July - September 2009

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TARDEC's 2009 Research and Development Achievement Award Winners

Collaboration Leads to Innovation

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US ARMY RDECOM

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Collaboration Leads to Innovation

Building Momentum Through Innovation and Leadership

At the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), our top priority is to deliver the most advanced technology solutions to improve the Nation's ground vehicle fleet. To do this effectively requires more than just hard work and dedication. It takes leadership, vision and the determination to execute that vision. To be truly successful in our efforts, we need to be able to lead, innovate, integrate and deliver. We believe so strongly that these are the four key elements to our success that they have become our motto.

So, what do these four words mean?

Lead
We lead by example. Each day we prove ourselves as leaders by taking initiative, driving positive change, making good decisions and doing all that we can to support our warfighters. Driven by the need to improve energy security for our troops and the Nation, we are at the forefront of bringing together the best minds in emerging power and energy technologies, including alternative propulsion, advanced batteries and alternative fuels. We lead the way in advancing unmanned ground vehicle capability. Our Intelligent Ground Systems technical directorate and the Joint Center for Robotics, collectively with the Robotic Systems Joint Project Office, comprise the Nation's unmanned ground systems center of gravity and develop robotic systems that can perform tasks deemed too dull, dirty or dangerous for our Soldiers.

We lead by influence. TARDEC's success is, in large part, based on the strength of its partnerships. We work with our partners across the Ground Systems Enterprise — the TACOM Life Cycle Management Command; Program Executive Offices and Project Managers; Research, Development and Engineering Command Technology Focus Teams; the Integrated Logistics Support Center; and U.S. Army Training and Doctrine Command — and collaborate with our industry and academic partners to ensure that we are addressing the present and future needs of our ground combat forces.

Innovate
For TARDEC, innovation is about creating opportunities where none previously existed. This means we cannot rest on our laurels. We must seek new approaches and consider different thought processes. We do this by fostering new relationships, developing dual-use capabilities with the automotive industry and finding new applications for integrating existing commercial products. Being the best means going above and beyond that which has been done before.

Integrate
TARDEC is the lead for ground systems integration for the Department of Defense. As such, we take a holistic approach to ensure the sum is greater than its parts. Successfully integrating technologies into a finished product requires a systems-level approach. Research, development, testing and analysis are all necessary, and no single element can be worked in isolation. All require integrated knowledge, processes and the relationships that make this level of systems integration possible. Since TARDEC plays the key role of systems integrator in the Ground Systems Enterprise, we set the tone for the way people think about advanced ground vehicle technologies.

Deliver
TARDEC's role — its responsibility — is to deliver advanced, integrated technology solutions to the Soldiers who need them, quickly. Achieving this goal helps ensure our Army is the most lethal, sustainable and survivable fighting force in the world. Ultimately, this is the reason we strive for uncompromising standards of excellence in maintaining the Army's technical superiority. Our Nation's warfighters depend on us to provide overmatch capability to successfully complete their missions, worldwide.

We live by these four principles every day. They are part of an overall effort currently underway to transform our image, and position TARDEC as the national asset it is. Other elements of this transformation include launching this magazine and unveiling a new brand that is more reflective of TARDEC's ongoing commitment to forward momentum and national energy initiatives. But, more importantly, we have a renewed commitment to our warfighters to lead, innovate, integrate and deliver the best ground combat vehicle systems in the world.

Dr. Grace M. Bochenek
TARDEC Director

Lead

[to be first; to direct the operations, activity or performance of]

TARDEC leads by creating opportunities where none previously existed. The work we do today sets the standard for tomorrow and beyond.

Innovate

[to make changes; to take something and put it together in a new way]

We provide and sustain the safest, most advanced and efficient ground vehicle systems and equipment for our Soldiers by bringing together nontraditional partners to create unexpected new capabilities. We then turn these capabilities into integrated engineering solutions that lead to innovative technology advancements. Innovation is achieved through People, Processes, Technology and Knowledge.

Integrate

[to form, coordinate or blend into a functioning or unified whole]

We have the technological knowledge and engineering expertise to bring all the pieces together and get them to work as one. We take a holistic, system-of-systems approach — People, Processes, Technology, Knowledge — ensuring that the whole is always greater than the sum of its parts.

Deliver

[to produce or exceed the promised, desired or expected results]

We deliver the most technologically advanced integrated solutions and sustainment expertise possible so that our Soldiers are protected by the best vehicle systems imaginable. We are the critical knowledge repository for the Ground Systems Enterprise.

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On the Cover: The cover design was created by BRTRC graphic designers Nojae Kim and Rhonda Wilt using an original photo shot by SGT Jason W. Fudge on location in Camp Taqaddum, Iraq. The photo image depicts a Cougar H 4x4 Mine Resistant Ambush Protected (MRAP) vehicle — which is representative of the entire MRAP vehicle fleet — deployed to support *Operations Enduring* and *Iraqi Freedom*. This image was selected because it depicts the dull, dirty and dangerous operational environments and weather and terrain conditions in which our Soldiers and their vehicle systems and equipment must operate. The computer drawings represent some of the new technology being integrated onto these vehicle platforms, which will be profiled in this edition of *accelerate* Magazine.

These integrated engineering solutions were developed for the MRAP vehicle fleet and other combat vehicle platforms by the Ground Systems Enterprise's (GSE's) engineers and their partners in the TACOM Life Cycle Management Command and supporting depots; Research, Development and Engineering Command and its supporting laboratories and R&D centers; Program Executive Office (PEO) Combat Support & Combat Service Support; PEO Ground Combat Systems; the Integrated Logistics Support Center; and the GSE's industry, academic and governmental partners.

Our theme, "Collaboration Leads to Innovation," is a testament to the expertise, collective knowledge and solution-centric capabilities this enterprise brings to systems integration. Because of this professional dedication and unconditional commitment to our warfighters, the whole is truly greater than the sum of its individual parts. TARDEC is proud to be a contributing member of the GSE, and this editorial team takes great pride in telling the enterprise's story.

Michael I. Roddin
Editor-in-Chief

RDECOM TARDEC

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FEATURES

FEATURES (CONTINUED)

Linking the Enterprise — Power in Collaborative Performance

accelerate Magazine showcases the latest developments and engineering solutions available from the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), giving you an in-depth look at the latest inventions, integrations and tactical vehicle improvements TARDEC and its enterprise partners have produced or are working through development or testing. In this and subsequent issues, ***accelerate*** will take a more community-focused approach to provide timely, relevant information about the exceptional work being performed by all enterprise partners in support of our Soldiers, their vehicles and equipment.

To successfully execute its mission, TARDEC leverages the power and capabilities of the entire Life Cycle Management Command (LCMC). Each technology discussed in this issue is a collaborative effort with support coming from the TACOM LCMC; Research, Development and Engineering Command and its assigned laboratories and R&D centers; the Program Executive Offices and their assigned Product/Project Management Offices; and members of industry, academia and other government agencies that contribute to product development success, technology advancement and expertly engineered solutions. Without our partners' dedicated support with research, materiel management, technology integration and Soldier interface, TARDEC could not provide America's warfighters the level of technological superiority and overmatch capabilities on which they depend.

On behalf of TARDEC Director Dr. Grace M. Bochenek, I take great pride in announcing this year's ***Army Research and Development Achievement*** (RDA) ***Award*** winners. TARDEC associates, and their collective partners, won five 2009 RDA Awards. This issue will profile those five awards, bringing you up close and personal to these product, research and technology developments. A brief explanation of the advancements achieved is below. In recognizing this year's outstanding scientific and technical achievements, Dr. Thomas H. Killion, Deputy Assistant Secretary of the Army (Research and Technology)/Chief Scientist, remarked, "These scientists and engineers distinguished themselves through their proven scientific and technical excellence or leadership. Their contributions promise to improve the Army's capability and enhance our national defense."

Lightweight Vehicle Underbody Protection System (LVUPS) Increases Crew Protection. In 2008, TARDEC Prototype Integration Facility (PIF) engineers designed, fabricated and demonstrated the LVUPS, which exceeds the blast threat requirements for blast/fragmentation protection thresholds on lightweight tactical vehicles. The Program Executive Office Combat Support and Combat Service Support's Product Manager Light Tactical Vehicles wanted TARDEC involved from the beginning, which would give both organizations the opportunity to gather data and design information to influence future production.

Moving Future Convoy Operations with Convoy Active Safety Technologies (CAST). CAST is a low-cost, platform-independent, kit-based, autopilot-like, autonomous following system for the tactical wheeled vehicle fleet. TARDEC developed CAST with support from the Army Research Laboratory Human Research Engineering Directorate and the U.S. Army Training and Doctrine Command's Combined Arms Support Command.

Finding Solutions Before the Rubber Meets the Road. Replacing broken track on an Abrams Main Battle Tank or a Bradley Fighting Vehicle is complex, expensive and dangerous work. Track is the second-highest cost driver on Army vehicles. If track fails in the field, an entire platoon must be mobilized to protect the vehicle and crew, putting U.S. Army Soldiers at risk in hostile areas.

JP-8 Ignition Database and Evaporation Methodology Spark Further Research. Though there have been numerous ignition studies on diesel fuel and oil since the Korean War, TARDEC Ground Vehicle Power and Mobility team members developed the first explicit comparison between modern jet propellant 8 (JP-8) and diesel fuel. These studies led to a first-of-its-kind JP-8 ignition database and a methodology for estimating JP-8 evaporation rates.

TARDEC and ARL Associates Develop Guarded Mobility System. The Army Research Laboratory (ARL) submitted this winning nomination for work in collaboration with TARDEC to develop a set of control aids to improve mobility in the Army's indirect vision, drive-by-wire ground vehicle systems. ARL and TARDEC addressed the problem of degraded operator perception and examined novel forms of guarded mobility, which concurrently integrate operator and autonomous control to prevent collisions.

Also in this issue, TARDEC's engineers and associates explain how they partnered with other organizations to deliver specific technologies to our warfighters and how those partnerships made their work possible.

Researchers Developing Fire-Resistant Fuel. Military vehicle fires, fed by onboard fuel, remain a serious threat to life and equipment. After 20 years of research, the Fuels and Lubricants Laboratory at the Southwest Research Institute campus in San Antonio, TX, has developed a self-extinguishing diesel fuel that can potentially revolutionize logistics capabilities and improve vehicle and Soldier survivability.

Hybrid-Electric (HE) Drive Knowledge Expanded Through Validation Testing. A new assessment program developed at TARDEC may improve the speed with which the Army integrates HE power systems into its future vehicle fleets.

Ergonomically and Safely Integrating Communication Equipment. In creating the One System Remote Video Transceiver (OSRVT) A-Kits, TARDEC solved several technical challenges. The A-Kits are an installation kit for the OSRVT, which allows remote communication with unmanned aerial vehicles. The A-Kit provides warfighters with a cost-effective, innovative mount for integrating needed equipment on Stryker vehicles.

Minimizing the Use of Hexavalent Chromium (Cr^{6+}). Anti-corrosion is a serious design consideration for Department of Defense (DOD) weapon systems and platforms. However, the traditional method of preventing corrosion, Cr^{6+}, may cause cancer. TARDEC's Materials and Environmental Team has found a potential solution that will eliminate Cr^{6+} from ground systems components and parts.

Vehicle Powertrain Engineering and Machining Process Optimization. Today's military vehicles, as well as civilian vehicles of all types, need improved engineering designs and manufacturing processes for these vehicles' powertrains to achieve four critical objectives: maximizing horsepower-to-weight ratios and fuel efficiency and minimizing emissions and the potential for leakage of combustion gasses and fluids that leads to engine or transmission failure.

This Wolf Has Claws — Quick Solutions Lead to Technologies That Protect Warfighters. In response to a focused threat, TARDEC's Mechanical Countermine Team developed a Wire Neutralization System that included the Wolf Claw, Wolf Tail and Wolf Collar devices. These devices increase Soldier and vehicle survivability when encountering either command or tripwire-operated improvised explosive devices.

Preparing Soldiers for Dire Rollover Situations. In conjunction with a Joint Operational Needs Statement from the U.S. Army Forces Command, Program Executive Office for Simulation, Training and Instrumentation and Red River Army Depot, TARDEC rapidly developed and tested the Mine Resistant Ambush Protected (MRAP) vehicle Egress Trainer.

Engineers Work Around the Clock to Save Lives. TARDEC PIF engineers and technicians spearheaded an effort with the Edgewood Chemical Biological Center and Aberdeen Test Center to provide a solution to a Secretary of the Army-directed challenge within 72 hours for an MRAP gunner restraint system.

Door Assist System Allows Easier Entry Into Heavily Armored Vehicles. The Electric Door Assist System (EDAS) is an integrated electric device that can be used on MRAP Expedient Armor Program (MEAP) vehicles. EDAS, developed by TARDEC's PIF, was designed to assist vehicle operators and passengers in opening heavily armored doors. The new system allows Soldiers to open and close the power-assisted doors easily by simply operating switches.

Blast Simulation Software May Reduce Costs, Save Lives. A new computational tool developed by TARDEC may prove instrumental in protecting Soldiers from landmine blasts. An advanced computational modeling and simulation tool kit was developed to provide an accurate, detailed analysis of the impact that landmine or improvised explosive device blasts have on the Army's ground vehicle fleet.

Sensors May Be Key to Better Protection. Small transducers may play a crucial role in protecting Soldiers from deadly attacks. Researchers at TARDEC have developed new technology that delivers accurate, real-time vehicle armor analysis. The technique uses sensors embedded in a vehicle's armor plates and has been in development since Soldiers requested it in 2007.

Condition-Based Maintenance — High-Tech Diagnostic Cleat Detects Mechanical Problems in Vehicle Suspension Systems. Spiraling operation and support costs for military weapon systems accounted for approximately 60 percent of the $500 billion DOD budget in 2006. To better ensure readiness and decrease these costs, the Army is developing health monitoring technologies for condition-based maintenance.

Our editorial team is committed to delivering high-quality, informative articles and providing an intellectual forum that will establish positive dialogue between LCMC members. Our pledge is to continue to tell that story, but we need your help. Send your article ideas, queries and Letters to the Editor to us at: **accelerate@conus.army.mil**. As a community we can continue to live up to our commitment to Lead • Innovate • Integrate • Deliver.

Michael I. Roddin
Editor-in-Chief

Researchers Developing Fire-Resistant Fuel

Bill Dowell

How different would the world be today if the World Trade Center's twin towers had not burned and collapsed following the Sept. 11, 2001, terrorist attacks?

"The towers really did amazingly well," Dr. W. Gene Corley, a structural engineer who led the World Trade Center Building Performance Study has been quoted as saying. "The terrorist aircraft didn't bring the buildings down. It was the fire which followed. It was proven that you could take out two-thirds of the columns in a tower and the building would still stand."

Chad Vollmer unloads a new fuel injection system being tested for the U.S. Navy on Detroit Diesel engines. (U.S. Army TARDEC photos by Bill Dowell.)

Much has been debated about what could, and should, be changed to build a terrorism-proof building. Most of those discussions centered on the fireproofing, which was said to have been "blown off" by the planes' initial impacts. But, for researchers at the U.S. Army Tank Automotive Research, Development and Engineering Center's (TARDEC's) Fuels and Lubricants Research Facility at the Southwest Research Institute (SwRI) campus in San Antonio, TX, the focus has been the fire and what intensified and nourished it.

SwRI's explorations have led them to fire-resistant fuel. "To me, when I first heard of it, I thought it was the craziest thing," exclaimed Fuels and Lubricants Research Facility Director Steve Marty. "What do you mean a fuel that doesn't burn? That seems idiotic."

Military vehicle fires, fed by onboard fuel, remain a serious threat to life and equipment.

Perhaps Benjamin Franklin heard similar comments when people saw him flying a kite in an electrical storm. Like Franklin, the men and women at the Army laboratory will not be deterred. They are reminded of how important their mission is every day. The Brooke Army Medical Center burn unit, the only one of its kind serving the Nation's military, is just a short drive from SwRI. "It hits home," said Marty. "We see a lot of Soldiers come back that didn't get hit by shrapnel or bullets — just burns."

Military vehicle fires, fed by onboard fuel, remain a serious threat to life and equipment. Weapon attacks sometimes ignite the fuel, often destroying the vehicle and reducing the likelihood of crew rescue or escape. After 20 years of research, the lab has developed a self-extinguishing diesel fuel. The table on the following page outlines the history of this research.

Self-Extinguishing Fuel Chemistry

The self-extinguishing, fire-resistant fuel TARDEC developed uses water as an additive. Most diesel mechanics are cringing at this idea, because the greatest enemy of diesel fuel injection components is water. If water enters the fuel system, it rapidly wears and rusts steel parts.

Cheresa Calhoun weighs residue left from impurities in a fuel experiment at TARDEC's Fuels and Lubricants Research Facility at SwRI in San Antonio, TX. The facility is a government-owned, contractor-operated laboratory.

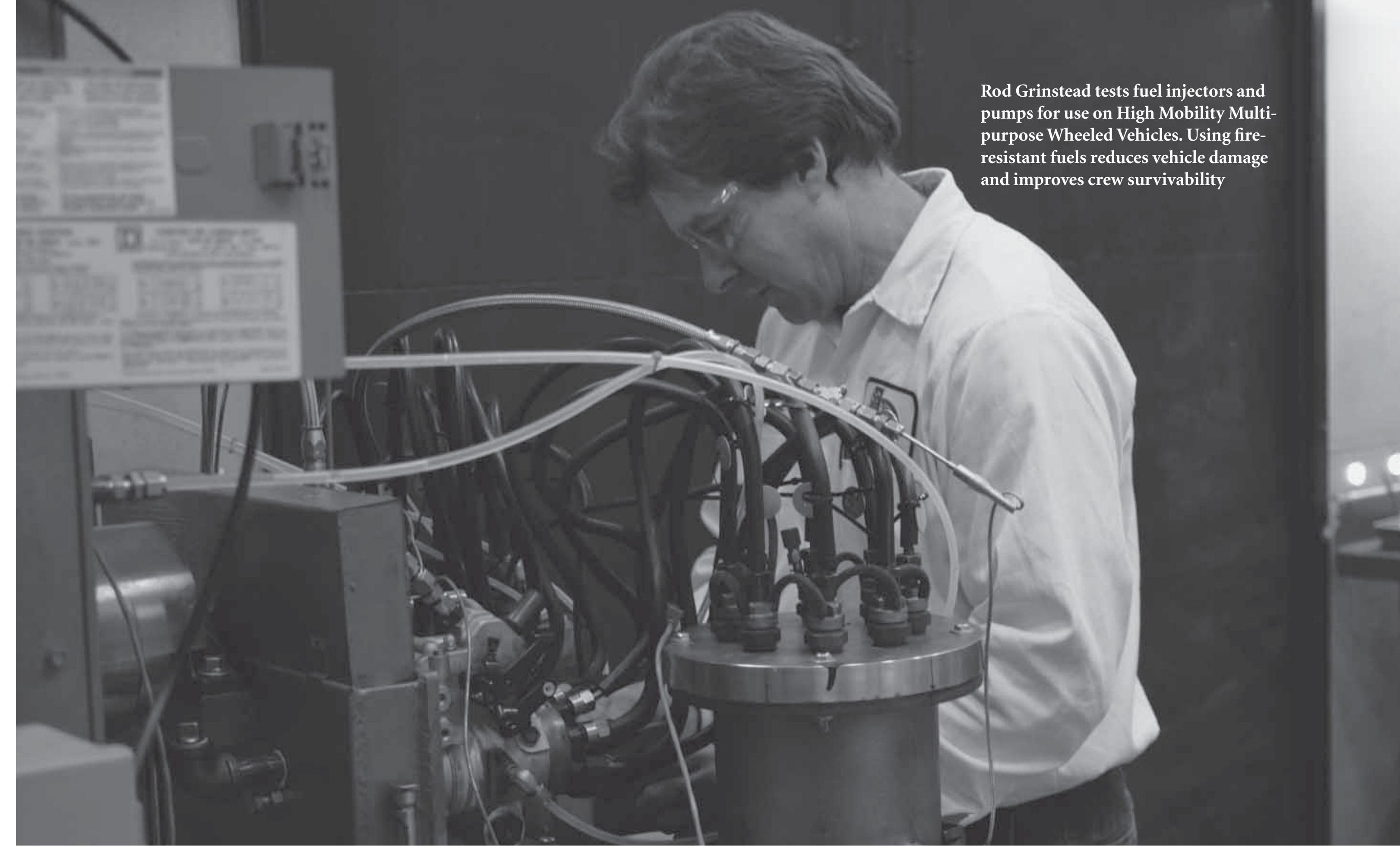
Fire-Resistant Fuel Development

DATE	TECHNOLOGY	STATUS
~ 1979–1986	Halogen blends	Engine corrosion (2 percent brumochloromethane)
	Inversion emulsions	Excessive viscosity
	Water-in-fuel emulsion	Fuel stability problems
	Water-in-fuel + anti-mist	1979 IR-100 award U.S. patent-4173455
~ January 2006	Explore JP-8 blending evaluation	Initial testing unsuccessful
~ May 2006	Explore fire-resistant fuel with JP-8	Successfully reestablish baseline blending and flammability testing
~ April 2007	Explore: JP-8 blending stability	Delay establishing gun system
	Engine performance	Established test facility
	Flammability	Defined blending parameters
~ March 2009	Finalize blending technology	Underway
	Conduct large-threat vulnerability testing	
	Investigate vehicular field testing	

However, the water in TARDEC's fire-resistant fuel is suspended as stable microscopic droplets. The researchers discovered as little as five percent of the emulsified water provides fire resistance to self-extinguish pool fires. Combining the water and fuel hydrocarbons is a relatively easy process, according to Bernie Wright, Project Manager for the Fire-Resistant Fuel Program, who has worked on the program in various capacities since its beginning. While the emulsified fuel extinguishes the fire after ignition, an initial fireball can cause burns and vehicle damage. "A mist-control additive suppresses ignition of fuel spray from fuel tank or fuel line ruptures," explained Wright. "The combination of the emulsion and mist-control additives practically eliminated fuel-fed fires in ballistics tests we have carried out."

SwRI's engine testing has shown these water-containing diesel fuels are compatible with current military engines. "The vehicle's power and range is slightly reduced because of the water content," stated Wright. "But the amount of water is low, so the impact is low. Other than that, the engines operate normally." Water-based emulsions reduce

Claudia Valenzuela performs an interfacial tension measurement to assess how well fuel will "shed" water in water separation filters commonly used on many diesel vehicles.



Rod Grinstead tests fuel injectors and pumps for use on High Mobility Multipurpose Wheeled Vehicles. Using fire-resistant fuels reduces vehicle damage and improves crew survivability

nitrogen oxide, sulfur oxides and particulate emissions.

"One Fuel Forward" Policy's Impact on Fire-Resistant Fuels

According to the Defense Department's "One Fuel Forward" policy, the military is supporting and developing logistic fuels, such as kerosene-based fuels like jet propellant 8 (JP-8). Nearly all tactical ground vehicles and generators use JP-8 in their diesel engines. JP-8 is the preferred fuel for the M1 Abrams series of main battle tanks that are powered by a gas turbine engine.

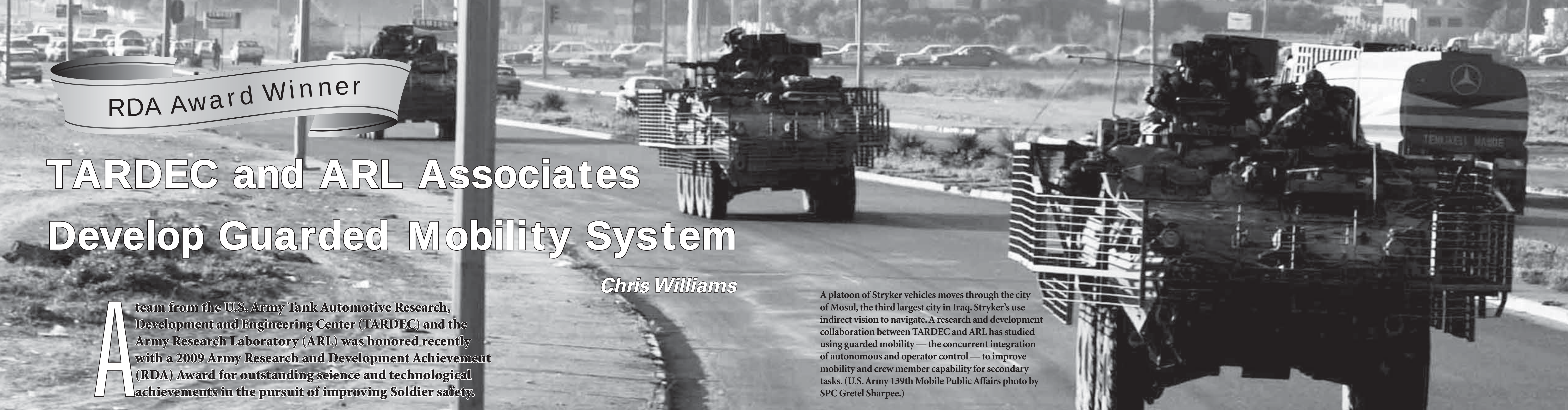
Because of the "One Fuel Forward" policy, the military's single fuel needs to be fire-resistant to allow it maximum flexibility and protect warfighters. JP-8, particularly, was difficult to make fire-resistant. "The higher volatility, or lower flash point, of JP-8 is the biggest hurdle," Wright explained. "The refining process can really affect the flash point of JP-8. This can cause a large range of flash points, and formulations for the right combinations must be developed and evaluated." The correct amount of fuel, stabilizing agent and water quality must be engineered to ensure a stable and effective mixture. JP-8's volatility challenges need further testing and development to make sure no issues remain.

"The combination of the emulsion and mist-control additives virtually eliminated fuel-fed fires in ballistics tests we have carried out."

After JP-8's volatility, the next hurdle, according to Marty and Wright, is distributing the fuel. "This will require a systems approach to the military fuel supply system," Marty stated. "Where and how the fuel will be deployed must be evaluated."

One idea for deploying the fuel is to use it in high-threat forward operating locations only. Blending stations would be co-located with forward area refueling points, and could mix and dispense treated fuel to those vehicles operating in high-threat areas. "That is the notion we have at this point in time," Marty said. "But we need to make sure that whatever we do, it works well the first time. Ultimately, the driver behind this is how the Quartermaster operators want to deploy the material."

Bill Dowell is a Senior Public Affairs Specialist with BRTRC and provides contract support to TARDEC's Strategic Communications team. He spent 23 years in the U.S. Air Force as a Public Affairs Specialist and retired as a Master Sergeant in 2006. He is a Defense Information School graduate and attends Jones International University.



RDA Award Winner

TARDEC and ARL Associates Develop Guarded Mobility System

Chris Williams

A platoon of Stryker vehicles moves through the city of Mosul, the third largest city in Iraq. Stryker's use indirect vision to navigate. A research and development collaboration between TARDEC and ARL has studied using guarded mobility — the concurrent integration of autonomous and operator control — to improve mobility and crew member capability for secondary tasks. (U.S. Army 139th Mobile Public Affairs photo by SPC Gretel Sharpee.)

A team from the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) and the Army Research Laboratory (ARL) was honored recently with a 2009 Army Research and Development Achievement (RDA) Award for outstanding science and technological achievements in the pursuit of improving Soldier safety.

TARDEC Electrical Engineers Victor Paul and Jillyn Alban, ARL Mechanical Engineers James Davis and Patrick Nunez, and ARL Supervisory Research Psychologist Dr. Kaleb McDowell all were recognized for their contributions in developing a set of control aids to improve mobility in the Army's indirect vision, drive-by-wire ground vehicle systems.

Army 1LT Adam Miles navigates his Stryker vehicle through the narrow streets of Buhriz, Iraq. Developments by the TARDEC/ARL team would allow Soldiers like Miles to navigate more effectively in the field and complete missions safely and efficiently. (U.S. Air Force photo by SSGT Stacy L. Pearsall.)

Improving Operator Perception

One issue the team addressed was the problem of degraded operator perception, which can result from indirect systems. To address this problem, the associates examined novel forms of guarded mobility, which concurrently integrates operator and autonomous control to prevent collisions and increases the operator's capability with respect to secondary tasking. The team's previous efforts have shown that integrating autonomous mobility on a manned ground vehicle can lead to decreased mission time, faster operator reaction times, increased operator multitasking while under vehicle motion and lower subjective operator workload. In 2007, TARDEC and ARL began developing a set of 10 aids for an integrated guarded mobility system. The following year, an integrated system for guarded mobility was demonstrated, and details of the 10 aids were transitioned to vehicle integrators.

The team also investigated time lags associated with manned and unmanned vehicles' indirect vision, semiautonomous and multimis-

"This work will serve as a springboard to the development of future ground vehicle crew stations as vehicle designers look to address the problems associated with indirect vision driving systems and vehicle crew member workload."

sion crew station control. Time lag is the delay in the control system between operator and input observation of the input's result, and direct observation revealed instabilities in many advanced vehicle control systems. In researching the impact that such lags have on human performance, the team discovered that predictive displays currently used in robotics applications could be developed as a potentially lower-cost solution to the problem. TARDEC began developing such a display in 2008. The effort led to a lag variability mitigation study conducted by ARL in 2008, which examined lag impact and revealed that a predictive display's presence improved speed, lane-following ability and operator workload.

Collaboration Key to Success

TARDEC and ARL's research and development will be used to develop systems that will keep Soldiers safe and increase their efficiency in the field. "This work will serve as a springboard to the development of future ground vehicle crew stations as vehicle designers look to address the problems associated with indirect vision driving systems and vehicle crew member workload," stated Paul.

"[This award] not only recognizes the work that was submitted in the award package but acknowledges a successful partnership between ARL and TARDEC."

This is not the first time these TARDEC and ARL team members have been recognized for their work. In 2008, Davis was awarded with a certificate of achievement. McDowell and Nunez received a 2007 RDA Award. However, the 2009 honor has special significance for the team, as it recognizes the work done by Nunez, who died in 2007. As the Crew Station Technology, Development, Integration and Evaluation Program Manager and Driving Control and Local Situational Awareness Team Leader, Nunez codeveloped the overarching concepts for guarded mobility and laid the groundwork for the successful work recognized in the 2009 RDA Award. "I am very proud to receive this award as a member of the TARDEC, ARL [Human Research and Engineering Directorate] team," Paul acknowledged. "It not only recognizes the work that was submitted in the award package but acknowledges a successful partnership between ARL and TARDEC. I am most grateful that the award recognizes the work that Pat Nunez contributed right before his passing."

TARDEC Electrical Engineer Patrick Nunez served as Crew Station Technology, Development, Integration and Evaluation Program Manager and Driving Control and Local Situational Awareness Team Leader. Before his death in 2007, Nunez codeveloped the overarching concepts for guarded mobility and laid the groundwork for the successful work recognized in the RDA award. (U.S. Army TARDEC photo.)

Chris Williams is a Writer/Editor with BRTRC and provides contract support to TARDEC's Strategic Communications team. He has a B.A. in communication from Wayne State University in Detroit and has previously written for *The Source* newspaper in Shelby Township, MI, and *The Macomb Daily* and C & G Newspapers in Macomb County, MI.

RDA Award Winner

JP-8 Ignition Database and Evaporation Methodology Spark Further Research

Matthew Sablan

An Airman motions to a fuel truck on Ali Air Base, Iraq, during an offload of 64,000 gallons of JP-8 fuel. Thanks to the new technology developed by TARDEC, JP-8's ignition properties will be better understood. (U.S. Air Force photo by A1C Jonathan Snyder.)

The accelerate Magazine Editorial staff would like to congratulate Laura Hoogterp, Dr. Pete Schihl and Michael Radic and their team's efforts on winning the 2009 Army Research and Development Achievement Award for the High-Pressure Jet Propellant-8 Evaporation and Combustion Variances in Comparison to Diesel Fuel Number 2 project.

Though there have been numerous ignition studies on diesel fuel and oil since the Korean War, U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) Ground Vehicle Power and Mobility (GVPM) team members developed the first explicit comparison between modern jet propellant 8 (JP-8) and diesel fuel. These studies led to a first-of-its-kind JP-8 ignition database and a methodology for estimating JP-8 evaporation rates.

Soldiers from the 101st Airborne Division (Air Assault) deliver JP-8 fuel to a forward operating base in Iraq. The Army is steadily moving to one fuel on the battlefield for all ground combat systems and airframes. (U.S. Navy photo by P3 Shawn Hussong.)

To do so, the team used single-cylinder engine experimentation and constant volume bomb experiments and leveraged data developed by a contractor under an Army Research Office grant. It is anticipated that this new JP-8 database will serve as a critical source for further developing engineering models for assessing JP-8's impact on diesel engines designed to operate on diesel fuel 2 (DF-2) based on the results reported at the 2008 Army Science Conference (ASC), held Dec. 1–4, 2008, in Orlando, FL. Ignition data from a High Mobility Multipurpose Wheeled Vehicle (HMMWV) pre-chamber diesel engine application demonstrated that at ignition temperatures above 1,100 Kelvin (K), physical processes — liquid break-up, evaporation, mixing and wall impingement — are dominant during the ignition delay period. "In the research literature, you couldn't find any ignition data for JP-8 in diesel engines," stated TARDEC Senior Research Engineer Dr. Pete Schihl. "Years ago we were given an ignition delay issue to solve, and when we searched published literature for JP-8 ignition data, we came up empty. We said, 'We really need to generate such a data set.'"

It is anticipated that this new JP-8 database will serve as a critical source for further developing engineering models for assessing JP-8's impact on diesel engines designed to operate on DF-2.

To collect this data and further study the ignition instability problems, the GVPM team began developing a JP-8 ignition database and methodologies for estimating JP-8 evaporation rates and assessing potential pressure increase rate issues associated with JP-8 use in commercial diesel engines. Currently, JP-8 is the primary military ground vehicle fuel, which is converse to commercial applications that specifically use ultra-low-sulfur DF-2. Accordingly, there is little industry interest in better understanding JP-8's ignition and combustion behaviors in commercial diesel engines.

The JP-8 Ignition Database

The GVPM engine team's ignition database is the first to closely examine JP-8 combustion characteristics in U.S. Army-relevant compression ignition engines, an important first step toward predicting the start of combustion in diesel engines. The database exhibits variance in ignition delay between diesel fuel and JP-8 based on four factors: nozzle geometry, engine cylinder operating temperature and pressure, and injection velocity. To date, American engine combustion researchers have predominately focused on further understanding diesel fuel's ignition and combustion behaviors, given the commercial focus on addressing the Environmental Protection Agency's current and future engine exhaust emission standards.

TARDEC's team has been responsible for the JP-8 ignition database's experimental development — which includes a 450-data-point experimental matrix — through careful experimentation in a single cylinder research engine used in this study. Additionally, a TARDEC engineer spent one month as a visiting research assistant at the Sandia National Laboratory Combustion Research Facility (CRF) conducting constant volume bomb experiments to determine JP-8's ignition delay and evaporation behavior under simulated engine-like operating conditions.

The GVPM team's ignition database is the first to examine compression ignition engines, an important first step toward predicting the start of combustion in diesel engines.

TARDEC's findings were used to support the U.S. Navy in assessing potential combustion instability issues with a small-bore diesel engine by studying the impact of fuel timing, nozzle design and fuel type on cylinder pressure rise rate. This new JP-8 database will serve as a critical source for further developing engineering models for assessing JP-8's impact on diesel engines designed to operate on DF-2. For example, the JP-8 ignition database demonstrated that the cetane number— a measure of ignition quality analagousto octane that's used in gasoline cars —is the controlling chemical property for determining ignition delay along with injection velocity, which varies depending on the fuel density and viscosity.

Thus far, the Navy has used the output from the GVPM team's research efforts in assessing the combustion strategy of a small-bore, automotive-based diesel engine for an unmanned aerial vehicle required to operate on heavy fuels. The research also has assisted Program Manager (PM) Heavy Equipment Recovery Combat Utility Lift and Evacuation System (HERCULES), PM Light Tactical Vehicle and TARDEC's engine development PMs in addressing recent JP-8 combustion issues in their respective platforms.

The last output from this JP-8 ignition database and the evaporation rate model was the estimation of cylinder pressure rise rate based on a first-law analysis during a snapshot of time around the premixed burn profile's peak. The three phenomena modeled were: combustion rate, expansion or compression rate and heat transfer loss to the surrounding combustion chamber surfaces. The most difficult of these three phenomena is the combustion rate, and the JP-8 database was used to estimate the combustion rate contribution by relating the predicted evaporation rate to the experimentally determined peak premixed burn rate.

Two Soldiers close a block valve to a 50,000-gallon JP-8 fuel bladder at Kirkuk Regional Air Base, Iraq. This bladder farm provides enough fuel for five surrounding forward operating bases as well as Army and Air Force operations here at Kirkuk. TARDEC GVPM team members developed the first explicit comparison between modern JP-8 and diesel fuel. (U.S. Air Force photo by SA Bradley A. Lail.)

The peak premixed burn rate scales with evaporated fuel during the ignition delay according to nozzle size and possibly injection velocity. Therefore, pressure rise rate differences between JP-8 and diesel fuel are a mild to strong function of the evaporation rate, depending on the ignition temperature. "This is a first step toward putting our arms around these issues with JP-8," Schihl explained. Predicting pressure rise rate differences between JP-8 and diesel fuel in modern diesel engines allows for predicting potential combustion instability issues if engines are subjected to low-ignition-quality JP-8 with a sufficiently low temperature at the 90-percent volume distillation point, called the T90 point. Schihl noted, "The end game for this database is to allow these engine models to be used as design aids and help solve any future combustion or ignition issues."

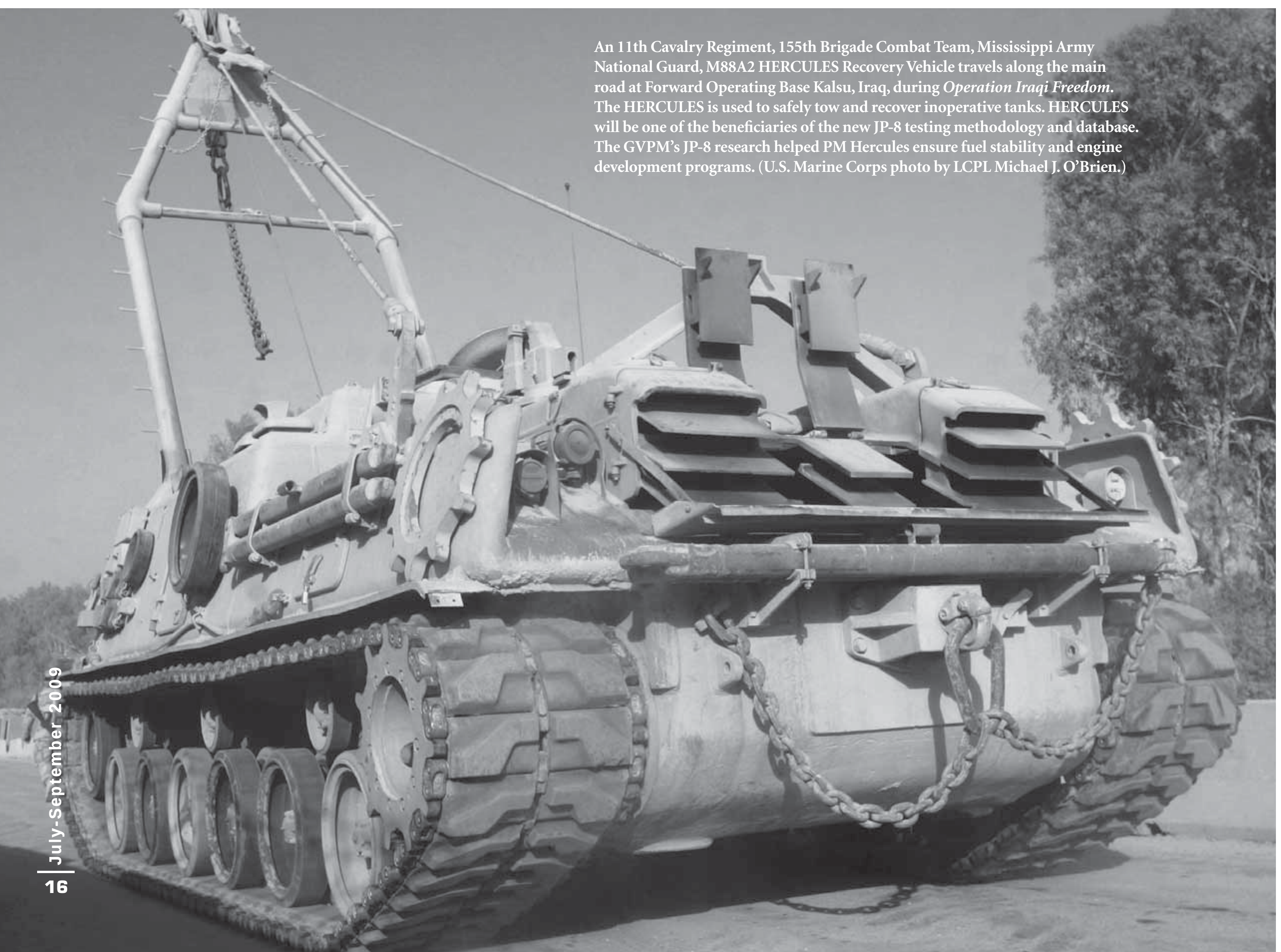
Evaporation Rate Impact on Assessing Potential Pressure Increase Rate Issues

The team's two models estimate JP-8 evaporation rates and create a methodology to assess potential pressure rise rate issues, allowing for the assessment of such variables as spray evaporation, ignition and fuel timing on the combustion behavior. The Army currently uses predominately JP-8 in the field, but most diesel engine combustion systems operate on diesel fuel. The evaporation model is part of a process to analyze and predict potential higher pressure rise rates in diesel engines when using JP-8. Higher rates can lead to premature engine failures. When the fuel vaporizes and ignites late, the associated higher burning rates lead to higher combustion pressures thus a larger 'bang'.

Schihl remarked, "At too high of peak firing pressures and pressure rise rates, you get engine failure from the inside out, usually starting with the piston area." Parts begin eroding, due to higher pressure rise rates in the vicinity of the piston bowl edge, which leads to greater damage and engine failure. Understanding JP-8's evaporation behavior is critical to address this problem.

The team post-processed in-cylinder pressure measurements to determine the global burning rate of each fuel using NETHEAT, an engine combustion analysis code developed by TARDEC. Subsequent analysis of the complete engine and bomb data for assessing ignition and evaporation variances between JP-8 and diesel fuel was presented by Schihl and Mechanical Engineer Laura Hoogterp in an award-winning 2008 ASC paper "On the Ignition and Combustion Variances of Jet Propellant-8 and Diesel Fuel in Military Diesel Engines."

The methodology developed for estimating JP-8's evaporation rate extrapolated initial diesel fuel evaporation modeling groundwork completed by the Sandia CRF. TARDEC's team created this model by developing a methodology using a mass weighting scheme — the mean evaporation coefficient approach — to determine JP-8's evaporation coefficient based on the T90 point. The methodology used dodecane, tetradecane and hexadecane as pure component surrogate mixture constituents.



An 11th Cavalry Regiment, 155th Brigade Combat Team, Mississippi Army National Guard, M88A2 HERCULES Recovery Vehicle travels along the main road at Forward Operating Base Kalsu, Iraq, during *Operation Iraqi Freedom*. The HERCULES is used to safely tow and recover inoperative tanks. HERCULES will be one of the beneficiaries of the new JP-8 testing methodology and database. The GVPM's JP-8 research helped PM Hercules ensure fuel stability and engine development programs. (U.S. Marine Corps photo by LCPL Michael J. O'Brien.)

TARDEC's team has been responsible for the JP-8 ignition database's experimental development — which includes a 450-data-point experimental matrix — through careful experimentation in a single cylinder research engine used in this study.

For example, the combination of 82 percent dodecane (T90 of 489 K) and 18 percent tetradecane (T90 of 526K) matches a JP-8 T90 point of 496K, while a combination of 35 percent dodecane and 65 percent tetradecane matches the heptamethylnonane T90 point of 513K. After detailed analysis, TARDEC concluded that dodecane was best suited as a representative JP-8 surrogate in this study.

This methodology is important for assessing combustion variances between JP-8 and DF-2 because JP-8's evaporation rate is 15- to 40-percent faster than DF-2. This variance in evaporation rate can lead to higher cylinder pressure rise rates for lower ignition quality JP-8, which can reduce engine durability under the wrong boundary conditions.

The next step toward characterizing combustion variances is to understand the auto ignition differences between JP-8 and DF-2. The team designed a set of experiments with 450 operating points that covered two JP-8 samples, one diesel fuel sample and three different injector nozzle geometries. Eventually, these 450 points will be expanded. Each nozzle had seven holes, varying in size from 0.176–0.210 mm per hole. These experiments covered a range of ignition temperatures and pressures, carefully adjusting both the intake manifold temperature and pressure while varying the injection timing from 15 to 0 degrees before top dead center, which is when a piston is farthest from the crankshaft.

The CRF conducted one month of constant volume bomb experiments. TARDEC's GVPM representative, Hoogterp, and CRF Staff Researcher Dr. Lyle Pickett acquired evaporation and ignition measurements for a JP-8 sample supplied by a local oil company. The data generated by Pickett and Hoogterp, along with the TARDEC engine data set and additional measurements taken in a shock tube by Stanford University, were used in the award-winning paper. Shock tubes measure combustion reactions, and by initiating the ignition event

"The end game for this database is to allow these engine models to be used as design aides and help solve any future combustion or ignition issues."

with a reflected shock wave, observers can measure the ignition delay. In comparison to TARDEC engine data, Stanford University's tests revealed an inverse pressure extrapolation of shock tube data from roughly 20 to 40 atmospheres. However, this pressure level is not representa-tive of a diesel engine making such ignition delay measurements difficult to extrapolate to real-world diesel operating conditions. TARDEC wants to continue to work with the academic community to facilitate more challenging future shock tube studies, which will approximate the higher pressures seen in diesel engines.

JP-8 Compatibility

By using the GVPM team's ignition database in conjunction with the evaporation model, TARDEC engine researchers are now beginning to predict pressure rise rates. The Army and its engine suppliers can leverage this methodology to aid in converting or developing future diesel-based combustion systems for JP-8 use, minimizing potential JP-8-based combustion instability problems. In addition to the technical merits of this work, it furthers TARDEC's goals in becoming the national energy hub as TARDEC working toward becoming a centralized source of data.

Ultimately, the GVPM team's aim is to transition this and future research toward engineering models that will aid the Army ground vehicle PMs in assessing potential future JP-8 combustion stability issues with commercially based diesel engines and allow engine design companies to develop JP-8-compatible engines for future Army powertrains.

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Editor's Note: *La Shara McCallum contributed to this article.*

Hybrid-Electric (HE) Drive Knowledge Expanded Through Validation Testing

Chris Williams

A new assessment program developed at the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) expanded an understanding of HE technology for military applications.

Sky's the Limit. An XM 1124 HE High Mobility Multipurpose Wheeled Vehicle (HMMWV) negotiates a 30-percent longitudinal slope at ATC. HEVs experience improved fuel economy in hilly conditions due to frequent braking, which restores kinetic energy and assists in charging the batteries. (U.S. Army TARDEC photo by Johnathon Putrus.)

TARDEC and ATC developed the HEVEA program to assess and evaluate the U.S. Army's HEV fleet. The program incorporates an HEV database, new TOP and a TARDEC-designed VPSET into its processes to ensure HEVs are accurately and efficiently integrated into the Army's future vehicle fleet. (U.S. Army TARDEC photo by Johnathon Putrus.)

California Gov. Arnold Schwarzenegger and TARDEC National Automotive Center Director Paul Skalny discuss an XM1124 HE HMMWV at the Society of Automotive Engineers (SAE) 2009 World Congress held in Detroit, MI, April 20, 2009. This hybrid has a diesel engine and electric motor generator, which combine to create a series hybrid that uses two traction motors to drive the front and rear axles. In addition, this vehicle can export up to 30 kilowatts of power to external sources. This year's SAE event theme was *Racing to Green Mobility*, and TARDEC's display featured alternative energy sources it has been developing. (U.S. Army TARDEC photo by Bill Dowell.)

When HE propulsion systems were first introduced, there were varying opinions about the fuel efficiency improvements that HE vehicles (HEVs) could provide. The HEV Evaluation Assessment (HEVEA) program was developed by TARDEC and the Army's Joint Light Tactical Vehicle (JLTV) program to obtain quantifiable and accurate results on the effects of using HE propulsion systems in Army vehicles. The vehicle testing and data analysis was performed at the Aberdeen Test Center (ATC), MD, where they compiled and analyzed the data and helped develop a test plan.

New Testing Procedures

All military vehicles traditionally conduct fuel economy testing on ATC's Munson Standard fuel economy course, which is comprised primarily of flat, paved surfaces with moderate slopes. HEVs that depend on electric energy to propel the vehicle, however, are heavily dependent on terrain, as braking frequency assists in recovering kinetic energy and charging the batteries. To properly evaluate HEVs' fuel economy, the HEVEA team is developing an accredited Test Operating Procedure (TOP) at ATC, which takes into account the energy gain and loss from the battery and compensates for it in equivalent fuel consumption measurement. To provide a greater understanding of HEVs' fuel economy capabilities, five driving courses — representative of conditions the vehicles will encounter in the field — were selected for the new TOP. "[The Munson Standard Course] doesn't give you the whole bird's-eye view of hybrid, because hybrid is terrain-dependant," remarked Johnathon Putrus, Project Manager for the HEVEA program. "An HE-powered vehicle on hilly terrain is going to have better fuel economy than on flat terrain because you're constantly going to be applying the brakes, which helps charge the battery."

The HEVEA program team also designed an HEV Performance Database, which offers a comparison of nine HEVs and their conventional counterparts and spans all tactical wheeled vehicle classes. A large range of HE-powered demonstrator vehicles were compared against an equivalent conventional counterpart, if one existed, and are currently being evaluated and placed into the database. The database will provide information about HEV capabilities to agencies throughout the military.

To properly evaluate HEVs' fuel economy, the HEVEA team is developing an accredited TOP at ATC, which takes into account the energy gain and loss from the battery and compensates for it in equivalent fuel consumption measurement.

Putrus stated that the HEVEA program team has already identified HE technology benefits. "There's definitely been improvement in a lot of different areas," he explained. "In regard to fuel economy, we've seen an increase in the vehicles that utilize a more robust hybrid architecture. We see improvement in other areas as well, in terms of onboard and export power generation, silent power, and other applications." The vehicles are still being evaluated, and there are still considerable hurdles that HEVs must overcome before being part of the Tactical Wheeled Vehicle fleet. Some of these hurdles include cooling for the power electronics and battery development to address capacity and space constraints. The hybrids' benefits will bring additional capability in the propulsion area and address onboard and export power needs for future weapons and survivability systems.

Testing Without Testing

A key product in the HEVEA program is the Vehicle Propulsion System Evaluation Tool (VPSET) Streamline Acquisition Process developed by TARDEC's Ground Vehicle Power and Mobility technical area's Modeling and Simulation (M&S) team in partnership with private industry. The process's objective is to provide an efficient, flexible and cost-effective method of evaluating conventional and HE propulsion systems without physical testing.

As TARDEC moves forward in its role as the Nation's military ground vehicle technology integrator, the HEVEA program will play a crucial role in testing and understanding HEVs' capabilities.

Previously, propulsion systems were evaluated using various contractor-submitted systems that required the acquisition of expensive licenses, contained variations in coding and required training for employees who were unfamiliar with the programs. There also was no assurance that the simulations handled the technical aspects with the same amount of fidelity, which made comparisons difficult. VPSET's implementation provides users with access to a standardized, government-owned tool that allows for a more accurate comparison between vehicles. Users enter parameters for the various vehicle components. The software generates vehicle system models that are then used to estimate performance, such as acceleration, braking and fuel economy. The government has complete access to the program's source code. The results save time and money by utilizing M&S capabilities as opposed to physical testing.

VPSET can be updated to incorporate new propulsion technologies as they develop and feature safeguards that allow the government to verify contractor model input and results. VPSET also can evaluate performance prediction and risk against technical requirements. VPSET is undergoing a comprehensive evaluation phase by TARDEC engineers and private industry to verify and validate the software predictions. Conventional and HEV test data from the HEVEA is being used for this effort.

Powering Forward

By establishing a new TOP, creating a new database for Army HEVs and utilizing VPSET, TARDEC's HEVEA program is increasing knowledge of HEV capabilities throughout the Army. As TARDEC moves forward in its role as the Nation's military ground vehicle technology integrator, the HEVEA program will play a crucial role in testing and understanding HEVs' capabilities. The program continues to optimize the work being done by TARDEC's Ground Vehicle Power and Mobility team to create and maintain reliable and state-of-the-art ground vehicles for Soldiers.

The XM 1124 HE HMMWV navigates one of five different test courses at ATC. The various courses, which simulate field conditions the vehicles are expected to operate under, provide the Army with an opportunity to evaluate and observe the full capability of HE propulsion systems. (U.S. Army TARDEC photo by Johnathon Putrus.)

Chris Williams is a Writer/Editor with BRTRC and provides contract support to TARDEC's Strategic Communications team. He has a B.A. in communication from Wayne State University in Detroit and has previously written for *The Source* newspaper in Shelby Township, MI, and *The Macomb Daily* and C & G Newspapers in Macomb County, MI.

RDA Award Winner

Lightweight Vehicle Underbody Protection System (LVUPS) Increases Crew Protection

James Capouellez, James Soltesz, Andrew Mikaila and Floyd Helsel

The accelerate Magazine Editorial staff would like to congratulate Andrew Mikaila, Jim Capouellez, Jim Soltesz and Floyd Helsel and their team's efforts on winning the 2009 Army Research and Development Achievement Award for the Lightweight Vehicle Underbody Protection System.

The entire HIP design team is assembled in front of an LVUPS demonstrator vehicle. These demonstrators were used to gather data about the new underbody protection system to dramatically improve vehicle crew survivability. (U.S. Army TARDEC photo.)

While Mine Resistant Ambush Protected (MRAP) vehicles are extremely durable and can withstand threats, their weight causes several logistics problems, including inability to use some bridges or be transported by C-130 aircraft, amphibious ships or helicopters. It was clear to warfighters and Department of Defense leadership that the U.S. military needed highly survivable, lightweight vehicles.

In 2008, engineers at the U.S. Army Tank Automotive Research, Development and Engineering Center's (TARDEC's) Prototype Integration Facility (PIF) began examining the challenge and then designing, fabricating and demonstrating the LVUPS. The Program Executive Office Combat Support and Combat Service Support's (PEO CS & CSS's) Product Manager Light Tactical Vehicles (PM LTV) wanted TARDEC involved from the beginning, which would give both organizations the opportunity to gather data and design information to influence future production.

Following the successful "Monster Garage" High Mobility Multipurpose Wheeled Vehicle (HMMWV) Improvement Program (HIP), TARDEC engineers assessed the available technology, using blast simulation data to verify whether proper protection levels were attainable. The tests proved it was possible to exceed blast threat and underbody improvised explosive device (IED) blast/fragmentation protection thresholds on a lightweight, tactical vehicle. A crucial innovation that made this level of protection possible is the HIP's double-V cab design.

Blast Simulation Data

Ground System Survivability Blast Mitigation Team Leader Kari Drotleff said, "The double-V design of the hull is by far the most innovative and effective countermeasure on this demonstrator for mitigating the blast from a mine or IED." Drotleff's team provided subject-matter expertise in the areas of crew protection and blast mitigation technology. "Our team's main contribution is in the design guidance provided to the team in the area of crew survivability," Drotleff remarked. "This included improved crew seating for blast protection, some lower-extremity protection measures, energy-absorbing seating, underbody armor kits and lower-extremity protection kits."

The TARDEC LVUPS team used the blast simulations and data previously provided by the U.S. Army Corps of Engineers Waterways Experimental Station to develop a blast model analysis. By using the data and analysis together, engineers were able to test various parameters, from weight and interior volume to blast energy. The process helped engineers streamline the cab design and find the vehicle's weakest point. Additionally, this data and analysis combination allowed the LVUPS team to strenuously test multiple potential designs much more quickly than in the past.

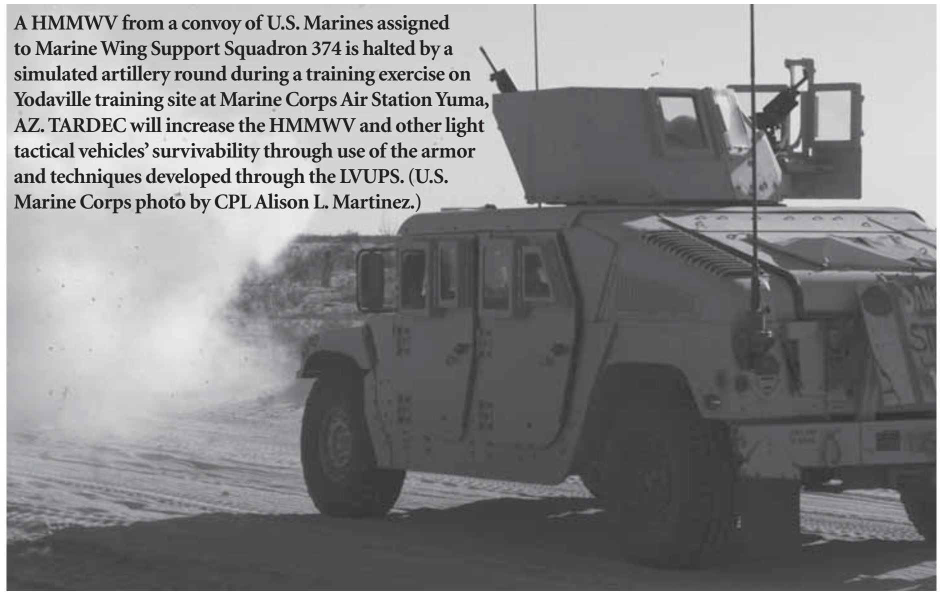
Once the blast simulations certify a particular design as acceptable, engineers had to build a demonstrator to verify the simulation, using innovative solutions to maximize protection without sacrificing speed or mobility. Initial simulations revealed that to meet these requirements, an advanced, lightweight material was needed — a significant challenge. "The hardest thing nowadays is finding a lightweight solution," remarked TARDEC Lightweight Structures Team Leader Don Ostberg. "We usually use steels, aluminums and ceramics."

Innovation-Derived Composites

After receiving the design from the LVUPS team, TARDEC's Lightweight Structures team built the vehicle's side armor using an aluminum lithium composite as the material. The only way to properly bond the composite is through a process known as friction stir welding (FSW). "The composite is a special, higher-strength alloy," Ostberg explained, "but you can't use fusion welding with it, and the welds in armor are usually the weakest part." To ensure that the

A U.S. Army Soldier sits at his HMMWV, which is mounted with a .50-caliber machine gun, during a live-fire exercise. Thanks to programs like LVUPS, America's fleet of vehicles can change potentially lethal attacks into attacks that leave each Soldier unharmed. (U.S. Army photo by SGT Ralls Micus.)

vehicle's armor system would hold together during a mine or IED blast, FSW was the only option. The LVUPS program's engineers pioneered many advances in FSW, including being the first to use an FSW armor hull on a lightweight tactical vehicle and using FSW on the most complicated design to date.


A HMMWV from a convoy of U.S. Marines assigned to Marine Wing Support Squadron 374 is halted by a simulated artillery round during a training exercise on Yodaville training site at Marine Corps Air Station Yuma, AZ. TARDEC will increase the HMMWV and other light tactical vehicles' survivability through use of the armor and techniques developed through the LVUPS. (U.S. Marine Corps photo by CPL Alison L. Martinez.)

Other innovations on the LVUPS to increase crew survivability included mine blast seats with crew restraint systems — two floor-mounted seats with crush bases and two roof-mounted hydraulic, shock-absorbent seats — and special foam floors. Throughout the process, as every potential innovation and material was considered, costs had to be controlled. "We also had to take a serious look at cost," Ostberg stated. "We wanted to have a relatively inexpensive, lightweight vehicle." Another design enhancement came from PM LTV's Laurie Austin, who helped develop a 2-door cab and the concept of splitting the blast. The "Monster Garage" program transferred this design to a 4-door cab.

As the first demonstrator neared completion, the U.S. Army Test and Evaluation Center (ATEC), TARDEC and PM LTV developed a test plan. ATEC supplied information on specific threats under Department of the Army guidance and determined the most critical threats and threat locations. PM LTV provided guidance for ATEC and gave them the opportunity to take data for future requirements and designs. The Army Research Laboratory (ARL) helped validate the tests and assess crew survivability.

Demonstrator 1

LVUPS Demonstrator 1 successfully passed the required blast threshold. The vehicle's occupant compartment remained intact, while the rear cargo area's design mitigated the blast. Examining the test results and test mannequins, ARL determined that, had this been a real event, only one crew member would have been injured — no crew casualties. Failures occurred in the upper cab and underbody joint, and TARDEC PIF engineers solved this by upgrading the bolts and interlocking the cab to the upper body.

With each successive test, the threat level was increased. TARDEC Assistant Associate Director Starlett Burrell stated the team's goal was to answer, "How much tougher can we make the double-V design to meet the objective threat?"

Following each test, the LVUPS team incorporated the lessons learned into the next demonstrator's performance and fabrication. Many common components and parts survived each test and were reused in future demonstrators. Among the Demonstrator's accomplishments was the strength of its welding. The cab never broke a weld throughout the testing's entirety.


Lightweight vehicles, like this artist's rendering, are more fuel efficient and have fewer logistics problems than MRAP vehicles. As a result of the LVUPS's design and prototyping processes, such vehicles will be able to withstand greater threats than current vehicle systems. (U.S. Army TARDEC drawing.)

Demonstrators 2 and 3

LVUPS Demonstrator 2 also was successful, again yielding only one injury according to ARL's review of the test mannequins. After making the required improvements, the LVUPS team used the simulation process to find a new subfloor concept that reduced the impulse load to the crew and identified the best position to integrate the foam floor design. Testing from TARDEC's ballistic laboratory helped engineers select material for the new shield that directs the impulse away from the crew and absorbs it with a crushable aluminum.

On Sept. 10, 2008, Demonstrator 3 passed its test against an objective IED blast simulation at Aberdeen Proving Ground, MD. This demonstrator also introduced four floor-mounted seats rather than the two floor-mounted and two roof-mounted seats found in Demonstrators 1 and 2. With Demonstrator 3, all mannequins ended the test intact — the crushable floor and seat bases worked as intended.

The LVUPS demonstrators allowed vehicles to recoup payload and mobility, creating a basis for future fuel reduction. The fuel savings will become increasingly pronounced as the vehicles are deployed to more remote locations, such as those of *Operations Enduring* and *Iraqi Freedom*. "It has also been a valuable experience in crew survivability-centric vehicle design," commented Drotleff. "There are many valuable lessons to be learned from this program."

Further Assessment and Lessons Learned

Additionally, the U.S. Army TACOM Life Cycle Management Command's Industrial Based Operations group performed an assessment on the composite materials and FSW under the LVUPS project and determined they were viable processes in a production setting. Further testing and development may allow for changes to other aluminum composites. The group also determined that this underbody system could be integrated viably and within a reasonable cost. The Vice Chief of Staff of the Army also praised the LVUPS design, acknowledging and commending TARDEC's success and project timeliness.

"The hardest thing nowadays is finding a lightweight solution."

The key to the project's success was TARDEC's ability to assemble and maintain good communication with a group of experts, "figuring out how to quickly bring the people together, pick their brains, bring all their data together to understand the problem, discuss and bring these technologies," Burrell remarked. Drotleff echoed that thought noting, "It is exciting to see how all of TARDEC, along with industry partners, can pull together and deliver as one integrated partnership." By facilitating communication with the various PEOs, PMs and experts, the team was able to evaluate technologies and collect data from multiple organizations. Another success factor, according to Burrell, was that "Jim Soltesz was able to balance the research, development and engineering with the PEOs' needs to successfully execute this program. He was able to maintain momentum at both the technology and management level."

The LVUPS met all of its goals and became a basis for improvements to all types of armored ground vehicles. The engineers' lessons learned, design approach and accomplishments have been shared with PEO CS&CSS's PM Joint LTV, PM LTV and Project Manager MRAP. The ultimate measure of success comes in terms of the warfighters' lives saved due to the new design and accompanying technological advances. TARDEC's PIF and its partners never lost sight of this goal, realizing it after multiple tests, simulations and months of focused design work.

James Capouellez is a Mechanical Engineer for TARDEC. He has a B.S. in mechanical engineering from Lawrence Technological University and has taken master's degree-level courses at the University of Madison, WI, and the University of Michigan-Dearborn. He currently holds patents for the Automatic Dynamic Track Tensioning Mechanism and Thermal Signature Reduction Wheel Shield. Capouellez is the inventor of the double-V concept.

James Soltesz recently retired from 42 years of dedicated civilian service. He previously served as the PIF Associate Director within TARDEC's Product Development Business Group. Soltesz has a B.S. in mechanical engineering from the University of Detroit and an M.S. in mechanical engineering from Wayne State University. During his distinguished career, he earned an Achievement Medal for Civilian Service and a Commander's Award for Civilian Service.

Andrew Mikaila is a Mechanical Engineer for TARDEC and a Program Manager on the PIF's Product Development Integration team. He has a B.S. in mechanical engineering from Oakland University. He was previously awarded the Commander's Award for Civilian Service.

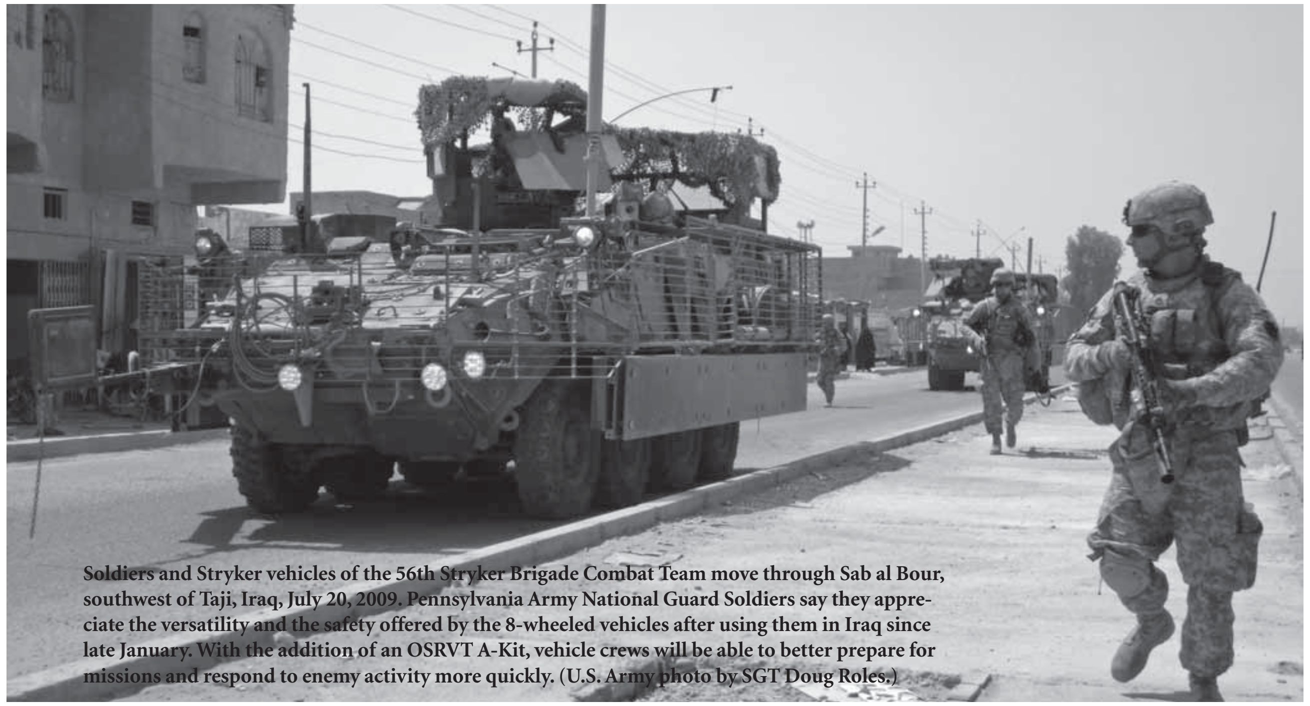
Floyd Helsel is a Mechanical Engineer for the TARDEC PIF Physical Prototyping Team. He holds a B.S. in electrical engineering from Wayne State University.

Ergonomically and Safely Integrating Communication Equipment

Robert Washburn and Jason McIndoe

In creating the One System Remote Video Transceiver (OSRVT) A-Kits, the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) solved several technical challenges. The A-Kits are an installation kit for the OSRVT, which allows remote communication with unmanned aerial vehicles (UAVs). The A-Kit provides warfighters with a cost-effective, innovative mount for integrating needed equipment on the Stryker to further their situational awareness (SA).

A Stryker BCT vehicle pops smoke for cover during troop movements in the East Rashid district of Baghdad, Iraq. With the addition of an OSRVT A-Kit, vehicle crews will be able to better prepare for missions and respond to enemy activity more quickly. (U.S. Air Force photo by TSGT Andrew M. Rodier.)



Soldiers and Stryker vehicles of the 56th Stryker Brigade Combat Team move through Sab al Bour, southwest of Taji, Iraq, July 20, 2009. Pennsylvania Army National Guard Soldiers say they appreciate the versatility and the safety offered by the 8-wheeled vehicles after using them in Iraq since late January. With the addition of an OSRVT A-Kit, vehicle crews will be able to better prepare for missions and respond to enemy activity more quickly. (U.S. Army photo by SGT Doug Roles.)

The current OSRVT is approximately 20 pounds and runs on a laptop computer, where the Soldier receives the UAV's reports. The UAVs can provide near-real-time surveillance images and geospatial data, which the OSRVT receives, either on manned ground platforms, such as High Mobility Multipurpose Wheeled Vehicles or airborne Black Hawk helicopters. The OSRVT is an enhancement of the Air Force's Remote Optical Video Enhanced Receiver III, which allows warfighters to receive imagery directly from manned and unmanned aircraft. The OSRVT provides the additional capability of receiving live feed from multiple vehicles.

The A-Kit provides warfighters with a cost-effective, innovative mount for integrating needed equipment on the Stryker to further their SA.

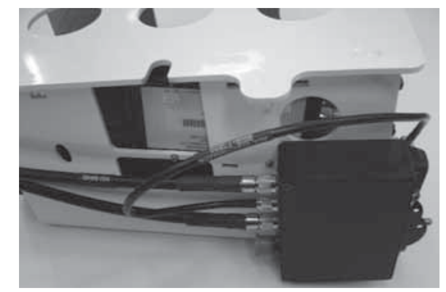
Soldiers with access to the OSRVT have higher SA and can use the data and video to better plan missions and respond to enemy activity. Consequently, in 2007, an urgent Operational Needs Statement came from a Stryker Brigade Combat Team (BCT) requesting 60 OSRVTs to be delivered in approximately six months. However, integrating the OSRVT onto the Stryker was not straightforward. Space had to be found or made inside the Stryker to accommodate the OSRVT ergonomically without creating an impediment to egress or other crew operational functions.

TARDEC engineers were able to develop an installation A-Kit that integrates the OSRVT neatly, ergonomically and safely on the Stryker platform. The A-Kit installs the OSRVT on a ceiling mount, which the engineers found to be the most efficient and safe use of space. Because space is at a premium inside vehicles, most equipment mounts are on the walls with cabling running along the floor, which creates an unacceptable tripping hazard during egress. The A-Kit uses the lightest possible material to support the structure, which makes ceiling mounting possible. In this position, the A-Kit is operational, while utilizing space that was previously unused and relatively inaccessible. This placement does not impede Soldiers' movement or make it difficult for them to access other equipment.

The OSRVT works with eight components, some requiring 12 volts and others requiring 24 volts. To eliminate the need for numerous cables running throughout the vehicle, TARDEC engineers designed a "spider-leg" cable to act as a hub for the eight device connections and as a single plug into the vehicle power system. Each connection draws power, at the proper voltage, to its respective devices.

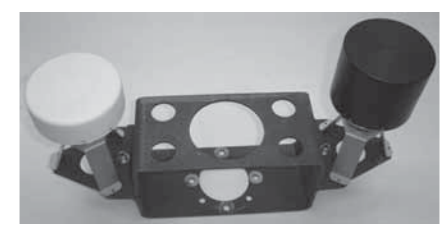
The next major integration challenge for the OSRVT was the placement of its two antennas. Normally, attaching them involves drilling holes and mounting the antennas in the new holes. However, the newly drilled holes may impact vehicle performance, so expensive tests and long wait times between studies are needed to ensure the addition doesn't have negative effects. To avoid this problem, the OSRVT was attached to an existing antenna mount that housed the Single Channel Ground and Airborne Radio System (SINCGARS). However, the SINCGARS's whip antenna proved problematic and damaging to the OSRVT's antenna. To preserve the OSRVT antenna, the new antenna bracket was designed to be mounted at a 45-degree angle to the SINCGARS's antenna hole pattern. The bracket allows access to every degree of orientation without having to drill new holes and gives the antenna limited range of movement.

The OSRVT A-Kit ceiling brackets allow Soldiers to mount the urgently needed technology in an out-of-the way place. By doing so, they still have access to the technology's full scope but are able to safely egress the vehicle in an emergency. (U.S. Army TARDEC photo.)



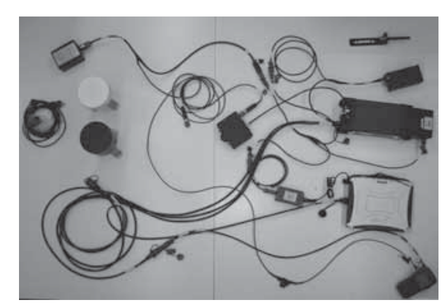
These various wires connect the OSRVT to the other Stryker equipment. Through the use of a multiband switch, Soldiers are able to gain access to multiple UAVs' video feeds. (U.S. Army TARDEC photo.)

The A-Kit installs the OSRVT on a ceiling mount, which the engineers found to be the most efficient and safe use of space.



TARDEC created this antenna mounting bracket to integrate the OSRVT antenna onto the Stryker platform alongside the SINCGARS. (U.S. Army TARDEC photo.)

The antenna mounting bracket was innovative in another respect — it was designed to keep it from interfering with the SINCGARS. Through work with outside vendors, the high-frequency Ku-C/L switch was invented. It enables the antennas to switch between Ku, C and L frequency bands. Since the OSRVT has one antenna input jack, using the antenna switcher eliminates the need to physically plug and unplug the two antennas when using different frequency bands. Soldiers monitoring the OSRVT can easily toggle among various UAVs and their respective frequencies, greatly expanding operational SA.



The A-Kit's various parts ensure that Soldiers have full access to the OSRVT. All of the wires and cabling are managed with a "spider-leg" cable that reduces stray cables and limits the number of plugs required. (U.S. Army TARDEC photo.)

TARDEC produced the first two A-Kit deliveries for the Stryker BCT. The first 11 kits arrived in January 2008, and an additional 26 kits were delivered in August 2008. They were designed to require only the most basic tools for installation and maintenance, making them ideal for field use.

For the future, other vehicle platforms are facing similar ergonomic challenges and, likewise, need to find a way to integrate valuable equipment into the vehicles' interiors. While the A-Kit itself is not designed to integrate the OSRVT onto other vehicles, the Ku-C/L-band antenna is a potential candidate for future integration. Program managers and engineers for different platforms, such as the Mine Resistant Ambush Protected vehicle, have expressed interest in using either the A-Kit itself or parts of it. As this kit is more widely adopted and leveraged for integration onto vehicles and ground platforms, its benefits will continue to expand Soldier capabilities accordingly.

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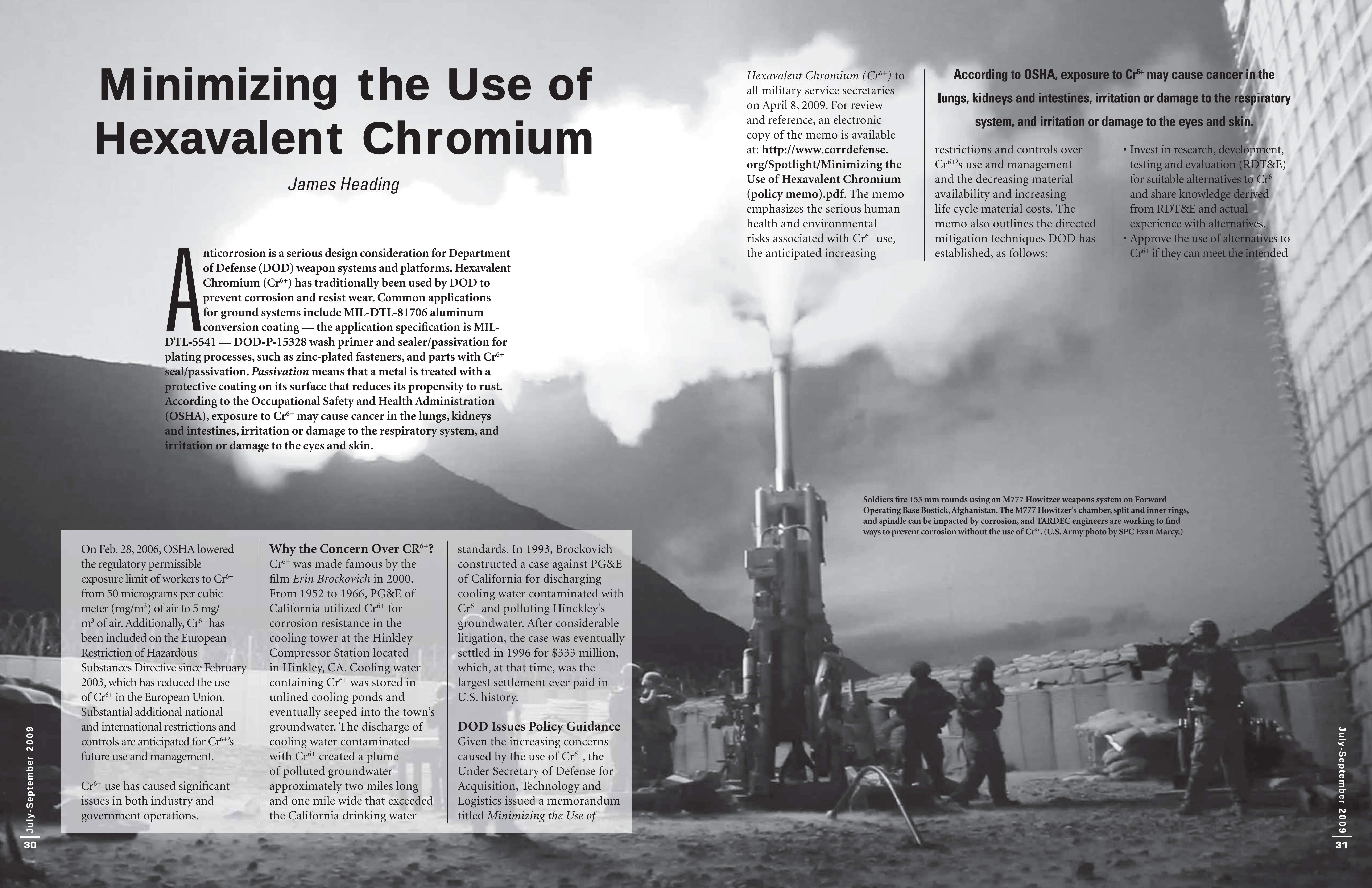
Jason McIndoe is a Stryker Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance Mechanical Engineer. He holds a B.S. in mechanical engineering from Ohio University.



Minimizing the Use of Hexavalent Chromium

James Heading

Anticorrosion is a serious design consideration for Department of Defense (DOD) weapon systems and platforms. Hexavalent Chromium (Cr^{6+}) has traditionally been used by DOD to prevent corrosion and resist wear. Common applications for ground systems include MIL-DTL-81706 aluminum conversion coating — the application specification is MIL-DTL-5541 — DOD-P-15328 wash primer and sealer/passivation for plating processes, such as zinc-plated fasteners, and parts with Cr^{6+} seal/passivation. *Passivation* means that a metal is treated with a protective coating on its surface that reduces its propensity to rust. According to the Occupational Safety and Health Administration (OSHA), exposure to Cr^{6+} may cause cancer in the lungs, kidneys and intestines, irritation or damage to the respiratory system, and irritation or damage to the eyes and skin.

On Feb. 28, 2006, OSHA lowered the regulatory permissible exposure limit of workers to Cr^{6+} from 50 micrograms per cubic meter (mg/m^3) of air to 5 mg/m^3 of air. Additionally, Cr^{6+} has been included on the European Restriction of Hazardous Substances Directive since February 2003, which has reduced the use of Cr^{6+} in the European Union. Substantial additional national and international restrictions and controls are anticipated for Cr^{6+}'s future use and management.

Cr^{6+} use has caused significant issues in both industry and government operations.

Why the Concern Over CR^{6+}?

Cr^{6+} was made famous by the film *Erin Brockovich* in 2000. From 1952 to 1966, PG&E of California utilized Cr^{6+} for corrosion resistance in the cooling tower at the Hinkley Compressor Station located in Hinkley, CA. Cooling water containing Cr^{6+} was stored in unlined cooling ponds and eventually seeped into the town's groundwater. The discharge of cooling water contaminated with Cr^{6+} created a plume of polluted groundwater approximately two miles long and one mile wide that exceeded the California drinking water standards. In 1993, Brockovich constructed a case against PG&E of California for discharging cooling water contaminated with Cr^{6+} and polluting Hinckley's groundwater. After considerable litigation, the case was eventually settled in 1996 for $333 million, which, at that time, was the largest settlement ever paid in U.S. history.

DOD Issues Policy Guidance

Given the increasing concerns caused by the use of Cr^{6+}, the Under Secretary of Defense for Acquisition, Technology and Logistics issued a memorandum titled *Minimizing the Use of Hexavalent Chromium (Cr^{6+})* to all military service secretaries on April 8, 2009. For review and reference, an electronic copy of the memo is available at: **http://www.corrdefense.org/Spotlight/Minimizing the Use of Hexavalent Chromium (policy memo).pdf**. The memo emphasizes the serious human health and environmental risks associated with Cr^{6+} use, the anticipated increasing restrictions and controls over Cr^{6+}'s use and management and the decreasing material availability and increasing life cycle material costs. The memo also outlines the directed mitigation techniques DOD has established, as follows:

According to OSHA, exposure to Cr^{6+} may cause cancer in the lungs, kidneys and intestines, irritation or damage to the respiratory system, and irritation or damage to the eyes and skin.

- Invest in research, development, testing and evaluation (RDT&E) for suitable alternatives to Cr^{6+} and share knowledge derived from RDT&E and actual experience with alternatives.
- Approve the use of alternatives to Cr^{6+} if they can meet the intended

Soldiers fire 155 mm rounds using an M777 Howitzer weapons system on Forward Operating Base Bostick, Afghanistan. The M777 Howitzer's chamber, split and inner rings, and spindle can be impacted by corrosion, and TARDEC engineers are working to find ways to prevent corrosion without the use of Cr^{6+}. (U.S. Army photo by SPC Evan Marcy.)

A Marine fires an M244 60 mm mortar system during a Tactical Air Control Party at a range outside Camp Taqaddum, Iraq. The M244 mortar system's elevation-traverse mechanics and bipod can be impacted by corrosion, and TARDEC engineers are working to find ways to prevent corrosion without the use of Cr^{6+}. (U.S. Marine Corps photo by CPL Jeremy Giacomino.)

application and operating environment standards.

- Update all relevant technical documents and specifications to authorize the use of suitable Cr^{6+} alternatives.
- Update the Program Environment, Safety and Occupational Health Evaluation for the system to document system-specific Cr^{6+} risks and efforts to qualify less-toxic alternatives and cost comparisons among alternatives, including disposal costs and system overhaul cycle times/costs due to any differences in corrosion protection.
- Require the program executive officer or equivalent, in coordination with the Military Department's Corrosion Control and Prevention Executive, to certify that there is no acceptable alternative to the use of Cr^{6+} on a new system.
- For such applications where acceptable alternatives to Cr^{6+} do not exist, Cr^{6+} may be used.

In addition, the memo describes that the Defense Acquisition Regulation Council has been tasked to prepare a clause to be added to all defense contracts — weapon system design, procurement and logistics support — that will prohibit the use of Cr^{6+}-containing materials unless specifically approved by the government. Additionally, the memo explains that the DOD "Advanced Surface Engineering Technologies for a Sustainable Defense" database will be expanded to incorporate knowledge management on RDT&E and experiences in using Cr^{6+} alternatives.

The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) Materials and Environmental Team (MET) has been working for many years to eliminate the use of Cr^{6+} from ground systems by inserting requirements into contracts prohibiting its use. In addition, the TARDEC MET participated in several pollution prevention projects to eliminate Cr^{6+}, including a project with Red River and Anniston Army Depots to evaluate alternative sealer/passivation chemistry to replace the Cr^{6+}-containing sealer/passivation currently used.

The TARDEC MET has identified and tested a feasible alternative to Cr^{6+} for fasteners and electrical connector shells using high-purity deposited aluminum.

The TARDEC MET also is participating in projects to find a single coating for electrical connector shells and fasteners to replace the cadmium and Cr^{6+} chemistry currently used.

The TARDEC MET has identified and tested a feasible alternative to Cr^{6+} for fasteners and electrical connector shells using high-purity deposited aluminum. High-purity deposited aluminum is described in further detail in a sidebar accompanying this article. The MET is proposing a DOD-wide policy to replace cadmium plating with high-purity aluminum on fasteners and electrical connectors in materiel and maintenance. In addition, work has been done by various DOD organizations to find alternatives to Cr^{6+}, such as qualification of a Cr^{6+}-free aluminum conversion coating — qualified under MIL-DTL-81706 as Type II — and a zinc phosphate process for steel substrates as a solution to DOD-P-15328 wash primer. Information on alternatives to Cr^{6+} may be obtained by contacting the TARDEC MET. The points of contact for inquiries are I. Carl Handsy at (586) 574-7738 and Pam Khabra at (586) 574-5954.

James Heading is a Professional Engineer and Certified Hazardous Material Manager who works as an Environmental Engineer with the TARDEC MET. He has a B.S. in environmental engineering from Michigan Technological University and is Level I certified in systems planning, research, development and engineering.

Single Replacement for Cadmium-Plated Fasteners and Electrical Connectors

I. Carl Handsy

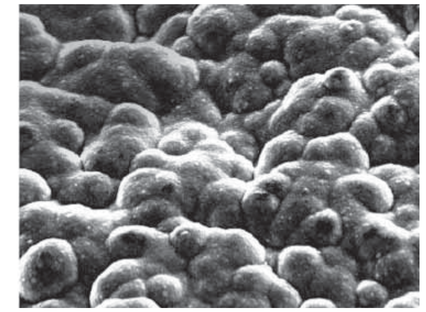


Figure 1. This Scanning Electron Microscope image depicts a plated surface shot at extremely high magnitude. A high-energy electron beam using a raster scan pattern produces the 3-D imagery.

TARDEC is proposing a policy to DOD components to replace cadmium plating for fasteners and electrical connectors in the procurement and maintenance of DOD materiel. This policy is driven by the need to reduce the quantity of toxic and hazardous chemicals and materials acquired, used and disposed of in DOD materiel. Cadmium and Cr^{6+} are known human carcinogens, and cadmium is required to be removed at the end of a product's life in conjunction with demilitarization. Except where specific requirements dictate a particular coating, all DOD fasteners and electrical connectors currently plated with cadmium should be procured with high-purity deposited aluminum coatings without hexavalent chromium treatment.

While several alternatives to cadmium plating exist, a single alternative has been selected after extensive testing to simplify the complexities within the supply and maintenance communities. There are thousands of different fasteners, and replacing them with multiple alternatives would be costly, would make parts inventories and national stock number management unwieldy and could introduce incompatible materials into maintenance operations. High-purity deposited aluminum has many benefits over cadmium, including:

- Superior corrosion performance at the same plating thickness as cadmium.
- Insusceptibility to hydrogen embrittlement, or grooving.
- The ability to be engineered for equivalent torque-tension.
- The ability to withstand high temperatures.
- High conductivity, which is necessary for electrical shell connectors.
- The ability to be produced without the use of Cr^{6+}, which has recently been restricted in an Under Secretary of Defense (Acquisition, Technology and Logistics) memorandum dated April 8, 2009, due to human health and environmental risks. The ability to withstand high temperature.

	AlumiPlate* Aluminum (Al)	Cadmium	Organic Coatings	Zinc Alloy Coatings	Ion Vapor Deposited Al
Nominal recommended thickness	0.3 mils	0.3 mils	1-2 mils	0.3 mils	0.3 mils
Salt spray (B-117) performance	1,000+ hrs	1,000 hrs	500 hrs	400-1,000 hrs	500 hrs
Non-embrittling	Yes	No	Yes	No	Yes
Fully dense and pore-free	Yes	Yes	Yes	Yes	No
Sacrificial protection	Yes	Yes	Partial	Yes	Yes
No galvanic reaction with Al parts	Yes	Yes	Partial	No	Yes
Complex geometrics and IDs	Yes	No	No	Yes	No
Tightly adhering	Yes	Yes	No	Yes	No
Environmentally friendly	Yes	No	Yes	No	Yes
High-temp. applicability	Up to 1,000 F	Up to 500 F	Up to 500 F	Up to 500 F	Up to 1,000 F
Drop-in gad replacement	Yes	—	No	No	No
No peening required	Yes	Yes	Yes	Yes	No
Ductile, formable and stampable	Yes	Partial	No	No	No
Low process temperature	Yes	Yes	Yes	Yes	No
Anodizeable	Yes	No	No	No	No

Figure 2. Aluminum Plating Performance Comparison.

The primary challenge to implementing this technology is industrialization. To attain needed capacity, the manufacturing base will need to be expanded. This may require licensing a proprietary process or developing refined technologies from an expired patent. It also may impact the timeframe to phase in the new materials.

However, the benefits to implementing this technology far outweigh the challenges due to the toxicity that results from traditional cadmium plating. The technology has been accepted and is now standard practice for industry in Europe and gaining traction in the U.S. Based on this expanding use and the test results obtained during projects at TARDEC and other DOD organizations, using high-purity deposited aluminum is the logical solution for alleviating common long-term corrosion and environmental issues.

I. Carl Handsy is a Senior Materials and Corrosion Engineer with TARDEC. He has a B.S. in chemistry from Lawrence Technological University and an M.S. in mechanical engineering from Wayne State University. He has taken post-graduate classes on organic coatings from the University of Missouri-Rolla. He is Level III certified in systems engineering.

Vehicle Powertrain Engineering and Machining Process Optimization

C.W. "Ron" Swonger

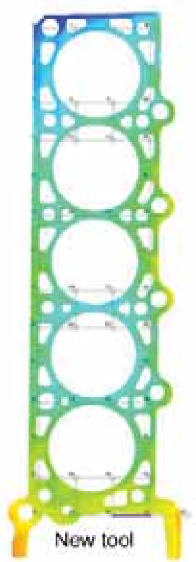
Today's military vehicles, as well as civilian vehicles of all types, face the need for improvement in multiple technically challenging dimensions. Improved engineering designs and manufacturing processes for these vehicles' powertrains offer the best opportunity for achieving improvements toward four critical objectives: maximizing horsepower-to-weight ratios and fuel efficiency and minimizing emissions and the potential for leakage of combustion gasses and fluids that leads to engine or transmission failure.

The keys to continuous improvement and control of powertrain engineering and manufacturing are a comprehensive knowledge of processes and an understanding of how part design relates to what a process actually produces. To be useful, this knowledge must be complete, timely and actionable. Technology research and development (R&D) has been packaged into metrology and defect detection solutions to provide such knowledge in plant-floor-ready form. Continuing R&D and factory floor validation programs are adding to this arsenal of proven engineering and manufacturing process optimization tools.

Powertrain Machining Process Critical Factors

Modern competitive powertrains must be powerful, efficient, "clean" and reliable. Strategic, mission, competitive, economical and environmental demands all call for facing these requirements simultaneously. Down in the trenches, where powertrain

U.S. Marines assigned to the 1st Marine Logistics Group (MLG) drive a Cougar H 4x4 Mine Resistant Ambush Protected (MRAP) vehicle through desert terrain near Camp Taqaddum, Iraq, Nov. 29, 2008. Today's up-armored tactical vehicles face the need for improved engineering designs and manufacturing processes for their powertrains to maximize horsepower-to-weight ratios and fuel efficiency. Well-engineered systems components, especially in powertrains, propulsion systems and transmissions, increase reliability and sustainability and help reduce costly maintenance repairs in high-operational-tempo environments. (U.S. Marine Corps photo by SGT Jason W. Fudge.)



In the 3-D HD holographic surface point clouds displayed here as color coded height maps, dozens of surface points are measured per square millimeter, each to an accuracy of 1 micron. The color coding shows high spots on the surface as red, low spots as blue and intermediate-height spots in a range of yellow and green shades.

The red circles on the right-hand 3-D holographic surface height map of this V10 engine block deck face show the zones in which the surface flatness has deteriorated and fallen out of specifications due to CNC cutting tool wear after 1,800 engine blocks have been processed with the same tool.

Figure 1.

critical mating parts and sealing surfaces are designed and manufactured, these multiple demands lead directly to specific requirements for:

- Mating surfaces that are flat — to within microns to reliably fit — and do not deform under high fastening forces.
- Surfaces that will not leak under increasingly high internal pressures that high-performance and high-fuel-efficiency designs require.
- Machining process operations that optimize tool changing actions, minimize tool breakage incidents and minimize production of defective parts made by worn and damaged tools.
- Detection of surface defects, including surface porosity and other machining artifacts, that lead to internal leakage or high-cost failures after powertrain parts are subjected to expensive downstream testing.
- Timely detection of process drift and machine failures causing machined features to be incorrectly located, incomplete or missing.
- Detailed comparison of parts as designed with computer-aided design (CAD) or simulation data and parts as actually built with 3-dimensional (3-D) measurement point clouds so deviations can be understood and processes or designs changed to achieve desired vehicle performance and other results, as illustrated by Figure 1.

High-Definition (HD) 3-D Technology

For more than 50 years, powertrain engineering and powertrain manufacturing were severely limited by inability of technology to supply comprehensive and timely information to enable product design, process launch and process control to fully address the factors previously listed. However, necessity breeds invention, and technologies advance as necessity requires and innovation occurs. Four critical core technologies have come together to make feasible — and deliver into engineering and manufacturing facilities — the value of rapid HD powertrain information capture and interpretation to deal with performance and reliability factors. Those core technologies are:

- High-resolution, affordable, digital photo-sensor technology, where many million samples of a manufactured surface can be captured in milliseconds without contacting the surface.
- Increasingly powerful image processing technology that benefits from *Moore's Law*, which is the prediction that transistor density on integrated circuits will double approximately every two years, leading to increased functionality and performance and decreased cost.
- Multi-wavelength laser technology, enabling the creation of instruments and gauges that measure manufactured surfaces to one micron accuracy, which is 1 percent of the diameter of a human hair, while sampling surfaces at dozens of samples per square millimeter in seconds.
- Measurement and visualization algorithms implemented in software, tying together the three technical revolutions listed above. This software technology produces visual answers that are immediately understandable and actionable by knowledgeable manufacturing processes or product engineers.

In the current era, in a sequence of ongoing industrial certification tests and experiments, it has been clearly demonstrated that powertrain engineering and manufacturing can obtain in seconds sufficient knowledge to engineer and manufacture superior powertrains. This replaces incomplete, often invalid, data that legacy devices provided only hours or shifts later after the corresponding part was produced. Working with HD metrology specialists at Coherix, Inc. and the University of Michigan Wu Manufacturing Research Center, powertrain engineering and manufacturing experts in vehicle manufacturing plants and laboratories in North America, Europe and Asia are continuously augmenting the repertoire of HD metrology knowledge production and achieving significant savings in modern powertrain design, launch and production.

The keys to continuous improvement and control of powertrain engineering and manufacturing are a comprehensive knowledge of processes and an understanding of how part design relates to what a process actually produces.

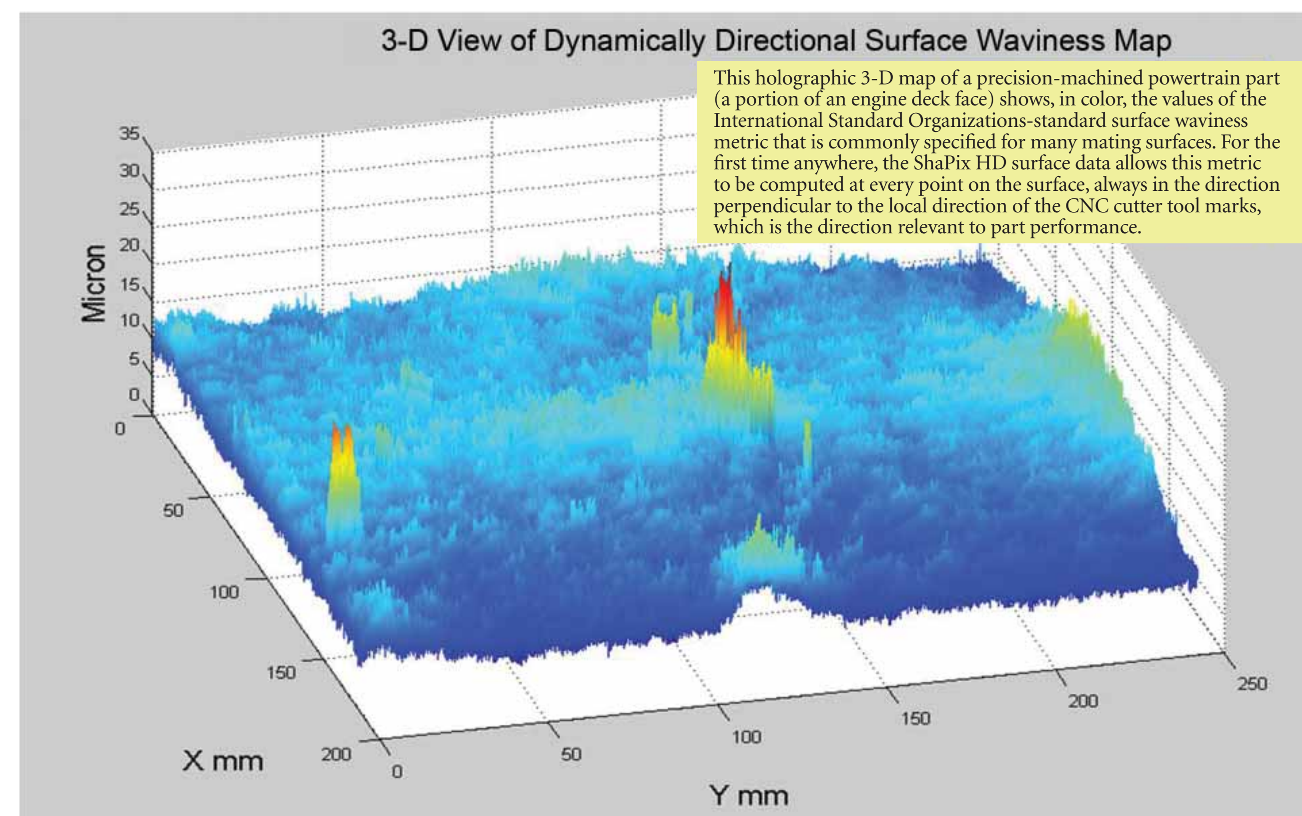
Knowledge Gems Gained

The mating surfaces of vehicle transmissions, engines, pumps and other critical assemblies must be flat to within microns to remain firmly sealed together. Under increasingly stressful high-pressure situations, shape fluctuations along the surface — "surface waviness" —must be minimized so combustion gasses, lubricants or cooling fluids do not leak, as depicted in Figure 2. The ability of gaskets to conform to an engine's shape, cylinder head and transmission part surfaces must be accurately modeled so any potential for leakage is evident before assembly occurs. Microscopic pores in machined surfaces that could produce leakage must be detected before surfaces are sealed together and expensive further powertrain manufacturing occurs. Precision part fastening into assemblies and mechanisms must not be allowed to distort parts in ways that would cause failure in field use. In combat, engine or transmission failure means much more than a dissatisfied customer.

Actionable Information as Opposed to Data

For years, supplying digital data representing precision part measurements has meant burying users in massive, incomprehensible numbers. Ironically, the massive numbers still produce final results missing 99 percent of critical surfaces. Often, data could not be understood within time spans that would allow process-correcting actions to avoid defective part production. Too often, these older manufacturing measurement methods left manufacturing engineers, product engineers and machine operators wondering about the rest of the story. To use a baseball analogy, it was like trying to discern who would win the World Series by watching only the season opener. In short, measurement systems produce too little data, too slowly and too late.

Currently, data results are derived from measuring the entire surface of a part to produce complex maps, or holograms,



This holographic 3-D map of a precision-machined powertrain part (a portion of an engine deck face) shows, in color, the values of the International Standard Organizations-standard surface waviness metric that is commonly specified for many mating surfaces. For the first time anywhere, the ShaPix HD surface data allows this metric to be computed at every point on the surface, always in the direction perpendicular to the local direction of the CNC cutter tool marks, which is the direction relevant to part performance.

Figure 2.

A 3rd Infantry Division Soldier walks toward an M2A2 Bradley infantry fighting vehicle at the conclusion of a security patrol in search of weapons caches near a village southeast of Salman Pak, Iraq. Today's military vehicles must be highly responsive to a variety of operational environments and battlefield deployments. Powertrain engineers and manufacturers must have a comprehensive understanding of how part and component design relates to the end user's exacting specifications. (U.S. Army photo by SGT Timothy Kingston.)

of part surfaces. Looking at color-coded, HD, 3-D maps of machined surfaces identifying microns of surface differences is a revelation. Figure 3 provides a 3-D, HD, holographic, micron-level measurement of the multisurface flatness, parallesism and separation of four precision-machined surfaces on a vehicle powertrain torque converter case. Today's knowledgeable manufacturing floor personnel can understand immediately what must be adjusted on which machine without needing any new training whatsoever.

The Real World of Powertrain Manufacturing

Micron-level, full-surface measurement of powertrain parts is far from the simple world of measuring small components in an optical laboratory. Single powertrain surfaces may have an area of several square feet. The relationship among multiple surfaces on a single large part may be vital to its performance. Surfaces may be separated by inches such that simple optical techniques cannot compare them. The measurements must be performed close to where the parts are made and must be made quickly. Then a significant fraction, or perhaps all, of the parts can be measured and confirmed before defective parts may be produced. The ShaPix holographic interferometer system family is routinely used in that operational plant floor environment to provide actionable process information where microns matter.

The Engineering and Manufacturing Value Equation

The value of HD, 3-D, micron-level surface metrology begins when each precision part is being designed and prototyped. It continues as process launches occur and pilot production is accomplished with minimum downtime and as few production cycles of unacceptable parts as possible, while all of the CNC machines are dialed in. The value keeps flowing in as process operations continue, productivity needs to be optimized and scrap and downtime need to be pushed toward zero. The typical time to recover the new measurement and defect detection system's cost is a few weeks or months, and the value continues to be delivered indefinitely. Meanwhile, R&D from multiple Michigan universities, with guidance from multiple collaborating civilian vehicle manufacturers, are adding to the repertoire and identifying additional applications for HD, 3-D technology. To complete the continuous deployment process, Coherix, Inc. performs the role of packaging these ongoing technology enhancements into fielded industrialized systems delivered to powertrain plants from Michigan to Georgia and beyond.

Proving the Point

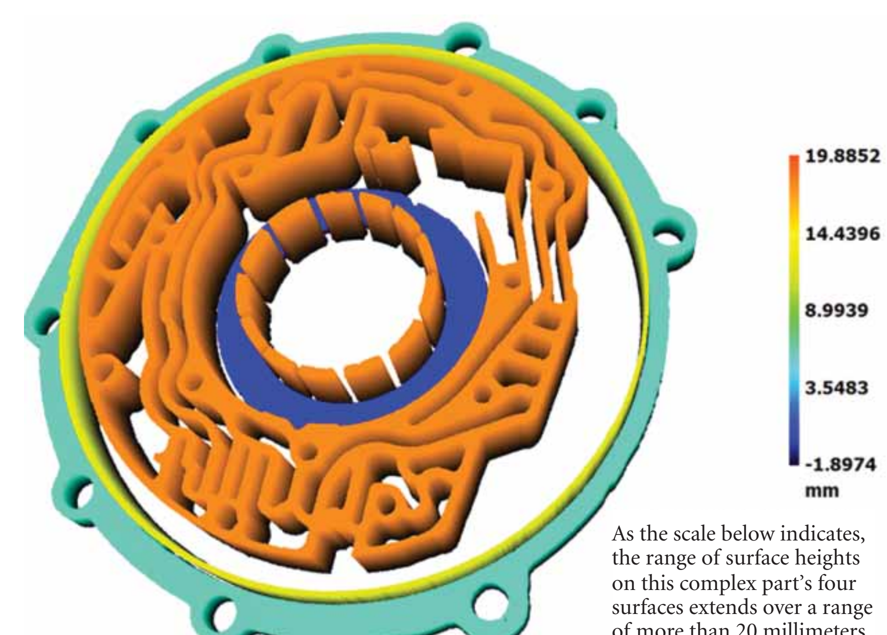
As with any game-changing technology, healthy skepticism is to be expected and must be overcome before widespread acceptance occurs. Ann Arbor, MI, the birthplace of HD holographic measurement technology and

The value of HD, 3-D, micron-level surface metrology begins when each precision part is being designed and prototyped.

where holography was originally demonstrated and applied for government use, was the ideal venue for proving the technology's benefits and value. Nearby powertrain plants of all domestic vehicle manufacturers have applied ShaPix Surface Detective systems to hundreds of different powertrain components across many vehicle lines. The technology has been subjected to industrial concept-ready and implementation-ready certification processes for more than four years for off-line and in-line production cycle times and in real-world powertrain plant environmental conditions. ShaPix systems have been delivered to multiple manufacturers and multiple sites per manufacturer, in multiple countries. The value delivered and the record of providing continuous manufacturing and engineering benefits is well established. Tier 1 suppliers, machine tool makers and system integrators have also learned that that they can supply parts or machines to end-user vehicle manufacturers more competitively by ensuring that the results consistently meet their micron-level specifications.

The National Bottom Line

In the current era, cost competitiveness and quality delivery are key prerequisites to the survival of U.S. manufacturers in many processes across all industries. Michigan-based research, development and application teams from multiple organizations are collaborating to make precision machining processes and their operating companies globally competitive. These revolutionary powertrain engineering and manufacturing solutions are available to employ for any organization seeking to outperform the ground systems, air systems and marine systems communities' rising demands, just as they have delivered results in the civilian sector.



As the scale below indicates, the range of surface heights on this complex part's four surfaces extends over a range of more than 20 millimeters. They are measured to 1 micron accuracy.

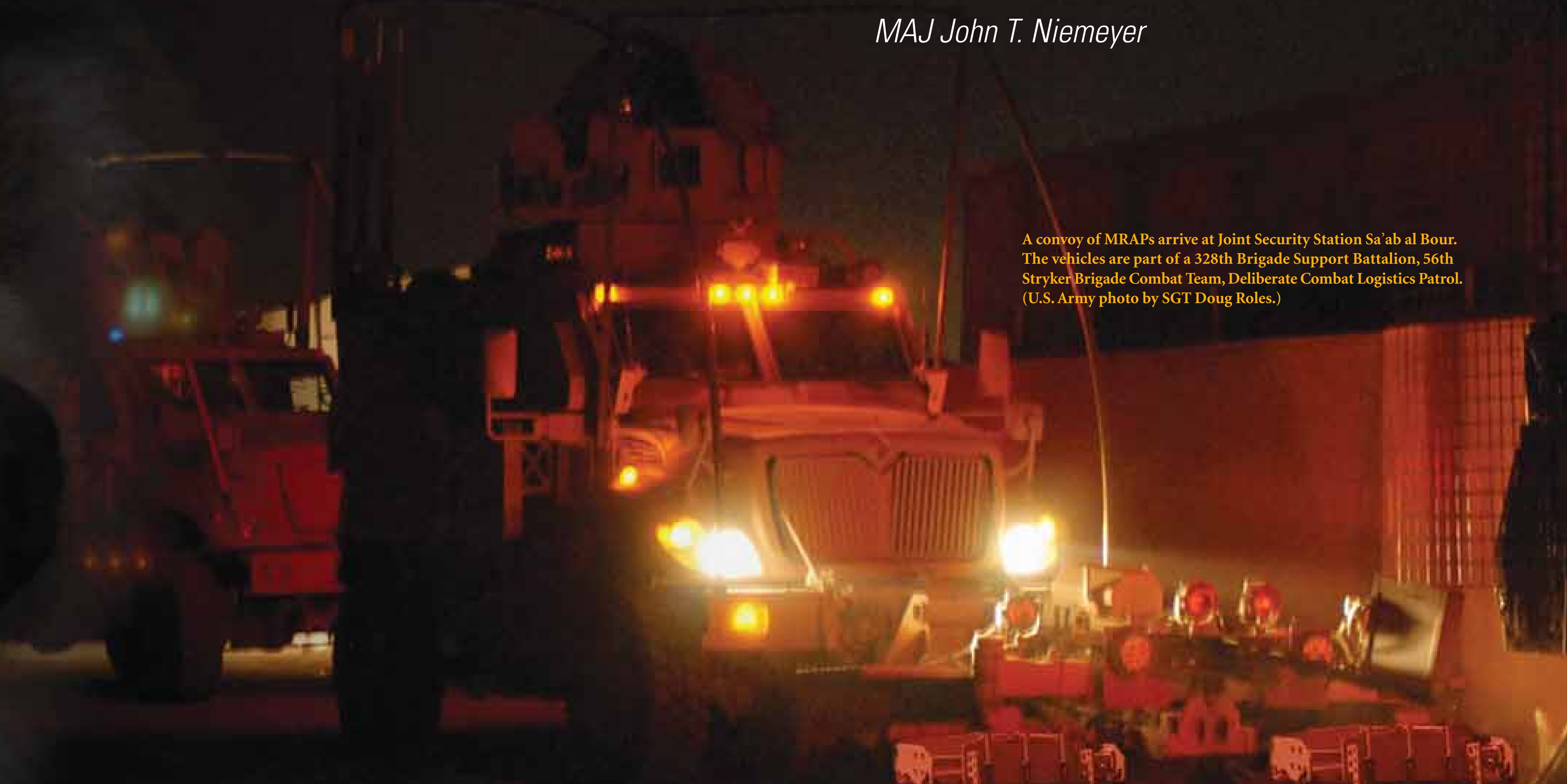
Figure 3.

C.W. "Ron" Swonger is Vice President, Advanced Technology for Coherix, Inc. He has technically contributed to, and led, development and delivery of advanced solutions for military targeting, machine vision, industrial metrology and other image-based applications for more than four decades. He served for six years on the U.S. Army Science Board. He holds a B.S.E.E. degree from Tufts University and an M.S.E.E. degree from the Massachusetts Institute of Technology.

This Wolf Has Claws — Quick Solutions Lead to Technologies That Protect Warfighters

MAJ John T. Niemeyer

When problems arise for Soldiers in the field, solutions have to be developed quickly to keep them safe. As enemies use a barrage of ever-changing weapons against U.S. forces, the people who support our Soldiers have to stay one step ahead in terms of protection development.



A convoy of MRAPs arrive at Joint Security Station Sa'ab al Bour. The vehicles are part of a 328th Brigade Support Battalion, 56th Stryker Brigade Combat Team, Deliberate Combat Logistics Patrol. (U.S. Army photo by SGT Doug Roles.)

In response to a focused threat, the U.S. Army Tank Automotive Research, Development and Engineering Center's (TARDEC's) Mechanical Countermine Team (MCT) developed a Wire Neutralization System (WNS) that includes the Wolf Claw and Wolf Collar devices.

TARDEC's MCT, comprised of six engineers and one Army officer, supports Product Manager (PM) Improvised Explosive Device (IED) Defeat/Protect Force and other organizations by providing Self Protective Adaptive Roller Kit (SPARK) technical and engineering support, component failure analysis support, and effectiveness testing and wire neutralization development. The team also works on wire neutralization, which is a PM IED Defeat/Protect Force-sponsored program, and they developed and transitioned surface-laid, command-wire IED defeat tools.

These developments' primary functions are to prevent limb loss or severe brain trauma, minimize vehicle or equipment damage, improve overall crew survivability and limit battle losses to vehicles operating in *Operation Enduring Freedom* (*OEF*)/*Operation Iraqi Freedom* (*OIF*). In a past Operational Assessment, the WNS products were the only engineered command wire IED defeat tool being used in either theater of operations.

"TARDEC supports PM IED Defeat/Protect Force in many ways, of which the SPARK and WNS are two examples," explained Andy Scott, Project Officer, IED Defeat/Protect Force. "The SPARK has had many successes since its fielding in 2007 and continues to prove itself over and over. The WNS devices are also crucial, providing a temporary materiel solution to our Soldiers against an increasing threat in both *OEF* and *OIF*."

IEDs have been responsible for approximately 40 percent of all U.S. casualties in *OIF*, according to LTC Karl Borjes, PM for IED Defeat/Protect Force. "We've documented many IEDs detonated by SPARKs, leading to many Soldiers saved by this program," said Borjes in a recent news release, whose office tracks every SPARK incident.

WNS

The WNS's development was a response to increased attacks from IEDs. To minimize the damage from these attacks, the initial fielding of 75 WNS Wolf Claw devices to Iraq and Afghanistan began in May 2008. The Wolf Claw is the latest addition to the WNS's spiral development efforts and showed great promise for use on tactical wheeled vehicle fleets. It is specifically designed to be highly effective against command and tripwire IEDs.

"The WNS products were developed quickly to meet a high-priority requirement from both *OEF* and *OIF*, where the specific threat that the WNS's were designed to counter was increasing," remarked Scott. "The WNS products were the only mechanical neutralization tool available to units to counter the command/

tripwire threat. A quick acquisition turnaround was vital to get a tool into the users' hands to help counter this particular threat in a timely manner."

A team installs the Wolf Claw on an up-armored HMMWV in theater. The Wolf Claw attaches directly to the HMMWV and to any SPARK VCMB. Adjustable to various standoff lengths, it is a useful tool that is defeating IEDs. (U.S. Army TARDEC photo by Andy Scott.)

Wolf Claw

The Wolf Claw includes a component that can be utilized in multiple ways during mission operations and is designed to be effective against both command and tripwire IEDs. Weighing approximately 75 pounds, the component can be deployed with the Wolf Claw, pulled behind a vehicle or operated in front of the SPARK roller. The component is comprised of a series of 24 hardened steel S-hooks and steel rollers. During testing, this configuration demonstrated high effectiveness and durability. The device has shown the ability to increase Soldiers' survivability in the field. This low-technology hardware attached to a vehicle's front end has test results indicating a very high success rate. The system is considered highly beneficial as an overall IED defeat mechanism. The Wolf Claw attaches directly to the High Mobility Multipurpose Wheeled Vehicle (HMMWV) and to any SPARK Vehicle Counter Measure Bracket (VCMB). Adjustable to various standoff lengths, the Wolf Claw is a useful tool used in both the *OEF* and *OIF* theaters of operation. It also is provided for use during pre-deployment training for Route Clearance Units at the U.S. Army Engineer School.

A Wolf Collar is attached to the front of an up-armored HMMWV's SPARK roller. (U.S. Army TARDEC photo by Andy Scott.)

A SPARK roller sits attached to a vehicle at a forward operating base in Afghanistan. (U.S. Army photo.)

The Wolf Claw is the latest addition to the WNS's spiral development efforts and showed great promise for use on tactical wheeled vehicle fleets.

Wolf Collar

The Wolf Collar kit is a system of chains that hooks easily onto the existing SPARK rollers, and it is another innovation derived by TARDEC engineers at the Joint Center for Ground Vehicle Enterprise at the Detroit Arsenal.

VCMB

Another TARDEC-derived development that attaches to the SPARK is the VCMB. This allows a vehicle to be configured with a variety of IED defeat tools. The VCMB accommodates the SPARK roller, Cyclone Blower, Wolf Claw and Rhino. The VCMB's introduction on Mine Resistant Ambush Protected (MRAP) and Route Clearance vehicles also allows for increased flexibility. The VCMB gives a unit commander the option to attach and re-attach a variety of counter-IED tools depending on the mission and threat.

TARDEC associates were crucial in developing the VCMBs. TARDEC's work on the VCMB has largely increased protection against IED attacks. The VCMB design analysis and research is beneficial across Department of Defense as well as for North Atlantic Treaty Organization allies. The desired VCMB attachment is now incorporated into the MRAP All Terrain Vehicle and the Joint Light Tactical Vehicle specifications. In the future, vehicles in production will come prepared for simplistic VCMB attachment without requiring extensive post-production engineering work.

"The VCMB is an extremely important tool that provides versatility to commanders since different systems are and can be designed to be installed on to it," commented Scott. "If multiple vehicles in a unit are equipped with the VCMB, systems that are designed to be installed onto it can be easily swapped between them if necessary."

TARDEC's work on the VCMB has led to a large increase in protection against IED attacks.

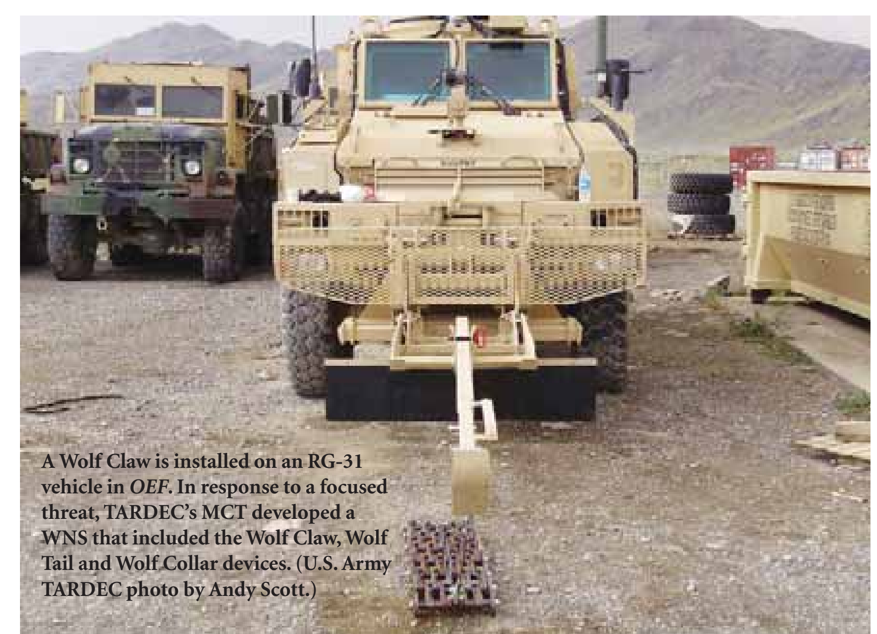
TARDEC engineers also provided integrated tow-eyes onto the VCMB, adding towing capability to vehicles that were originally unable to be pulled with standard tow and recovery processes. Development of a tow and recovery bracket from VCMB concepts allowed for lifting and towing of MRAP vehicles that did not previously meet Standardization Agreement tow and recovery requirements. If a vehicle broke down, got stuck or rolled over, the new towing capability helped get Soldiers and their vehicles out of dangerous situations. "Integrating tow hooks onto the VCMB gives the units a way to recover a vehicle quickly, reducing the amount of time that they are in harm's way," remarked Scott.

A Wolf Collar is installed on a SPARK roller. The Wolf Collar kit is a system of chains that hooks easily onto existing SPARK rollers to defeat a variety of IED threats. (U.S. Army TARDEC photo by Andy Scott.)

As Soldiers in Iraq requested that the roller or other items have the ability to be released quickly from the VCMB, an integrated VCMB with quick release was developed and tested on the Stryker platform. The quick release system allows a damaged roller to be removed seconds after an IED event.

The work done by TARDEC's MCT has gone a long way in keeping Soldiers safe in the line of battle, and the work was completed quickly and efficiently. "All vehicles are different, and all require a different VCMB design. Typically, when we get a request to design and procure a new VCMB, it was needed yesterday due to the threat. It's not easy, but we work hard to get the equipment into the field as quickly as possible," Scott said proudly.

The ability to patrol through cities and towns with a reduced threat of damage from an IED attack thanks to the Wolf Claw and VCMB system has given Soldiers an increased sense of safety that would not be possible without the MCT's research, development and hard work. "The WNS and VCMB are just two examples where the MCT is supporting the Soldiers on the ground in *OEF* and *OIF*," remarked Scott.



A Wolf Claw is installed on an RG-31 vehicle in *OEF*. In response to a focused threat, TARDEC's MCT developed a WNS that included the Wolf Claw, Wolf Tail and Wolf Collar devices. (U.S. Army TARDEC photo by Andy Scott.)

MAJ John T. Niemeyer is the PM for TARDEC's MCT, which provides engineering support to PM IED Defeat/Protect Force and conducts research and development for improved counter-mine/IED technology. He holds a B.S. in aeronautical technology from Purdue University and is a U.S. Army Acquisition Corps member.

Finding Solutions Before the Rubber Meets the Road

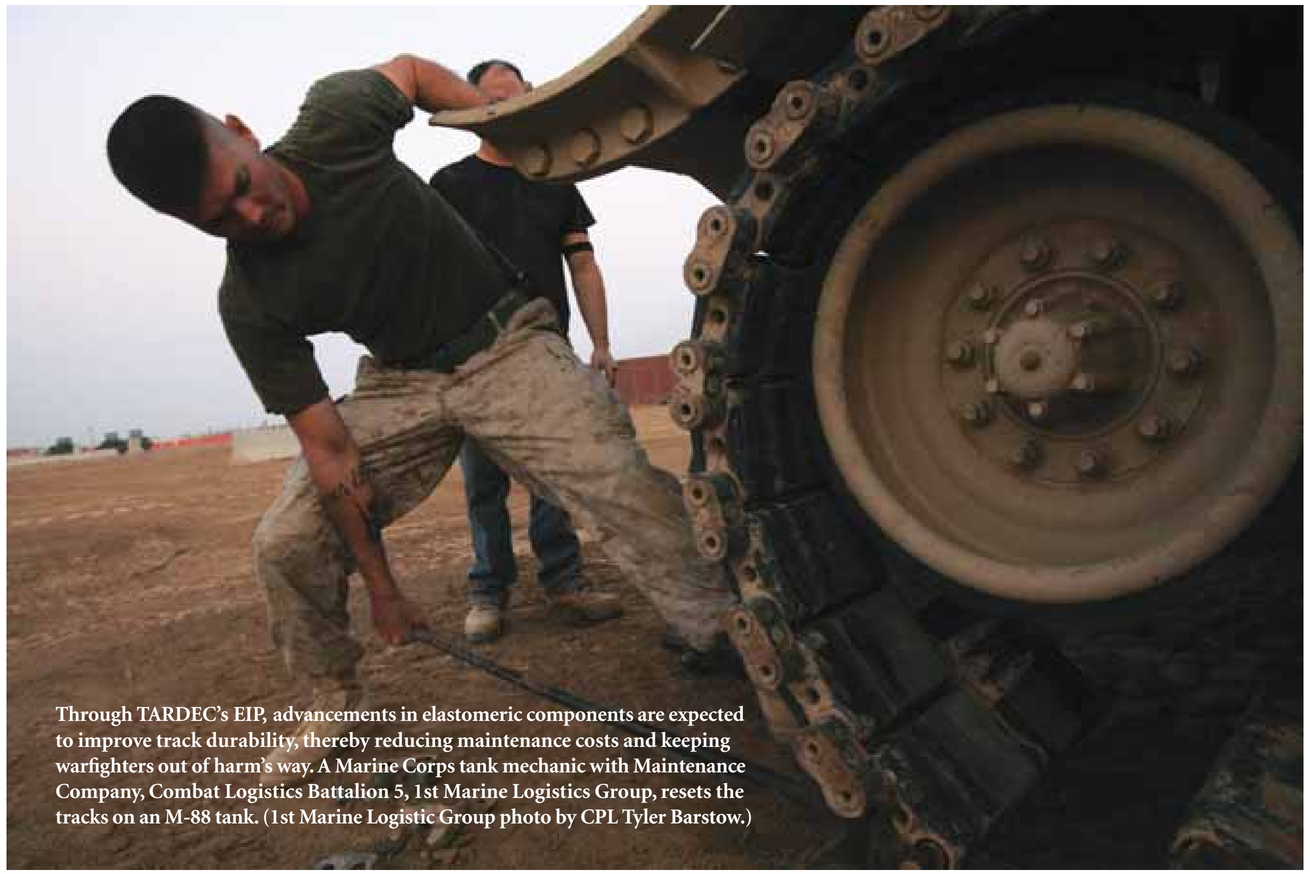
Chris Williams

The accelerate Magazine editorial staff would like to congratulate William Bradford and his team's efforts on winning the 2009 Army Research and Development Achievement Award for the Elastomer Improvement Program (EIP).

Replacing broken track on an Abrams Main Battle Tank or a Bradley Fighting Vehicle is complex, expensive and dangerous work. Track is the second-highest cost driver on Army vehicles. If track fails in the field, an entire platoon must be mobilized to protect the vehicle and crew, putting Soldiers at risk in hostile areas. A track's main failure mode is typically related to specialized rubber components, such as elastomeric bushings, backer pads and road wheels. To protect Soldiers and reduce costs, it is essential that the Army create and maintain more durable elastomeric components for its tracked ground vehicle fleet.

The EIP was created by TARDEC associates to gauge elastomeric components' failure modes on Army vehicle track systems, such as these Bradley Fighting Vehicles. Track failure is the second-highest cost driver for the Army, behind propulsion. The EIP team hopes its research will lead to more durable and consistent elastomeric components for tracks. (U.S. Army 4th Brigade Combat Team photo by PFC Rebekah Lampman.)

A Technology Transfer Agreement (TTA) between Program Manager (PM) Heavy Brigade Combat Team and the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) catalyzed the development of the Elastomer Improvement Program (EIP). The EIP is tasked with improving bushings on the Abrams T-158LL by more than 50 percent. Army engineers and scientists are determining why elastomeric track components fail and have established a roadmap to develop higher-quality rubber products that will improve track durability and performance.



Through TARDEC's EIP, advancements in elastomeric components are expected to improve track durability, thereby reducing maintenance costs and keeping warfighters out of harm's way. A Marine Corps tank mechanic with Maintenance Company, Combat Logistics Battalion 5, 1st Marine Logistics Group, resets the tracks on an M-88 tank. (1st Marine Logistic Group photo by CPL Tyler Barstow.)

The EIP Laboratory

A key component of the TTA was the establishment of a specialized laboratory at the Detroit Arsenal in Warren, MI. A state-of-the-art research and development (R&D) facility was constructed and made operational in 2008 for testing, categorizing and improving rubber compounds for tracked vehicle systems. Acquiring knowledge on how elastomeric components' fail assists in identifying the specific elastomeric components which limit durability of the entire track system and negatively impact force effectiveness. "With track programs in the past, teams were limited to working with improving individual components and compiling these improvements into one major track program," explained Bill Bradford, R&D Scientist for TARDEC's Mobility R&D Center. "Using a baseball analogy, they swung for the home run, targeting improvements with road wheel backer pads, bushings, ground pads and road wheels, creating a test matrix with too many variables and a subsequent knowledge gap. We are attempting to understand the true causes for track failure, specifically the elastomeric components. Through the EIP, we started to look at this from a component perspective, then from a system perspective, which allows for a holistic understanding of the track system, which has never been done before." Specialized life cycle component testing methodology was developed to advance knowledge of the onset of failure for the respective elastomeric track components.

To protect Soldiers and reduce costs, it is essential that the Army create and maintain more durable elastomeric components for its tracked ground vehicle fleet.

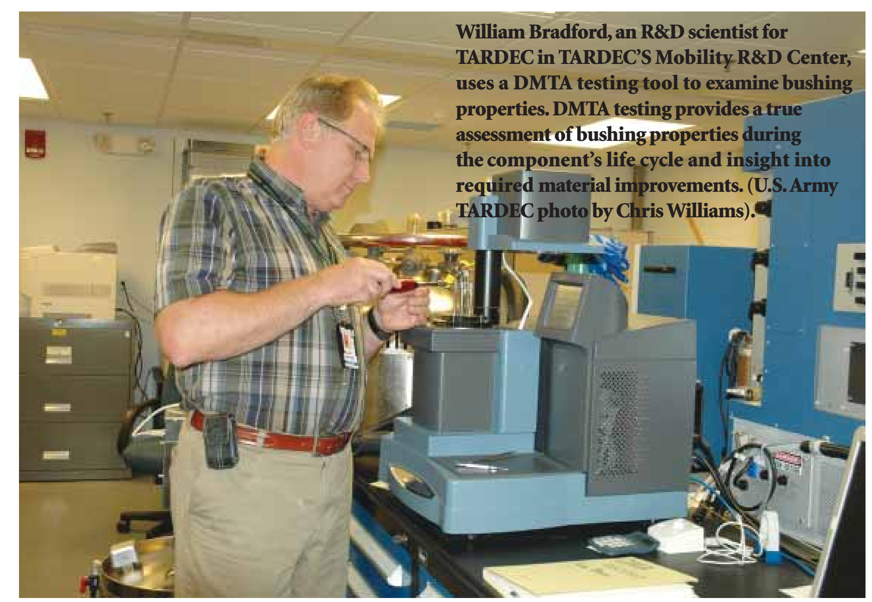
Improved Bushing Testing

The bushing tester is an essential piece of laboratory equipment. It allows for on-site bushing qualification and replaces a 30-year-old test that could not duplicate field failure modes. The equipment provides cutting-edge screening capabilities for benchmarking current product track bushings as well as improved designs incorporating improved rubber compounds. The bushing tester, in combination with a Finite Element Analysis (FEA), currently in development, enables rapid assessment of design and material improvements.

Understanding bushing failure has enabled the EIP to develop improved materials and avoid expensive and time-consuming physical testing. "Our customized bushing test duplicates the failure mode experienced in the field and significantly improves our confidence," Bradford remarked. "We now have a lab process to look at new designs and new materials and down-select the best designs and materials prior to vehicle testing at Yuma Proving Ground (YPG). Testing at YPG costs about $350,000, and, on average, you can only conduct about two tests a year. Consequently, improving our R&D test and screening processes is necessary."

"Through the EIP, we started to look at this from a component perspective, then from a system perspective, which allows for a holistic understanding of the track system, which has never been done before."

The EIP lab has been instrumental in establishing baseline hyper-elastic data for improving an FEA model for Abrams track bushings. Associates acquired commercial track bushing compounds and generated hyperelastic data in simple, biaxial and planar tension test modes at various temperatures and established the baseline for the 2- and 3-dimensional FEA models. These models have been successfully developed, optimized and utilized to predict field strains and provide invaluable information into the preferred bushing geometry for the Abrams T-158LL bushing. The development and adoption of this FEA bushing model is an industry first. This capability provides key requirements for improving the component's durability by 50 percent. "Although this is an aggressive target, the 2008 operating and support costs for Abrams track was $32 million," explained Bradford. "During the height of our conflict in Southwest Asia, I'm certain this number was doubled. Track durability has plagued Abrams vehicles for more than 20 years, and the bushing durability has decreased due to vehicle weight creep from 63 tons in 1986 to more than 70 tons in 2009. Improving the bushing by 15 percent will deliver a minimum savings of $5 million annually."



William Bradford, an R&D scientist for TARDEC in TARDEC'S Mobility R&D Center, uses a DMTA testing tool to examine bushing properties. DMTA testing provides a true assessment of bushing properties during the component's life cycle and insight into required material improvements. (U.S. Army TARDEC photo by Chris Williams).

The EIP also developed new testing methodology to extract rubber bushings from track components through specialized shiving techniques that produce consistent sample geometry for Dynamic Mechanical Thermal Analysis (DMTA). This testing provides a true assessment of the component's properties during its life cycle and insight into required material improvements. This method revealed a 55-percent drop in bushing properties after assembly, a fact previously unknown to the track supplier. "That immediately told us that we had a problem with creep resistance and, given this poor retention of the bushing's properties resulting from the manufacturers' design and assembly process, a red flag was hoisted that indicated significant drops in bushing properties without any mileage on the track," Bradford clarified. "Because we identified creep resistance as a key property to monitor, our R&D screening activities have targeted bushing compounds with improved creep resistance and better retention of other key properties. This DMTA screening tool has enabled the selection of improved bushing compounds, and preliminary bushing tests have confirmed a 50- to 75-percent improvement in durability. The detailed 'cause-and-effect' methodology, coupled with new screening tests in the EIP laboratory, has reduced development time, vehicle test time and testing costs."

Examining Integrated Elements

Primarily, the EIP's mission is to understand how failures with elastomeric components impact the entire track system. To that end, the program has created new testing methods for benchmarking and screening road wheels and also plans to develop screening tests for road wheel backing pads in the future. Often, a component will appear to work properly, but its impact on the rest of the track may prove disastrous. Bradford said it is crucial to understand how each element interacts and affects performance. "From a component perspective, you could perform well in a test and believe you have a great road wheel," explained Bradford. "When, really, you may not have a great road wheel because all the energy and vibration is going into the test fixture, which translates into the backer pad or the rest of the track, subsequently increasing backer pad temperature and destroying the bushings."

"The whole deal with track system is trying to understand the total energy management and contribution and impact from each component," Bradford continued. "What do the suspension, track components, road wheels and backer pads contribute to the energy of the track? How is it transferred to the elastomeric components, and what do we need to manage that energy better from a design and material perspective to make those tracks last 4,000 or 5,000 miles? If they last 3,000–5,000 miles at YPG, that means they will have reduced durability in aggressive environments. The goal is that if we increase the durability of our current track systems from 2,500–4,500 miles, we've lowered our cost and reduced the risk and exposure of the Soldier and the vehicle."

As part of its mission to understand how the components interact, EIP developed an accelerated road wheel test that reduced test time by approximately 80 percent. The accelerated test uses specially designed thermocouples and real-time data acquisition capabilities and monitors the onset of road wheel failure. This accelerated test replicates the failure mode and provides a reproducible test to benchmark current production, significantly reducing test time and costs. "The new road wheel tester duplicates the higher load profiles of current Abrams vehicles, tracks failure onset through precise internal temperature loggers, is reproducible and is completed in 70–90 minutes as compared to current test that runs for two-and-a-half days," Bradford remarked. "This is significant to PMs and contractors, enabling a low-cost laboratory screening process to evaluate new materials and designs, thus reducing vehicle test time and test costs and accelerating the development cycle by years."

Maintenance crews at the Anniston Army Depot utilize a track roller to repair track on a tank. The roller cuts down on the replacement time of track components. (U.S. Army photo by Jeremy Guthrie.)

"We're pretty excited about what we can do for not only the current legacy fleet but the new fleet, the 2015 Abrams modernization, and how we spiral this into Bradley modernization, the M-88 and any track for future vehicles."

Current road wheel qualification testing is conducted at 3,500 pound-force (lbs/F) at 30 mph. These test conditions are underspecified for tanks. These vehicles often carry between 3,500 and 9,000 lbs/F at the outboard and inboard road wheel positions. The EIP developed an interdisciplinary approach to understanding the interaction and influence of Abrams suspension on the durability of the track components and road wheels. An innovative pressure measuring capability, utilizing pressure paper and pressure pads has uncovered gross imbalances between the inboard and outboard road wheel stations resulting in excessive energy in the outboard positions. Combining recently developed thermal mapping techniques of the track components with the pressure mapping process has validated these imbalances and R&D activities to quantify the impact of these imbalances on track life are underway. The R&D objective is designed to understand any potential imbalances in the Abrams suspension, determine its impact on the track and road wheel life and recommend cost effective design improvements that will extend track life.

EIP is also planning to test road wheels and track components at higher temperatures to replicate current field conditions. "A lot of the track systems were developed for the Cold War," explained Bradford. "So they were worried about low-temperature performance, and they weren't so worried about high-temperature performance. Most of what's going to happen in the future will take place in more aggressive climates; therefore a focus on higher-performance materials will be necessary."

On the Right Track

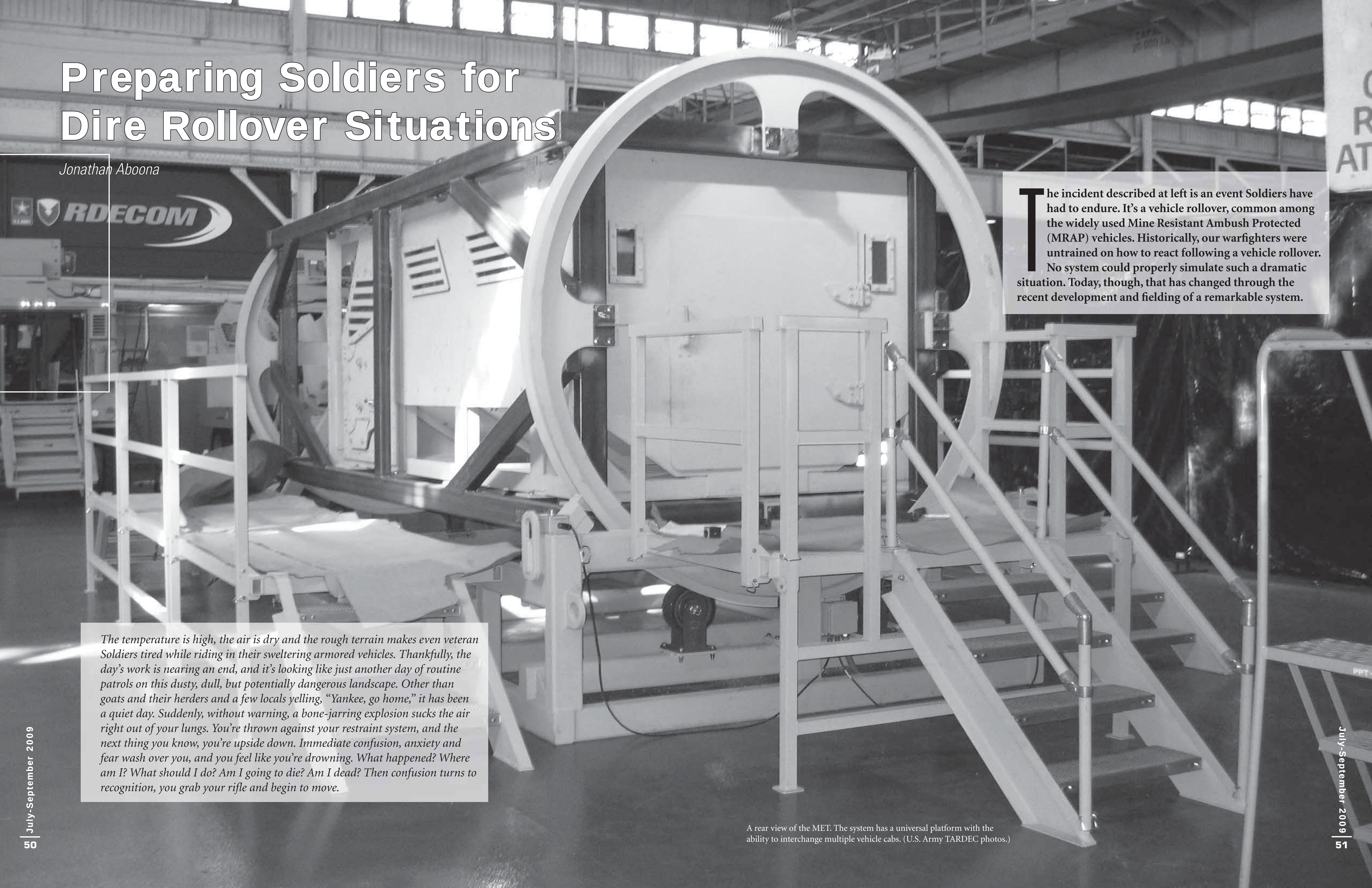
Bradford believes that that the EIP has the potential to discover issues and implement solutions that will vastly improve the durability, reliability and performance of track systems for the Army with the added benefit of significantly reducing the life cycle costs. Conducting failure analysis, FEA and validation are only the first steps in that process. After TARDEC engineers determine why elastomeric components fail, they can begin to design and develop new materials to create more durable tracks. "We are confident that leveraging our R&D activities with our suspension and track partners will enable improvements that will benefit Soldiers," Bradford stated. "We're pretty excited about what we can do for not only the current legacy fleet but the new fleet, the 2015 Abrams modernization, and how we spiral this into Bradley modernization, the M-88 and any track for future vehicles."

EIP testing has discovered that bushings undergo 55-percent deterioration after assembly, which can lead to track and component failure. TARDEC researches are trying to create bushings made of more durable, consistent material that will improve track durability and performance in harsh terrain. (U.S. Army TARDEC photo by Chris Williams.)

Chris Williams is a Writer/Editor with BRTRC and provides contract support to TARDEC's Strategic Communications team. He has a B.A. in communication from Wayne State University in Detroit and has previously written for *The Source* newspaper in Shelby Township, MI, and *The Macomb Daily* and C & G Newspapers in Macomb County, MI.

Preparing Soldiers for Dire Rollover Situations

Jonathan Aboona



The temperature is high, the air is dry and the rough terrain makes even veteran Soldiers tired while riding in their sweltering armored vehicles. Thankfully, the day's work is nearing an end, and it's looking like just another day of routine patrols on this dusty, dull, but potentially dangerous landscape. Other than goats and their herders and a few locals yelling, "Yankee, go home," it has been a quiet day. Suddenly, without warning, a bone-jarring explosion sucks the air right out of your lungs. You're thrown against your restraint system, and the next thing you know, you're upside down. Immediate confusion, anxiety and fear wash over you, and you feel like you're drowning. What happened? Where am I? What should I do? Am I going to die? Am I dead? Then confusion turns to recognition, you grab your rifle and begin to move.

The incident described at left is an event Soldiers have had to endure. It's a vehicle rollover, common among the widely used Mine Resistant Ambush Protected (MRAP) vehicles. Historically, our warfighters were untrained on how to react following a vehicle rollover. No system could properly simulate such a dramatic situation. Today, though, that has changed through the recent development and fielding of a remarkable system.

A rear view of the MET. The system has a universal platform with the ability to interchange multiple vehicle cabs. (U.S. Army TARDEC photos.)

In response to and in conjunction with a Joint Operational Needs Statement (JONS) from the U.S. Army Forces Command, Program Executive Office (PEO) of Simulation, Training and Implementation (STRI) and Red River Army Depot (RRAD), the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) rapidly developed, tested, and has started to field the Mine Resistant Ambush Protected (MRAP) Egress Trainer (MET). The MET trains Soldiers how to properly exit an overturned up-armored vehicle, running them through training scenarios that may, one day, save their lives.


Marines exit the MET, positioned here to simulate an overturned vehicle during trainer evaluation testing at TARDEC in Warren, MI. TARDEC rapidly developed the MET in response to and in conjunction with a Joint Operational Needs Statement from PEO STRI and RRAD.

Historically, our warfighters were untrained on how to react following a vehicle rollover.

While warfighters experience several mental and physical side effects following a vehicle rollover, there are other obstacles that make exiting an overturned up-armored vehicle difficult, such as loose equipment, locked seatbelts and wedged doors. Soldiers are better able to face these obstacles after MET training. TARDEC executed the system's design, prototype fabrication and initial electrical kit production; PEO STRI oversaw entire program management; and RRAD supported structural production and assembly. Together, the groups realized a system that is the U.S. Army's standard for egress training for MRAP vehicles. In fact, the MET, which TARDEC unveiled on Dec. 17, 2008, and fielded in May 2009, will now be part of all Soldiers' required training. "Watching armed service personnel gain experience and improve reaction time when exiting the MET gave me a sense of satisfaction for all we have accomplished," remarked TARDEC Electric Engineer Jason Schrader.

The system is especially remarkable for its high-innovational standards, from interchangeability to unique design. The MET, capable of conducting egress training at 90- and 180-degree positions, will ultimately be used to train with seven different types of MRAP cabs. This interchangeability reduces life cycle costs by decreasing system footprint design, hardware and operation finances.

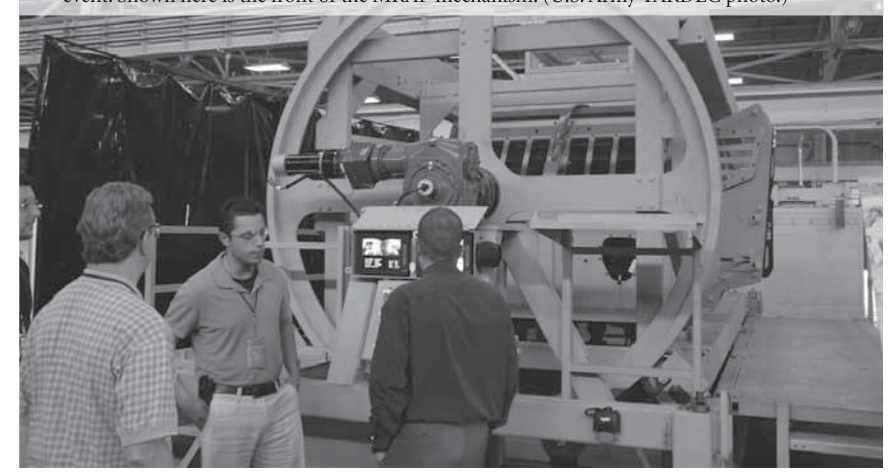
Such an undertaking challenged engineers to design a system that was sufficiently robust to rotate up to a 20,000-pound load and modular to be disassembled and transported. The engineers' design focus on parts helped establish a technical basis for subsequent military improvement that can be readily procured by any Department of Defense (DOD) organization and used with the same electrical drive motor and gear case that automotive assembly lines currently use, providing high reliability with low maintenance.


A Soldier exits the MET, simulating a vehicle on its side, during trainer evaluation testing at TARDEC. The MET is capable of conducting egress training at 90- and 180-degree positions.

The system is especially remarkable for its high-innovational standards, from interchangeability to unique design.

Other key MET innovations include simulated components, such as ammunitions cans, weapons, water bottles, fire extinguishers, battery-powered mobile turret units, Blue Force Trackers and radios made of foam material, acrylic windshields, a durable cage over the gunner's hatch and folding rail platforms on the vehicle's sides and rear. The MET's electrical system was designed to allow the entire cab's electrical system to be disconnected from one location, and the MRAP cab is held in the trainer with just 64 bolts. This reduces downtime during cab substitution, thus maximizing utilization.

The MET, which provides Soldiers invaluable training on how to react following a vehicle rollover, was showcased at the TARDEC Prototype Integration Facility (PIF) Open House June 23, 2009. Warfighters now feel safer and more prepared for the common, dramatic event. Shown here is the front of the MRAP mechanism. (U.S. Army TARDEC photo.)



An important MET component is its safety features should an emergency occur during training. The system's operator/instructor can monitor six cameras placed throughout the cab and a host of displays, including combat lock status, degree of rotation and emergency-stop status. There are also safety items, such as six emergency-stop push buttons and a 2-way intercom system. If any of the emergency-stop buttons are pressed, the system's motion ceases immediately. The intercom allows communications between the operator/instructor and Soldiers inside the cab. The system allows the operator/instructor to hear the Soldiers at all times without having to press any buttons, yielding quick action when necessary. Accompanying the intercom is a microphone switch on the operator/instructor panel that can override the microphone inside the cab to give commands to Soldiers inside the MRAP cab.

The MET, with its inclusion of a slip-ring, is the only Army device that can rotate and stop in various positions and undergo continuous rotation, allowing Soldiers to be trained in several simulated scenarios that expose the occupants to realistic rollover situations, furthering the extensive training experience. The training does not stop when the Soldiers exit the MET. Capturing each training session are six wide-angle cameras mounted on the cab's interior. The video from these cameras and audio from the intercom are recorded with a TV/VCR for after-action reviews.

"Watching armed service personnel gain experience and improve reaction time when exiting the MET gave me a sense of satisfaction for all we have accomplished."

More than its impact on our warfighters, the MET also contributes to national welfare through potential use by warfighters from the U.S. Marine Corps, Air Force, Special Operations Command and Navy, as well as DOD civilians and contractors, first responders and other defense agencies around the world. When Soldiers complete egress training, they are confident that they will survive hostile action — an achievement remarkable in itself and one that the TARDEC team is proud to have developed. "It was exciting to be part of a project team that used cooperation, hard work and diverse skills to develop a product that is really needed and wanted by our Soldiers," TARDEC Mechanical Engineer Peter Pfister concluded.

Jonathan Aboona currently serves as Product Development Integration Team Program Manager in TARDEC's PIF. He has a B.S. in mechanical engineering from Wayne State University and is currently working toward an M.B.A.

Engineers Work Around the Clock to Save Lives

James Soltesz

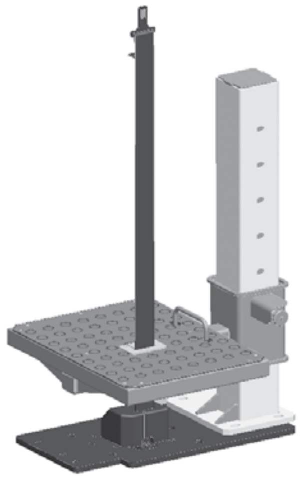
While visiting the Regional Command East and Joint Task Force-101 at Bagram Air Field in Afghanistan on Sept. 20, 2008, Secretary of the Army Pete Geren became aware of a deficiency that required an urgent resolution. He and other Army leaders discovered that Mine Resistant Ambush Protected (MRAP) vehicles did not have Gunner Restraint Systems (GRS), an Army safety feature that entails a harness attached to the vehicle. Without a restraint system, gunners are prone to being thrown from their vehicles in the event of accidents or rollovers on the battlefield. The MRAP's extreme weight alone — some models weigh more than 52,000 pounds — accounted for 51 rollovers from November 2007 to August 2008, according to 3rd Sustainment Command (Expeditionary) safety officials.

Soldiers patrol the warzone in MRAPs featuring the recently fielded GRS. The GRS provides warfighters in theater with a greatly enhanced protection level that will ensure turret gunners' safety in MRAP accidents or rollover situations. (U.S. Air Force photo by SA Jacqueline Romero.)

On Sept. 24, 2008, Geren ordered the engineers and technicians at the U.S. Army Research, Development and Engineering Command's (RDECOM's) Tank Automotive Research, Development and Engineering Center (TARDEC) to develop a solution — within 72 hours. As a result, TARDEC Prototype Integration Facility (PIF) engineers and technicians first initiated and then spearheaded a collaborated effort with the Edgewood Chemical Biological Center (ECBC) and Aberdeen Test Center (ATC) to provide the solution. Together, they assessed, designed, fabricated, integrated, tested, adapted and produced a universal restraint system to improve Soldiers' safety. The entire team adapted an existing 5-point restraint harness and retractor engineered for the High Mobility Multipurpose Wheeled Vehicle to be integrated into each of the seven MRAP variants.

On Sept. 24, 2008, Geren ordered the engineers and technicians at RDECOM's TARDEC to develop a solution — within 72 hours.

"There were several challenges to overcome," said TARDEC



A CAD drawing of one MRAP GRS variant. TARDEC and ECBC engineers and engineering technicians developed two universal kits to fit seven variants. (U.S. Army TARDEC drawing.)

A CAD drawing of an MRAP Cougar variant GRS. TARDEC design engineers began the entire restraint process by physically measuring bolt hole locations in each MRAP vehicle variant. (U.S. Army TARDEC drawing.)

Former TARDEC Military Deputy LTC Andres Contreras (left) discusses the MRAP GRS with TARDEC Director Dr. Grace M. Bochenek (center) and TACOM LCMC Commanding General MG Scott G. West (right). TARDEC PIF engineers and engineering technicians spent 72 hours designing the GRS with ECBC, Aberdeen Proving Ground and ATC personnel. (U.S. Army TARDEC photo.)

Engineer Mike Manceor. "No drawings or [computer-aided design (CAD)] models were available, and no two MRAP variants share the same bolt patterns." This meant each MRAP variant required individual testing and designs.

Despite these difficulties, the TARDEC Advanced Collaborative Environment team made preparations to provide CAD data as needed, while designers climbed into vehicles and physically measured bolt hole patterns. On Sept. 26, 2008, less than 48 hours after Geren's order, TARDEC's MAJ Anh Ha and CW3 Jason Greegor led a team of TACOM Life Cycle Management Command (LCMC) Soldiers in conducting a human factors operational evaluation to provide early feedback for the design effort. The physical testing and human factors engineering were coordinated with TARDEC's Physical Simulation Team, the TACOM LCMC Safety Office and ATC. TARDEC's engineers made design changes in response to test results, while PIF engineering technicians fabricated new components in preparation for potential repairs and modifications. The entire team worked through the weekend, as ECBC and TARDEC engineers developed, fabricated and integrated a solution for the one MRAP variant not available at TARDEC.

At the end of the 3-day haul, the team created two designs to work with the different MRAP vehicle variations. One design fit five variants, and the other fit the remaining two. After the GRS withstood 500 pounds more than the required 2,500 pounds of

"No drawings or CAD models were available, and no two MRAP variants share the same bolt patterns."

TARDEC Engineer Mike Manceor measures bolt hole locations in an MRAP gunner's platform. TARDEC PIF engineers and engineering technicians worked closely with ECBC and ATC personnel to create two universal systems in three days. (U.S. Army TARDEC photo by Bill Dowell.)

pressure during testing, it was evident that the team completed its task with results that exceeded expectations. TARDEC provided designs and 50 Gunner's Kit platform plates to Blue Grass Army Depot, KY, and supported Rock Island Arsenal, IL, with continued manufacturing. In addition, designs, prototypes and a bill of materials for all MRAP variants were completed, while kits were fabricated, assembled and shipped to theater.

The MRAP GRS was first fielded on Oct. 2, 2008, and by the end of 2008, 2,482 kits were delivered to support *Operation Enduring Freedom*, and 5,890 were delivered to support *Operation Iraqi Freedom*. "The systems are arriving in theater daily," stated CPT Jude Verge, 3rd Expeditionary Sustainment Command logistics maintenance officer. "There has just been a big shipment of [GRS] to our subordinate brigade in [Contingency Operating Base] Adder."

The MRAP GRS were first fielded on Oct. 2, 2008, and by the end of 2008, 2,482 kits were delivered to support *Operation Enduring Freedom*, and 5,890 were delivered to support *Operation Iraqi Freedom*.

With an incredible amount of work completed in little time, the MRAP GRS effort significantly increased protection and survivability for our warfighters. The new system provides Soldiers in theater with a greatly enhanced protection level that will ensure turret gunners' safety in MRAP accidents or rollover situations by keeping them snugly in their slings inside the vehicle.

"This was great work by the whole team," remarked former RDECOM Commanding General MG Fred D. Robinson Jr. who retired in December 2008. "It also shows how far we have come as a command when [TARDEC] engineers are tied in with the ECBC … to maximize time and effort."

James Soltesz recently retired from 42 years of dedicated civilian service. He previously served as the PIF Associate Director within TARDEC's Product Development Business Group. Soltesz has a B.S. in mechanical engineering from the University of Detroit and an M.S. in mechanical engineering from Wayne State University. During his distinguished career, he earned an Achievement Medal for Civilian Service and a Commander's Award for Civilian Service.

Door Assist System Allows Easier Entry Into Heavily Armored Vehicles

John Schmitz and
Michael Manceor

The Electric Door Assist System (EDAS) is an integrated electric device that can be used on U.S. Marine Corps International MaxxPro Mine Resistant Ambush Protected (MRAP) Expedient Armor Program vehicles. The solution, developed by the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) Prototype Integration Team (PIF), was designed to assist vehicle operators and passengers in opening heavily armored doors. The system replaces an air-assisted original equipment manufacturer (OEM) door opener that could not function under the newly armored vehicle's weight. The new system allows Soldiers to open and close the power-assisted doors easily by simply operating switches. It provides a much safer environment for Soldiers by mitigating the opportunity for strained muscles or fingers slammed in doors. In May and June of 2008, 50 kits were fielded to Iraq and Afghanistan.

U.S. Soldiers assigned to the 1st Infantry Division received two new MRAP vehicles at Joint Security Station Ghazalia II, Iraq, last year. The TARDEC-developed EDAS and PQRS helped provide a new level of safety and security for deployed Soldiers. (U.S. Air Force photo by SA Daniel Owen.)

The system's inception came about when PIF associates and program managers recognized the problem that up-armored doors were difficult to open. PIF employees felt it was necessary to develop the door assists, and they nurtured the project from the concept to the kit production stage. "The team developed a complete electrical door system from a concept to reality very quickly," explained former TARDEC PIF Associate Director James Soltesz. "This includes a motor controller, Pin Quick Release System (PQRS), door switches, actuator and additional combat lock features."

"The new system allows Soldiers to open and close the power-assisted doors easily by simply operating switches."

While there is a need for management structure and a chain of command, people have to work together in pursuit of a common goal if anything is to be achieved. For this project, program managers, teams, engineers, technicians and procurement specialists worked cohesively to achieve their shared goals, thereby fulfilling a TARDEC strategic transformation goal of collaboration to achieve a successful end result. "John Schmitz and Michael Manceor led the team and worked diligently to create solutions-based technologies that meet warfighters' needs," Soltesz remarked.

Prior to the EDAS's development, doors often seemed impossible to open, even when a vehicle was on level ground. The problem was due to the lack of air pressure on vehicles that had been shut off for a long time, which made entry a challenge using the OEM air-assisted mechanism — no air pressure, no entry.

U.S. Army SSG Shay Thiede (left), a troop master driver assigned to Bravo Troop, 1st Infantry Division, shows PFC Yordan Garcia how to operate the driver's switches on a MaxxPro Plus MRAP vehicle at Joint Security Station Ghazaliya II, Iraq. A troop master driver trains and is licensed on all military vehicles assigned to his or her unit, both in theater and at home. (U.S. Air Force photo by SA Daniel Owen.)

The upgraded electric system is always prepared for doors to be opened or closed. The electric door opener uses an electrical actuator, digital controller and switches. The electrical actuator is capable of thrusting with 2,200 pounds of force total. It works by pushing against a slide block, which existed on the OEM version. The 24-volt actuator motor is driven by a digital motor controller, which is mounted on the dash and the vehicle's exterior and can be programmed with soft-start settings for smooth operation. The controller also can be programmed to limit the motor current so as not to damage the actuator under high loads.

"The team developed a complete electrical door system from a concept to reality very quickly."

The dash-mounted interior door switches are arranged in the dashboard's center so either the driver or passenger can open either door. The switches fit into an existing pocket, thereby saving space. There are also limit switches mounted inside the doors to shut the system off if the doors are mechanically combat locked. The exterior switches were designed to resemble standard door handles and be durable enough to sustain long life. They had to be designed for ruggedness and longevity. To achieve durability, the handles are supported on sleeve bearings, making them very difficult to damage. Several switches were successfully subjected to blast tests. While other parts of the system were destroyed, the switches would retain their function.

Another crucial aspect of improving the OEM version was being able to release the doors in an emergency. The PQRS was designed so that the vehicle occupant could push a lever and the EDAS would allow the door to swing open. Additionally, the PQRS can be set up to allow first responders to open the door by pulling on a cable on the outside, thereby improving crew member safety and survivability.

"Anything that improves Soldier safety while keeping the solution simple makes us feel as if we've accomplished our goal."

Both the EDAS and PQRS are electromechanical solutions that can be easily installed and operated by Soldiers in theater, are reliable and are simple to repair if damaged. With so many benefits, this device has potential for far-reaching applications in the law enforcement, explosive ordnance disposal and first responder communities. Secondary uses for commercial and automotive industry applications include armored trucks, heavily armored passenger cars and sport utility vehicles.

For TARDEC, the increase in readiness, survivability and capability made the EDAS and PQRS vital components in the optimization process for developing systems that increase Soldier sustainability. "The EDAS meets crew safety and survivability needs by making it effortless for first responders to gain entry," explained Soltesz. "Anything that improves Soldier safety while keeping the solution simple makes us feel as if we've accomplished our goal."

This EDAS's switches have been installed and mounted to the vehicle's dashboard. It fits into an existing pocket, which saves space. By placing it in a central location, both driver and passenger can operate the system. (U.S. Army TARDEC photo by Mark Fuller.)

John Schmitz is a Senior Electrical Engineer at the TARDEC PIF. He received the Research Development Achievement Leadership Award in 2007 for his work on the Forerunner Remote Control High Mobility Multipurpose Wheeled Vehicle (HMMWV). He holds a B.S. in electrical engineering from Lawrence Technological University and an M.S. in electrical engineering from the National Technological University in Minneapolis, MN. He is a licensed Professional Engineer in Michigan.

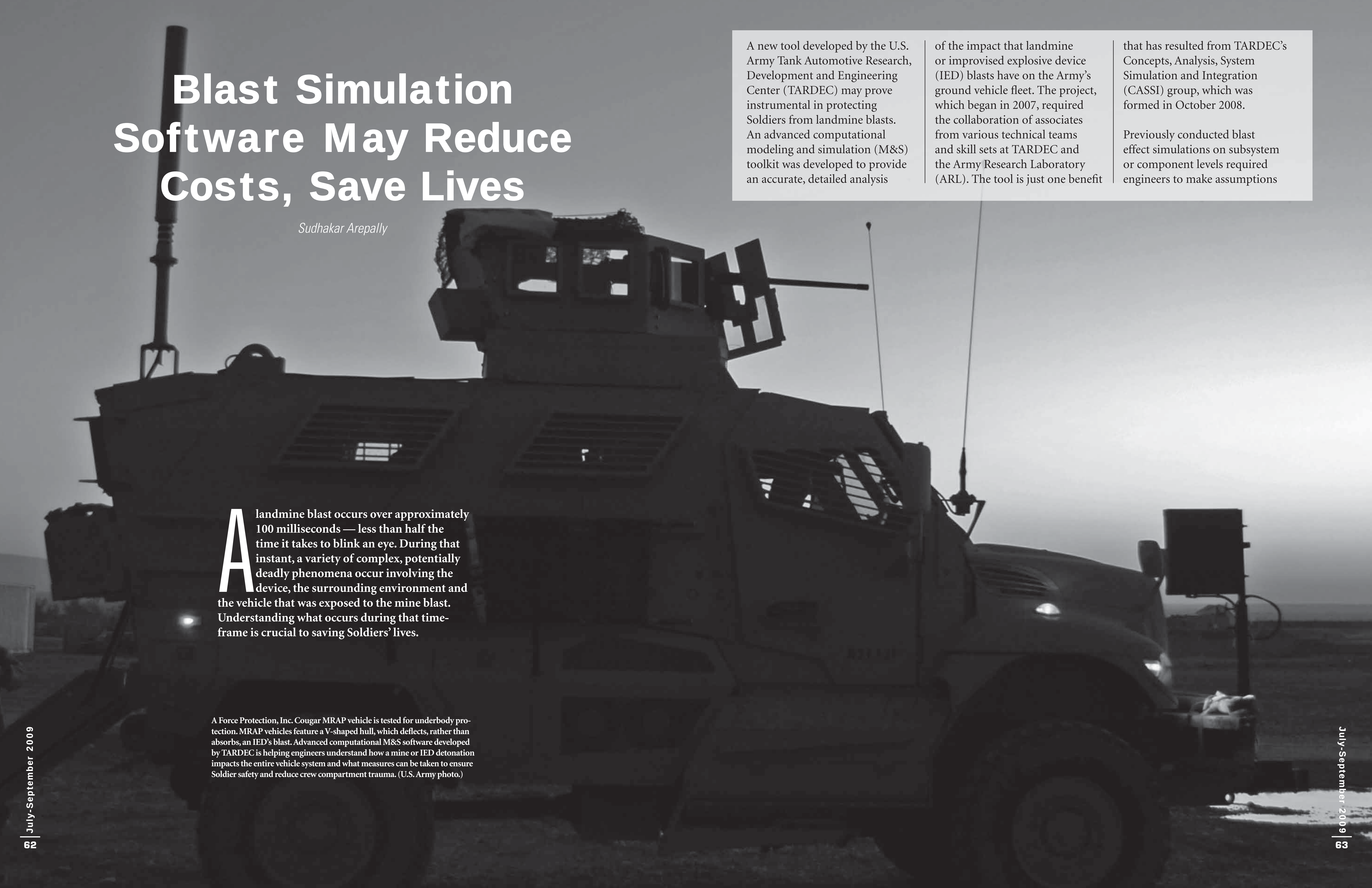
Michael Manceor is a Senior Mechanical Engineer at TARDEC. He has received a Ten Outstanding Army Materiel Command Personnel of the Year Award, a Top Ten Greatest Inventions Award and the Army Research and Development Achievement Award in 2004 for his work on the HMMWV Add-on-Armor project. He has a B.S. in mechanical engineering from the University of Michigan.

Blast Simulation Software May Reduce Costs, Save Lives

Sudhakar Arepally

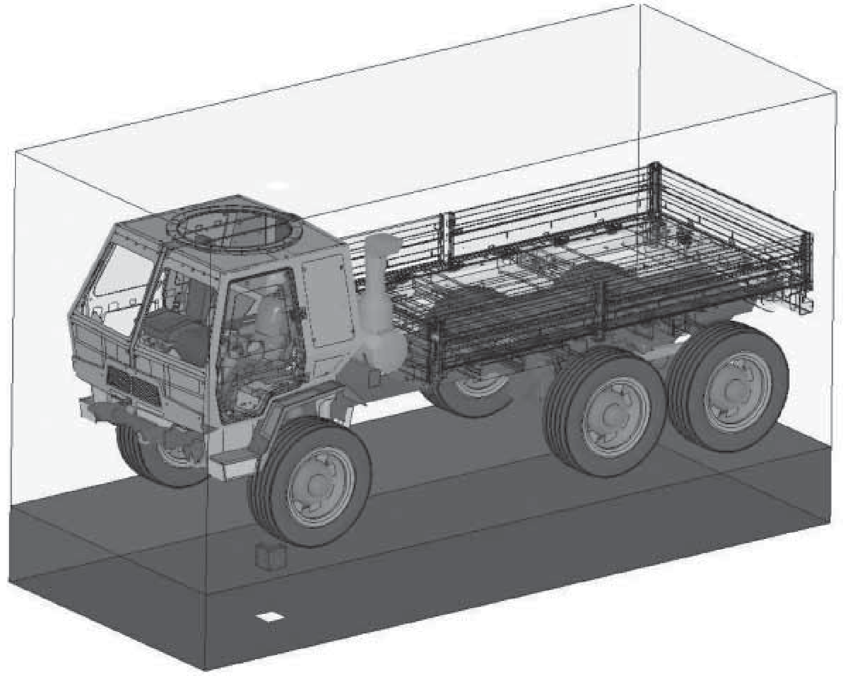
A new tool developed by the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) may prove instrumental in protecting Soldiers from landmine blasts. An advanced computational modeling and simulation (M&S) toolkit was developed to provide an accurate, detailed analysis of the impact that landmine or improvised explosive device (IED) blasts have on the Army's ground vehicle fleet. The project, which began in 2007, required the collaboration of associates from various technical teams and skill sets at TARDEC and the Army Research Laboratory (ARL). The tool is just one benefit that has resulted from TARDEC's Concepts, Analysis, System Simulation and Integration (CASSI) group, which was formed in October 2008.

Previously conducted blast effect simulations on subsystem or component levels required engineers to make assumptions



A landmine blast occurs over approximately 100 milliseconds — less than half the time it takes to blink an eye. During that instant, a variety of complex, potentially deadly phenomena occur involving the device, the surrounding environment and the vehicle that was exposed to the mine blast. Understanding what occurs during that time-frame is crucial to saving Soldiers' lives.

A Force Protection, Inc. Cougar MRAP vehicle is tested for underbody protection. MRAP vehicles feature a V-shaped hull, which deflects, rather than absorbs, an IED's blast. Advanced computational M&S software developed by TARDEC is helping engineers understand how a mine or IED detonation impacts the entire vehicle system and what measures can be taken to ensure Soldier safety and reduce crew compartment trauma. (U.S. Army photo.)



This image depicts how new computational methods developed by TARDEC incorporate an entire vehicle's system into simulation. Previous M&S programs examined blasts on a component level. The new program allows for a more integrated look at blast effects across the entire vehicle. (U.S. Army TARDEC image by Sudhakar Arepally.)

about boundaries that could be rendered invalid by a change in variables. The new program provides a system-wide evaluation of detonations' effects on a ground vehicle and its occupants. "In one straight-shot computer simulation, you're able to understand the charge and how it detonates," explained Paul Decker, TARDEC Acting Associate Director for Analytics with CASSI. "In an interactive and integrated fashion, you have the back-and-forth exchange of information, the physics and the math that goes on. You have a streamlined flow of information between the structure and the occupant."

Understanding Complex Phenomena

The reactions during the mine blast's short timeframe are difficult to quantify in physical testing due to instrumentation constraints, making M&S programs ideal for understanding blast events' impact, dissecting each phenomenon's element and determining cause-and-effect relationships. "Basically, we are able to get tremendous insight into the event, so that we can improve and enhance the product quality and performance," Decker remarked. "Based on those insights, we are able to develop solutions, or countermeasures, very quickly as opposed to making it a guessing game. We are intelligently and efficiently addressing the issue."

A landmine blast occurs over approximately 100 milliseconds — less than half the time it takes to blink an eye.

The program takes into account variables that affect the amount of damage that occurs during the event, including the threat, its location and the system's structural elements and protective materials. "What you're trying to do is nail down the region that is the focus of your analysis and be able to put in the constraints, the boundary conditions, the topology and the material characteristics that go into play," stated Decker. "All of those things are very important in the entire analysis scheme so that you get results that are believable, match the physical tests closely and that you can predict even before running the test."

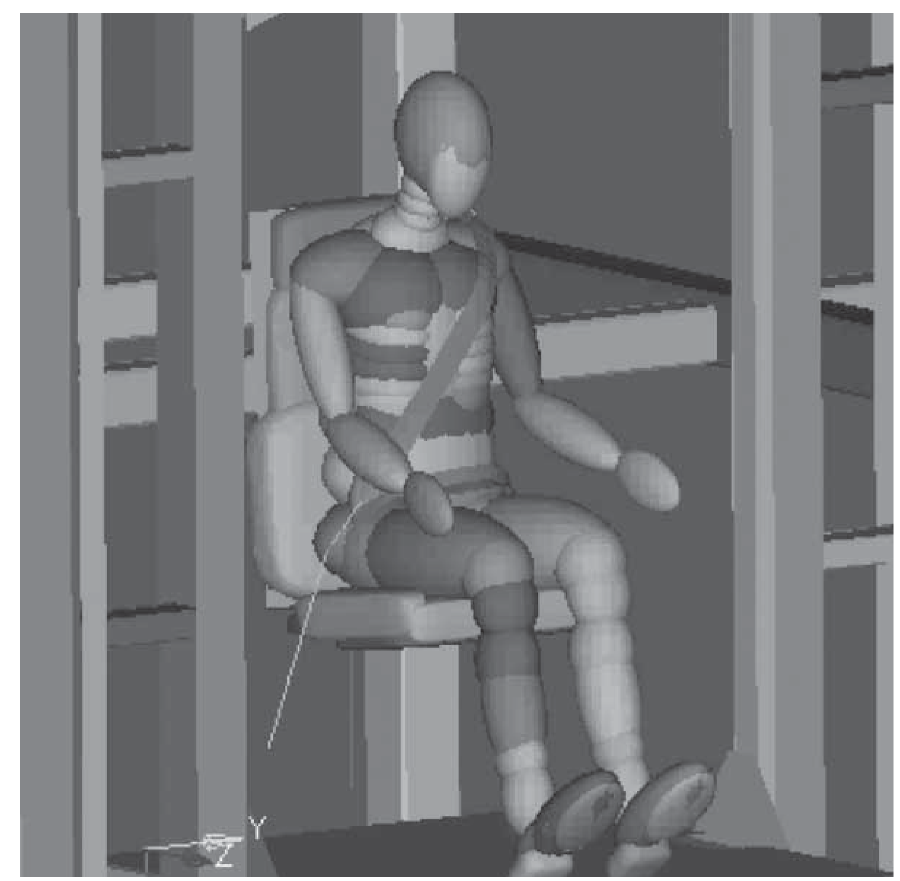
To understand a detonation's effect on the entire system, it is essential to account for each vehicle component. When applied to the Army's Family of Medium Tactical Vehicles, data representing each piece of the vehicle, including the underbelly, engine block, transmission case and occupant compartment, was input into the program. The simulation also accounts for the materials involved in the event, including the type of mines used, the system's armor and the variations in soil and air surrounding the mine or IED. The complex equations involved — simulating the blast itself requires the calculation of nearly two million degrees of freedom — require using multiple central processing units and various software programs. TARDEC engineers were heavily involved in creating algorithms and methods to integrate the software so the components could communicate effectively.

By utilizing computer simulations, the Army is able to reduce costs on physical testing. Simulations conducted during the product's development life cycle allow developers to identify and implement performance-enhancing designs rapidly and manufacture and field products more efficiently. Identifying designs at the architectural level positions engineers to meet and possibly exceed expected targets and deliver superior-performing vehicles to Soldiers in a timely manner. "This is helpful not only from a current threat standpoint, but it also allows us to address future threats, because we now have a wider, bigger design space to address effortlessly and with less cost because we have the infrastructure in place," said Decker. "We have the models in place, and, at the click of a button, we can run hundreds of runs, as opposed to conducting hundreds of tests to look at the design space. So we're narrowing down the design space and approaching the issue very smartly."

Since the program's completion, TARDEC associates have captured the interaction among charges, soil, air and vehicles and the effect it has on a system's structural behavior during a blast event. Data acquired from the simulation has been compared to results from physical tests conducted at the Army Test and Evaluation Command (ATEC). The comparison levels have been "quite satisfactory," Decker voiced. The current framework is being used for several Army Technology Objectives (ATOs), including the Future Combat Systems Armor ATO, High-Performance Lightweight track ATO and Tactical Wheeled Vehicles ATO.

Engineers have been creating computer simulations using the framework to compare various underbelly kits and create countermeasures to protect the occupant compartments. "We were also instrumental in developing alliances within the Army Evaluation Center and Aberdeen Test Center communities to help augment them in their pre-shot evaluations with these [M&S] capabilities," Decker continued. "Their intent is to reduce the costs of testing, and the way they'll be able to do that is by making use of the M&S. They can actually run many simulations before a test and improve not only the quality and performance of the end product, but there is also an opportunity to reduce costs significantly as well, because blowing up a Mine Resistant Ambush Protected vehicle is extremely expensive. It's not just the product cost, but you're also talking about engineering time, the resources used and so on."

By using the system, the Army cuts back on research and development costs and, more importantly, protects Soldiers from mine blasts' deadly impact. "By evaluating blast effects on vehicle structures, particularly the occupant crew compartment, and understanding how the load wave transfers through the vehicle structure into the crew cabin, we can better understand how it affects the crew and be able to assess the injury risk," Decker said. "The speed at which we deliver the product to the customer is really important — this is a matter of life-and-death, especially on a battlefield."



TARDEC's computational M&S also allows engineers to study a blast's effect on the crew compartment occupants, leading to technology that can be used to save Soldiers' lives. (U.S. Army TARDEC image by Sudhakar Arepally.)

Sudhakar Arepally serves as TARDEC's Team Leader for Energetic Effects and Crew Safety and is the technical expert for planning, directing, reviewing and coordinating efforts of personnel engaged in research, development and engineering. He has an M.E. in industrial engineering from Tennessee Technological University and an M.B.A. from the University of Michigan.

Sensor-Enhanced Armor May Be Key to Better Vehicle Protection

Chris Williams

HEMTTs from the 101st Airborne Division carry combat-modified versions of M998 High Mobility Multipurpose Wheeled Vehicles back to Forward Operating Base Remagen, Iraq, from a desert location. Sensor-enhanced armor testing developed by TARDEC has been implemented for a HEMTT prototype. (U.S. Army photo by SPC Teddy Wade.)

Small transducers may play a crucial role in protecting Soldiers from deadly attacks. Researchers at the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) have developed new technology that delivers accurate, real-time vehicle armor analysis. The technique uses sensors embedded in a vehicle's armor plates and has been in development since Soldiers in the field requested it in 2007.

Because damaged plates sound different than healthy plates, armor was inspected with a "tap test" in which Soldiers tapped the armor and listened to the sound it made to determine whether plates had sustained damage. The technique was an accurate form of nondestructive testing, but it also had drawbacks. "The ear is very sensitive, but the problem is that the technique is not repeatable from Soldier to Soldier," explained Dr. Thomas Meitzler, Team Leader for TARDEC's Non-Destructive Testing and Evaluation (NDTE) Laboratory. "Some Soldiers lose part of their hearing because of exposure to all of the explosives and blasts. What we did was develop an automated version of this testing that lets the computer do the processing and determination of whether it's a healthy or damaged plate."

The technique was developed to evaluate body armor and used sensors attached to the armor,

"We generate a shockwave through the plate, which picks up the reflections of that sound wave and converts it to an electrical voltage from which we can determine its spectrum and whether the plate is cracked."

which was then scanned with a handheld device attached to an oscilloscope. When TARDEC's Survivability Non-Destructive Evaluation (NDE) Team was tasked to update the technique for use on vehicles, many of the system's components were retained, although the sensors now transmit to a computer instead of a handheld wand. "The key component is the piezoelectric transducer, which both generates and receives voltages," Meitzler remarked. "We generate a shockwave through the plate, which picks up the reflections of that sound wave and converts it to an electrical voltage from which we can determine its spectrum and whether the plate is cracked."

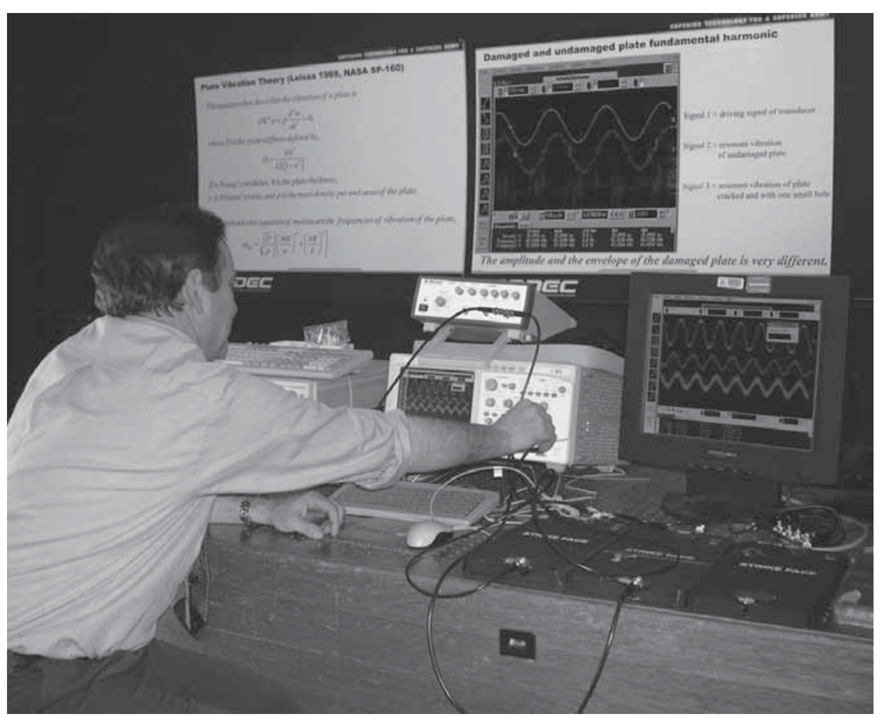
Through experimentation, TARDEC researchers discovered the best locations and number of transducers to embed into a plate in the manufacturing process.

Through experimentation, TARDEC researchers discovered the best locations and number of transducers to embed into a plate in the manufacturing process. During testing, an ultrasonic signal is sent through the plate at 200 different frequencies, varying from one kilohertz (kHz) to 200 kHz. The test is repeated several times under various environmental conditions to collect data that will comprise the plate's baseline, or "fingerprint." The fingerprint captures the plate's characteristics in an undamaged state. Data is stored on a chip so that the system recognizes an undamaged plate's signature. The plate can be tested again, and variations from that original signature reveal whether the plate is damaged and to what extent.

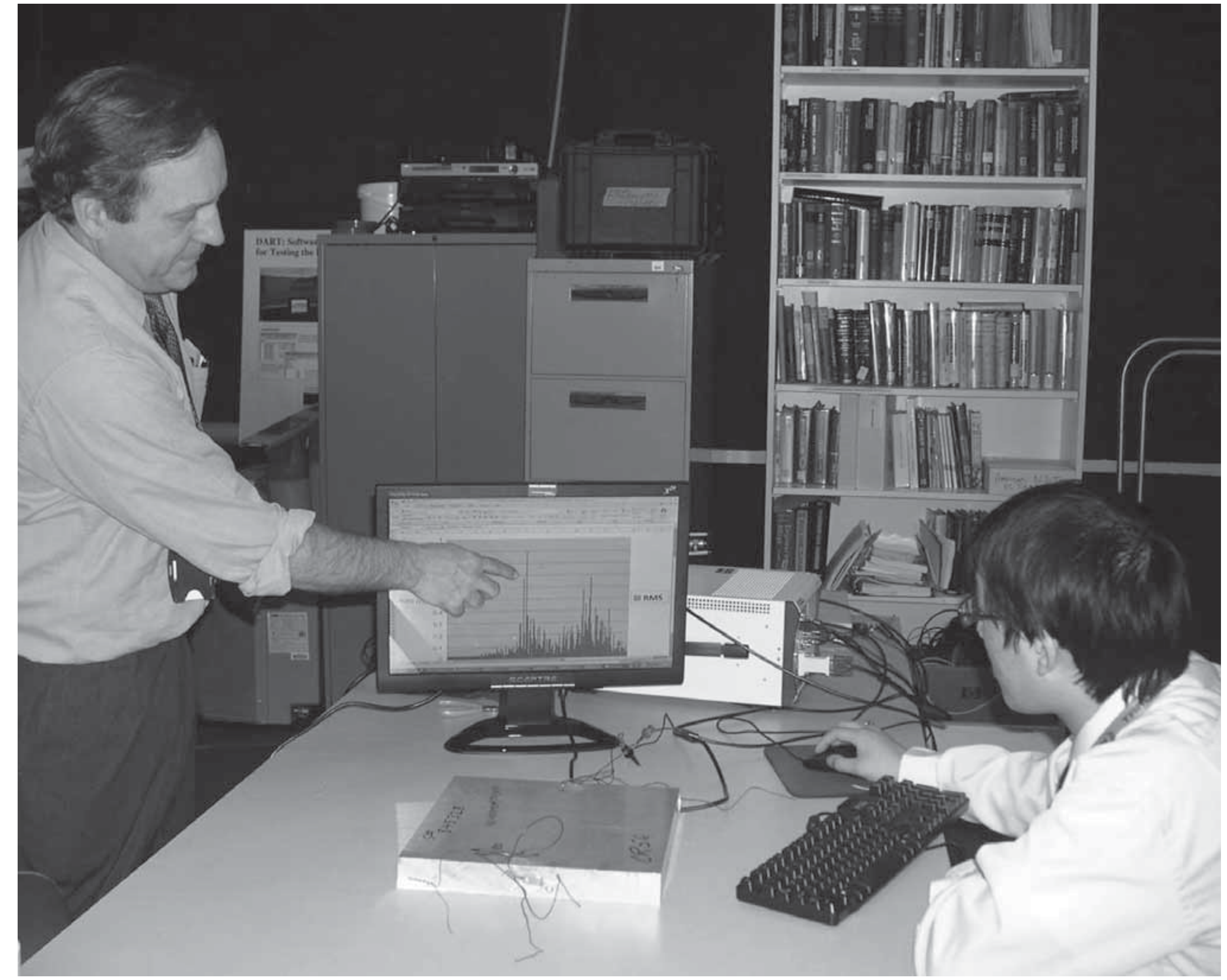
The sensors are developed specifically for the material that comprises the armor plates. Each sensor's shape is the same as the plate component itself for optimal readings. Ultrasonic testing is an ideal form of nondestructive testing and can be used on several armor materials and composites.

"Most of the armors we've been dealing with are based on some kind of silicon carbide or brittle ceramic, which makes the use of ultrasound appropriate," Meitzler continued. "But we have also seen success with some materials that you wouldn't think of using. For instance, pellet armor is a composite in itself. You wouldn't normally think you could use ultrasound for it. But it turns out that because of the way it's made, with the pellets touching each other, it transmits ultrasound very well."

The technique currently utilizes its own computer system, which will eventually be scaled down and integrated into warfighter displays on future vehicles. It uses a red-green-black color readout that easily identifies armor damage. The device will increase situational awareness by supplying Soldiers with real-time indicators when the vehicle is under attack, alerting them to any armor damage and assisting in determining whether to continue with a mission or return for repairs.



TARDEC NDTE Team Leader Dr. Thomas Meitzler studies the computer signature provided by sensors embedded in vehicle armor. This test capability studies armor fingerprints and uses comparisons to determine whether armor plates have sustained damage. (U.S. Army TARDEC photo by Chris Williams.)

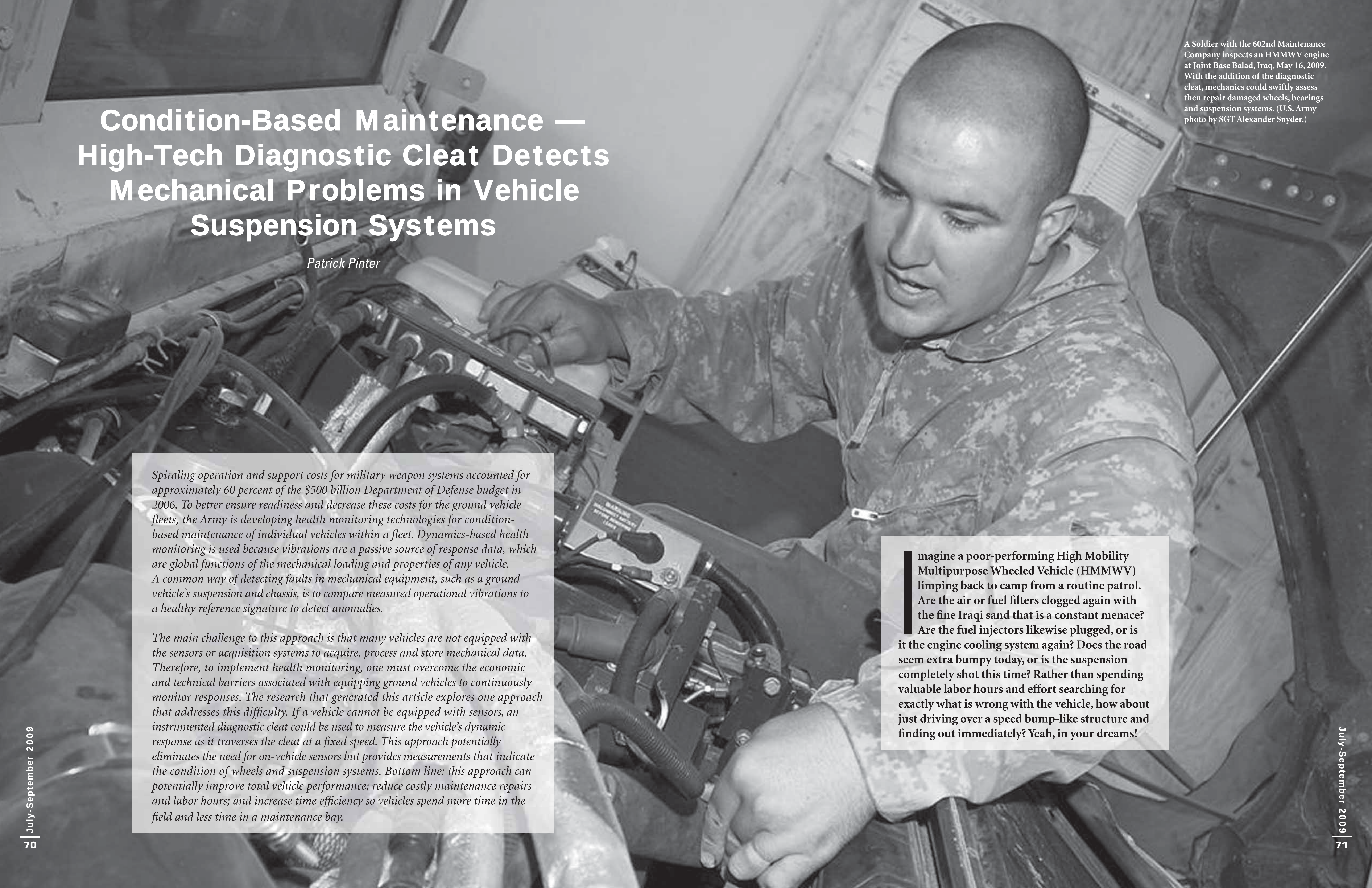


TARDEC's Dr. Thomas Meitzler (left) and TARDEC Engineer Ivan Wong study the test results for a new armor component. (U.S. Army TARDEC photo by Chris Williams.)

"For the Soldier, this gives them a greater understanding of what level of protection this armor is capable of giving, which impacts their survivability and helps them decide if they could do other missions, what kind of missions they could do or whether they should do something else," Meitzler explained. "It also provides more information for life cycle management, because if we have a tool to help decide if a plate is good or bad, we can cut down on the number of new plates needed because there is now a computer system to help decide if it's still usable."

Sensor-enhanced armor has been implemented on one prototype for tactical wheeled vehicle systems on a Heavy Expanded Mobility Tactical Truck (HEMTT) as part of a field spinout. TARDEC is also in the process of implementing the technique as a prototype for Ground Vehicle Combat Development and two more demonstrators for tactical wheeled vehicle systems. More research is required before the device will attain a desired technology readiness level, but Meitzler believes the system shows promise. "So far, it looks very optimistic," he said. "We're still doing a combination of test models to verify the scaling. We have to get some full-size panels from manufacturing and see what we have to do in terms of number of sensors. The physics will be the same, but the number of sensors may be different," Meitzler concluded.

Chris Williams is a Writer/Editor with BRTRC and provides contract support to TARDEC's Strategic Communications team. He has a B.A. in communication from Wayne State University in Detroit, MI, and has previously written for *The Source* newspaper in Shelby Township, MI, and *The Macomb Daily* and C & G Newspapers in Macomb County, MI.



A Soldier with the 602nd Maintenance Company inspects an HMMWV engine at Joint Base Balad, Iraq, May 16, 2009. With the addition of the diagnostic cleat, mechanics could swiftly assess then repair damaged wheels, bearings and suspension systems. (U.S. Army photo by SGT Alexander Snyder.)

Condition-Based Maintenance — High-Tech Diagnostic Cleat Detects Mechanical Problems in Vehicle Suspension Systems

Patrick Pinter

Spiraling operation and support costs for military weapon systems accounted for approximately 60 percent of the $500 billion Department of Defense budget in 2006. To better ensure readiness and decrease these costs for the ground vehicle fleets, the Army is developing health monitoring technologies for condition-based maintenance of individual vehicles within a fleet. Dynamics-based health monitoring is used because vibrations are a passive source of response data, which are global functions of the mechanical loading and properties of any vehicle. A common way of detecting faults in mechanical equipment, such as a ground vehicle's suspension and chassis, is to compare measured operational vibrations to a healthy reference signature to detect anomalies.

The main challenge to this approach is that many vehicles are not equipped with the sensors or acquisition systems to acquire, process and store mechanical data. Therefore, to implement health monitoring, one must overcome the economic and technical barriers associated with equipping ground vehicles to continuously monitor responses. The research that generated this article explores one approach that addresses this difficulty. If a vehicle cannot be equipped with sensors, an instrumented diagnostic cleat could be used to measure the vehicle's dynamic response as it traverses the cleat at a fixed speed. This approach potentially eliminates the need for on-vehicle sensors but provides measurements that indicate the condition of wheels and suspension systems. Bottom line: this approach can potentially improve total vehicle performance; reduce costly maintenance repairs and labor hours; and increase time efficiency so vehicles spend more time in the field and less time in a maintenance bay.

Imagine a poor-performing High Mobility Multipurpose Wheeled Vehicle (HMMWV) limping back to camp from a routine patrol. Are the air or fuel filters clogged again with the fine Iraqi sand that is a constant menace? Are the fuel injectors likewise plugged, or is it the engine cooling system again? Does the road seem extra bumpy today, or is the suspension completely shot this time? Rather than spending valuable labor hours and effort searching for exactly what is wrong with the vehicle, how about just driving over a speed bump-like structure and finding out immediately? Yeah, in your dreams!

U.S. Army Soldiers from the 4th Brigade Combat Team, 1st Armored Division, repair their vehicles while at a Joint Security Station on the Iranian border on June 15, 2009. (Photo by SSG Brendan Stephens.)

That idea is becoming a reality, thanks to research the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, MI, is doing in collaboration with both Purdue University and Honeywell International, Inc. Damaged vehicles could be driven over a diagnostic cleat sensor, which is similar in structure to a speed bump. By driving over the sensor, called triaxial accelerometers, the system would then measure vibrations created by forces that a vehicle's tires would apply to the cleat. Damage is detected in the tires, wheel bearings and suspension components by using signal processing software to interpret the sensor data.

"In theater, some vehicles may be used at checkpoints, while others may be hauling supplies hundreds of miles," remarked Joseph Gothamy, Deputy Associate Director for Analytics within the Concepts, Analysis, System Simulation and Integration (CASSI) group at TARDEC. "Even if the same vehicle variant is used, they are on very different missions, and trying to use the same regular maintenance schedule for both isn't always efficient or effective."

When problems arise on the battlefield, a quick solution is imperative to keep Soldiers safe and their vehicles running. Now, developers have come up with this simple and cost-effective technology that can quickly detect damage to critical suspension components in military vehicles. This system does not require specialized training to operate, and it is relatively inexpensive, costing approximately $1,500 per unit.

"The last thing you want is Soldiers out in the field with equipment failure."

"The diagnostic cleat is designed to be quick and easy to use," said Gothamy. "The last thing we want to do is take time from already overburdened Soldiers and maintenance officers. The cleat is a quick first check to determine what's mechanically wrong with a vehicle before wasting time hunting for potentially simple problems." Previously, when a vehicle suffered damage on the battlefield, it was extremely difficult and time consuming to narrow down exactly how the damage had affected the entire vehicle.

An Oshkosh Truck Corp. test technician prepares a new independent suspension system to be installed on an MRAP as an Oshkosh senior test technician observes the process June 3, 2009, at the Combat Center's Exercise Support Division maintenance bay. Detecting mechanical faults in suspension systems by comparing measured operational vibrations could revolutionize vehicle component diagnostics. (U.S. Marine Corps photo by CPL Margaret Hughes.)

"The main idea is to save time and maintenance costs. We want to catch the problems and undetected damage before it leads to systems failure in the field. The last thing you want is Soldiers out in the field with equipment failure," said Dr. Douglas E. Adams, an Associate Professor of Mechanical Engineering and Director of Purdue University's Center for Systems Integrity. "Operating and maintenance costs for military vehicles account for a large amount of money annually," commented Adams. "Better diagnostic and prognostic technologies could reduce this expense and ensure readiness of ground vehicle fleets."

By using the instrumented cleat and other condition-based maintenance methods, the military could reduce costs by performing work on vehicles when needed based on the condition of parts instead of performing scheduled maintenance on vehicles just because the calendar indicates it's time for a periodic checkup. "If you get into the field and you have problems with a tire or the suspension, the cleat can tell you to turn around before you set course on a long mission with this vehicle," remarked Adams. "If there is a problem, the cleat identifies it so the maintenance personnel don't have to troubleshoot the vehicle. They know what to fix."

"Better diagnostic and prognostic technologies could reduce this expense and ensure readiness of ground vehicle fleets."

Research findings on this project were detailed in a technical paper presented during the Society of Automotive Engineers World Congress in Detroit in April 2009. The team of researchers from TARDEC included Gothamy; Paul Decker, Acting Director for Analytics within CASSI; David Lamb, Team Leader for Reliability Modeling and Data Analysis; and Chief Scientist Dr. David Gorsich. Also contributing were Purdue mechanical engineering graduate student Tiffany DiPetta, Purdue senior research engineer David Koester and Adams.

The partnership between Purdue University and TARDEC benefits both sides. The joint venture has been positive for TARDEC because it helps develop and integrate solutions for current vehicle programs and encourages academic institutions to play a vital role in Army research and development (R&D) initiatives. For Purdue, this has been an opportunity to focus on R&D that could truly make a difference for commercial vehicle fleets.

"We have the ability here to work on some interesting problems, but the question is, sometimes, 'Are we working on the right problems?' TARDEC helps us focus on solving the right problems," remarked Adams. "Interacting with TARDEC engineers gives us great satisfaction. The ability to work with people who have so much subject-matter expertise is a great opportunity. The technology we develop has a real chance to help the Soldier."

Purdue Associate Professor of Mechanical Engineering Dr. Douglas E. Adams and graduate student Tiffany DiPetta display the diagnostic cleat sensor they developed in conjunction with TARDEC researchers and engineers. When completed, this technology will help detect damage to critical suspension components in military vehicles. (Purdue News Service photo by Andrew Hancock, used with permission.)

Patrick Pinter is a Writer/Editor with BRTRC and provides contract support to TARDEC's Strategic Communications team. He has a B.A. in journalism and political science from Western Michigan University.

Editor's Note: *Tiffany DiPetta, David Koester and Dr. Douglas E. Adams, Center for Systems Integrity, Purdue University, provided the introduction for this article.*

RDA Award Winner

Moving Future Convoy Operations with Convoy Active Safety Technologies (CAST)

Edward Schoenherr

The accelerate Magazine Editorial staff would like to congratulate Edward Schoenherr, Jeff Jaster, James Davis and Bernard Theisen and their team's efforts on winning the 2009 Army Research and Development Achievement Award for the Convoy Active Safety Technologies project.

The operational ability to project and sustain forces in distant, difficult-to-access environments poses challenges for combatant commanders. In particular, conducting sustainment convoy operations is critical for providing combatant commanders with the right support, at the right time and place and in the right quantities. The ability to conduct sustainment convoys in a variety of hostile environments requires force protection measures that address enemy threats and protect Soldiers.

The CAST system helps alleviate some of these challenges. CAST is a low-cost, platform-independent, kit-based, autopilot-like, autonomous following system for the tactical wheeled vehicle fleet. CAST increases vehicle crew members' situational awareness (SA) by providing additional vehicle security, allowing for rest and performance of other necessary duties, while providing collision avoidance, decreased convoy misdirection, synchronized emergency braking and low-visibility and night operations assistance. As a driver-in-the-loop system with the ability to return manual vehicle control to the operator at any time, CAST is well- suited to engender warfighters' trust in and acceptance of automation, while providing them with secure mobility during convoy operations.

Semiautonomous Mobility

The path to autonomous mobility for ground operations requires a phased approach, ranging from basic teleoperation to fully unmanned systems, progressing toward a driver assist capability to automate the driving function during routine convoy operations. The CAST system is moving technology forward on this path and, thus far, its main achievements are fourfold:

The Nevada Army National Guard tested CAST, which is transitioning into a fieldable, robot-controlled system that promises to decrease driver workload and fatigue while increasing SA and reducing vehicle collisions. (U.S. Army TARDEC photos by Paul Tremblay.)

- Developed and demonstrated the convoy driver assist capability.
- Gathered direct user feedback and evaluated the system's capability.
- Tested and evaluated the CAST-equipped vehicle performance utility, as well as direct physiological effects on and benefits to the vehicle operator.
- Developed related capability requirements documentation.

CAST's ability to switch from manual to automatic driving modes with the push of a button provides Soldiers with instantaneous manual control. The system maintains a preset distance between vehicles and automatically adjusts vehicle speed. It also can shift gears, maneuver around corners and navigate robust terrain. In autonomous mode, if an obstacle suddenly appears, the vehicle will avoid it or stop, and the system can assume command automatically if the lead vehicle becomes inoperable. Some system features include single-button operation, obstacle detection and avoidance, limited-visibility operations, non-convoy vehicle handling and night-vision driving.

The CAST program is an excellent example of joint organizational efforts working toward an operationally feasible and valuable system. The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) developed the technology with support from the Army Research Laboratory Human Research Engineering Directorate (ARL HRED), which provided experimental design and execution, and the U.S. Army Training and Doctrine Command's (TRADOC's) Combined Arms Support Command (CASCOM), which framed performance and utility measures and developed and linked requirements documentation.

The CAST program is an excellent example of joint organizational efforts working toward an operationally feasible and valuable system.

A TARDEC associate prepares a vehicle for CAST testing. CAST will give vehicles autonomous following capabilities and decrease Soldier fatigue.

The CAST program and TARDEC have been partnered with ARL HRED since 2006 through a series of warfighter experiments. ARL HRED specializes in human factor testing and analysis, specialized training, testing practices and methodologies. This partnership allows for a more robust, thorough experimentation, and having a third-party, non-biased analyst collecting and verifying information produces more reliable data. This, in turn, facilitates building support for the program and accelerating the system's development.

Convoys are critical to providing combatant commanders with the right support, at the right time and place and in the right quantities. CAST makes this truck and its cargo more likely to reach its destination in a timely manner.

"The CAST program is a great example of how TARDEC is working in its new role as the lead for the U.S. Army Research, Development and Engineering Command's Ground System Integration Domain," explained Deputy Associate Director of Intelligent Ground Systems (IGS) Jeff Jaster. "With the help of our partners in the Department of Defense (DOD) centers and labs, we have successfully integrated a low-cost, semiautonomous solution for convoy operations. We have also been working with the user community to ensure that we are addressing their needs as they relate to future requirements development. The technology outcomes from the CAST program directly support the logistical needs of our Soldiers."

Notable improvements since 2007 include a 93-percent reduction in manual control takeovers and a 25-percent increase in operator target awareness.

Technology Tested

CAST underwent testing Nov. 14, 2008. The system is currently in the process of transitioning into a fieldable, robot-controlled system that promises to decrease driver workload and fatigue while simultaneously increasing SA and reducing vehicle collisions. Rear-end collisions are a leading cause of convoy breakdown in theater. Consequently, CAST was developed with the overall goal to improve convoy safety, security, survivability and sustainment by providing lateral and longitudinal control of various tactical vehicles relative to a lead vehicle.

The CAST system has made significant advancements since its initial testing at Fort AP Hill, VA, in fall 2007. Notable improvements since 2007 include a 93-percent reduction in manual control takeovers, a 25-percent increase in operator target awareness and more than 100 miles of continuous autonomy with a 50-mph capability on paved roads and 35-mph capability on dirt roads.

Soldiers from the Nevada Army National Guard participated in the CAST testing to assess its SA and threat identification capabilities. During testing, Soldiers wore an ARL HRED

During the testing, Soldiers wore an ARL HRED neuroergonomic cap to record brain waves related to their reactions to driving autonomously. Neuroergonomics, the study of brain and behavior at work, combines neuroscience and human factors. Through the ARL HRED and TARDEC engineering partnership, test results indicate that CAST will decrease driver workload.

neuroergonomic cap to record brain waves related to their reactions to driving autonomously. The test results show that CAST helped Soldiers immensely by:

- Simulating threat identification, which increases the ability to identify roadside threats, a major operational issue in convoy activity.
- Implementing an emergency braking capability that allows for simultaneous convoy braking in panic situations. Operationally, this can reduce the number of friendly rear-end collisions that occur.
- Potentially increasing throughput or operating speeds during dusty or night operations, which could have a direct impact on mission completion times and overall success.

Through the partnership among ARL HRED, CASCOM and TRADOC, TARDEC has integrated the right future technology into existing ground vehicle platforms on light and medium tactical vehicles as well as M915 tractors. Mechanical Engineer Bernard Theisen remarked, "It is important that we not only work with the user rep [CASCOM] but the other Army labs [such as ARL HRED] from the beginning to get the best technology solutions to the Soldier."

Continuation of efforts is planned through 2009. A third experimentation and user assessment is to be held at Fort Hood, TX, this fall in collaboration with the Army's III Armored Corps. LTG Rick Lynch, III Armored Corps and Fort Hood Commanding General, has initiated a large-scale robotics development and fielding effort throughout DOD. One portion of this effort is robotic convoy and re-supply. In response to this capability request from the III Armored Corps, TARDEC plans to have the CAST material solution demonstrated and evaluated by the Corps this fall. If the assessment is successful, it is possible that Army units could be training on field-ready, CAST-equipped vehicles as early as the third quarter of fiscal year 2010.

Edward Schoenherr is Project Manager for CAST, part of TARDEC's IGS technical area. Schoenherr holds a B.S. in computer engineering from the University of Michigan. He is an Army Acquisition Corps member and is Level II certified in systems planning, research, development and engineering.

accelerate Writer Guidelines

accelerate is a quarterly professional journal published by the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), the Department of Defense's Ground Systems Integrator.

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Purpose
To instruct members of the ground systems community about relevant technology; research development and engineering; and innovative business processes for managing technology and to disseminate other information pertinent to the professional development of the ground systems workforce.

Subject Matter
Subjects may include, but are not restricted to, research and development initiatives, engineering integration initiatives, program accomplishments, technology developments, business transformation, policy guidance and technology excellence. All articles must be in compliance with security, export control and operations security (OPSEC) requirements. Our Soldiers deserve the technological overmatch being developed today. We owe it to the warfighters to field not only systems that work, but systems that are unsurpassed.

OPSEC Review Process
All articles prepared by government employees must be reviewed and approved by the responsible supervisor, must undergo a security classification, export control and OPSEC Review (STA Form 7114) and must be approved for public release (Distribution A: Distribution Unlimited). All articles prepared by a contractor or an academician under contract to the U.S. government must be reviewed and approved by his/her Contracting Office Technical Representative, must undergo a security classification, export control and OPSEC review (STA Form 7114) and must be approved for public release (Distribution A: Distribution Unlimited). An individual may use his/her organizational OPSEC Review Form. If the individual does not have access to an OPSEC Review Form, then the U.S. Army TACOM Life Cycle Management Command. STA Form 7114 will be used and be attached to the author's submission.

Submission Procedures
Articles must not exceed 1,600 words. Manuscripts are to be prepared in Microsoft Word and should be approximately eight typed, double-spaced pages using a 20-line page and Times New Roman 12-point font.

A minimum of three photos, illustrations or charts should accompany each article to help illustrate a process or technology in files separate from the manuscript. The photographs should focus on the technology and not individuals. Any copyrighted photographs, illustrations, charts or other material must be accompanied by a consent/release from the copyright owner. Images are subject to the same review process as the article.

Given counterterrorism and counterintelligence concerns, personally identifiable information about who has participated in a project, and where tests have been conducted must be protected. Photographers' names and organizations are to be included for each photo submitted. Artwork must be accessible for editing and not embedded in the manuscript. Photos may be color or black and white. Illustrations must be black and white and must not contain any shading, screens or tints. Illustrations and photographs may be submitted via e-mail to **accelerate@conus.army.mil**. All electronic photo files must have a minimum 300-dpi resolution and be in TIFF or JPEG format. The higher the resolution, the better. If they do not meet this requirement, glossy prints of all photos must be submitted via U.S. mail, FedEx, etc., to the address listed on this page. Photos and illustrations will not be returned.

Acronyms used in manuscripts, photos, illustrations and captions must be kept to a minimum and must be spelled out on first reference.

Articles submitted to *accelerate* will not be accepted if they have been scheduled for publication in other magazines.

All submissions must include the author's and photographer's mailing address, e-mail address and office phone number.

Biographical Sketch
Include a short (approximately 65 words or less) biographical sketch of the author(s) that includes current position, educational background and acquisition or other certifications, if applicable. The biographical sketch must also undergo an OPSEC review and will not include information about security clearances or special access programs.

2010 Submission Dates

Issue	Author Deadline
January-March 2010	Oct. 30, 2009
April-June 2010	Jan. 29, 2010
July-September 2010	April 30, 2010
October-December 2010	July 30, 2010

***Editor's Note:** Space constraints, changing priorities and articles with perishable information may be referred for publication in TARDEC* S&T News Update *monthly.*

LETTERS TO THE EDITOR

I was at TARDEC today taking a tour and was given a copy of your *accelerate* Magazine. Would it be possible for us to get a subscription of *accelerate* Magazine sent to the Ground Robotics Research Center at the University of Michigan? I think the students would enjoy reading it.

— Dr. Dawn Tilbury

Editor: Thank you for your recent request for additional accelerate *Magazines being sent to the University of Michigan Ground Robotics Research Center. We are thrilled you would like to display accelerate at the GRRC. We've added you to our subscription list, and we'll mail future issues to you directly.*

Nice job on new look for TARDEC magazine, *accelerate*! Looks sharp and professional. Are you able to add a private contractor to the address list for future mailings for *accelerate*?

— George A. Fulton
Operations Research Analyst
TACOM
Cost & Systems Analysis Office

Editor: Yes, Mr. Fulton, we are able to send a copy of the magazine to our industry partners.

I attended the Automotive-Robotics Cluster Initiative Partnership Workshop at Oakland University last month, and there was a magazine called *accelerate* available of which I was able to get a copy. Would it be possible to get more?

As Workforce Development Supervisor here at Automation Alley, the information within your publication is vital. It's an opportunity for our educational institutions — secondary and post-secondary — to see the cutting-edge technologies going on in their own backyards. Thank you again for your assistance.

— Alysia R. Green
Workforce Development Supervisor,
Automation Alley

Editor: Yes, we are happy to send copies of accelerate *and we will include you on our mailing list.*

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As the Department of Defense's Ground Systems Integrator, TARDEC is at the forefront of technological innovation. That is not possible without you, the engineers, researchers, scientists and technicians. *accelerate* is your vehicle — so, help us get the best component parts under the hood and on our pages. Write for *accelerate* today!

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S&T NEWS UPDATE

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S&T News Update, which has a subscriber base of more than 1,200 individuals and is forwarded to the approximately 1,200 TARDEC employees, seeks to inform members of the Ground Systems Enterprise and its partners about activities, events, awards and technological developments.

Call for Articles

If you work in or with ground vehicle systems technology, engineering, robotics, survivability, or power and energy, your expertise would be of interest to our readership. TARDEC is the Nation's laboratory for advanced military automotive technology. The publication's readership includes members of Congress and their staff, military and non-military government personnel and other members of industry and academia.

Article Submission

Get published by submitting your article and any corresponding images to TARDEC's editorial staff at **S&TNewsUpdate@tardec.info.** Please include all author names and biographies in your submission.

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