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Maximizing Commercial-off-the-Shelf (COTS) Technology in Army Acquisition: The impact of Army-unique requirements on Program Executive Office (PEO) Combat Support and Combat Sustainment Support's (CS&CSS) ability to field "best value" COTS in the future

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ABSTRACT

PEO CS&CSS and CCDC GVSC, in partnership with Industry partners, are working to ensure the next generation of power generation sets and tactical wheeled vehicle systems maximize the usage of COTS, are compatible with Industry Standards, are supportable, and have growth potential to meet the needs of our Soldiers. Increasing regulations on emissions worldwide will impact commercial availability of high sulfur fuel / Jet Propulsion (JP)-8 compatible engines. It is recommended that the Army relook its regulation for JP-8 as the single fuel on the battlefield, in comparison to the potential cost of modifying COTS powertrains or procuring military unique engines in the next generation of tactical wheeled vehicles and power generation sets. The Army will realize additional performance with the ability to procure modern commercial powertrain technology, including potential improvements in power density and fuel efficiency. The Army should also consider operational requirements that may allow for vehicle electrification, hydrogen fuel cell technology and hybrid solutions for specific applications. Lastly, requirements best practices must be followed by the combat and materiel developer to ensure that the Army is able to take advantage of the latest in commercial technology at the lowest cost to provide the best value solution to meet Warfighter needs.

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1. INTRODUCTION

To begin this effort, PEO CS&CSS partnered with subject matter experts in the CCDC GVSC and Industry partners to discuss Industry technology and review technology roadmaps. The goal was to identify key areas where the Army's specific requirements add cost and schedule to develop existing COTS solutions in tactical vehicles and power generation or eliminate the ability to procure COTS altogether. As COTS technology is modified to meet Army requirements, system validation and testing further drives up the cost of modification.

For many of the systems in the PEO CS&CSS portfolio, the Army is an extremely low volume customer in a much larger market - so much so that some companies do not even bother to propose to develop or modify their COTS to meet Army requirements. PEO CS&CSS and CCDC GVSC initially focused this study on Industry's divergence from Army powertrain requirements, specifically looking at the impact of the Army's regulation for JP-8 as the single fuel on the battlefield; electrification; and to gain further Industry insight to guide the Army's Fluid Modernization Strategy including the development of the Synthetic Multipurpose Powertrain Lubricant (SMPL).

As emissions regulation is driving engine technology, PEO CS&CSS and CCDC GVSC identified a risk that COTS engines may not be compatible with the Army's JP-8 requirement in the future. As discussions with Industry progressed through this study, the team expanded the effort to include deep dive discussions on technology advancements in hydrogen fuel cells, hybrid diesel, autonomy, and condition based maintenance. PEO CS&CSS and CCDC GVSC team members visited Caterpillar, Cummins, Mack Volvo, Navistar and Daimler Truck to meet with business development and engineering experts to discuss the future of vehicle (with a focus on powertrain) and power generation technology. This open dialogue with Industry led to interesting findings on where COTS technology is going and will give the Army an opportunity to course correct to take advantage of the best Industry has to offer in vehicle technology and power generation.

2. POWERTRAIN TECHNOLOGY

2.1. Fuel

Low-sulfur "clean" diesel fuel has been mandated in the US and Europe where emissions are strictly controlled and monitored. The quality and sulfur content of diesel fuel varies significantly in other parts of the world – particularly in the Army's theater of operations. Army Regulation 70-12 implements a single high-sulfur kerosene-based fuel (SKBF) for commonality (commodity management) and quality assurance as follows: "continental United States (CONUS)-the fuel type F–24 (Jet A with status dissipater additive (SDA), fuel system icing inhibitor (FSII), and corrosion inhibitor/lubricity improver (CI/ LI)) shall be used for operations, training, and testing, as appropriate for the ambient temperatures; outside the continental United States (OCONUS)-the fuel type Jet Propulsion (JP)-8 shall be used for operation, training, and testing as allowed when availability and costs factors are considered by the theater commander."

The future availability of military engines will be market- and business-case driven for all Industry partners visited. As long as lesser emissions-regulated regions of the world continue to have a demand for high-sulfur-fuel compatible engines, the Army can still expect to procure COTS engines produced for these lesser regulated regions for vehicle powertrain and power generation systems. Currently, little to no engine modification is required to make the majority of COTS engines supplied to lesser regulated countries JP-8 compatible. If modifications are required, they are minor and not significant cost drives such as changes to injectors and valve seats. However, as demand for high-sulfur-fuel compatible engines are reduced, Army JP-8 compatible engines will require more and more modification of current emission-compliant engines at higher cost and schedule. This pathway involves heavy cost due to the removal of all sulfur sensitive emissions control systems and the re-calibration (reprogramming of engine control module) of the resultant hardware for military use. Industry partners will need to sell enough of these engines to recover the engineering and production costs.

As emissions regulations become more stringent, certain engine models may include base hardware that cannot be modified for military use without excessive cost per unit. There are already some European engines that cannot be modified for military use. While some Industry partners visited in this study expect to support and provide JP-8 compatible engines to the Army for the foreseeable future, others expect that in the 10-30 year timeframe, they will exit this market and no longer provide JP-8 compatible engines for Army use. Some manufacturers stated that production of high sulfur fuel compatible engines are expected to move overseas.

A power generation / generator set manufacturer specifically discussed a technology development effort that they are pursuing for a generator that can accept both high- and low-sulfur fuel types (without engine modification). Currently, Army suppliers of power generator sets modify commercial generator set engines to support military high sulfur fuel requirements by replacing a Tier 4 engine with a Tier 3 engine generator set.

Additionally, the latest in engine technology is not being incorporated into older JP-8 compatible engine technology. Engine technology is advancing beyond technology advances incorporated solely to meet emissions regulations. Technology improvements focused on power density, fuel efficiency, and ventilation, heat, and noise improvements is a constant focus for Industry partners. These include improvements in firing pressure, turbocharging systems, after treatment, engine friction, and more. Additionally, engine development is occurring rapidly – with a typical engine development time of three to five years. Some of these technology advances improve fuel efficiency by 10% or more in comparison to engines produced in the previous decade. However, these technology advances are not incorporated in older-model, non-emission compliant engines, as there is no profitable market demand for continued development of these engines. It was recommended by one supplier that the Army should consider the development of a specialized non-production certified engine compatible with JP-8 that incorporates fuel savings technology.

It is recommended that the Army conduct a cost benefit analysis comparing the potential cost of modifying COTS powertrains or procuring military unique engines in the next generation of tactical wheeled vehicles and power generation sets versus the cost and impacts of converting from a primary single fuel (Jet Fuel with military additives) to two primary fuels (Jet Fuel with military additives and Ultra Low Sulfur Diesel Fuel).

2.2. Diesel Fuel Alternatives

Each vendor discussed that continued investment in next-generation fuel-alternative propulsion systems will again be market driven. Each company is investing heavily in electrification, battery technology and hydrogen fuel cell technology, and have technology roadmaps/strategies dedicated to diesel-alternative power. Fuel cells are viewed as the competitor to Battery Electric Vehicles (BEV), and many companies expect that battery technology improvements will outpace fuel cell improvements but that neither are ready for line-haul trucking applications now. One supplier projected that battery power density is expected to double in the next three years. Both BEV and fuel cell costs are extremely high and projected to decrease based on volume; but, while fuel cell cost is projected to get closer to diesel costs, BEV will always be higher. From a cost and performance perspective, it was the consensus that in 2030, 90% of commercial line-haul trucks will still have diesel internal combustion engines.

Port, construction and mining operations are all aggressively being targeted as early adopters of electrified vehicles. This is because the associated duty cycle is conducive to life cycle fuel cost savings or have significant environmental challenges that can be solved through electric drive propulsion systems. Each of these companies are actively partnering with city organizations around the world to field trial vehicles and/or continuing development of BEVs available on the market now for specific applications. One example of such an effort is a full electric transit bus powertrain that will also explore range extension in the near future using a second energy source. Some electrified construction / material handling equipment applications in use now discussed with the team was a 400 kW powered front loader that includes a top speed of nearly 25 mph. Another company has a tractor with the ability to tow 80,000lbs for 150 miles. Yet another company is expecting significant technology advancements in 16-27 ton two- and three-axle electrified trucks and buses that are expected to get to the 420 mile range in 2021, compared to its current range of 120 miles.

Although advancements in batteries are moving at an extremely fast pace, leading to better range for electric vehicle technology, the significant challenge is the infrastructure that needs to be established for wider adoption of on-road vehicle electrification. Discussions indicated that diesel powertrains will be around a long time due to issues with range and required uptime, especially for line-haul operations. The downtime to recharge a battery is a significant issue being worked with a combination of vehicle storage and infrastructure solutions. These infrastructure challenges are being invested in heavily by companies like Tesla. However, this type of infrastructure is not expected to be in place in the Army's operating area in the foreseeable future, making full vehicle electrification for long-range operations not a possibility for the Army next generation of tactical vehicles. However, short-range, short-duty cycle operations are good applications for the Army to consider electric vehicles in the future. The Army should consider these possibilities when developing requirements for construction and materiel handling equipment or like applications.

Hydrogen fuel cells have a better fuel refill time than BEVs and begin to be advantageous over BEVs above the 200-mile range or when transporting heavy loads. Size requirements for storing hydrogen on the vehicle are a challenge due to cost and volume requirements of the currently accepted technology; however the Department of Energy is aggressively targeting this along with industry to improve storage efficiencies. Production and logistics of hydrogen to support a Brigade will be an infrastructure challenge as well, due to the need to add new equipment. Moving to a low sulfur diesel fuel would simplify and reduce the cost of hydrogen production through fuel reformation, which is the most likely scenario for the military in the near term. Current reformers remove sulfur through cheap replaceable filters that will have extended operational time with lower sulfur fuel. Fuel reformation, hydrogen storage, and hydrogen dispensing can all be accomplished in mobile ISO container configurations. The technology is scalable and can be adapted to meet a projected vehicle roll-out strategy. Multiple companies believe this technology will be competitive with conventional powertrain technology between 2030 and 2040, and are investing heavily. The Military should be able to leverage commercial fuel cell systems without much, if any, modification due to the rigorous requirements for heavy duty and automobile applications. Hydrogen produced from diesel or JP-8 fuel is still hydrogen, which can be produced from many different methods. Multiple truck manufacturers are participating in demonstration projects in California in an effort to reduce pollution in the Ports of Los Angeles and Long Beach. Commuter trains, busses, and fleet delivery vehicles are currently operating in other countries in Europe and Asia and sporadically around the United States. Specifically, companies visited discussed planning or conducting fuel cell demonstration projects for urban bus applications and for static applications such as powering computer server banks.

These companies are also exploring non-traditional powertrains including mild diesel hybrid, battery electric, and fuel cell electric technology. These would switch between battery electric and series/parallel hybrid powertrain modes based on duty cycle. These solutions could mitigate range, infrastructure, volume, and recharge issues. One major regulation driver for such technologies will be any future zero-emission requirements for a given application/vehicle class.

2.3. Powertrain Fluids

Recommended and acceptable engine oil API performance category and viscosity is based on specific engine design. Several Original Equipment Manufacturers (OEM) are shifting to new fuel-efficient, lower-viscosity oils for new engine designs. OEMs are moving toward non-standardized, proprietary specialty fluids for new transmissions.

The team discussed the GVSC-developed Synthetic Multipurpose Powertrain Lubricant (SMPL), a fuel efficient low-viscosity synthetic oil, which was originally intended to replace all lubricants in the Army inventory as the Army's single synthetic powertrain lubricant. Although none of the Industry partners stated that SMPL would not work or that powertrain components would require modification to comply with SMPL, most powertrain OEMs specifically stated that they develop their fluids to maximize performance for specific powertrain components. While the current Army MIL-PRF-2104 oil is a multipurpose oil used as a common fluid across powertrain applications the trend toward specialized fluids to maximize performance and durability is likely to result in reduced engine/component life for a number of SMPL applications. Due to the difference between commercial durability requirements of 1,000,000 miles versus less than 100,000 for the Army, the acceptability of this reduction must be included in future programmatic decisions on the use of SMPL. As discovered by the SMPL IPT led by CCDC GVSC, most companies have asked for funding to do additional testing to validate performance with SMPL before approving use on individual powertrain components. The Army has decided to include SMPL in the inventory to replace arctic oil and as an option for use in place of the primary Army oil.

OEMs are using a wide variety of coolants including older standard life coolants, which the Army currently uses, and newer extended life organic acid technology coolants. Several OEMs even offer multiple coolant options for their engines based on customer requirements. OEMs noted that there is no standardization within coolants and there are concerns with compatibility of some coolants with different materials which can lead to corrosion issues. There are also compatibility issues between coolants which can result in precipitation or gelling impeding coolant flow and leading to overheating.

Engines with Selective Catalytic Reductant (SCR) emissions controls will require a new fluid, Diesel

Exhaust Fluid (DEF). DEF is added to a separate tank and required for vehicle operation. The Canadian Army has procured a HEMMT class vehicle with EURO 5 engine, SCR emission control only. This vehicle requires the use of DEF. There is an emergency override to continue to operate at rated performance without DEF. Accidental DEF contamination of fuel will severely damage the fuel injection system by causing crystallization that seizes up valves and injectors. Once contamination occurs the entire fuel system must be replaced, otherwise the problem will propagate into the fuel subsystems and cause repeated failures.

As a result of discussions with these Industry partners, CCDC GVSC is partnering with NDIA to develop a Fluid Modernization Consortium to inform the next generation of Army fluids with an Industry perspective and develop a modernization strategy.

2.4. Other Powertrain Subsystems

Industry is investing further in the electrification movement with a strategy to develop electric axles (e-axles) within the next five years for specific applications. E-axles will aid in improving fuel economy during transient and forward-looking operation – where the operator can perceive terrain and adjust the powertrain control to reduce fuel consumption. This technology solution allows for faster response but will require integration of additional energy storage on-board. Electrified hubs and electrified differentials were also discussed with electrified hubs being deemed not appropriate for military or off-road use could present shock/vibration issues.

Technology advances in wider range transmissions were also discussed. Wider range transmissions can offer the same benefits as e-axles but at a slower response time so they may not be optimal for specific operational mobility requirements. Automated Manual Transmissions (AMTs) automatically control the clutch and shifting. Road conditions, vehicle speed, acceleration, torque demand, vehicle weight and resistance is continuously monitored, resulting in a more efficient shifting pattern. AMTs provide fuel economy savings and are operable by more eligible drivers, a benefit for the Army as many Soldier drivers do not have experience with manual transmissions. But, a requirement for a torque converter transmission would drive the Army away from these particular advances in transmission technology. It is recommended that the Army have a clear understanding of vehicle system duty cycles and perform comprehensive mobility studies of its vehicles to make good power transmission decisions for vehicles.

3. AUTONOMY

While some of the companies visited are investing heavily in autonomy, others are relying on the R&D conducted by other companies or subsidiaries to pave the way for autonomous trucks. Europe is ahead of the United States in commercial truck autonomy, while the United States is ahead of Europe in commercial vehicle autonomy.
The Society of Automotive Engineers (SAE) determines the intelligence level and automation capabilities of vehicles, ranking through 0 to 5 (See Appendix: SAE Automated Driving Levels). These companies expect to achieve SAE Level 2 autonomy in 2020 and SAE Level 4, high automation, in the near future but do not see SAE Level 5, full automation, as achievable in the near future. Some already have autonomous vehicles operating in confined and semi-confined road patterns (construction, mining, port operations). Many have started or are planning to start field trials on platooning operations (front vehicle with driver, following vehicle/s no driver) in 2020-2021 with companies like FedEx driving this capability. Additional technical challenges discussed were: visibility sensing issues with rain, dust, snow, and cloud cover. One supplier projected that

autonomous vehicles will require significant LiDAR power and will need high-voltage power system on board to support.

The motivation for Industry to pursue autonomy may be different than the motivation for the Army. The Army is aggressively pursuing autonomy to remove drivers/operators from the vehicle, reducing the number of Soldiers required to perform sustainment operations. An example of this is the Army's investment in the Tactical Wheeled Vehicle Leader Follower (TWV-LF) capability. The TWV-LF is a suite of robotic applique sensors and vehicle by-wire and active safety upgrades to provide an unmanned capability to a TWV Fleet for convoy operations at the squad level with one manned leader and up to nine unmanned follower vehicles as an objective requirement. While Industry certainly recognizes the advantage of removing drivers from vehicles or reducing the dependence of driving on the operator, Industry sees a fuel savings advantage to autonomy and has demonstrated platooning operations similar to the TWV-LF. However, one supplier indicated that platooning or pairing of trucks in field trials so far did not give expected returns in fuel savings - the lateral placement of the secondary truck has a big impact on fuel savings. Too close of a follower reduces cooling air-flow in the second truck and can actually lead to increased fuel consumption.

The strategy may be different in the commercial Industry than or the Army. While Industry expects to take advantage of "drop-in" autonomy kits, CCDC GVSC subject matter experts do not expect the availability of a "drop-in" autonomy COTS solution at any SAE level for broad Army utilization. Since most Army platforms are larger than commercial platforms, the sensor location is typically outside the recommend placement locations and calibration is needed. Some of the COTS sensors are capable of self-calibration, but require common infrastructure e.g. road lines, which are not available in an off road setting. Many of the commercial systems today are only allowed to operate on certain well mapped areas (geofencing). This requires good Global Positioning System (GPS) signal, while the Army has a requirement for systems to operate GPS-denied environments. Additionally, most vendors are doing over-the-air (OTA) incremental autonomy software upgrades and software sustainment which is not possible in a military environment from a cybersecurity perspective. With COTS, OEMs self-certify their product's performance and safety; this creates a challenge unique to the Army for receiving a software safety confirmation in accordance with MIL-STD-882E. The Army safety community looks at these systems as "black-boxes" and immediately assigns them as "high risk" because they do not have access to the source code or the necessary information to conduct a supply chain risk assessment.

Other challenges associated with product liability, and ethical and safety considerations, for full employment of autonomous vehicles in the commercial marketplace seem to be the primary concern among companies visited. They indicated that legislation changes would be required before significantly advanced autonomy configurations will be available in the open environment. Without legislation intervention, full autonomy in the commercial market may be considered too high risk for many companies.

4. REQUIREMENTS BEST PRACTICE

The team was able to discuss system-unique COTS deviations with current suppliers of active program components. The team uncovered instances where very specific program requirements on programs drove the Army unknowingly away from a potentially better performing technology at a lower cost. In many cases this was due to performance requirements dictating a material solution instead of specifying performance criteria. Program offices are investigating potential cost-saving Engineering

Change Proposals (ECP) for these specific findings and, as a result of this dialogue, will incorporate lessons learned into future performance specifications. PEO CS&CSS has developed a robust Requirements Management Process, a Common Requirements Module, and associated training. These stress the importance of operationalizing requirements vs. dictating materiel solutions from user requirements generation through requirements decomposition to a final Industry and Peer-Reviewed performance specification and verification plan that incorporates best practices and lessons learned. Further, it is important to keep abreast of Industry technology to ensure that the cost/benefit trades of Army requirements continue to allow us to field the best-value solution for the Army. PEO CS&CSS plans to continue its partnership with Industry through GVSC Subject Matter Experts to educate the user community and ensure that performance requirements allow for the best value solution for the Warfighter.

5. OTHER ARMY UNIQUE REQUIREMENTS

There are other Army unique requirements that can drive costly modifications to COTs systems that were not included in the scope of this study. These include but are not limited to the requirements for Army Technical Manuals, Chemical Agent Resistant Coating (CARC), military ruggedization, fire suppression systems, soldier interface accommodations, environmental hardening, and the requirements for lifting and tiedown provisions for interoperability with the transportation systems available for military movement. PEO CS&CSS continues to analyze the applicability of Army unique requirements, often driven by Army regulation, to systems across the portfolio and seek exemptions or requirements changes in collaboration with CCDC GVSC, the combat developer, and the sustainment command.