Figure 1. The advanced ground mobility vehicle. *(General Dynamics Land Systems illustration)*

How a New Drive Train Can Get the Armed Forces' Tactical Vehicles Off-Road and Avoid Improvised Explosive Devices

by Richard G. DuVall and Bob Hoeltzel

Our adversaries in the current conflict have rediscovered the American and European weakness of being very casualty-adverse. Everywhere forces are located has become a danger zone. The improvised explosive devices and mines have made the logistic side of the battle as dangerous as the urban infantry fight.

In the past, when planners planned an offensive operation, securing enough routes for logistic support had been a paramount part of their process. The large arrows on the map ran up the few existing road networks that could handle the weight and volume of traffic. In conventional warfare, this allows the enemy to refine his defensive strategy since he can read a map as well as we can. In unconventional warfare, these same limitations allow IED/mine users to target these areas and inflict casualties and vehicle losses.

But what if we didn't always have to use the few existing road networks? What if the tactical/logistic vehicle fleet had mobility comparable to the combat vehicle fleet? Adoption of several technologies and their application to existing vehicles could allow planners to draw the big arrows over a far greater area of the map. If IED/mine users don't know where the convoys are routed, since convoys no longer rely on the road network, they will find it very difficult to plant their devices in the right spot. This, of course, doesn't eliminate chokepoints in terrain, but these can be viewed as danger points and cleared accordingly.

The technologies we recommend are:

- Use in-hub hybrid-capable electric drive as the drive train.
- One of several very high-wheel travel suspensions with an (optional) add-on active capability would be coupled with the drive train.
- Finally, choose a selectable central tire inflation system, coupled with the latest military-tire tread system with run-flat capability.

IHED

The IHED consists of a diesel engine that drives a generator that provides electric power to wheel motors (mounted inside the wheel hub with a gearbox) that provides motive power to the tires, eliminating the entire mechanical drive train. The e-drive can be augmented (the optional hybrid portion) with a battery pack and battery-power converter, providing power for burst acceleration, periods of silent watch (six to 12 hours), silent movement (up to 20 miles on level terrain), power recovery/storage from regenerative braking, a second source of power and mobile-power-generation capability with an uninterrupted power source.

What does IHED provide vs. conventional mechanical drive? It provides very large quantities of electric power for on-vehicle and export uses. These include communications; navigation; command, control, communications, computers and intelligence / battlefield information; reconnaissance-surveillance-targeting; sensors; unmanned aerial vehicle / unmanned ground vehicle control; electric-powered weapons; electric armor and countermeasures; electric tools; and portable-device battery recharge. It also augments/eliminates trailer-mounted generators.

IHED improves system reliability. The total system-parts count is greatly reduced by 30 percent to 45 percent. (If it isn't on the vehicle, it can't break or fail.) E-drive has very few friction points and some bearings on shafts; all else are magnetically coupled – no friction, no heat, no wear points.

The IHED family of components has 25 years of e-drive maturation in place. Military test vehicles have included systems in Germany, France, South Africa and the United States. U.S. vehicles have accumulated more than 23,000 test miles. Fleets covered more than 60 vehicles that included buses, vans and automobiles. Total mileage driven was more than 10 million kilometers (greater than 6 million miles) with a failure rate at this time of 1.2 million kilometers/90,000 hours for

Vehicle	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8
RSTV-3	720	--	360	450	380	600	190	450
*RSTV-4	380	700	300	465	830	980	580	605
IFAV	--	--	--	--	960	1,160	1,510	1,210
GMV	480	730	910	810	--	--	--	730

Table 1. Detection ranges (meters) in Windy Mountain stealth test (acoustic test). *Squeaky suspension bushings, reported in the Marine Corps Warfighting Lab Report.

motors/generators and 500,000 kilometers/40,000 operating hours for electronics.

IHED increases mobility because having no half-shafts allows uncomplicated, very large wheel travel. The suspension increases cross-country speed, reduces crew/vehicle fatigue and increases weapons effectiveness and survivability. IHED raises the vehicle's ground clearance by eliminating the mechanical drive train and, in many cases, increases stability and safety. It also provides for computer-controlled all-wheel traction control, anti-lock braking system and stability control.

RSTV

For example, the U.S. Marine Corps' reconnaissance, surveillance, targeting vehicle has received high marks. The Marine Corps Warfighting Lab Report of Dec. 31, 2003, reported that "[t]he traction and suspension of the RSTV, and its resulting mobility characteristics, are far superior to any other vehicle tested. … Some operators said that inasmuch as the vehicle could do nearly everything attempted at these sites [on Yuma Proving Ground, AZ], a more challenging site needed to be used."

The same report compared vehicles: "Mobility testing was performed on the Rock Ledge Course, a three-mile course of extremely rocky roads and a few steep slopes. The RSTV (e-drive) handled the course with ease. The test organizers … set aside the [humvee] after its first trip out of concern that it would be damaged. … De-facto mobility testing also occurred at the Windy Mountain site. … This overland driving was actually more challenging than the Rock Ledge Course, but again the operators praised the performance of the RSTV (e-drive), saying it performed feats of which the interim fast-attack vehicle, [humvee] and ground mobility vehicle were incapable."

The RSTV also shattered the speed record for the Army's Rock Ledge Course at Yuma with a time of 13 minutes, 50 seconds. The previous record was more than 32 minutes.

The Marine Corps Warfighting Lab Report found that "[i]n all cases, the shooting score from weapons mounted on the RSTV was superior to those of the other vehicles under test."

Stealth

The IHED increases crew and system survivability by providing-silent movement capability and long silent-watch periods. It provides greater redundancy (fewer single-point failures). The raised ground clearance mentioned earlier provides greater standoff distance from mine/IED blasts. It allows hull shaping for ballistic protection without loss of ground clearance since there is no drive train. IHED also provides dual-power-source usage (engine plus batteries or capacitors or flywheel, etc.).

The Marine Corps Warfighting Lab Report found that "[t]he RSTV outperformed the baseline vehicles in stealth." Other vehicles tested included the IFAV and GMV.

The advanced ground mobility vehicle, another vehicle using the IHED, received similar high marks in stealth. "The driver and company commander reported [that] the silent-running mode (hybrid mode) allowed the AGMV to sneak up on an enemy observation post within a distance of roughly 60 meters," stated the Army Expeditionary Warrior Experiment Spiral F final report (2010).

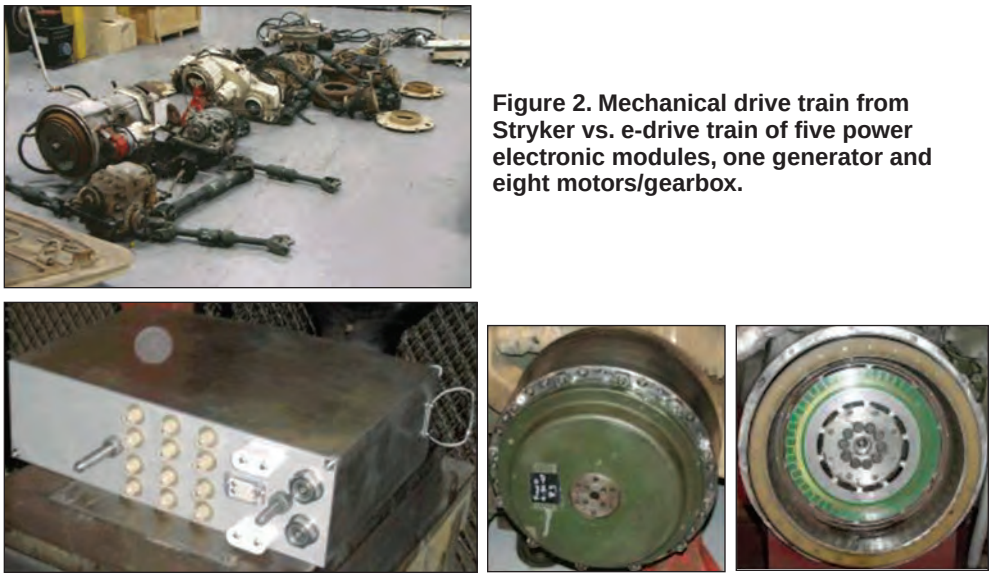

Figure 2. Mechanical drive train from Stryker vs. e-drive train of five power electronic modules, one generator and eight motors/gearbox.

Weight, fuel savings

IHED improves logistics and reduces the expeditionary footprint. Analyses based on Aberdeen Proving Ground, MD, testing shows that a reduction in fuel consumption of greater than 40 percent is possible. The longer silent-watch periods reduce fuel use as well as increasing survivability and stealth. On an IHED system, all wheel stations and supporting electronics are common parts, reducing system-part count and spares by eliminating the mechanical drive train (for example, greater than 42 percent less line-replaceable units on the e-drive Stryker vs. the present Stryker).

IHED can lower system lifecycle costs 40 percent to 50 percent

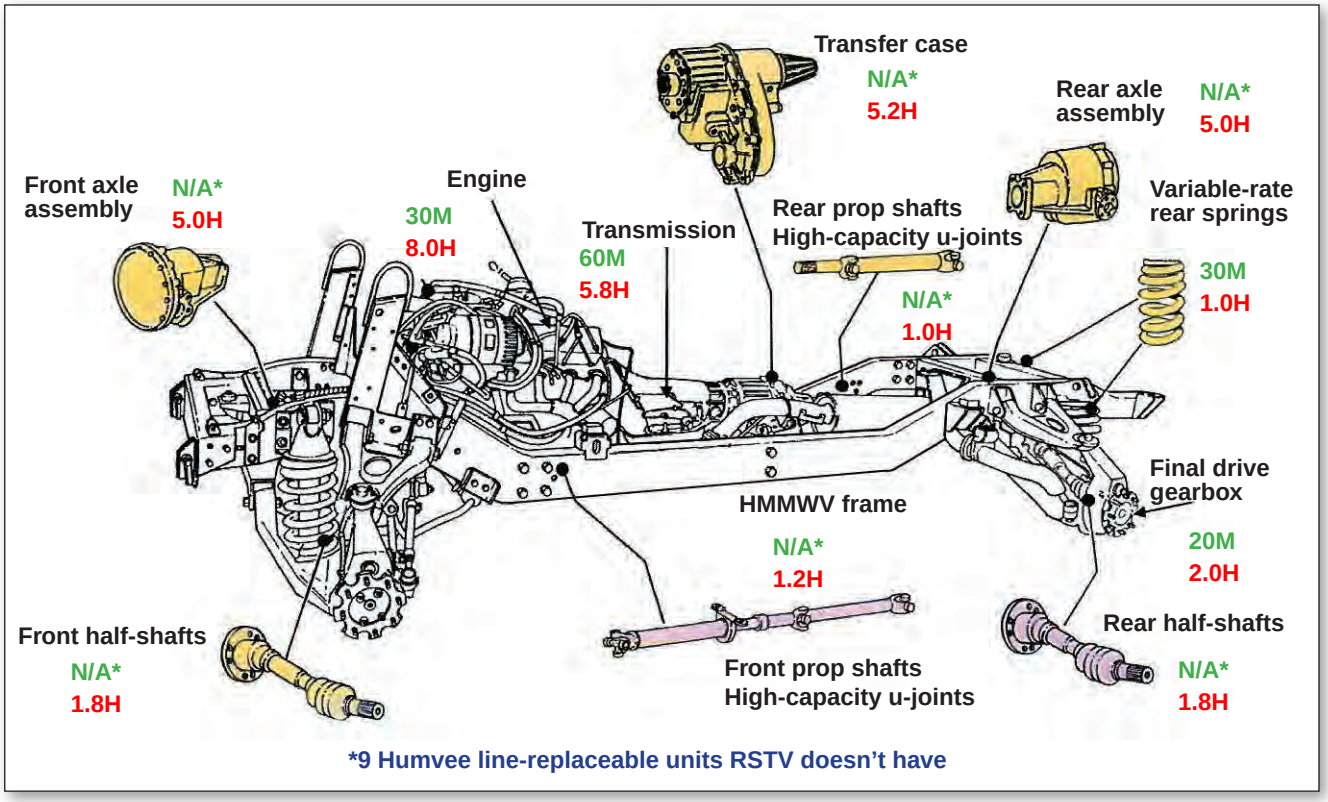

Figure 3. Humvee drive-train schematic with RSTV replacement time comparisons. RSTV maintenance times are in green and are minutes; humvee maintenance times are in red and are hours. Humvee maintenance times come from Army figures. RSTV times are derived from testing. Items marked N/A represent LRU that do not exist on the e-drive RSTV. For example, in place of a transmission, the RSTV has a generator and, in place of a final drive gearbox, the RSTV has an in-hub motor and gearbox.

based on the United Kingdom's Future Rapid Effects System Study, which compared the Light Armored Vehicle III to an 8x8 IHED vehicle. Reliability is raised by eliminating so many parts and using proven electric technology. IHED's modular nature provides easy upgrade when enhanced or new technology appears. IHED also allows the system designer to easily integrate the drive system and exploit a family-of-vehicles concept. It simplifies and reduces maintenance workload and times (fewer parts). It reduces training for operators and maintainers (system simplicity and commonality, not complexity).

Another side benefit is that the battery-pack technology can be used on other vehicles. For example, the M1 tank uses a lot of fuel, resulting in application of an auxiliary power unit. By applying this battery-pack technology to the M1, APU use could be reduced to just recharging the battery pack after a number of hours of silent watch (dependent on battery-pack size and vehicle-system usage). The battery pack would also provide a very robust starting system for the main engine and APU.

Mobility, power

The high-wheel travel suspension allows the vehicle to move at greater speed over broken terrain while keeping crew ride within a tolerable level. The addition of an active component keeps the wheel in contact with the ground for greater periods of time, increasing driver control of change of direction and braking. It will also provide energy recovery that can be put back into the power-budget system. The new tread patterns being applied to military tires, coupled with a CTIS, have led to dramatic increases in wheeled-vehicle mobility.

Several IHED 4x4 vehicles have undergone testing at Aberdeen Proving Grounds. They also have a number of user evaluations from Regular Army and Marine units, as well as Special Operations Forces, at Yuma Proving Grounds and Fort Benning, GA. Test reports have confirmed that vehicles equipped in the manner described have much greater mobility than current vehicles.

An example of mobility gained by the lower ground clearance offered by IHED

Vehicle	Slope degrees, percent, distance	Slope degrees, percent, distance	Slope degrees, percent, distance	Slope degrees, percent, distance
	0, 0, 80 meters	6, 11, 81 meters	9, 16, 78 meters	12, 21, 64 meters
RSTV (8125 pounds)	9.5 seconds	11 seconds	11.5 seconds	11.75 seconds
RSTV (battery only)	12 seconds	14 seconds	16.33 seconds	18 seconds
IFAV (7190 pounds)	16.5 seconds	Did not finish	Did not finish	Did not finish

Table 2. Sandy-slope hill climb times, in seconds.

was achievement of 85 percent to 90 percent side-slope capability and operation at Yuma on 60 percent side slopes routinely. In the soft sand slopes constructed at Yuma, these vehicles were the only wheeled vehicles tested that went up all the slopes on engine and battery only; all other wheeled vehicles became stuck on the first slope.

Having participated in all the demonstrations of these vehicles, the authors heard experienced tracked-vehicle officers from the U.S. Army, Canada, Great Britain, Germany and Australia state that they had been driven in IHED vehicles across terrain they wouldn't have tried with their tracked vehicles.

No half-measures

The benefits are many, but beware of those who would take half-measures. Adding a generator and replacing a dropbox or differential with a motor in the mistaken belief it reduces risk is incorrect. If the electric system is layered over the mechanical system, all the mechanical system's drawbacks and weaknesses are still there. The risk factor has gone up, not down. The humvee is an example; all four half-shafts are different and are the mechanical fuse in the system. They break to save more expensive parts from breaking. The SOF teams informed the authors that they take four or five sets of half-shafts with them because they break so often.

If an electric motor is substituted for the differential, the half-shaft problem remains. In the world of reliability, the numbers would not get better – they would get worse. IHED drive trains are magnetically coupled and can't break; a strong gearbox can take punishment, as this magnetic coupling feature provides protection. Eliminating the mechanical system for an IHED drive train reduces the number of LRU 30 percent to 45 percent; if an LRU is not on the vehicle, it can't break or fail.

So the question is, with so many compelling benefits, why hasn't IHED been put into military service? The answer, up to recently, has been performance risk and lack of an adequate production base. The remaining technical risk of electromagnetic-impulse compatibility has been successfully addressed in recent component/subsystem-level qualification testing.

The final barrier to production and fielding of IHED is availability of an adequate U.S. production base. This barrier is being rapidly eliminated with substantial U.S. investment in electric traction motors, power electronics and battery-production facilities for hybrid electric cars. This production base will very soon accommodate military needs with a minimum of investment and risk, and will provide enough competition at the component level to assure affordability.

All this is important, but we need to keep in mind that the real benefit is to provide a revolution in combat, tactical/logistic wheeled-vehicle mobility. By changing the way we operate and opening up our options in routing our logistic tail, we can reduce our casualties in personnel and vehicles, and significantly reduce the impact of IEDs/mines on our forces. Employment of silent movement, coupled with high mobility, will allow us to stealthily approach objectives from directions thought impassable by our opponents. The indirect approach, tactically and logistically, becomes a reality with IHED employment.

Richard DuVall is a retired Marine infantry officer. He served as the Marine liaison officer on the U.S. Army Armored Family of Vehicles Task Force, where he handled all light systems, and retired from the Marine Corps Research and Development Command. DuVall helped form the first LAV battalion in the Marine Corps. His civilian employment has included Teledyne Continental Motors and General Dynamics Land Systems. He was program manager for the low-profile turret, now on the Mobile Gun System vehicle, and the following electric-vehicle programs: armored-systems modernization program 55-ton automotive test rig, RSTV, advanced hybrid electric drive 8x8 and AGMV. He earned a bachelor's of arts degree in history at Old Dominion University. He resides in Spring Lake, MI.

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Figure 4. The Shadow RSTV with 4x4 hybrid electric drive. *(General Dynamics Land Systems illustration)*

Motors Defense as the supervisor, advanced turret systems; six years at Teledyne Continental Motors as supervisor, advanced concepts; and 10 years at General Dynamics as lead / chief engineer for advanced hybrid electric vehicles, including the RSTV and AGMV / Joint Light Tactical Vehicle. He holds a bachelor's of science degree in electrical engineering and a master's of science degree in industrial engineering from Michigan Technological University and Texas A&M University. Now retired, he splits his time between Michigan and Florida.

Acronym Quick-Scan

AGMV – advanced ground mobility vehicle
APU – auxiliary power unit
CTIS – central fire inflation system
GMV – ground mobility vehicle
IED – improvised explosive device
IFAV – interim fast-attack vehicle
IHED – in-hub hybrid-capable electric drive
LAV – light armored vehicle
LRU – line-replaceable unit
RSTV – reconnaissance, surveillance, targeting vehicle
SOF – Special Operations Forces

Figure 5. U.S. Marines in the intermediate fast-attack vehicle with a tube-launched, optically-tracked, wire-guided missile system. *(Photo by U.S. Marine Corps)*

Manuscript deadlines 2012-2013

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November-December 2012	Sept. 7, 2012
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