National Defence Défense nationale

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HYBRID-ELECTRIC MILITARY VEHICLES FOR THE CANADIAN ARMY

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JCSP 42

Service Paper

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PCEMI 42

Étude militaire

Avertissement

CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES
JCSP 42 – PCEMI 42
2015 – 2016

JCSP SERVICE PAPER – PCEMI ÉTUDE MILITAIRE

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Word Count: 2256

Compte de mots: 2256

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AIM

1. This paper will provide a background on hybrid-electric powertrains for land combat and logistics vehicles, and will recommend the initiation of a project which will replace the Canadian Army's light logistics vehicle with a hybrid-electric militarized vehicle. This technology will lead to a condensed sustainment footprint, including a reduction in personnel, maintenance, and fuel dependency. While a hybrid-electric vehicle (HEV) can provide the Canadian Armed Forces with all of the capabilities that the current fleet provides, it also provides a number of benefits, such as improved fuel economy, low thermal-and noise-signature operation, and power generation for operational support. As a proof-of-concept project, once the benefits have demonstrated superiority over the concerns, it is recommended that this technology be expanded to the remainder of the Canadian Army fleet.

INTRODUCTION

2. Energy is an essential element for all military activities. Military vehicles are particularly extremely energy-intensive, and this energy is generally obtained from either diesel or gasoline. As the world's armies, including the Canadian Army, are becoming more vehicle-dependent on larger and heavier combat and logistics vehicles, sustainment has grown to meet the demands. For example, in 2007, the United States' Department of Defense used 4.6 billion gallons of fuel per year, more than many countries of the world.[1] In addition, due to the asymmetric threat in the non-linear, non-contiguous modern battlefield, it has become increasingly dangerous to move supplies between secure areas provided by forward operating bases. As a result of the need for self-defence, the supply system has placed more demands on both personnel and equipment. The

[1] USA International Business Publications, *United States Department of Defense Handbook, Volume 1: Organization, Strategic Information, Policies*, (Washington: 2011), 16.

modern military must consider efficient use of the supplies that are delivered to the forward tactical units.

3. The recent conflicts in Afghanistan and Iraq are a good example of the vast amount of logistics required on a modern battlefield. In this case, the supply chain had to travel long distances in non-secure areas which used large amounts of resources: personnel, equipment and money. According to data from the United States Army Materiel Command, “fuel makes up 70% of the bulk tonnage needed to sustain a military force on the battlefield … [and] can cost as much as $40-50 per gallon.”[2] This represents a significant number of soldiers on the battlefield; soldiers that would otherwise be available to conduct operations. In other words, if the vehicles had greater fuel efficiency, fewer resources would be needed for the supply chain, and more could be used to win the conflict. Latest indicators are also suggesting that personnel levels within the CAF are trending lower, which are exasperating this problem. For example, the recent Speech from the Throne calls for a “leaner, more agile, and better-equipped military”[3] and this speaks to the shift in focus the CAF must take in its day-to-day business.

4. HEVs utilize a large battery for energy storage and electrical motors for some or all of the motive power. In this design, the internal combustion engine remains and provides motive power either directly to the wheels, or can be used as a generator to produce electricity to power forward. The arrangement depends on the size of the battery and the energy demands of the vehicle. For military applications, it is expected that the diesel engine would be able to move the

[2]General Paul Kern, “US Army Materiel Command,” (presentation, NDIA 2003 Tactical Wheeled Vehicles Conference, Monterey, CA, January 2003).

[3]House of Commons, *42nd Parliament of Canada's Speech from the Throne*, 4 December 2015, http://speech.gc.ca/en/content/making-real-change-happen.

vehicle with the electrical system assisting. It is also anticipated that the electrical system could also move the vehicle with a limited range to provide silent movement.

DISCUSSION

5. None of the current fleets of land combat and combat-support vehicles within the Canadian Army presently utilize hybrid-electric technology for motive power, even though these powertrains have become common in civilian passenger and commercial vehicles. The slow adoption of hybrid technology within the military can be attributed to a number of different factors, including long life cycles of military vehicles, unknown reliability and maintainability, and challenging military applications, such as ballistic protection and robust off-road capabilities.

6. At present, all standard military pattern (SMP) land vehicles use a diesel internal combustion engine for motive power. These range from a small 4 cylinder engine in the Light Utility Vehicle Wheeled (LUVW) SMP, to a very large 12 cylinder engine in the Leopard 2A6 main battle tank. The electrical generators that are used to power field installations like command posts and medical stations also use diesel-powered engines. The benefit of using common fuel in all field vehicles and generators is that it alleviates some of the logistics requirement and simplifies the procurement process.

7. The Logistics Vehicle Modernization (LVM) Project is seeking to replace most of the land logistics vehicles before 2020. There are two vehicles to be procured through this project, a light vehicle, known as the Combat Logistics Support Vehicle (CLSV), and a heavy vehicle,

known simply as the LVM Heavy. This project has not identified the requirement for HEV technology within the Statement of Requirement (SOR).[4]

8. In recent years, the CAF has not ignored alternatively-powered vehicles. The civilian, non-militarized, fleet of staff cars and pick-up trucks have been utilizing hybrid technology for several years. As a result, maintenance personnel have had to obtain new training to support the fleet. However, this has been incorporated into the regular training scheduled for vehicle technicians. When the latest Light Armoured Vehicle Land Reconnaissance Surveillance System (LRSS) enters into use, it will be using a large lithium-ion battery to power a silent watch capability. This battery pack will be built by Revision Military Incorporated, and will be a ballistic-protected, field-serviceable energy storage solution that will silently power on-board sensor suites for up to 12 hours.[5] This battery pack is very similar to that used in HEV technology, and could be utilized in the future for this purpose.

9. There has been significant research on hybrid military vehicles within the United States (US) military where the use of electric drive has been considered for 50 years. However, an intensive focus was applied starting in 2005 with their hybrid-electric vehicle experimentation and assessment program. There were also several other US programs throughout the 2000s that developed hybrid vehicles through either a joint government-commercial or solely commercial projects. These programs developed a number of hybrid vehicles for testing purposes over the past few years. For example, several high mobility multipurpose wheeled vehicles (HMMWV) were developed that utilized a variety of hybrid technologies. The HMMWV is a similar vehicle

[4]Treasury Board of Canada Secretariat, Business Case: Logistics Vehicle Modernization (LVM) Project, Canadian Army – Director Land Requirements (Ottawa, 2009).

[5]Revision Military Incorporated, “Revision wins new $20M contract to supply silent watch battery systems for Canada’s reconnaissance light armored vehicles,” last accessed 3 February 2016, https://www.revisionmilitary.com/news/silent-watch-battery-pack-systems/.

to the CLSV which is part of the Logistics Vehicle Modernization Project. The studies determined that there are many benefits to a military HEV, and also determined that the technology was feasible. For example, a HMMVW could see fuel economy improvements up to 68%, although this is very dependent on the type of technology used and the environment.[6]

10. There are many advantages of hybrid-electric powertrains for the Sustain Operational Function. The fuel economy benefits have been clearly demonstrated through the civilian passenger and commercial vehicles. For example, many transit corporations are moving to diesel-electric hybrids. This severe-duty application where efficiency and reliability is critical, demonstrates that this technology can be adapted to military conditions. For the military, reduced fuel consumption would have a direct impact and reduce the quantity of fuel needed at forward battlefield locations.

11. HEVs also have the advantage that they tend to have fewer parts due to the configuration of the powertrain. For example, in these vehicles, the transmission and torque converter are usually replaced by an electric motor. A reduction in parts means that there is direct reduction in spare parts required to sustain the vehicle. The electric motor also splits the duty of providing motive power between it and the diesel engine. This reduces the strain and operating time on the engine leading to reduced preventative maintenance time.

12. In addition to the logistics benefits that this technology generates, there are other benefits that support the Sense, Shield, Command and Act Operational Functions:[7]

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[6]Denise M. Kramer and Gordon G. Parker, "Current state of military hybrid vehicle development," *International Journal of Electric and Hybrid Vehicles* 3, no. 4 (2011): 378.

[7]Department of National Defence, B-GJ-005-300/FP-001, *Canadian Forces Joint Publication 3.0: Operation* (Ottawa: DND Canada, 2011), 1-6.

a. Sense. In addition to a silent watch capability, similar to the LRSS system, the power storage unit would also be able to move the vehicle silently as well. With a hybrid powertrain, not only would the vehicle be able to watch silently, but also move silently to a new location to obtain a better vantage point, or retreat if a threat was detected;

b. Shield. The thermal signature of diesel-powered land vehicles is difficult to conceal on the battlefield. Using commercially available thermal imagers, anyone could spot a carefully visually-concealed vehicle, particularly during the night. It was determined that the Al-Qaeda fighters as early as 2003 had thermal imagers available to them during Operation ANACONDA in Afghanistan. While using battery-powered electrical motors for movement, and batteries for surveillance, there is very little thermal signature given by the vehicle. Being able to move and sense without detection would give the Canadian Army technological superiority;

c. Command. The large size of the battery in a military HEV could also provide electrical power for operational support structures, such as command posts or medical installations. The power available could be taken directly from the vehicle, and while the large battery is charged, could also operate silently as well. When the battery becomes low on stored energy, the diesel engine would still need to run as a generator to charge the battery, however in this instance, the engine would be running at peak efficiency and shut down when the battery is full. This is opposed to the current operating procedure which sees the generators running 100% of the time, and at most times, at less than peak efficiency because the power draw is generally much lower than can be produced; and

d. Act. The hybrid-electric system also adds something that in the early days of hybrid cars was not expected: better acceleration and handling. This is due to the power delivery of the electric motor, which has an instantaneous torque curve and delivers all of its power immediately. This would be beneficial to military vehicles as they need the ability to move rapidly in order to improve their offensive or defensive positions. Finally, one last benefit sees the improvement of integration of future communications and sensor systems into the vehicle. Presently, the electric power for these sub-systems is provided by an alternator or generator attached to the diesel engine. In the future, with the developing weapons, armour, electronic counter-measures technology, and associated computers and sensor systems, more energy will be required. This demand would overwhelm today's power generation on diesel vehicles. The large battery required for hybrid operation would be an ideal energy store for these systems.

13. The integration of a hybrid-electric system into a military vehicle does not come without trepidation. The biggest concern is cost as the battery used for these technologies is fairly large and expensive. The present cost of lithium-ion large-format cells is approximately $145 per kilowatt-hour (kWh).[8] It is unknown at this time what is required without a comprehensive electrical demand study, but it is expected that a light logistics vehicle would probably have a battery that is between 25-40 kWh (for comparison, an early hybrid HMMWV had a 24kWh

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[8]Inside EVs, "GM: Chevrolet Bolt Arrives In 2016, $145/kWh Cell Cost, Volt Margin Improves $3,500," last accessed 4 February 2016, http://insideevs.com/gm-chevrolet-bolt-for-2016-145kwh-cell-cost-volt-margin-improves-3500/.

battery[9]). In addition to the cost of the battery, there are also costs associated with charging and battery management systems, electrical motor(s), and cabling and control processers. These costs should be partially off-set by the lower lifetime operating costs (fuel, parts and maintenance).

14. The hybrid system also adds additional weight, although much of this can be off-set from the reduced size of the diesel engine. In addition to the battery cells, the thermal regulation system, power management, and electric drive components all add to the weight of the system. These components also add complexity and maintenance concerns. The field technician must be specially trained to be able to diagnose and repair these systems in austere conditions. New technology has been added to many of the modern military vehicles and there has been a training requirement with each technology. HEV technology would be no different, and should not be onerous.

15. New technology also comes with a fear of the unknown. As these systems are not widely employed in military vehicles, there is a concern about reliability and maintainability, known as first adopter concerns. These quickly diminish with successful integration and training. However, they will need to be addressed when introducing HEV technology. There is also the concern that since this technology is developing and improving rapidly, the current state could be obsolete within a few years. To address this, many of the systems should be modular, and therefore be either updated or upgraded in the future as new technology is developed.

CONCLUSION

16. There are many different hybrid-electric vehicles on the civilian road today, from passenger cars to large-scale commercial applications such as transit buses. A hybrid-electric

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[9] Margaret Ducusin, Sonya Gargies, and Chunting Mi, "Modeling of a series hybrid electric high-mobility multipurpose wheeled vehicle," *IEEE Transactions on Vehicular Technology* 56, no. 2 (2007): 558.

powertrain for a military land vehicle will have many of the same benefits as their civilian cousins, but also several others, including logistics efficiency, tactical concealment, and electrical power for operational support. The LVM Project does not presently stipulate the requirement for hybrid-electric technology, however due to the clear advantages, it should be incorporated. All of the benefits of a HEV answer the call for a leaner and better-equipped Canadian Army.[10] The military needs to focus on more efficient use of its resources, and HEV permits reductions of personnel, equipment and money.

RECOMMENDATION

17. It is recommended that the requirement for HEV technology should be added to the SOR for the LVM Project, particularly for the CLSV. This project should be used to demonstrate the feasibility and the overwhelming benefits for this technology, and as a result future projects to replace land vehicles should all incorporate this innovative technology.

[10] House of Commons, *42nd Parliament of Canada's Speech from the Throne…*

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