Hybrid-Electric Vehicle Experimentation and Assessment (HEVEA) Program Supports the Army’s Need for Increased Power Demands

MAJ Christine E. Allen, Ghassan Khalil, and Michael Pozolo

The Army’s future vehicles will require new technologies to fulfill projected power and energy demands. Hybrid-electric power has been identified as a potential technology that can meet the Army’s future needs and provide expanded mission capabilities to the warfighter. The capability improvements include onboard and export power generation availability, silent operations, fuel economy improvements, and synergy with high pulsed loads such as electric weapons and electromagnetic armor.
Before fielding military hybrid-electric vehicles (HEVs), the technology has to be evaluated for its relevance to military operations and must withstand the harsh military environment. This includes varied terrains — from fully paved to hilly cross country — and extreme environmental conditions — from arctic to desert. In addition to the mobility performance, military HEVs must meet safety, reliability, maintainability, and availability requirements under all shock, vibration, and environmental conditions. To address the above challenges, the U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC) has established the HEVEA program.

The program has three key products: the HEV performance database that includes lessons learned; an established and accredited Test Operations Procedure (TOP) to assess fuel economy for hybrid and conventional vehicles; and a validated Vehicle Propulsion System Evaluation Tool (VPSET) to predict hybrid-electric and conventional vehicle automotive performance as well as projected fuel economy. Additionally, the program includes measurement of the onboard and export power capability from a hybrid platform and the effects of extreme temperature conditions on hybrid-electric performance.

Improving Testing Methods

For the HEV performance database, a total of nine hybrid-electric and nine conventional mechanical vehicles were evaluated over five different test courses. These vehicles span all weight classes of tactical wheeled vehicles. Traditionally, the military conducts vehicle fuel economy tests at the Munson standard fuel economy course at the U.S. Army’s Aberdeen Test Center (ATC), MD. The Munson test course is mainly flat, paved terrain with some moderate slopes. Although the Munson standard fuel economy course can be used to test the HEVs, it does not provide the opportunity to explore the full benefit of hybrid-electric fuel economy. HEV fuel economy is heavily influenced by the frequency of braking to recover kinetic energy from the brakes.

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vehicle experiences throughout its life cycle. Although different vehicles have different mission profiles, using vehicle data from the five terrains traversed can provide valuable predictive information on performance variance as the mission profile is varied.

Evaluating Fuel Economy
A hybrid-electric propulsion system contains two sources of power: an engine and a battery pack. Therefore, it is necessary for fuel economy evaluation to compensate for the energy usage from the battery. Statistical models based on regression analysis were used to derive a functional relationship between the mean fuel economy (miles per gallon (mpg)), the average road speed (miles per hour (mph)), and the delta State of Charge of the battery. Residual analysis was performed to validate this statistical model. This method proved to be adequate when the vehicle is going through varying driving conditions. Under these conditions, the battery is continuously supplying energy to supplement the engine when needed, and then regaining the same energy when the engine power is sufficient enough for mobility and battery charging. It should be cautioned that when attempting to compare vehicle results, gross vehicle weights (GVWs) should be similar to make an accurate comparison on performance. Otherwise, results could be skewed in favor of the lighter GVW vehicle.

The data in Figure 1 show a fuel economy gain of 11 percent over ATC’s hilly, cross-country, Churchville terrain and 5 percent over the Munson flat, paved terrain. The same model, with a 95-percent confidence band for the mean fuel economy, is shown in Figures 2 and 3. The statistical model developed by TARDEC is used to validate a VPSET. VPSET was also developed by TARDEC to assess performance in support of program manager (PM) programs.

TARDEC’s VPSET Streamlines Acquisition Process
The VPSET has been developed by the TARDEC Ground Vehicle Power and Mobility Modeling and Simulation (M&S) Team in partnership with Southwest Research Institute. VPSET has great potential to streamline the acquisition proposal evaluation process for ground vehicles by both the U.S. Army and the U.S. Marine Corps. As M&S-based acquisition becomes more prevalent, there is a greater need for common, well understood software tools to support technical analysis during the acquisition process. VPSET provides a flexible, easy-to-use tool to evaluate a wide range of conventional and hybrid-electric propulsion system types in a consistent and timely manner.

In past acquisitions, contractors submitted propulsion system/vehicle performance models to the Source Selection Evaluation Board (SSEB) using many different commercial and in-house software tools. Execution of these performance models by the SSEB was cumbersome because of software license issues as well as user training required for unfamiliar programs. Also, there was no assurance that the various models handled all technical aspects with the same level of fidelity, making comparison of outputs more difficult. VPSET was developed to address these issues by creating a standardized evaluation tool for propulsion analysis in support of the acquisition proposal evaluation process. While not intended to replace commercially available codes, the data inputs and computational approach are similar and will be familiar to the contractor’s M&S staff. Both government and contractor personnel will have a clear understanding of model inputs, component properties, assumptions, and performance predictions. The code supports development of first-order propulsion system models for a wide variety of powertrains,
including conventional diesel-mechanical and series or parallel hybrid electric. Higher fidelity models can also be developed with additional component input data.

Code modularity will facilitate future updates to VPSET to incorporate new propulsion technologies. VPSET will enable the government to verify contractor model input and results and to evaluate performance prediction and risk against technical requirements while achieving considerable time savings. Use of a single evaluation tool will provide greater clarity for both evaluators and contractors when comparing M&S results from different concepts. VPSET model output is being extensively validated with conventional and HEV test data obtained during the HEVEA program. The Office of Naval Research, Naval Surface Warfare Center, is also pursuing further development of VPSET for assessing fuel efficiency-enabling technologies. This tool has already been used and displayed its relevance throughout TARDEC to assess performance in support of PM programs.

In conclusion, the previously used standard fuel economy TOP has been revised to include the HEVs over the courses described above. The draft TOP was sent out to government agencies, industry partners, academia, and engineering societies, such as the Society of Automotive Engineers and Environmental Protection Agency, for review and comments. Once all comments to the draft TOP are collected, the new TOP will be finalized and adopted as a standard test for fuel economy evaluation. The VPSET will continue to be validated as additional data are available from the HEVEA program and other field vehicle testing. The HEVEA vehicle testing is continuing through the end of 2009 and all the test data generated to date has been stored in a government database for future reference.

MAJ CHRISTINE E. ALLEN is the Assistant PM Mobility Common Systems, Future Combat Systems Manned Systems Integration. She previously was the PM HEVEA, TARDEC Ground Vehicle Power and Mobility. Allen holds a B.S. in aerospace engineering from Embry Riddle Aeronautical University. She is a U.S. Army Acquisition Corps (AAC) member.

GHASSAN KHALIL is the Team Leader for Hybrid-Electric Mobility, part of TARDEC Ground Vehicle Power and Mobility. Khalil holds both a B.S. and an M.S. in mechanical engineering from Wayne State University.

MICHAEL POZOLO is the Team Leader for Powertrain M&S, part of TARDEC Ground Vehicle Power and Mobility. He holds a B.S. in mechanical engineering from Wayne State University and an M.B.A. from Western Michigan University. He is an AAC member and is certified Level III in systems planning, research, development, and engineering.