The Fuel Efficient MTVR

Paving the path to a more fuel efficient fleet of vehicles through technology

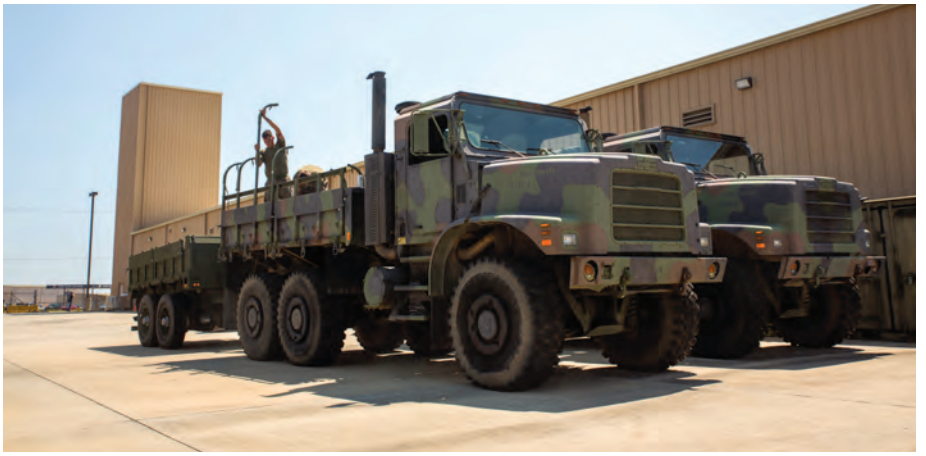
by Trung Huynh, Ulysses "Lee" Morton, Giang "James" Pham, Anita Tate & Edward Wright

The desire for enhanced fuel efficiency has been well documented and supports several strategic initiatives within the Marine Corps. Financially, reduced fuel consumption leads to significant savings. Accounting for delivery and security, the fully burdened fuel cost is typically a multiple of the commodity market fuel price, reaching tens of dollars per gallon or higher for wartime missions closer to the front lines. Operationally, higher fuel economy improves warfighters' combat effectiveness by reducing their logistical footprint, increasing their expeditionary capability, and extending the operational range of fuel-powered equipment.

As far back as 2002, the CMC policy memorandum, *Increased Warfighting Capability Through Reduced Fossil Fuel Burden*, recognized and stressed that "dramatic improvements in the fuel efficiency of the Marine Corps platform and systems are critical enablers to achieving fuel reduction objectives of the Joint Vision 2020." In 2009, the CMC created the USMC Expeditionary Energy Office, which collaborates with program offices in meeting Joint Vision 2020 objectives across all warfighting functions.

The fuel efficient medium tactical vehicle replacement (FE MTVR) effort is realizing this vision for the MTVR family of vehicles through technically vigorous selection and mission-based, cost-conscious evaluation and adoption of mature, fuel-saving technologies.

FE MTVR began as an Office of Naval Research (ONR) Future Naval Capability (FNC) project. The groundwork for the FE MTVR FNC program started in the late 2000s after a report published by the Naval Research Advisory Committee showed that tactical vehicles, including the MTVR, consumed greater than 50 percent of all fuel used by the Marine Corps' ground vehicle fleet. The FNC project was then specifically formed to research, develop, and integrate affordable fuel-saving technologies that would be effective in the unique Marine Corps off-road operational environment.



An MTVR being prepared for operations in support of hurricane relief. *(Photo by LCpl Niles Lee.)*

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>>>>Ms. Tate is the Project Officer for the FE MTVR effort. She leads the Integrated Product Team and manages day-to-day activities in achieving acquisitions goals.

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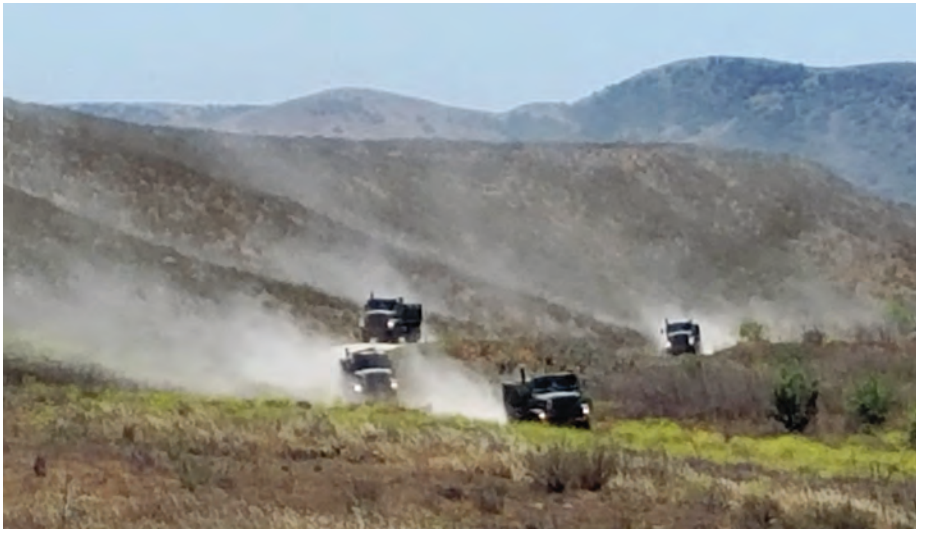
Through extensive collaboration with industry, academia, and Government experts, over 200 potential technologies were evaluated, ranging from simple software-based recalibration to more extensive hardware modification of the engine, driveline, engine-driven accessories, and the integrated vehicle-human system. These candidates were analyzed and simulated for selection based on efficiency potential, component cost, performance impact, size and packaging, weight, availability, and technology maturity or readiness. Down-selected technologies were further technically characterized and then tested in different combinations within a highly complex trade space, i.e., achieving substantive fuel efficiency improvement across the driving cycles representative of the MTVR's operational conditions while maintaining the platform's affordability, current mobility, transportability, and survivability capabilities.

To support this evaluation, a number of sophisticated modeling and simulation tools were developed, including an MTVR fuel efficiency simulator that predicts fuel use from prescribed velocity profiles and terrain and an MTVR design space simulator that enables the comprehensive evaluation of vastly varying combinations of fuel-saving technologies. A set of MTVR drive cycles was also constructed and refined based on extensive field data to permit a more realistic assessment of the vehicle's fuel economy improvement. Subsequently, the most optimal combinations (kits) that could meet the early targets of fifteen percent fuel saving, demonstrated through limited vehicle dynamometer and field fuel consumption testing, at a maximum $10,000 cost per kit, were transitioned to the Program Manager, Medium and Heavy Tactical Vehicles (PM, MHTV) in September 2016 for acquisition.

Working in concert with the Marine Corps System Command, ONR, and industry partners, the PM, MHTV, continued to develop and refine programmatic and engineering objectives and execute plans to meet evolving fiscal, schedule, and fuel-saving performance requirements. On 8 March 2017, the Deputy Commandant, Combat Development and Integration (DC, CD&I), issued a Capability Requirement Change to the MTVR operational requirements document that mandated a minimum ten percent fuel economy improvement for the armored MTVR cargo variants. A technology readiness assessment gauged the maturity of critical, fuel-efficient technologies using defined technology readiness levels and provided the initial pool of candidate technologies for a trade study. With Marine Corps Systems Command's Systems Engineering, Interoperability, Architectures, and Technology Office assistance, the trade study identified candidate technologies based on the training readiness assessment, identi-



FE MTVRs at Camp Pendleton, CA. *(Photo by author.)*

fied scoring criteria, and applied the criteria to the candidate technologies. Taking into account cost constraint, fielding schedule, user input, and critical operational requirements, the result was a down-select of a kit consisting of three technologies: fuel-efficient engine calibration, transmission calibration, and reduction in engine idle speed.

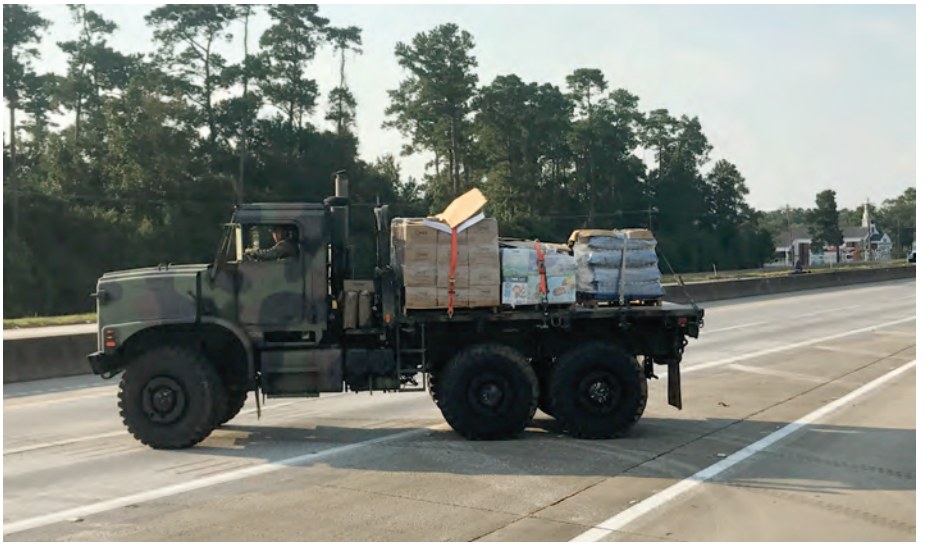
To verify fuel economy improvement with higher fidelity, the PM, MHTV, collaborated with Aberdeen Test Center (ATC) to develop new test methodology that is more standardized and closely reflects the MTVR Operational Mode Summary and Mission Profile (OMS/MP). The methodology built upon the ONR-developed drive cycles by incorporating realistic terrain elements such as road grade and soil type collected from established MP courses at ATC. This resulted in standardized dynamometer-based test procedures, using drive cycles based on the OMS/MP, that enable a more credible assessment of fuel consumption for the MTVR. Mr. Jim Bohley, Chief Engineer for the PM, MHTV, has stated:

> The development and implementation of the dyno-based test profiles was probably one of the most exciting aspects of this project. We now have the proven ability to determine fuel consumption across the full spectrum of terrain without having to worry that the results are skewed by driver changes, weather, or other environmental factors. All we need are the truck, the drive files, and the dyno lab and we can evaluate any future changes.

Test and evaluation to date, on four armored MTVR cargos at ATC, has demonstrated OMS/MP fuel economy improvement ranging from eleven percent to fourteen percent with the FE kit. Automotive testing, as part of a pre-production qualification test at ATC, and a field user evaluation with I MEF Marines at Camp Pendleton, CA, further demonstrated no degradation in operational capabilities of the FE MTVR. The FE kit is on track to start fielding in late fourth quarter, fiscal year 2018, ahead of the previously planned third quarter, fiscal year 2019. Through should-cost and trade-off analyses, accounting for all developmental, test and evaluation, future installation, maintenance, and sustainment costs, the FE kit price tag is projected to be at least 25 percent less than the original cost target. In the big picture, as the second largest tactical wheeled vehicle fleet in the Marine Corps with close to 10,000 assets, a ten percent improvement in MTVR fuel efficiency is expected to reduce fuel consumption by millions of gallons annually. The MHTV Deputy Program Manager, John Campoli, has stated:

> With the recent additional 20-year extension of the MTVR's exit item date by DC, CD&I, the long term cost savings to the Marine Corps will be substantial. The added benefits, such as longer operational range and smaller logistic foot print will also be invaluable to the warfighters.

The FE MTVR's expected success has wide implications beyond the Program Office's immediate objectives. Its novel engineering and testing methodologies and products are highly transferrable and can be adopted and scaled to meet other fuel-saving targets not only for the MTVR but for other ground vehicles within the DOD.



An MTVR during hurricane relief operations. *(Photo by MSgt Richardo Morales.)*