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.

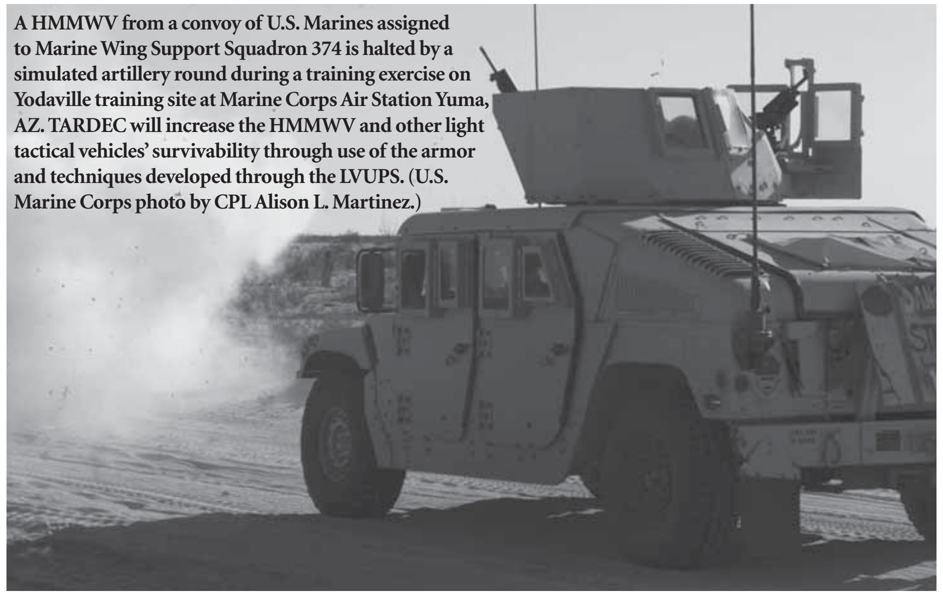
Once the blast simulations certify a particular design as acceptable, engineers had to build a demonstrator to verify the simulation, using innovative solutions to maximize protection without sacrificing speed or mobility. Initial simulations revealed that to meet these requirements, an advanced, lightweight 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.

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