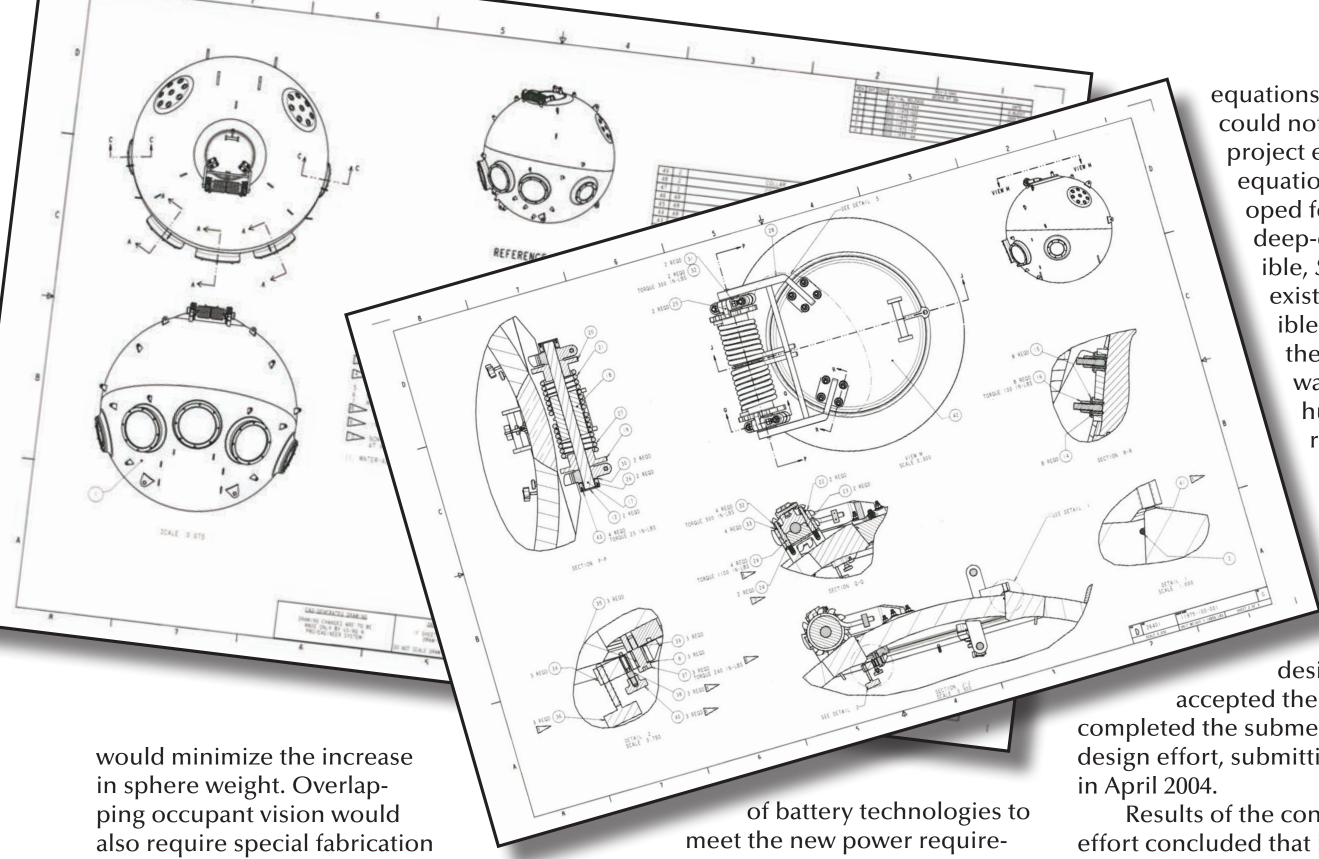
Author Jerry Henkener (second from left), a staff engineer in SwRI's Mechanical Engineering Division, specializes in equipment design and systems engineering for large manned and unmanned submersibles and other large equipment for a variety of industries. With him at Alvin's May 2013 bon voyage *celebration are (from left) SwRI Mechanical Engineering Division staff members Joe Crouch, manager of the Marine and Offshore Systems Section; Vice President Danny Deffenbaugh; and Tim Fey, director of the Structural Engineering Department.*

In the late 1990s, WHOI engineers began investigating options for either upgrading or replacing *Alvin*. The submersible had been a workhorse for the scientific community, but its 4,500-meter depth limit was out of step with competing countries. On the international scene, the French had been operating their deep-diving submersible, *Nautile*, since 1984; the Russians had been operating their MIR submersibles since 1987; and the Japanese had been operating their *Shinkai* 6500 since 1989. All of these foreign, deep-diving submersibles had greater depth capabilities than *Alvin*. The *Nautile* and MIR submersibles had an operating depth of 6,000 meters, while the newer *Shinkai* 6500 had an operating depth of 6,500 meters, allowing scientists to cover 98 percent of the ocean floor.

Engineers at WHOI were particularly interested in increasing *Alvin's* depth capabilities, enlarging the personnel space and adding more viewports with improved visibility for the scientists. WHOI engineers began collecting information related to *Alvin* improvements during visits with the French, Russian and Japanese submersible operations. From these visits, they identified desirable changes to *Alvin*, including a personnel sphere with an internal diameter of 2.1 meters, larger windows for the main three viewports and an increased depth rating of 6,000 meters.

In 1999, SwRI was under contract to WHOI to perform an initial concept layout and cost estimate for a replacement submersible. SwRI was selected because of its previous work on *Alvin* and a joint effort with WHOI engineers on a habitat system conceptual design for the National Oceanic and Atmospheric Administration (NOAA). SwRI also had a long relationship with International Submarine Engineering (ISE) Ltd., of Canada, which was well known to WHOI engineers because of its manned submersible design and fabrication history going back to the *Pisces* submersibles, the forerunners of the Russian MIR submersibles. ISE was named a major subcontractor for the replacement submersible concept study.

The initial concept study called for a maximum operating depth of 6,000 meters and was based on meeting stringent functional and design requirements. The new submersible had to operate from the existing support ship, *Atlantis*; have overlapping optical vision, allowing the scientists to see what the pilot sees; transit to the bottom in two hours, with a bottom operating time of 10 hours; and have a larger internal space in the sphere for equipment and personnel comfort. Because the new submersible would be larger and heavier, materials had to be selected that



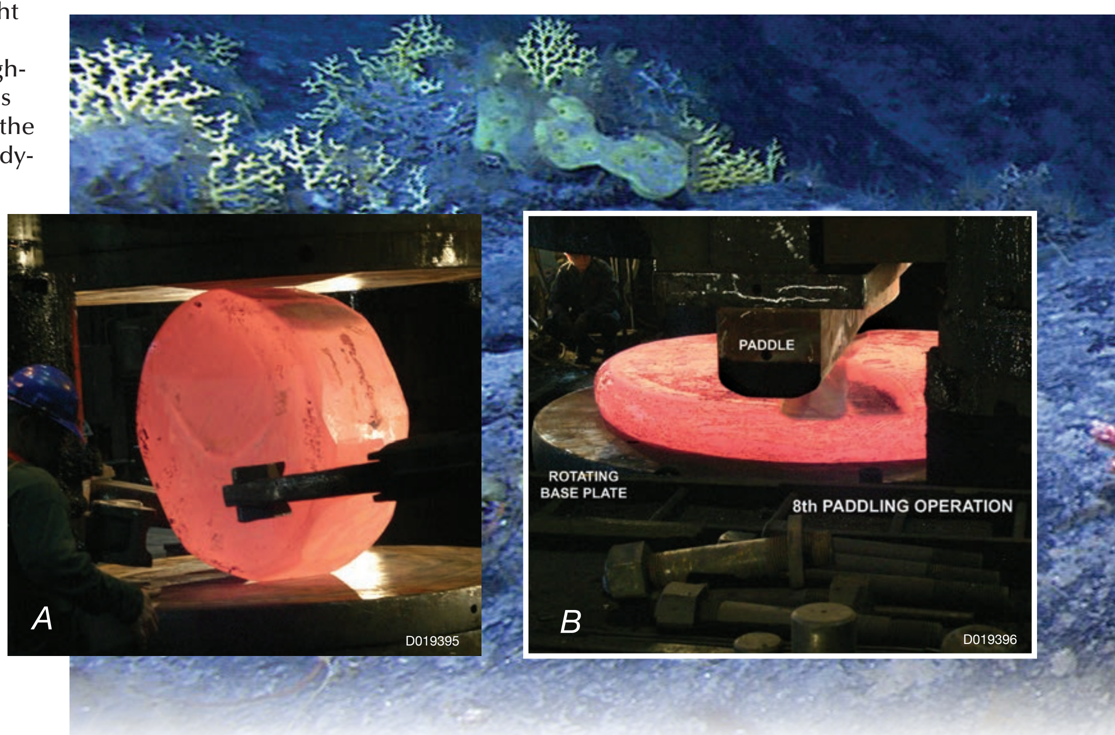
would minimize the increase in sphere weight. Overlapping occupant vision would also require special fabrication techniques and improved hydrodynamics would be necessary to transit faster to the bottom.

SwRI submitted its initial concept study to WHOI in March 2000, and was awarded a follow-on contract to develop a more detailed conceptual design for a replacement submersible with an extended depth capability to 6,500 meters. The conceptual design effort included a tradeoff study of three materials: titanium alloy 6Al-4V ELI, titanium alloy 5111 and Maraging steel. Titanium alloy 6Al-4V ELI was selected because of its availability, higher strength-to-weight ratio and use in other subsea applications where strength and fracture toughness are important considerations, as is corrosion resistance. ISE assisted with the conceptual design effort for the hydrodynamic analysis and a tradeoff study of battery technologies to meet the new power requirements. Expert consultants were also hired for their inputs to acrylic window design and ballast system improvements.

Designing *Alvin* II

The conceptual design was developed to meet American Bureau of Shipping (ABS) requirements for submersibles, but U.S. Navy certification requirements were used where needed. For example, to meet the hull weight target of 10,500 pounds, the standard equations required by ABS could not be used. Instead project engineers used equations and rules developed for the U.S. Navy's deep-diving submersible, *Sea Cliff*, and the existing *Alvin* submersible. After submitting the analysis report, it was clear that the ABS hull thickness design rules could not be followed to meet the target weight. SwRI engineers had to obtain ABS approval to substitute the U.S. Navy design rules. ABS accepted the change, and SwRI completed the submersible conceptual design effort, submitting its final report in April 2004.

Results of the conceptual design effort concluded that it was feasible to design and fabricate a replacement submersible that was capable of operating to 6,500 meters and still meet WHOI's other functional requirements. The report also showed that the major risk was forging the hull hemispheres. It recommended the team pursue purchasing titanium ingots and proceed with the detailed design of the new personnel sphere. It also recommended developing lighter weight syntactic foam and lithium-ion battery packs without the need for heavy housings.



To create Alvin's personnel sphere, each of two titanium billets (a) was formed to create identical 130-inch diameter, 6.5-inch thick plates that would be forged into hemispheres. After reaching a certain diameter, the material was paddled (b) to achieve the desired thickness and diameter. Each flattened billet was then placed in a press (c). After the hemispheres were formed, they were heat-treated and underwent rapid quenching to attain the desired high-strength material properties (d).

It was clear that developing a new submersible would involve three significant areas of risk: designing and fabricating the personnel sphere, developing improved syntactic foam to minimize the expanded volume caused by heavier components for the deeper depth, and improving battery power for better transit speed and bottom duration. SwRI was awarded the personnel sphere fabrication contract while other companies were awarded contracts for the foam investigation and battery study.

SwRI developed a detailed specification for the design and fabrication of the personnel sphere and was under contract by the end of 2005. To minimize SwRI's risk and to ensure that all technology issues were addressed, SwRI retained expert consultants in titanium materials and titanium welding, and an expert with experience in manned submersible finite element analysis (FEA) to meet both NAVSEA and ABS requirements. SwRI also enlisted help from several experienced NAVSEA personnel with expertise in underwater materials and structural analysis. With a team in place, SwRI took on the challenges of designing the personnel sphere.

Design challenges

These challenges included optimizing material properties to achieve high strength, adequate fracture toughness and good deformation characteristics, allowing for the sphere to be designed with minimum weight. Another challenge was optimizing the front viewport window size and configuration to permit fabrication and welding with minimal distortion, yet with the windows close enough to allow a field-of-view overlap. Deformation characteristics and requirements also had to be determined because compressive deformation data for titanium alloy 6AI-4V ELI was almost nonexistent. Finally, the team needed to ensure that the sphere could withstand the maximum operating pressure with an adequate margin for buckling.

The SwRI team worked with the titanium ingot manufacturer to tailor the ingot's chemistry with high oxygen content within the ELI (extra low interstitial, or higher purity) range, to result in high-yield strength while maintaining adequate fracture toughness, and with low iron and hydrogen content to maximize material creep strength. The front viewport windows were designed to allow for welding a minimum diameter titanium insert to house the acrylic window.

The biggest challenge to the visual overlap was avoiding high stresses in the hull. Any significant bending stress would require added material and weight to provide an adequate safety margin against buckling and material creep.

The design specification required no material creep at the maximum operating depth regardless of duration, and no material creep-to-buckling failure for 88 hours should the submersible be trapped at the established emergency depth of 6,800 meters. Because the Navy's *Sea Cliff* hull was studied extensively for material creep, results from that study were used for direct comparison. The requirements for the new hull made of 6AI-4V ELI material had to be equal to or better than the material creep strength of the 6211 material used in *Sea Cliff*. Tests showed that the material creep strength for 6AI-4V ELI was slightly better than that of 6211. The buckling analysis was a significant challenge because neither NAVSEA nor ABS had an acceptable or validated methodology for determining the point of buckling. Buckling was determined using the equations previously developed for *Sea Cliff* and *Alvin* with a generous factor for uncertainty and fabrication differences. SwRI also developed an FEA nonlinear methodology for determining a load for buckling failure that agrees with the equation results. Although the buckling analysis was accepted for the *Alvin* personnel sphere, future work needs to be done to validate the SwRI-developed FEA buckling methodology.

Instead, an *Alvin* upgrade

Before the personnel sphere design was completed, WHOI learned that the National Science Foundation budget could not support a full replacement submersible. WHOI decided to proceed with upgrading the existing *Alvin* until funding was available. Sphere fabrication began after the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Once the hemispheres were welded together, the sphere was mounted in a rotating fixture to allow electron beam welding of the viewports and other inserts.

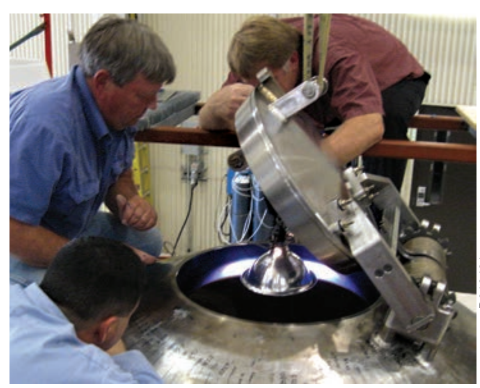
design and analysis reports were completed and accepted. SwRI engineers had already received more than 40,000 pounds of titanium ingot. The first major fabrication challenge and area of greatest risk was forging the personnel sphere components. Currently no company in the U.S. can roll wide, thick titanium plate to the size used previously for *Sea Cliff* and *Alvin*. Therefore, the discs for the hemisphere forgings had to be carefully formed and paddled, each from a 17,000-pound, 36-inch diameter ingot. Any mistake or unexpected cracking along the many steps of the process would have resulted in a scrapped hemisphere. The project was totally success-oriented with no plans for a spare ingot and no guarantees from the forger in case of unexpected problems. Fortunately, the skill and experience of the forging company provided excellent results.

The second major challenge was welding the hemispheres together and welding eight inserts into the machined hull. The design and the 6,500-meter depth rating depended upon the sphericity of the hull being near-perfect, with less than 0.125 inches deviation. Sphericity deviation greater than this would require decreasing the submersible's operating depth because the hull could not withstand the greater pressures. To minimize distortion, especially with the close-fitting front viewport inserts, electron beam welding was selected. Electronic beam welding uses no filler material and has proven capable of welding thick sections of titanium with minimal distortion. Thick titanium samples were used to demonstrate that electronic beam welding was a viable process for the hull.

A near-perfect sphere

The new *Alvin* sphere is believed to be the largest thick-section titanium sphere — nearly three inches thick — fabricated in the U.S. using electronic beam welding. The weld joints required extremely close-fitting parts to help minimize weld shrinkage and resulting distortion. The overall result was even better than anticipated. Although the allowed sphericity deviation was 0.125 inches, the final measurements showed that the sphericity deviations around all of the weld joints were 0.035 inches or less. Overall, the new sphere is an inch thicker than the previous one and provides 27 cubic feet more interior space for the crew.

By 2010, the higher risk steps in the fabrication process were completed. Also in 2010, the sphere was vacuum stressed-relieved and shipped to SwRI where



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SwRI technicians attach the hatch to the personnel sphere.

studs and attachment lugs were welded and the hatch components were assembled and tested. All major components required detailed assembly and validation test procedures to ensure personnel safety and process repeatability. The sphere was instrumented with 80 strain gages for final hydrostatic pressure testing, which was performed in a large test chamber at a facility in Annapolis, Md., to a pressure equivalent to the 6,500-meter operating depth and the 6,800-meter emergency depth. Results showed strains slightly less than predicted and no measurable material creep strain at either 6,500 meters or 6,800 meters. The target material creep strain values were so low that it was difficult to distinguish the difference between material creep and data collection noise. Extensive data analysis led to the conclusion that no measurable material creep was detected. The hull was proof-tested in accordance with the ABS requirements to 1.25 times the maximum operating depth pressure or about 12,000 psig. The measured strain levels at proof pressure were acceptable and matched the expected levels indicated by SwRI's finite element analysis. The personnel sphere was cleaned and shipped to WHOI, where it was installed in the upgraded *Alvin* submersible.

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SwRI technicians install 80 strain gages in preparation for final hydrostatic pressure testing.

Bon voyage, *Alvin*!

Near the end of 2011, the National Science Foundation decided the upgraded *Alvin* submersible required both ABS and U.S. Navy certification. This change was also applied to the personnel sphere and resulted in additional analysis as well as design and fabrication justification. The Navy certification process stretched the schedule, and after the *bon voyage* ceremony in late May 2013, the upgraded *Alvin* was awaiting certification by the Navy. However, the SwRI personnel sphere within was accepted for certification by the Navy. The documentation for designing, fabricating and testing was reviewed and found to be acceptable to ABS as well.

Epilogue

SwRI was invited to the *bon voyage* ceremony held at WHOI. The completed *Alvin* upgrade with the installed personnel sphere was on its support ship, *Atlantis*, in preparation for sea trials. After the ceremony, the support ship left WHOI for operations in Oregon. Sea trials were completed this past November in San Francisco, paving the way for U.S. Navy certification. When certified for its new operating depth, *Alvin* is expected to travel to many previously unexplored areas for years to come, adding to its already impressive résumé.

Questions about this article? Contact Henkener at (210) 522-3350 or jerry.henkener@swri.org.

The upgraded Alvin *was mounted on its support ship* Atlantis. *After the bon voyage celebration,* Atlantis *headed to the west coast for* Alvin's *sea trials.*

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LOGISTICAL SUPPORT

Supplying, maintaining, updating, testing and developing the equipment that supports warfighters and military machines is a significant part of Southwest Research Institute's research and development activity and a representative sample of the Institute's interdisciplinary and interdivisional capabilities.

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Photo Staff Sgt. Shane A. Cuomo, U.S. Air Force

***Technology Today* recently brought together a panel from three technical divisions to discuss projects and processes that address SwRI's logistical support workload.**

TT: How do you view the scope of logistical support at SwRI?

Griffin: It's not just "beans and bullets" to the guy in the trenches. This is care and feeding of all the systems, essentially as soon as they transition out of the purchasing office and into service.

Kluger: When you consider that it takes four people to support every soldier on the field, what we're doing for logistics capacity broadly puts our hands around not only the development, but also the implementation of technology, supporting the warfighter when he needs that technology.

Bessee: That is why TARDEC Fuels and Lubricants Research Facility, known as the Army Lab, was founded in 1957. It is a liaison between the commercial and government worlds. The government has unique requirements for its fuels, lubricants and hardware. They can leverage what's happening in the industry and adapt it for government service so that we're not re-inventing the wheel.

Stange: The logistics behind what we have done for the A-10 program over the years has been to reduce the support footprint required for the aircraft and people that are needed to make it fly. We design multiple variants of a particular tester that do the same thing for different functions. A lot of our designs, plus things that our mechanical engineering staff has done in structures analysis, are focused on making sure it's easier for the maintenance crews to maintain the A-10 downrange, where the aircraft is used in combat.

Bessee: In the fuels and lubricants area, logistical support is a major aspect. We now have the military Single Fuel Forward Initiative, where instead of having nine fuels, we will supposedly just have one. That reduces the logistics burden on the military so that they can use JP8 for all their platforms. We also have the Single Common Powertrain Lubricant (SCPL), where again we're trying to reduce the footprint. You have one lubricant for the whole powertrain — engine, transmission, etc. — instead of two or three. We also have projects that involve multiple branches of the military. Alternative jet fuels are a big area for us. It's unique because we're working with all four services. The Marine Corps is under the Navy, the Air Force is leading it, and it also goes into Army vehicles. So all the research, verification and testing is being used by all the branches. I think that's really of benefit.

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*Panelists taking part in this discussion include (top row, left to right): **Gary Bessee**, director of the Fuels and Lubricants Technology Department and U.S. Army TARDEC Fuels and Lubricants Research Facility, Fuels and Lubricants Research Division; **David A. Ogden**, director of the Aerospace Engineering Department, Aerospace Electronics, Systems Engineering and Training Division; and **Michael W. Stange**, manager of the Aircraft Avionics Sustainment Section, Aerospace Electronics, Systems Engineering and Training Division; and (bottom row)* **Dr. Kenneth E. Griffin**, *manager of the Aerospace Structures Section, Mechanical Engineering Division; and **Michael A. Kluger**, senior program manager, Fuels and Lubricants Research Division.*

TT: How do you deal with age issues in logistics support?

Griffin: The mechanical engineering focus is to try to keep these older mechanical systems functioning. That's engines, that's the drivetrains that come off of the engines, that's the airframe itself and the different systems that go in the airframe. If you look at the T-38, that airplane was designed in the late 1950s. They started putting together parts in the early '60s. Well, do you remember what you were driving in 1959? Think about trying to find a particular part for an air conditioner for a car that was built back then. We end up doing a lot of reverse engineering. We try to provide a lot of pieces that you can't commercially find any more. It's a broad range of different subjects, trying to keep these systems going. They're still viable, they're still useful. They're just long in the tooth.

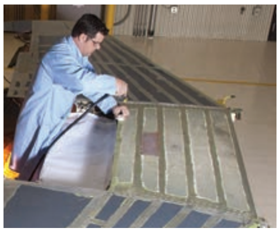
Ogden: That's a common aspect with a lot of the aerospace that we do, too. The military has these assets, and they've got to keep them all running. We see that in both the Army and the Air Force. A lot of the things we're replacing with new technology have been in use for 40 years. Transmission testing, engine testing, electronics — we've seen things go through generations. The electronics may have rolled over a couple of times, but the mechanical systems are still there. There are a lot of age issues there. When we're fielding a system, we've got to worry about how it is going to be supported. If you buy a PC for part of a system, it's got nine months before it's obsolete, so what are you going to do about that? How do you give them a reliable system? We're working a project right now for a foreign air force where we're trying to design a system that they'll use for 20 years, and it's full of electronics. So the age issue is a big one.

Bessee: We've got the same thing on engines. You've got engines from the 1980s and '90s that don't have the newer technologies used now, such as electronic control modules. And today you've got high-pressure common rail fuel-injection systems. You've got to take care of antiquated engines and have the lubricants work in those, but also work in these newer engines.

TT: How do you ensure that legacy systems meet modern standards of reliability?

Kluger: One of the most important things we do is to assure commanders and warfighters that the products they're using in the field have absolute reliability. Toward that end, we build test stands that aggressively test components and systems that are no longer supported by the manufacturer. But the most important thing is that the warfighter should have absolute confidence that when a vehicle is used in the field it can work to that absolute upper limit, of the capability for which it was designed. Building these test stands is extremely challenging because they involve a multitude of disciplines such as mechanical, electrical, pneumatic, hydraulic, instrumentation and data acquisition and controls. The challenge is making it all fit within the dynamics of a repair depot. Beyond that, we also build test stands for the engineering centers that develop the next generation of vehicles.

Bessee: Another area is these alternative fuels that are coming into use. We have bio-diesels for the diesel area, and now there are bio-aviation fuels. We need to capitalize on alternative fuels and on reducing the dependence on foreign oil, but we've got to make sure that they will work in diesel engines when they were really designed for aviation. For example, bio-aviation fuels don't even measure a cetane number, yet they'll be put into a compression-ignition engine, for which a fuel quality evaluation requires a cetane number. We have to accommodate those two standards somehow, because we have to verify these new fuels will operate in a transport, combat or earth-moving vehicle.



Griffin: We're also being asked to carry some of these devices much longer than they were originally planned for. The airframes that we're flying — the A-10 and T-38, for example — were tested to a certain expected lifetime. Now they're trying to go longer, sometimes by a factor of two or even more. We end up doing design engineering, trying to work up pieces and fixes so these older systems can continue to function. We have to build test stands that to some degree are replications of what they had to build when the system was originally accepted, to carry the design life to these extra lengths. And it's not trivial.

Stange: There are big challenges behind a lot of the things we do. The A-10, when it was originally built, was strictly an analog aircraft. It had very few onboard digital avionics systems, other than the instrumentation, which is easy to change out. We've taken it into the next decade, where now everything is digital. Taking those older airframes into what's considered the Digital Age is always a challenge. With the A-10 specifically, we've gone from basically no displays to color displays in the cockpit with satellite imagery. That means the pilot can get information back from other aircraft so he understands what's going on on the battlefield. If he needs to, he can call in support without even having to talk to anybody.

Ogden: Also, we've been working with the Air Force on jet engines. They have engines that have been around for decades, just like these other things we've been talking about. Adding sensors to those legacy systems is very expensive, so we've been working on statistical analysis of the data that comes off their existing systems. We're using what they already have to get a better idea of what the condition of their system is. This is part of our nSPCT™ program. Condition-based maintenance technology is one of our thrusts.

Kluger: One of the services SwRI provides is filling in where a lot of the original equipment manufacturers have stepped away. Taking test stands as an example, you're talking about systems that are 20, 30, 40 years old. Repair depots are faced with a tremendous challenge: first, their equipment may have been modified over the years without being properly documented, or the original documentation may not even exist. What SwRI does, is to provide mechanical, electrical and software engineers who can replicate these systems and their functionality. There are tremendous challenges associated with doing this: for example, you have to understand power flows, the component function being replaced which many times no longer exists and you have to provide equivalent functionality. We retrace electrical circuits and determine voltage, currents, capacitance, inductance and impedance values. We work to understand what the original design intent was for the system, while simultaneously meeting the requirements of very complex, unusual and demanding systems. In addition, we address the operating speeds and elevated power levels associated with military equipment. So there's a technical challenge in meeting those operational requirements.

TT: If anyone has a particularly rewarding project that their group was involved in, talk a little about that.

Bessee: In the Army Lab, there are several of them. David (Ogden) and I had one, RIFTS, for Rapidly Installed Fluid Transfer System, which was a great idea. [Editor's note: RIFTS was a reel-type, flexible pipeline, including pumps and leak-detection equipment that could transfer fuel from a rear-area supply depot and refuel combat vehicles near the front.] It was needed — it's still needed — but the military sponsor had to drop it due to the war effort and lack of funding. There is one example where we are stretching the technologies, stretching the capabilities, by coming up with new materials.

Stange: The A-10 is one of those pieces of equipment taken from a '70s to '60s-era technology base that is still being used on the battlefield in today's environment. One challenge we faced in mechanical and electrical engineering was to install a capability called "Precision Engagement," to bring into the field something that pilots could use to help the Army on the ground. When I talked to pilots who had flown the aircraft on the battlefield, both prior to Precision Engagement and today, they said that prior to Precision Engagement they'd be flying at night and the Army would say, "Hey, I need help, we are under attack." And the pilot would say, "I can't see where my enemy is, other than tracer rounds, and if the enemy is not shooting at you, I can't shoot." Precision Engagement infrared technology came along and changed that, and added various new displays in the cockpit that Dave (Ogden) alluded to. Now, pilots can view the battlefield at night. Another technology that came along was the moving map. This application allows the pilots to see their location on a map display driven by GPS positioning.

A pilot whom I have known for quite a few years told me about an event that took place on a cloudy day. The A-10s were flying above the clouds at about 22,000 feet. They couldn't see anything below them, so they loitered for three hours or so in their patrol area. Before heading back to base they started getting calls from troops that were under attack while trying to move through a canyon about 20,000 feet below them. The pilots couldn't see to get down there. They had two choices: Trust what the aircraft moving map told them about their position, or else fly all the way back to base, go low-level to get beneath the clouds and then go into the canyon and find the troops, which would have taken about 40 minutes. They chose to trust the technology, and they came down through the clouds knowing where the troops were in relation to the enemies from the location on the moving-map coordinates. The pilot had his targeting pod ready, so he could evaluate the situation. He was able to start his gun run before he even got out of the cloud base, and was able to save the troops. It gives me a good feeling and I am very proud that SwRI has this level of engineering experience to have a direct impact on that type of ability.

Kluger: One of our reverse-engineering projects has been particularly gratifying because it was urgently needed by our military client while also being greatly challenging from a technical standpoint. The project involved a transmission valve body test stand. It consisted of an extensive grouping of hydraulic circuitry, mechanical movements, and control functions for which no documentation existed. This was a critical component within the military maintenance depots. It was even more challenging because much of the pass/fail test information was interdependent and buried deeply within software. We were able to overcome these problems and replicate the test stand for our client. It took a combination of capabilities and skillsets that reside here at SwRI, such as well-defined engineering problem-solving skills, multidisciplinary project teams, and creative thinking along with a foundation and understanding of equipment and systems.

TT: What about SwRI's collaborative, multidisciplinary efforts?

Griffin: The diversity of this place can really bail you out in situations that you didn't calculate. You can run into materials that surprise you, or materials not normally used in the systems you're working with. But chances are somebody here at SwRI has been working with it, and if you ask them they can tell you some basic characteristics and things to look for. You don't have to go off the grounds. You can talk to a guy who, in five minutes, can save your project.

Bessee: A perfect example of that is that Dave's (Ogden's) group has a large B-52 program at Tinker AFB. They're doing all the hardware, design and fixing for everything they have up there. So when we need to know simple things related to B-52s, like what hydraulic oil do we use, where do we get it, we may not know anything about it. But that division deals with it every day. It's just a matter of knowing what resources we have, and going to the right people.

Ogden: We've been able to tap people from all of the other divisions at one time or another. We're able to use the invested capital and the expertise those guys have, so we don't have to invest in our own. When we did our multivariate statistical research program and developed our nSPCT analysis tool, we used Dr. Robert Mason, who is a nationally recognized expert in those kinds of statistics. We were able to take some of the technology he's been working with, automate it and create something that's useful in our business area.

Bessee: We've even gone and looked at new technologies. One of the big things in the chemistry world is called 2DGC/MS, or two-dimensional gas-chromatography/mass-spectrometry. It's brand-new technology, and it requires very expensive equipment. We were looking at buying it for our use, and then we found out the chemistry group already had one. We assumed they were fully utilizing it for pharmaceutical testing and found out we could use it for our purposes. We acquired the software and a removable hard drive, and now we ask them to run tests for us and give us the analysis. We drop it in the hard drive, and our chemists go in and reduce all the data. We're still the experts, and we didn't have to pay $400,000 for a piece of equipment, then have two of them sitting around partially utilized — now it's being efficiently utilized. We've got the capability of leveraging the other division's knowledge of chemistry, and the 2DGC/MS. It expands the Institute's capabilities.

Kluger: We've done a couple of multidivisional projects between the fuels and lubricants research and aerospace groups such as helicopter component repair studies where we looked at depot processes and recommended how their work flows and process equipment could be improved... Some of these transmissions can be six or eight feet high and four or five feet in diameter, passing hundreds of thousands of foot-pounds of torque through them. We were trying to see how repair depots could improve their repair processes, including the materials they were using in order to improve their throughput times and costs in order to deliver a better product to the warfighter.

Ogden: Another new technology we're working on is replacing the testing technology they've been using to test helicopter jet engines at an Army depot. We're taking out a water-brake system, which had an MTBF (mean time between failure) of about 100 to 200 hours. They spend about $1 million a year to keep their water brakes running. We're putting in an electric dynamometer using a high-speed, 2.5-megawatt motor as the load. It's a good example of new technology, and this is the first application of its kind for a motor of that size and speed.

We're putting in four right now, and they plan to build brand-new test cells over the next decade that this technology would transition over to. Plus, there are other potential customers around the world — other military depots, and also commercial applications.

Questions about this article? Contact Technology Today *Editor Joe Fohn, (210) 522-4630 or jfohn@swri.org.*

Protecting the Warfighter in Combat

U.S. Army photo by Sgt. Justin A Moeller

SwRI researchers develop human head surrogate for behind-helmet blunt trauma research

By Christopher J. Freitas, Ph.D., James T. Mathis, Nikki Scott and Rory P. Bigger

Combat helmets have been in use since around 700 B.C. The earliest ones were made of bronze and offered limited protection. With improvements over the centuries, the helmet's popularity grew and it has remained an essential part of the warfighter's uniform.

Today's U.S. warfighter goes into combat with a suite of state-of-the-art protective elements. Known as personal protection equipment or PPE, the equipment typically consists of upper and lower torso body armor designed to protect against small caliber rounds such as those fired from handguns and rifles. The personal protection equipment also includes a helmet.

Today's helmets are made of advanced composite materials that are lightweight and provide enhanced protection from fragments and small caliber bullets. The helmets also weigh less than previous generations of U.S. military helmets. As an example, the U.S. Personal Armor System Ground Troops (PASGT) helmets were made of Kevlar® and generally weighed 3.6 pounds. Now helmets are composite laminate structures that still may include Kevlar but also advanced materials such as Spectra™ or Dyneema®.

While these newer materials offer improved protection from bullet or fragment penetration, the lower weight has resulted in an increased risk of what is termed "behind-helmet blunt trauma." This injury is a blow to the head caused when the helmet is hit by a nonperforating bullet or fragment, and can range from a skin laceration to extensive skull fracture and brain damage. Pad suspension systems have been designed for combat helmets to lessen blunt head impact forces. These systems, however, D019377-6195

Researchers in the Engineering Dynamics Department in SwRI's Mechanical Engineering Division teamed to develop the human head surrogate. Pictured are (from left) Engineer Nikki Scott, Program Director Dr. Christopher Freitas, Research Engineer Rory Bigger and Principal Engineer James Mathis. Scott specializes in high-rate testing. Freitas, who has more than 35 years of experience in computational fluid dynamics and fluid mechanics, has developed numerous computational codes for a variety of applications. Bigger's area of expertise is computational fluid dynamics and computational mechanics. Mathis' focus is evaluating various protective systems such as armors for military applications.

are designed for events such as motor vehicle accidents, tripping or falling incidents and parachutist impact conditions rather than ballistic impact, which is a much more energetic event.

In general, increased helmet weight implies increased stiffness of the helmet structure. Stiff-structured helmets tend to have less back-face deflection during ballistic impact and thus have better protection against behind-helmet blunt trauma. As the helmet weight is reduced, however, stiffness also tends to decrease. The current generation of combat helmets tends to exhibit greater back-face deflection; thus these helmets are a cause for concern. Understanding the mechanics of the transfer of energy and the momentum from the strike face to the back face of the helmet is critical to PPE designers, and the interaction of the dynamic back-face deformation with the head and cranium is critical to warfighter survivability.

Building a human head surrogate

To help PPE designers address these concerns, mechanical engineers at Southwest Research Institute (SwRI) have developed an experimental methodology to evaluate behind-helmet blunt trauma. The project was funded by the U.S. Office of Naval Research as part of its Future Naval Capability program called Lightweight Individual Modular Body armoR (LIMBR). The cornerstone of the methodology is a high-fidelity human head surrogate developed by SwRI. This surrogate fills the void between post-mortem human subject testing and commercially available ballistic head forms. The SwRI-developed human head surrogate comprises an actual human cranium and synthetic soft tissues to simulate the brain, dura and skin, supported by a HYBRID III® 50-percent male neck assembly. The hybrid neck is designed to behave as a human neck would.

The human craniums are processed craniums commercially available from a number of sources. Because they are fully processed, they are not considered under federal law to be human subject testing. These craniums typically have been dehydrated due to the processing method used to clean and dry them. Processed cranial bone typically is more brittle than live or fresh bone because of the processing procedures. To function as part of the human head surrogate, the cranium requires rehydration to achieve the desired ductility

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The human head surrogate's performance was evaluated through a series of ballistic tests. Projectiles included explosive ordnance fragments, 9-mm handgun rounds and rifle rounds.

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The human head surrogate has a suite of embedded instrumentation for measuring intracranial pressure, cranial strain and triaxial accelerations. The surrogate is supported by a 50-percent male neck assembly (right).

and strength. The SwRI research team developed and investigated several techniques for this. The technique producing the best results involved soaking the cranium for 30 minutes in a shellac solution of ethanol, isopropanol, methyl isobutyl ketone, pure shellac and water.

To evaluate the ductility and strength of the refreshed craniums, the SwRI team conducted three-point bending tests. Test results were compared to the same three-point bending test of a “fresh” bone sample, and that result showed the shellac solution method was the best choice.

To represent the brain, dura, cerebral spinal fluids and external skin in the human head surrogate, SwRI researchers used a variety of materials. The brain and external skin were manufactured from Perma-gel®, a colorless, transparent petroleum-based thermoplastic material. At room temperature, the material allows bullet penetrations equal to FBI-standard 10 percent 250 A ordnance gelatin at 39.2 degrees F, which simulates swine muscle tissue. The Perma-gel for the external skin was molded to the cranium with skin thicknesses ranging from 0.2 to 0.3 inch, depending on where it was located on the head.

The dura, the soft tissue between the cranium and brain, was simulated using a layer of silicon with a thickness of 0.02 inch. Typically the thickness of the human dura is 0.01 to 0.03 inch, depending on the age of the human. Finally, water was used to simulate the cerebral spinal fluid.

Two heads are better than one

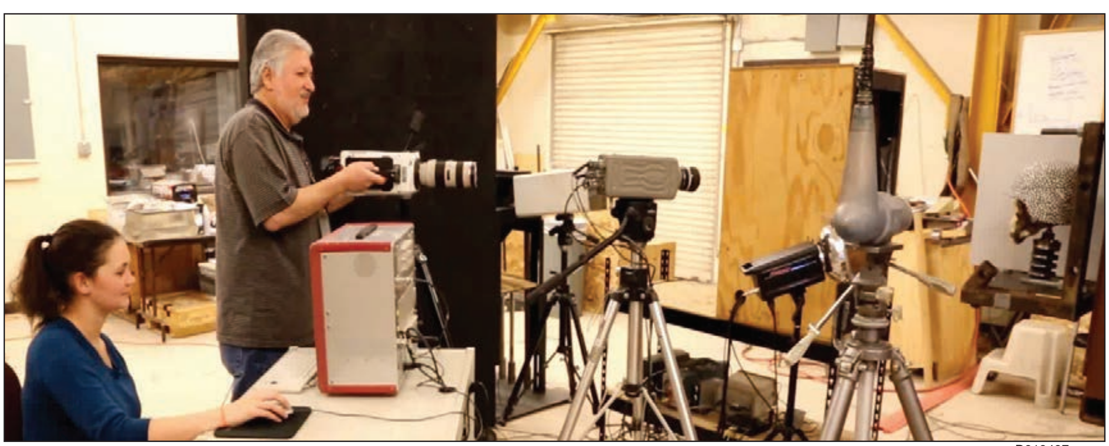
Two different versions of the human head surrogate evolved as the system was being developed and tested. One is a full-face version fully representing the scalp and facial skin features. The other is a “skull cap” of Perma-gel that covers the cranium sufficiently to represent the skin covered by the helmet, but still with the proper interface between the helmet suspension system and the cranial skin.

Both versions provided similar dynamic results and injury conditions; however, the skull-cap version requires less time to assemble. In general, the mass, size and thickness of all the surrogate components can be adjusted to represent actual human tissues.

A gasketed ring assembly was used to mount the human head surrogate to the neck assembly. The assembled head and neck were then rigidly mounted to a steel plate and angled for a normal surface impact prior to testing.

Adding instrumentation

The human head surrogate includes a suite of embedded instrumentation for measuring intracranial pressure, cranial strain and triaxial accelerations. Pressure transducers are used to measure intracranial pressures. Four gauges are typically embedded directly into the surrogate brain. These gauges measure the overpressure generated in the cerebral spinal fluid that surrounds the brain resulting from the dynamic deflection of the cranium caused by interaction with the back-face deflection of the helmet materials.



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The test setup includes ballistic light screens to measure impact velocity, a digital chronograph to measure time, a universal gun mount system, high-speed video cameras and flash X-ray imaging systems, among other instrumentation.

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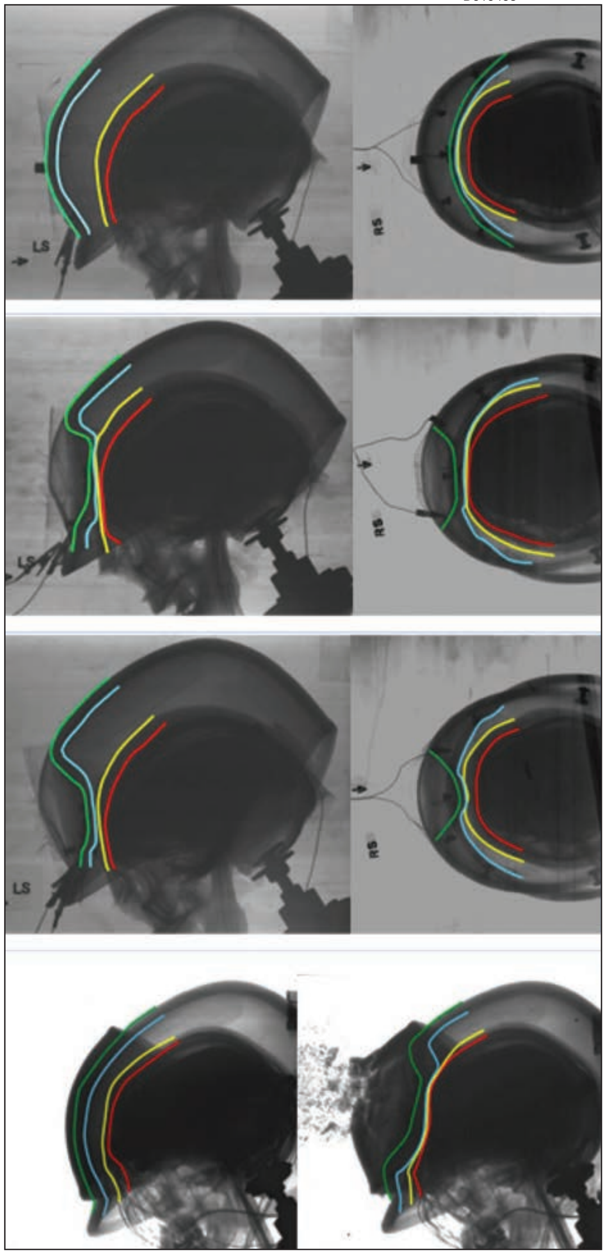

This sequence shows a helmeted human head surrogate. The first is a reference image prior to testing. In images two and three, a 9-mm projectile was fired at two speeds, with no fracture in image two and moderate injury at higher speed (image three). The last image shows the damage caused by an M80 rifle round, which resulted in a critical injury.

Triaxial strain gauges measure cranial bone strain during ballistic impact. Twelve of these gauges were installed, arranged in groups of three and deployed in a triangular pattern around anticipated impact or target points. The gauges were bonded directly to the refreshed cranium and then the surrogate skin was molded over them.

Finally, two triaxial accelerometers, one installed in the hard palate of the head and the other in the helmet, measure the dynamic motion of the impact. Data from these gauges are captured in digital form using a high-speed data acquisition system with a sampling rate of one million data points per second.

Ballistic testing

Once the human head surrogate was fully instrumented, its performance was evaluated by subjecting it to a series of ballistic tests. The objective was to study the effect of back-face deflection on the helmet caused by nonperforating ballistic impact, so great care was taken to ensure that no perforations occurred.

These tests were designed to study the effects of projectile types, hit locations, pad suspension configurations and ceramic armor applique effects. Projectiles included explosive ordnance fragments, 9-mm handgun rounds and rifle rounds. Impact speeds for the projectiles ranged from 1,500 feet per second to 2,850 feet per second.

To measure the projectile's impact velocity, two ballistic light screens were placed one meter apart. A digital chronograph was connected to the screens to measure the time the projectile breaks the light beam at each screen. Projectile velocity was then calculated based on the time difference. The projectiles were fired from a universal gun mount system placed two meters in front of the first light screen, with the human head surrogate and mount assembly placed two meters behind the second screen. High-speed video, with frame rates ranging from 15,000 to 250,000 frames per second, was used to document each experiment. Flash X-ray imaging also captured the event from two angles, a side view and a top view.

Cranial fractures are described as simple (linear), basilar or depressed, and clinical treatments are based on head injuries defined as critical, moderate and minor. A similar system was used for the human head surrogate. Minor fractures or injuries that occurred during testing were characterized as simple surface fractures, with no penetration through the thickness of the cranial bone. Moderate fractures were characterized by fractures that do penetrate through the thickness of the cranium, but the fractures are not dislocated and the cranium is still intact as a single structure. For critical or significant fractures or injuries, the cranium is fractured such that it is no longer a single structure and is fragmented into large pieces or segments.

During testing involving a 9-mm round, helmets with suspension pads outperformed those with no padding. The padded helmet tests resulted in no injury, while the other resulted in moderate injury. In tests using an M80 rifle round, the helmet successfully protected against the round penetrating it. However, the force of the impact caused a critical injury, demonstrating the need to better protect against behind-helmet blunt trauma.

Improved testing will lead to improved designs

The SwRI-developed human head surrogate and its test methodology show great potential for providing insights into injuries resulting from a variety of ballistic threats. With it, designers will be able to craft helmets that offer improved protection for warfighters.

Based on the success of this project, SwRI researchers have submitted a white paper to the NFL Under Armour GE Head Health Challenge II, an initiative for developing new technologies and materials for protecting professional football players' brains from traumatic injury.

Questions about this article? Contact Freitas at (210) 522-2137 or christopher.freitas@swri.org.

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A Driving Force

SwRI engineers expand electric vehicles' role in managing the power grid

By Sean Mitchem and Yaxi Liu

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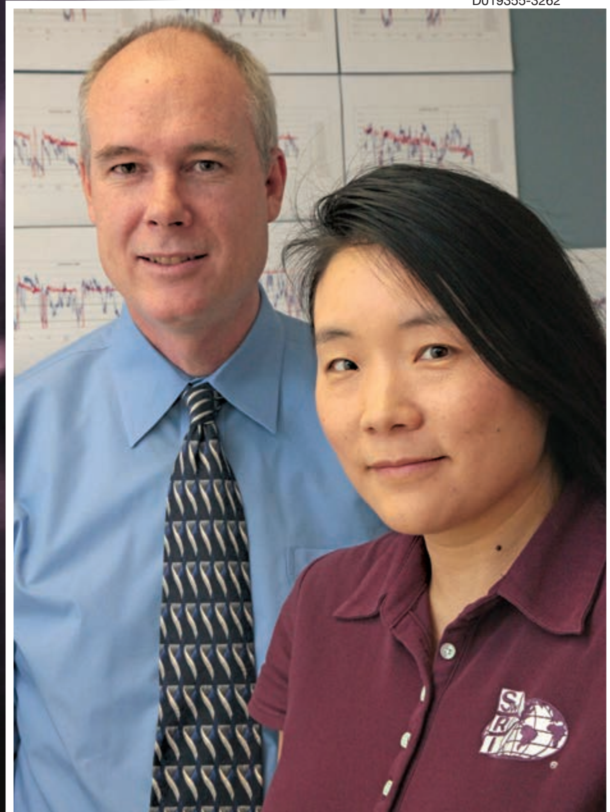


Sean C. Mitchem is a principal analyst and acting group leader of the Smart Energy Technologies Group within the Communications and Embedded Systems Department, Automation and Data Systems Division. He is a system engineer, software architect and project manager whose current focus area is smart-grid energy systems. Yaxi Liu is a research analyst within the Smart Energy Technologies Group. Her research interests include software development ranging from enterprise applications to embedded systems implementation, to smart-grid related technologies.

Thunder roared in the distance, and dark clouds cloaked the sky as if under a wicked wizard's spell. Pikes Peak towered over a fleet of five medium-duty electric trucks with their batteries charging at a rate of 50 kilowatts. Nearby, a team of Southwest Research Institute (SwRI) engineers watched an array of monitors and gauges beneath a makeshift rain shelter. The SwRI-built aggregation system confirmed that the five-vehicle fleet was pulling a total load of 250 kilowatts from the power grid.

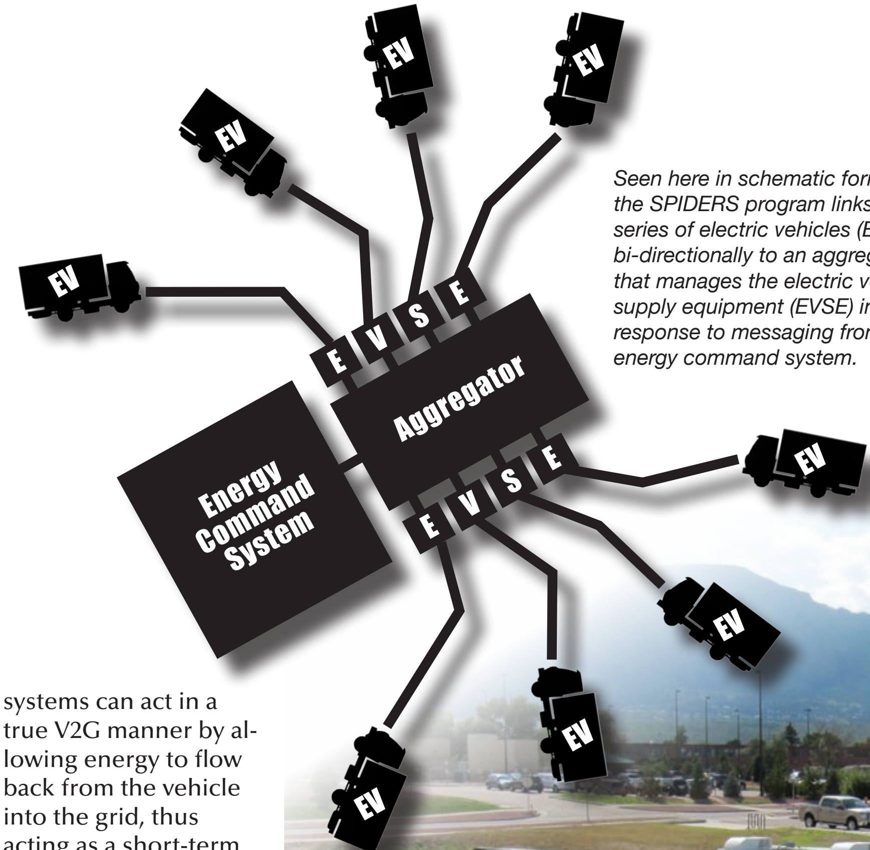
Suddenly, the grid made a request of the energy aggregator: Become an energy generator and provide the grid with 250 kW of power. The aggregator processed the request and commanded the charging stations to reverse energy flows on the vehicles. A second later, the five vehicles were pushing energy from their storage batteries back into the grid.

As the storm neared, a second request came in: Become a load resource and absorb 100 kW from the grid. The aggregator analyzed the vehicles' charge schedules and issued commands to stop sending energy into the grid and start absorbing it, while also prioritizing the battery charging according to anticipated vehicle use. As commands kept coming in, the wicked wizard finally had his way and rain poured as the soaked SwRI engineers tried to read one more number from the chargers.

That was one of many testing operations carried out in September at Fort Carson Army Base, Colo., successfully demonstrating vehicle-to-grid technology in military operations thanks to an SwRI-developed electric vehicle aggregation system.

As the smart grid continues to evolve, the desire and need for new energy storage systems to support it continues to grow. Integrating renewable energy, such as wind and solar, into the grid means those energy sources' varying output must be balanced with the energy load across the grid. Energy storage systems can help; the problem is, they are neither cheap nor simple to build and integrate. Additionally, many technologies, such as flow batteries or large-scale lithium-ion systems, have yet to be proven viable and cost-effective. This has led toward development of an alternative to centralized large-scale storage — distributed energy storage solutions using electric vehicles. The SwRI team is pushing electric vehicle technology forward for grid energy storage through two research programs: one for the U.S. Department of Defense and another for a commercial vehicle fleet.

Using vehicles during their idle times (which can account for up to 90 percent of the time) to support the electrical grid using the vehicles' battery storage capability is called vehicle-to-grid (V2G) technology. Many chargers only allow power to flow into the vehicle. Such unidirectional systems can provide demand/response services, where the demand (load) imposed by charging the vehicles' batteries is curtailed during peak demand periods. Unidirectional systems also can provide frequency regulation services where the chargers can be turned on or off to help maintain overall grid frequency. Bidirectional charging



Seen here in schematic form, the SPIDERS program links a series of electric vehicles (EV) bi-directionally to an aggregator that manages the electric vehicle supply equipment (EVSE) in response to messaging from an energy command system.

systems can act in a true V2G manner by allowing energy to flow back from the vehicle into the grid, thus acting as a short-term generation resource. Bidirectional systems also can manage and move power during times when they are not taking load from the grid. In the military aggregator developed by SwRI, the chargers and vehicles are able to support an emergency "island" microgrid by supplementing the typical diesel generators used for backup power.

Electric vehicle (EV) aggregation is the concept of managing a collection of electric vehicles or charging stations for power management purposes. The aggregator is a control system that sits between an energy command system and the vehicle chargers to dispatch power flow requests to the EV fleet. It collects status information from each fleet unit, such as connection status, state of charge, real and reactive power levels and flow directions, and maximum available charge and discharge power. It aggregates this data into a fleet perspective to define the fleet's energy status and presents the fleet perspective to a supervisory control system. When the control system sends a power request to the aggregator, the aggregator evaluates the request against the fleet situation and dispatches individual requests to each EV fleet member to change its power usage. Factors such as vehicle-use schedules and EV maximum power flows can be used to make the best decisions for the fleet while implementing the power request.

SwRI became involved in EV aggregation as a member of the team that designed and implemented the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) program. SPIDERS involved creating a secure microgrid on Fort Carson to provide energy certainty to critical infrastructure when grid power is unavailable. The base's energy generation capabilities include a 2-megawatt solar array and a fleet of five medium-duty electric vehicles that use direct current (DC) for high-power, bi-directional transfers. SwRI team members developed an aggregation system that manages the electric vehicle supply equipment (EVSE) to charge and discharge the vehicles. The SwRI system also proved capable of providing significant on-demand reactive power services to the grid, giving the army base even more economic reward for running the system.

The entire system — vehicles, EVSEs and aggregator — was the first to implement Society of Automotive Engineers (SAE) standards for bi-directional, DC fast charging. SwRI was the lead EVSE engineering team for the project, responsible for coordinating all development work required to implement and deploy to SAE standards. SwRI staff worked with two EV manufacturers to refit their vehicles to the SAE Combo Connector for DC fast charging. Additionally, SwRI brought vehicle and EVSE manufacturers together to develop an interface control document that clearly defined the messaging

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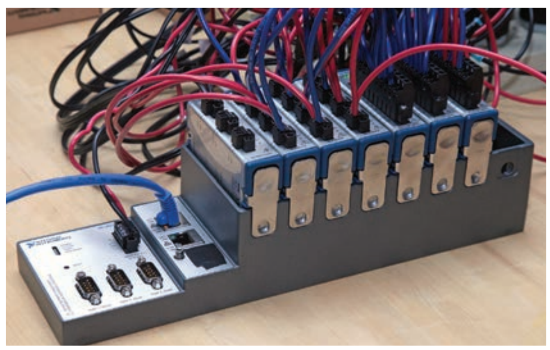

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In a commercial application, an SwRI-designed aggregation system (inset) allows electric delivery truck fleet owners to earn revenue by using normal vehicle charge times to assist utilities in managing grid frequency by automatically suspending charging to some or all of the vehicles whenever the frequency deviates significantly from the normal 60-Hertz standard. A laboratory test framework using light bulbs (background) in place of the vehicle chargers allows engineers to test and fine-tune the system pre- and post-deployment.

between EVs and chargers to the SAE standards. The SwRI-developed distributed software system is secure, self-recoverable and adaptable for various operation modes.

The SwRI team is working on a second program involving the use of a commercial EV delivery fleet to provide very fast responses in frequency regulation on the grid. Grid power frequency in the United States is maintained at 60Hz. When loads exceed the energy being generated, the grid's frequency drops. Conversely, frequency increases when generation exceeds load. To effectively manage frequency changes, the energy market incurs millions of dollars in costs annually to have idle capacity available to quickly add or remove energy from the grid. As part of a pilot program for the Energy Reliability Council of Texas (ERCOT), the state's regional independent system operator, the vehicle fleet will provide frequency regulation services in what is known as the "regulation-up" market, removing charge loads from the grid in less than one second — significantly faster than the ramp capabilities of coal, oil or natural gas fueled power plants. The SwRI-built hardware/software solution monitors grid frequency and EV power usage at 40 times per second. The software aggregator manages the EV fleet, turning chargers on or off as needed to meet grid power requirements in response to frequency changes. The technology proves electric vehicles are able to generate revenue for fleet owners while also lending extra support for the grid and increase the ability to use variable renewable generation through enhanced frequency regulation. Recently the SwRI aggregation system became the first system qualified to bid electric vehicle energy into the ERCOT Fast Response Regulation Services market.

The work also pushes the boundaries of electric vehicle capabilities. Potential revenue opportunities for vehicle owners when their vehicles are idle may spur interest in electric vehicle ownership, which in turn could bring a widespread electric vehicle-supported grid a step closer to reality.

While research has indicated potential benefits of using electric vehicles for V2G services through analysis and simulation, few examples have been available to evaluate real results. By successfully deploying two V2G systems within true operational environments and demonstrating the value of V2G on a daily basis with vehicle fleet owners, the SwRI team has tossed the first rocks down the mountain of electric vehicle energy that may someday become a landslide change to both transportation technology and electrical grid management.

Questions about this article? Contact Mitchem at (210) 522-2698 or sean.mitchem@swri.org, or Liu at (210) 522-3513 or yaxi.liu@swri.org.

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TECHNICS

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

SwRI scientists to study rock glaciers in Europe

Scientists at Southwest Research Institute (SwRI) and West University of Timisoara, Romania, will use remote-sensing technology to study the evolution and movement of rock glaciers in the Carpathian Mountains of Eastern Europe.

The international collaboration, funded by a grant from the National Science Foundation, is led by Dr. Marius Necsoiu, a principal scientist in SwRI's Geosciences and Engineering Division. The team will use new methods based on complementary analysis of high-resolution optical and radar satellite imagery to quantify rock glacier dynamics.

"This collaboration is significant in several ways," notes Geosciences and Engineering Division Vice President Dr. Wesley Patrick. "It combines the multidisciplinary expertise of international colleagues, leverages and extends current technologies, and aims to establish a measurement protocol that will improve our ability to monitor stability of materials that can affect transportation infrastructure and safety."

Unlike the better-known glaciers that are essentially rivers of ice, rock glaciers are composed of frozen rock and soil. Rock glaciers can be found at high elevations, even in more temperate parts of the world.

"Rock glaciers are the most important form of high mountain permafrost, yet they are little-studied," Necsoiu said. "Investigating rock glacier dynamics is a key factor in understanding the evolution and movement of permafrost-related formations under changing climate conditions."

The study's results will serve as a baseline for future investigations of rock glacier movements in Central and Eastern European alpine regions where information on glacier rock dynamics is scarce or missing. Knowledge gained from this study could be applied to rock glaciers elsewhere, such as in the Front Range in Colorado or the La Sal Mountains in Utah.

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SwRI's Wilson receives IASH Lifetime Achievement Award

George R. Wilson, a principal scientist in the TARDEC Fuels and Lubricants Research Facility in the Fuels and Lubricants Research Division at Southwest Research Institute (SwRI), has received the Lifetime Achievement Award from the International Association for Stability, Handling (IASH) and Use of Liquid Fuels Inc. for his sustained work testing the thermal stability of liquid fuels.

Wilson received the award for technical achievements in the area of jet fuel specification testing and test method development, for research that resulted in significant improvements to the evaluation of jet fuel thermal oxidative stability and development of tube chemistry criteria that eliminated magnesium migration as an issue in jet fuel, according to the IASH award nomination. He received the award at the 13th IASH International Symposium held in Rhodes, Greece.

Wilson, who joined the SwRI staff in 1999, has more than 30 years of experience in jet fuel specification testing and test method development and specializes in evaluating fuel in critical operations with an emphasis on thermal stability. He holds six U.S. patents.

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Walker named 2014 O'Donnell Award recipient

Dr. James D. Walker, an Institute scientist in Southwest Research Institute's Mechanical Engineering Division, has been named a recipient of the 2014 Edith and Peter O'Donnell Award, given by The Academy of Medicine, Engineering & Science of Texas (TAMEST).

Walker and three other O'Donnell Award recipients were honored Jan. 16 during TAMEST's 11th Annual Conference.

The Edith and Peter O'Donnell Awards "recognize rising Texas researchers who are addressing the essential role that science and technology play in society and whose work meets the highest standards of exemplary professional performance, creativity and resourcefulness," according to the TAMEST web site.

Walker, whose research efforts have focused on the mechanical response of a variety of systems and materials to impact loads, will receive the Technology Innovation Award "for his pioneering work, development and modeling in impact theory, penetration mechanics and material characterization and response under dynamic loading."

Walker's research centers on personnel protection ranging from vests worn by soldiers and police officers to designs for ground vehicles, the International Space Station and satellites. In 2003, Walker and SwRI colleagues were part of a team that helped determine the cause of the loss of the space shuttle Columbia. He also performed studies in support of the space shuttle return-to-flight program.

The author of more than 100 papers and publications, Walker holds bachelor's, master's and doctoral degrees in mathematics from the University of Utah. He is a member of ASME, American Institute of Aeronautics and Astronautics, American Mathematical Society, Association for Computing Machinery, Hypervelocity Impact Society, International Ballistics Society, Mathematical Association of America and the Society for Industrial and Applied Mathematics.

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SwRI launches Automotive Consortium for Embedded Security (ACES™)

As vehicles become increasingly dependent on computers to operate integrated systems, from engine timing to anti-lock brakes, it is crucial to safeguard those systems from outside threats. To investigate leading-edge technologies and understand and reduce the risk of attack, Southwest Research Institute (SwRI) is forming the Automotive Consortium for Embedded Security (ACES).

The joint industry program aims to provide pre-competitive and non-competitive research in automotive embedded systems security to protect the safety, reliability, brand image, trade secrets and privacy of client members' future products. It is open to original equipment manufacturers and affiliated businesses in the automotive industry. Companies can join the three-year program at any time by paying the annual membership fee. The formal kickoff of ACES is scheduled in 2014.

"The automation and connectivity that make automobiles safer, more efficient and more responsive also expose them to higher risk of malicious cyber attacks, which could compromise safety and damage an automaker's reputation," said Mark Brooks, a senior research engineer in SwRI's Automation and Data Systems Division.

Embedded systems are processors designed for a specific function within a larger system, such as the whole automobile. They typically handle a specific task and have been optimized to reduce size and cost and increase reliability and performance. Vehicles typically have dozens of embedded computer systems.

SwRI has been working with embedded systems security in areas such as electrical smart grids and residential smart meters, as well as industrial control systems and distribution centers to help secure them from attackers and terrorist threats.

The advantage of consortium membership is that the impact of the yearly contribution is multiplied by the number of participants, providing substantially more pre-competitive research than would be possible with funding from a single client. In addition, members will have access to autoTREAD™ software, an SwRI-developed automotive tool that provides a framework for analysis and detection of anomalies on the controller area network (CAN) bus. The Institute also will pursue patents for technology developed by the ACES program, and participants will receive a royalty-free license to use the ACES-developed technology.

For more information about ACES and to learn more about the Oct. 23 information exchange, see *aces.swri.org*.

Contact Brooks at (210) 522-3727 or mbrooks@swri.org.

Image credit: NASA/ESA/K. Retherford/SWRI

Hubble Space Telescope sees evidence of water vapor venting off one of Jupiter's moons

NASA's Hubble Space Telescope has observed water vapor above the frigid south polar region of Jupiter's moon Europa, providing the first strong evidence of water plumes erupting off the moon's surface.

Previous scientific findings from other sources already point to the existence of an ocean located under Europa's icy crust. Researchers are not yet certain whether the detected water vapor is generated by water plumes erupting on the surface, but they are confident this is the most likely explanation.

Should further observations support the finding, it would make Europa the second moon in the solar system known to have water vapor plumes. The findings were published in the Dec. 12 online issue of *Science Express*, and reported at the meeting of the American Geophysical Union in San Francisco.

"By far the simplest explanation for this water vapor is that it erupted from plumes on the surface of Europa," said lead author Lorenz Roth of Southwest Research Institute (SwRI) in San Antonio. "If those plumes are connected with the subsurface water ocean we are confident exists under Europa's crust, then this means that future investigations can directly investigate the chemical makeup of Europa's potentially habitable environment without drilling through layers of ice. And that is tremendously exciting,"

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Md., manages the telescope. The Space Telescope Science Institute (STScI) conducts Hubble science operations. The Association of Universities for Research in Astronomy Inc. in Washington operates STScI for NASA.

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Technical Staff Activities

Publications

Alexander, C.E., R.W. Walsh, S. Régnier, J. Cirtain, A.R. Winebarger, L. Golub, K. Kobayashi, S. Platt, N. Mitchell, K. Korreck, B. DePontieu, C. DeForest, M. Weber, A. Title and S. Kuzin. "Anti-parallel EUV Flows Observed along Active Region Filament Threads with Hi-C." *Astrophysical Journal*. Letters, 775, (2013): L32.

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Brown, M., P. Chuang and R. Roebuck. "Processes, Procedures and Tools for Performing Structured Qualification and Certification Testing of Connected Vehicle Devices." Paper presented at the ITS World Congress, Tokyo, October 2013.

Brown, M., R. McDonough and T. Richter. "Enabling the Connected Commercial Vehicle." Paper presented at the ITS World Congress, Tokyo, October 2013.

Brun, K. and S.B. Coogan. "Micromix Combustor for High Temperature CSP Air Braytown Cycle Systems." Paper presented at the SunShot Concentrating Solar Power Program, Phoenix, Ariz., April 2013.

Brun, K., R. Kurz and M. Nored. "Gas Turbine Packaging Options and Features." Paper presented at the Second Middle East Turbomachinery Symposium, Doha, Qatar, March 2013.

Brun, K., R. Kurz and M. Nored. "The Impact of Compressor Station Piping Acoustic Impedance on Centrifugal Compressor Surge Limits." Paper presented at the Gas Machinery Conference, Albuquerque, N.M., October 2013.

Chan, K.C., M.P. Enright, J. Moody and S. Fitch. "Mitigating Time-dependent Crack Growth in Ni-Base Superalloy Components." Paper presented at the International Conference on Fatigue Damage of Structural Materials X, Hyannis, Mass., September 2013.

Chirathadam, T.A. "Gas Turbine Remaining Life Assessment." Paper presented at the Saudi Aramco Global Reliability Forum, Houston, Texas, June 2013.

Chirathadam, T.A., B.A. White and N. Hajje. "Metal Mesh Dampers for Piping Support and Vibration Control." Paper presented at the Gas Machinery Conference, Albuquerque, N.M., October 2013.

Cobb, A.C., C.E. Duffer and G.M. Light. "Evaluation of the Feasibility for Detecting Hidden Corrosion Damage in Multi-layer Gusset Plates Using Multiple Inspection Techniques." Paper presented at the American Society for Nondestructive Testing Annual Conference, Las Vegas, Nev., November 2013, and at the Quantitative Nondestructive Evaluation (QNDE) Conference, Baltimore, Md, July 2013.

Cook, J.C., S.A. Stern, J.-Y. Chaufray, P.D. Feldman, G.R. Gladstone, K.D. Retherford and the LAMP Science Team. "Lunar Atmospheric H2 Detections by the Lyman Alpha Mapping Project (LAMP) UV Spectrograph on the Lunar Reconnaissance Orbiter." Paper presented at the Division for Planetary Sciences (DPS) Meeting, Denver, Colo., October 2013.

Dannemann, K.A. and D. Benac. "Living and Working in the Material World." Invited Lecture before the UTSA Mechanical Engineering Department, San Antonio, November 2013.

Technical Staff Activities

Davis, M.W., G.R. Gladstone, J. Goldstein, B.R. Sandel, T.K. Greathouse, K.D. Retherford and G.S. Winters. "An Improved Widefield Camera for Imaging Earth's Plasmasphere at 30.4 nm." Paper presented at the 2013 SPIE Optics and Photonics Conference, San Diego, Calif., August 2013.

DeForest, C.E. and T.A. Howard. "Solar and Terrestrial RElations Observatory/Sun Earth Connection Coronal and Heliospheric Investigation (STEREO/SECCHI) Level 2 Heliospheric Data: Status and Availability." Paper presented at the American Astronomical Society, SPD meeting No. 44, (#100.132), Bozeman, Mont., July 2013.

DeForest, C.E., T.A. Howard and W.H. Matthaeus. "Imaging the Inner Boundary of the Solar Wind." Paper presented at the American Astronomical Society, SPD meeting No. 44, (#100.131), Bozeman, Mont., July 2013.

Dellenback, S. "The Future of Transportation Safety: Safety Impacts of Technologies Even Jules Verne Couldn't Imagine — Automated Vehicles." Paper presented at the Texas Safety Conference, Fort Worth, Texas, June 2013.

Dellenback, S. "Off-road Autonomy and Next Steps." Paper presented at the Florida Automated Vehicles Summit, Tampa, Fla., November 2013.

Do, T. "Vehicle Network Security Research." Invited presentation at the American Petroleum Institute (API) Cybernetics Committee Meeting, San Antonio, September 2013.

Edwards, S. "ROS Industrial — An Open Source Approach to Advanced Industrial Automation." Paper presented at the SAE 2013 AeroTech Congress & Exhibition, Montreal, September 2013.

Elliott, H.A., R.A. Frahm, J.R. Sharber, T.A. Howard, D. Odstrčil, H. J. Opgenoorth, D. Andrews, O.G. Witasse and M. Fränz. "The Influence of Corotating Interaction Regions and High Speed Streams on Electrons in the Martian Magnetosheath and Ionosphere." Paper presented to the General Assembly 2013 of the European Geophysical Union, Vienna, (EGU2013-14060), April 2013.

Evans, P. "The New, New Manufacturing Center: Products & Systems for the 21st Century, from Idea to Implementation." Paper presented at Micro Society, San Antonio, July 2013.

Fisher, J.L., G.M. Light, J. Crane, A.J. Parvin and Y. Sugawara. "Inspection Technique for BWR Core Spray Thermal Sleeve Weld." Paper presented at the Electric Power Research Institute (EPRI) 10th International Conference on Nondestructive Evaluation in Relation to Structural Integrity for Nuclear and Pressurized Components, Cannes, France, October 2013.

Fisher, J.L., K.A. Bartels, A.E. Schaefer, E. Shiina, T. Shimomura and T. Hamano. "Portable Piping Thickness Measurement System." Paper presented at the EPRI 10th International Conference on Nondestructive Evaluation in Relation to Structural Integrity for Nuclear and Pressurized Components, Cannes, France, October 2013.

Frahm, R.A., J.D. Winningham, J.R. Sharber, H.A. Elliott, T.A. Howard, C.E. DeForest, D. Odstrčil, E. Kallio, S. McKenna-Lawler and S. Barabash. "Plasma Characteristic Determination During the Coronal Mass Ejection Associated with the January 27, 2012 Solar Storm." Paper presented to the General Assembly 2013 of the European Geophysical Union, Vienna, (EGU2013-14062), April 2013.

Freitas, C.J. "ASME Committee on Verification and Uncertainty Quantification." Paper presented at the ASME Technical Committee Meeting, Orlando, Fla., October 2013.

Freitas, C.J. "SwRI Human Head Surrogate." Paper presented at the NeuroCognitive Assessment Branch, U.S. Army Medical Command, Fort Sam Houston, Texas, October 2013.

Fritz, S.G., J.C. Hedrick and J. Rutherford. "Locomotive Emissions Measurements for Various Blends of Biodiesel Fuels." Paper presented at the SAE Internal Combustion Engine Conference, Capri, Italy, September 2013.

Fritz, S.G. "Locomotive Biodiesel Updates." Paper presented at the National Biodiesel Board Technical Workshop, Kansas City, Mo., October 2013.

Garcia, R. and J. Gassaway. "Negative Obstacle Detection from an Unmanned Aircraft Perspective." Paper presented at the 2013 SAE AeroTech Congress, Montreal, September 2013.

Gladstone, G.R., K.D. Retherford, A.J. Steffl, J.S. Eterno, M.W. Davis, M.H. Versteeg, T.K. Greathouse, M.F. Araujo, B.C. Walther, K.B. Persson, S.C. Persyn, G.J. Dirks, M.A. McGrath, P.D. Feldman, F. Bagenal, J.R. Spencer, E. Schindhelm and L.N. Fletcher. "The Ultraviolet Spectrograph (UVS) on ESA's Jupiter Icy Moon Explorer (JUICE) Mission." Paper presented at the Division for Planetary Sciences (DPS) Meeting, Denver, Colo., October 2013.

Gladstone, G.R., K.D. Retherford, A.J. Steffl, J.S. Eterno, M.W. Davis, M.H. Versteeg, T.K. Greathouse, M.F. Araujo, B.C. Walther, K.B. Persson, S.C. Persyn, G.J. Dirks, M.A. McGrath, P.D. Feldman, F. Bagenal, J.R. Spencer, E. Schindhelm and L.N. Fletcher. "The Ultraviolet Spectrograph on the Jupiter Icy Moons Explorer (JUICE) Mission (JUICE-UVS)." Paper presented at the European Planetary Sciences Congress, London, September 2013.

Glenar, D.A., T.J. Stubbs, P.D. Feldman, K.D. Retherford, G.T. Delory, A. Colaprete, R. Elphic and W.M. Farrell. "Search for a High Altitude Dust Exosphere: Observational Status Prior to the Lunar Atmospheric and Dust Environment Explorer (LADEE) Mission." Paper presented at the Lunar Exploration Analysis Group (LEAG) Meeting, Columbia, Md., October 2013.

Goldstein, J., C. Kletzing, W. Kurth and S. DePascuale. "Plasmapause Test Particle Simulation for the Van Allen Probes Mission: Comparison with EMFISIS Electron Density." Paper presented at the RBSP-ECT meeting, University of New Hampshire, Durham, N.H., September 2013.

Hanley, J. "On Chlorine Salts: Their Detection, Stability and Implications for Water on Mars and Europa." Poster presented at the Division of Planetary Sciences 45th Annual Meeting, (#400.09), Denver, Colo., October 2013.

Hendrix, A.R., K.D. Retherford, G.R. Gladstone, D.M. Hurley, P.D. Feldman, A.F. Egan, D.E. Kaufmann, P.F. Miles, J. Wm. Parker, D.G. Horvath, P.M. Rojas, M.H. Versteeg, M.W. Davis, T.K. Greathouse, J. Mukherjee, A.J. Steffl, W.R. Pryor, M.A. Bullock and S.A. Stern. "Lunar Reconnaissance Orbiter (LRO) Lyman Alpha Mapping Project (LAMP): Regional Variations in Far-UV Lunar Signatures." Paper presented at the Division for Planetary Sciences (DPS) Meeting, Denver, Colo., October 2013.

Hollingsworth, L. and G. Bessee. "Determination of Water Droplet Size Distributions in Diesel Fuel." Paper presented at the American Filtration and Separation Society (AFS) Spring 2013 Conference, Minneapolis, May 2013.

Hooper, D.M., S.W. Ximenes, M. Necsoiu and E.L. Patrick. "Lunar Reconnaissance and Site Characterization at the Marius Hills Skylight." Paper presented at Golden Spike Human Lunar Expeditions: Opportunities for Intensive Lunar Scientific Exploration, Lunar and Planetary Institute, Houston, (Abstract 6022), October 2013.

Technical Staff Activities

Howard, T.A. and C.E. DeForest. “The Launch and Early Evolution of a CME Flux Rope.” Poster presented at the American Astronomical Society, SPD meeting No. 44, (#100.14), Bozeman, Mont., July 2013.

Howard, T.A., C.E. DeForest and D. Odstrčil. “Remotely Measuring Features in the Solar Wind Using Polarimetry.” Poster presented at the American Astronomical Society, SPD meeting No. 44, (#100.124), Bozeman, Mont., July 2013.

Iturrarán-Viveros, U. and J.O. Parra. “Permeability and Porosity from Integrated Multi-attributes and Well Log Data Using Smooth Regression: Application to a South Florida Aquifer.” Paper presented at the Society of Exploration Geophysicists Annual Meeting, Houston, (Expanded Abstracts, 2013, 1888-1893), September 2013.

Johnson, J. “Cloud Computing Benefits for Intelligent Transportation Systems.” Paper presented at the 2013 Society of Intelligent Transportation Systems (ITS) Texas, Houston, November 2013.

Karnes, P.L., K.D. Retherford, G.S. Winters, M.W. Davis, S.M. Escobedo, E.R. Schindhelm, E.L. Patrick, E. Bassett, J. Wm. Parker, G.R. Gladstone, L.M. Feaga and S.A. Stern. “Radiometric Calibration of the SwRI Ultraviolet Reflectance Chamber (SwURC) Far-ultraviolet Reflectometer,” Paper presented at the Society of Photo-Optical Instrumentation Engineers (SPIE) Meeting, San Diego, Calif., September 2013.

Kastner, K.S. “A Gentle Introduction to Machine Learning.” Paper presented at the Scientific Computing with Python Conference 2013 (SciPy2013), Austin, Texas, June 2013.

Killough, R. “Car Hacking.” Paper presented at Texas State University Cyber Security Awareness Day, San Marcos, Texas, October 2013.

Killough, R. “Challenges in Transportation Security.” Paper presented at the Intelligent Transportation Systems (ITS) World Congress, Tokyo, October 2013.

Killough, R. “Software Engineering Processes for Class D Missions.” Paper presented at SPIE Optics and Photonics 2013 – Earth Observing Systems XVIII, San Diego, Calif., August 2013.

Kirchoff, M. “Can Spatial Statistics Provide Another Approach to Understanding Impact Crater Saturation Equilibrium?” Paper presented at the Division of Planetary Sciences 45th Annual Meeting, (#417.08), Denver, Colo., October 2013.

Korendyke, C., G. Doschek, H. Warren, P.R. Young, D. Chua, D.M. Hassler, E. Landi, J.M. Davila, J. Klimchuck, S. Tun, C. DeForest, J.T. Mariska, the Solar C Spectroscopy Working Group, Large European Module for solar Ultraviolet Research (LEMUR) and the UV/EUV high-throughput Spectroscopic Telescope (EUVST) Development Team. “Progress Toward High Resolution EUV Spectroscopy.” Paper presented at the American Astronomical Society, SPD meeting No. 44, (#100.143) Bozeman, Mont., July 2013.

Kurz, R. and K. Brun. “Introduction to Gas Turbine Applications.” Short Course presented at the Gas Machinery Conference, Albuquerque, N.M., October 2013.

Kurz, R., K. Brun, J. Thorp and E. Zentmyer. “Probabilistic Approach for Compressor Sizing and Plant Design.” Paper presented at the Proceedings for the Forty-second Turbomachinery Symposium, Houston, September 2013.

Lamb, D. and C. DeForest. “Observations of Synchronous Magnetic Flux Emergence.” Paper presented at the American Astronomical Society, SPD meeting No. 44, (#100.106), Bozeman, Mont., July 2013.

Lamb, D., C. DeForest, A.R. Davey and R. Timmons. “Update on SouthWest Automatic Magnetic Identification Suite (SWAMIS) Emerging Flux Detection and Magnetic Feature Tracking for Solar Dynamics Observatory/Helioseismic and Magnetic Imager (SDO/HMI).” Paper presented at the American Astronomical Society, SPD meeting No. 44, (#100.100), Bozeman, Mont., July 2013.

Lamm, R. “Autonomous Vehicles — Technical Challenges.” Paper presented at the ITS World Congress, Tokyo, October 2013.

Lamm, R. “Evaluation of Cooperative and Automated Driving.” Paper presented at the ITS World Congress, Tokyo, October 2013.

Lamm, R. “Technical Approach Variability and its Impact on the Evaluation of Cooperative and Automated Systems.” Paper presented at the ITS World Congress, Tokyo, October 2013.

Laurent, G.T., D.M. Hassler, C. DeForest, T.R. Ayres, M. Davis, B. De Pontieu, U. Schuehle and H. Warren. “Status of RAISE, the Rapid Acquisition Imaging Spectrograph Experiment.” Paper presented at the American Astronomical Society, SPD meeting No. 44, (#100.145), Bozeman, Mont., July 2013.

Livadiotis, G. and D. J. McComas, “Large-scale Quantization in Plasmas.” Paper presented in the Bulletin of the APS (Vol. 58, Plasma Physics, Abstract #GO6.00005), November 2013.

Livadiotis, G. and D.J. McComas. “Large-scale Quantization in Space Plasmas.” Paper presented in Proceedings of the 11th International Conference of the Hellenic Astronomical Society, Athens, Greece, September 2013.

Livadiotis, G. and D. J., McComas. “Understanding Kappa Distributions in Space Physics.” Paper presented in Proceedings of the 11th International Conference of the Hellenic Astronomical Society, Athens, Greece, September 2013.

Livi, R., J. Goldstein and J. Burch. “Adiabatic Heating of Hot Electrons in Saturn's Inner Magnetosphere.” Paper presented at SwRI, San Antonio, October 2013.

Livi, R., J. Goldstein and J. Burch. “Plasma Analysis in Saturn's Magnetosphere.” Invited talk at the University of California at Berkeley, Berkeley, Calif., November 2013.

Martinez, J. “Autonomous Vehicles: State of the Practice and Applications.” Paper presented at the ITS Florida 2013 Technical Forum, Orlando, Fla., October 2013, and at the Florida International University ITE Student Chapter Meeting, Miami, Fla., October 2013.

Martinez, J. “Mileage Based User Fees & Autonomous Vehicles: State of the Practice and Applications.” Paper presented at the Floridians for Better Transportation 2013 Transportation Summit, Coral Gables, Fla., July 2013.

Mason, R.L., Y.M. Chou and J.C. Young. “A Distribution-free Procedure for Removing Multivariate Outliers.” Paper presented at the 173rd Annual Meeting of the American Statistical Association, Montreal, August 2013.

McKenna-Lawlor, S., E. Kallio, R.A. Frahm, M. Alho, R. Jarvinen, S. Dyadechkin, C.S. Wedlund, T.L. Zhang and G.A. Collinson. “High Energy Particles and Mars and Venus: Phobos-2, Mars Express and Venus Express Observations and Their Interpretation by Hybrid Model Simulations.” Paper presented at the 2013 General Assembly of the European Geophysical Union, Vienna, (EGU2013-3040), April 2013.

McKinnon, W.B., M. Kirchoff and M. Bland. “Does Extension Play a Role in Ionian Tectonics? Potential Effects of Preexisting Bounding Faults, Local Brittle Failure and Sulfur Pore Pressure on Crustal Stresses.” Paper presented at the Division of Planetary Sciences 45th Annual Meeting (#501.06), Denver, Colo., October 2013.

Technical Staff Activities

Mitchem, S. "DC Fast Charging and Effects to the Grid." Paper presented at the Edison Electric Institute Transmission, Distribution and Metering Conference, Charleston, S.C., October 2013.

Mitchem, S. "Electric Vehicle Aggregation in the SPIDERS Microgrid." Paper presented at the Defense Energy Summit, Austin, Texas, November 2013.

Mitchem, S. "Electric Vehicles and the Grid." Paper presented at the Border Energy Forum XX, San Antonio, November 2013.

Mitchem, S. "Technology Innovations in the SPIDERS Microgrid." Paper presented at the Defense Energy Summit, Austin, Texas, November 2013.

Mitchem, S., D. Massie and P. Curtiss. "Application of Bi-directional Vehicle Aggregation in a Cyber Secure Microgrid Controller." Paper presented at the Ground Vehicle Systems Engineering and Technology Symposium, Troy, Mich., August 2013.

Mitchem, S. and J. Redfield. "Playing the Market — PEVs as Grid Resources." Paper presented at Plug-In 2013, San Diego, Calif., October 2013.

Moore, M. "Networking Military Vehicles." Invited presentation for panel on Convergence in Connectivity from Other Mobility Industries, SAE 2013 Electronic Systems for Vehicle Propulsion and Intelligent Vehicle Systems Symposium, Troy, Mich., September 2013.

Pickett, D., C. Manepally, P. Shukla, X. He, A. Ghosh, S. Stothoff and O. Pensado. "Technical Activities Supporting the U.S. Nuclear Regulatory Commission's Geologic Disposal Program." Paper presented at the Annual Meeting of the Geological Society of America, Denver, Colo., October 2013.

Popelar, C.F. and B.J. Bichon. "Bonded Composite DCB Testing and Mechanics." Paper presented at the ASTM D30 Meeting, Wichita, Kan., October 2013.

Puchot, A.R., A.C. Cobb, C.E. Duffer and G.M. Light. "Inspection Technique for Above Ground Storage Tank Floors Using MsS Technology." Paper presented at the QNDE Conference, Baltimore, Md, July 2013.

Ransom, D.L. and B. Winters. "Design, Development, and Testing of the Antares Pogo Suppressor." Paper presented at the AIAA 49th Joint Propulsion Conference, San Jose, Calif., July 2013.

Rathbun, J.A., R.M. Lopes, C. Tsang and J.R. Spencer. "Active Ionian Volcanoes from New Horizons: Combining Information from LOng Range Reconnaissance Imager (LORRI), Multispectral Visible Imaging Camera (MVIC) and Linear Etalon Imaging Spectral Array (LEISA) Data." Poster presented at the 44th Lunar and Planetary Science Conference (p.1418), The Woodlands, Texas, March 2013.

Rathbun, J.A., J.R. Spencer, C. Tsang and R. Lopes. "Io During the New Horizons Era: Insights from Ground-based and Spacecraft Data." Poster presented at the Division of Planetary Sciences 45th Annual Meeting, (#418.01), Denver, Colo., October 2013.

Samara, M. "Auroral Morphology and Implications for Generation Mechanisms." Invited talk before the International Association of Geomagnetism and Aeronomy, XIIth Scientific Assembly, Merida, Mexico, August 2013.

Saur, J., L. Roth, S. Duling, P.D. Feldman, D.F. Strobel, K.D. Retherford, M.A. McGrath, F. Musacchio and A. Wennmacher. "Auroral Processes at the Galilean Satellites." Paper presented at the European Planetary Sciences Congress, London, September 2013.

Smart, K.J., G. Ofoegbu, A.P. Morris, D.A. Ferrill and R.N. McGinnis. "Geomechanical Modeling of Hydraulic Fracturing: Importance of Mechanical Stratigraphy, Stress State and Pre-existing Structures." Paper presented at the 2013 Geological Society of America Annual Meeting, Denver, Colo., October 2013.

Trevino, G. "GPS Time Synchronization Cybersecurity Concerns." Paper presented at the Border Energy Forum XX, San Antonio, November 2013.

Trevino, G. and B. Abbott. "Solving PMU GPS Clock Security Vulnerabilities Using FPGA-based Flexible Intelligent Electronic Devices." Paper presented at the North American SyncroPhasor Initiative (NASPI) Work Group Meeting, Rosemont, Ill., October 2013.

Trevino, G. and J. Casey-Snyder. "Answering the GPS Synchronization Problem." Paper presented at National Instruments (NI) Week, Austin, Texas, August 2013.

Tsang, C. "Observations of Venus from a Commercial Reusable Suborbital Vehicle." Paper presented at the Division of Planetary Sciences 45th Annual Meeting, Denver, Colo., October 2013.

Tsang, C., C. Conrad, D. Durda, C.A. Olkin and S.A. Stern. "Commercial Jet Training in Preparation for Future Suborbital Spaceflights — Public Service Information." Poster presented at the 4th Next-Generation Suborbital Researchers Conference, Broomfield, Colo., June 2013.

Tsang, C., J.R. Spencer, K.L. Jessup, N. Cunningham, K.D. Retherford, L. Roth and J. Saur. "Io's Atmosphere after Eclipse: Evidence for Volcanic Support on the Jupiter Facing Hemisphere." Paper presented at the Division of Planetary Sciences (DPS) Meeting, Denver, Colo., October 2013.

Tsang, C., J.R. Spencer, K.-L. Jessup, N. Cunningham, K.D. Retherford, L. Roth and J. Saur. "Io's Post-eclipse Atmosphere: Evidence Against Atmospheric Collapse During Eclipse." Paper presented at the Division of Planetary Sciences 45th Annual Meeting (#501.02), Denver, Colo., October 2013.

Vinogradov, S.A., E. Laiche, J.L. Fisher and K. Krzywosz. "Development of a Fuel Rod Guided Wave Inspection System." Paper presented at the EPRI 10th International Conference on Nondestructive Evaluation in Relation to Structural Integrity for Nuclear and Pressurized Components, Cannes, France, October 2013.

Walker, J., S. Chocron, M. Moore, G. Willden and C. Anderson. "Adaptive Vehicle Make Design Performance Verification through Physics-based Simulation." Paper presented at the Society for Industrial and Applied Mathematics (SIAM) Conference on Geometric and Physical Modeling, Denver, November 2013.

Wilson, G. "Heat Transfer Evaluation by Small-scale Tube-in-Shell Simulator,. Paper presented at the (USA) International Symposium on Stability, Handling, and Use of Liquid Fuels (IASH), Rhodes, Greece, October 2013.

Wilson, G. and J. Bramer. "Maximizing Efficacy of Field Evaluations of Thermal Oxidative Stability." Paper presented at the (USA) International Symposium on Stability, Handling, and Use of Liquid Fuels (IASH), Rhodes, Greece, October 2013.

Wilson, G. and L. Zuziak. "Additive Effects on Alternative Fuels, Immediate and After Long-Term Storage." Paper presented at the (USA) International Symposium on Stability, Handling and Use of Liquid Fuels (IASH), Rhodes, Greece, October 2011.

Technical Staff Activities

Internal Research

Funded October 1, 2013

Bauta, W., T. Reeves and J. Bohmann. "Development of Novel Drugs for Influenza Based on Inhibition of HA Protein Function."
Brooks, D., E. DuPont and C. Mentzer. "Object Ranging and Classification Using 3-Dimensional Shapes."

Casey, R. "Signal Classification from a Sub-Nyquist Sampled Data Stream."

Durda, D., C. Tsang, E. Schindhelm, A. Stern and K. Ennico. "Validation of SwRI Suborbital Program Experiments Through Zero-G Flight Demonstration of Flight-Ready Hardware."

Feng, M. and Z.-G. Feng. "Development of a Low-Cost Method of Treating Flow-back Water from Hydraulic Fracturing."

Ghosh, A. and G. Walter. "Developing Methodologies for Gravity-Assisted Solution Mining."
Kastner, K. "Frontier Modification for Redhawk Integration."

Lemmer, S., M. Alban and D. Chambers. "Determination of Sensor Confidence Independent of External Data."

Libardoni, M. "Laser Thermal Desorption Multi-Bounce Time-of-Flight Mass Spectrometry for Organic Molecule Detection."

Ling, J. and J. Ong. "Development of a Novel Drug-Loaded Composite Scaffold as Bone Graft Substitute Using Advanced Material Technology."

Necsoiu, M. and R. McGinnis. "Landslide Investigations Using Satellite-Based Multi-temporal Synthetic Aperture Radar Techniques."

Nixon, J., K. Baldor and D. Van Rheeden. "Real-Time Digital Adaptive Beamformer."

Stillman, D., R. Grimm and R. McGinnis. "Testing Frequency-Dependent Geoelectrical Methods and Processing Techniques to Characterize Subsurface Ice."

Van Rheeden, D. and W. Music. "Exploiting Reference Signals for LTE Geolocation."

Walter, G. and M. Necsoiu. "Investigation Using Satellite-Acquired Multispectral and Synthetic Aperture Radar Data to Detect and Monitor Road Degradation from Heavy Truck Traffic."

Winters, G., M. Davis, G. Dirks, K. Retherford, T. Greathouse, R. Gladstone and P. Wilson. "Development of a Compact Raman Visible Spectrograph Design for a NASA Mars 2020 Rover Mission Instrument."

Young, E. "Modified Commercial-off-the-Shelf Telescopes as Inexpensive Balloon-Borne Payloads."

Patents

Alger, T. "Closed Loop Control of Fuel Viscosity in Multi-fuel Engine." U.S. Patent No. 8,583,346. November 2013.

Arps, James H. and K. Coulter. "Two-dimensional Composite Particle Adapted for Use as a Catalyst and Method of Making Same." U.S. Patent No. 8,524,364. September 2013.

Alley, K., R. Lopez and R. Somers. "Optical Imaging System for Unmanned Aerial Vehicle." U.S. Patent No. 8,581,981. November 2013.

Broerman, E.L. III, D. Deffenbaugh and R.J. McKee. "Multi-frequency Pulsation Absorber at Cylinder Valve Cap." U.S. Patent No. 8,591,208. November 2013.

Brun, K., M.A. Wilcox and E.L. Broerman III. "Energy Storage and Production Systems, Apparatus and Methods of Use Thereof." U.S. Patent No. 8,534,058. September 2013.

Burkes, J.M., P.T. Evans and C.J. Scribner. "Method to Construct and Physically Join Building Blocks into a Near-net Shaped Part Using an Interfacial Reaction-activation Mechanism." U.S. Patent No. 8,606,389. December 2013.

Cheng, X. and V.Z. Poenitzsch. "Aligned Polymers Including Bonded Substrates." U.S. Patent No. 8,557,956. October 2013.

Feng, M. and R. Zhan. "Ketone/water Mixtures for NOx Removal." U.S. Patent No. 8,535,627. September 2013.

Gingrich, J.W. and S.H. Almaraz. "EGR Distributor Apparatus for Dedicated EGR Configuration." U.S. Patent No.8,561,599. October 2013.

Hanson, H.S. and N. Nitin. "Wound Healing Sensor Techniques." U.S. Patent No. 8,535,282. September 2013.

Koci, C.P., D. Mehta and C.E. Roberts Jr. "Internal Exhaust Gas Recirculation for Stoichiometric Operation of Diesel Engine." U.S. Patent No. 8,594,909. November 2013.

McGehee, J. "Signal Detector Using Matched Filter for Training Signal Detection." U.S. Patent No. 8,619,909. December 2013.

Megel, M.C., M.A. Tussing and B.E. Westmoreland. "Cylinder Head Sleeve for a Fuel Injector or Ignitor of an Engine." U.S. Patent No. 8,544,450. October 2013,

Miller, M.A. "Plasmonic Structures for Mediating Chemical Transformation." U.S. Patent No. 8,574,407. November 2013.

Oxley, J.D. and J.J. Finkbiner. "Layer by Layer Modification of Microcapsules with Inorganic Materials." U.S. Patent No. 8,557,382. October 2013.

Oxley, J.D., J.J. Finkbiner and N.Nitin. "Fluorescent Monitoring of Microcapsule Oxidation." U.S. Patent No. 8,589,209. November 2013.

Necsoiu, D.M., J.N. Mitchell, J.O. Burkholder and W.T. Gressick. "White Light Optical Profilometer for Measuring Complex Surfaces." U.S. Patent No. 8,593,644. November 2013.

Roberts, C.E. Jr., "Control of NO/NOx Ratio to Improve SCR Efficiency for Treating Engine Exhaust." U.S. Patent No. 8,562,924. October 2013.

Rothbauer, R.J., C.E. Roberts Jr. and T.W. Ryan III. "Piston Bowl with Deflecting Features." U.S. Patent No. 8,555,854. October 2013.

Sasaki, S. "Diagnosis of Sensor Failure in Airflow-based Engine Control System." U.S. Patent No. 8,521,354. August 2013.

Waynick, J.A. "Mixed Base Phenates and Sulfonates." U.S. Patent No. 8,586,517. November 2013.

Wei, Q. "Sample System for Gaseous Emission Measurement." U.S. Patent No. 8,516,908. August 2013.

Willden, G.D., D.R. Poole Jr., B.A. Abbott and R. T. Green. "Sensor Network for Detecting Riverbed Scour." U.S. Patent No. 8,560,240. October 2013.

Zhan, R. and P.A. Weber. "Exhaust Aftertreatment Systems for Gasoline and Alternative-fueled Engines with Reduction of HC, CO, NOx and PM." U.S. Patent No. 8,522,536. September 2013.

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