Electric Military Vehicle (HMMWV): Tomco's Innovative Solution

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***Abstract*—This research paper investigates the historical evolution and advancements in the integration of electric vehicles (EVs) within the military domain, with a primary focus on the conversion of conventional military vehicles to electric platforms. The research examines the military sector's ongoing efforts to adopt sustainable and efficient mobility solutions, spanning from the conversion of the T-23 in 1943 to the contemporary focus on hybrid electric vehicles (HEVs). An important innovation in this regard is Tomco's adoption of the electric skateboard design, offering a modular and adaptable methodology for the conversion of military vehicles, notably the HMMWV, to electric. This design eliminates the need for extensive modifications like drilling, or welding, presenting a cost-effective approach. The paper systematically assesses the advantages and challenges associated with the deployment of hybrid electric military vehicles, emphasizing critical benefits such as fuel efficiency, reduced mechanical complexity, and low acoustic signatures. Tomco's solution is examined in the context of its potential impact on military logistics, maintenance, and operational adaptability. The analysis incorporates an evaluation of conventional HMMWV configurations and some case studies providing support for the practicality and feasibility of electric military vehicles. Regarding future developments, the paper evaluates Tomco's proposed advancements in electric military vehicle solutions. These include enhancements in battery technology, drivetrain efficiency, autonomy, stealth features, and adaptability. Additionally, the paper explores potential collaborations with the private sector, global adoption strategies, and considerations for economic and environmental sustainability.**

***Index Terms*—HMMWV, hybrid, electric military vehicles, tomco's solution**

I. Introduction

Since 1943, electric vehicles have been given importance in the military sector, especially the US military. One major conversion of conventional to hybrid electric vehicle was in 1943 when T-23, a medium class vehicle, was converted to electric. Although the idea was promising, it received less attention following World War II. Recently, due to the increasing costs of fuel, low power output and some other factors, there is some interest developed in hybrid electric vehicles. Hybrid Electric Vehicles or HEVs offer a variety of advantages over diesel powered engines. One such advantage is fuel efficiency. HEVs use electricity for the power needed during startup, when the engine consumes a lot of fuel. In this way, a lot of fuel is saved. Moreover, the electric motor can be used to draw more power from the brakes when the vehicle is descending. This optimization can result in saving up to 20 percent of the fuel. Another advantage of using HEVs is fewer moving parts. A conventional engine uses a lot of machinery to get the vehicle to drive. However, an HEV directly powers the wheels, thus eliminating a lot of moving parts. Further, the noise in an HEV is extremely low, making it suitable for silent operations for military use. The hybrid electric vehicle can also produce power for different applications such as electric weapons and armory. The power generated from an electric motor is far more compared (more than 10 kW) to a fuel engine, as well as much reliable and consistent. There are some challenges, however, faced by a hybrid electric vehicle. One such challenge is the cooling system, which draws too much power from the motor that also runs the vehicle. The reason for the large cooling system is to prevent the silicon-based chips and the battery pack from heating up, as they require low operating temperatures to work efficiently. Secondly, the costs associated with an HEV are huge compared to conventional vehicles. The commercial development in this sector is low due to which the costs are high [1].

II. Current Challenges with Fossil Fuel-Powered Military Vehicles

Antonis, Jonathan, Justin and Ali describe the comparison of conventional HMMWV M-1097A2 versus the hybrid configuration [2]. The conventional HMMWV, being a fossil powered engine, has some drawbacks compared to the hybrid one which is largely electric. For the hybrid configuration, the paper describes two modes, series and parallel. Additionally, for each mode, two configurations were tested. In the initial setup, the vehicle's overall power was kept the same, with adjustments made to both the internal combustion engine (ICE) and electric motor (EM) powers to achieve the desired hybridization factor. In the second setup, the ICE power remained constant, while variations were introduced to the electric motor power. Additionally, a configuration featuring an integrated starter alternator (ISA) was examined, where the engine's power remained same, while the ISA's power was modified to attain the targeted hybridization factor. For military vehicles such as HMMWV, gradeability and acceleration hold key importance rather than fuel economy. In a series configuration, the engine operates independently of vehicle speed, with the electric motor providing all tractive power. This setup enhances fuel economy in urban driving by allowing the engine to shut off

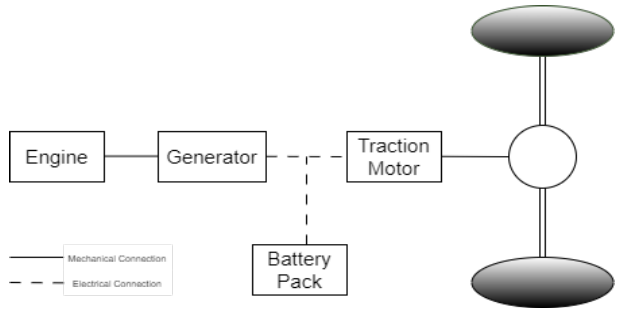

Fig. 1. Series Configuration.

during low-load conditions. However, a drawback which is important for military operations is that if the electric drive fails, the vehicle becomes immobile. Pure electric and hybrid operations offer similar performance until the battery's state of charge limits power delivery to the motor. In a parallel

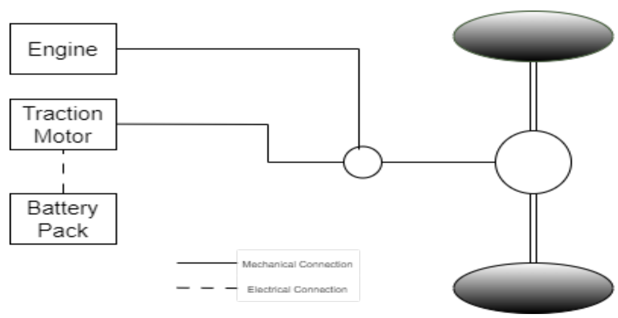

Fig. 2. Parallel Configuration.

configuration, the control strategy allows for flexible operation, either emphasizing the engine with electric assist or relying on electric motors with occasional engine support. The parallel setup often features better highway fuel economy than series configurations due to direct engine-driven vehicle operation. Additionally, if the electric drive system fails, the vehicle can continue functioning at reduced power using the conventional engine power transmission path, providing a "limp home" capability [3]. Comparing the series and parallel types, the best method for hybridization is by changing the internal combustible engine's power and the power of electric motor to achieve the desired HF (Table 1). Therefore, with an ISA configuration, good acceleration and gradeability can be achieved along with an increase in fuel economy. But it does not provide additional tactical benefits which other configurations like series offer.

III. Off the Shelf Electric Swap Kits

Traditional vehicles like the internal combustible engine vehicles can be converted into electric vehicles or hybrid electric vehicles through electric swap kits or conversion kits which comprise of all the components needed for the conversion process. These kits generally include an electric motor, battery packs with management system, a power inverter, a charger, and various control systems and mechanical parts. The goal is to replace the vehicle's conventional assembly with an electric one. There are various companies which offer off-the-shelf conversion kits for the military HMMWV. Some of them are listed below:

A. Hummer H1/HMMWV® Vehicle Duramax Conversion Kit

Duramax offers a conversion kit for the Hummer H1. It includes parts like custom engine mounting brackets, aluminum radiator, Y-bridge, oil fill tube etc. Installing the kit requires welding components like Y-bridge, mounting new brackets, cooling fan, radiator, and air intake tubes. The cost of the kit ranges from $13,000 to $18,000 USD [4].

B. Tesla-Powered Hummer H1 Electric Vehicle by North American EV

Canadian company North American EV has converted a Hummer H1 into electric by installing dual Tesla motors. The company claims that the "Cyber-Hummer" has a range of up to 750 miles and a horsepower of 1,272. It has a torque of 3,987 lb.-ft., towing capacity of 10,000 lbs., and accelerates from 0 MPH to 60 MPH in less than 3 seconds. The starting price for these conversions is around $100,000 USD [5].

C. MATBOCK LLC Hybrid Hummer

Although MATBOCK LLC does not offer conversion kits for the HMMWV yet, the company might offer it in the future. Currently, it offers a 1/1 hybrid 1992 M998 Hummer for $2 million USD. The company claims that the HEV has a combined range of 950 miles with 350 miles of battery only range. It has a 25-gallon diesel tank, a top speed of 70 mph, does 0–60 MPH in under 6 seconds, has 650 horsepower with 675 ft-lbs. torque. Additionally, it has a 25kW built-in range extender, 15kW worth of 120v AC and 5kW of 24v DC voltage export power. The company also offers wireless charging for an additional $100,000 USD [6].

Conversion kits are designed for easy installation, allowing quick modification to the existing vehicle. These kits are cost-effective and can be easily integrated with the current infrastructure of the vehicle. They also offer wide scalability for electrification of large fleets. Therefore, they are important for military vehicles.

IV. Tomco's Innovative Solution

Since the first skateboard platform was developed by General Motors in 2002 for the EV concept car "Autonomy", there has been an upward trend in the development of such designs [7]. In traditional chassis, just changing the wheelbase of a car or truck requires the whole assembly to be redesigned and reconstructed which is an expensive process. The electric skateboard design allows the designers to place all the required components like batteries and motor in the chassis with a body attached on top (Fig. 3). This design is adjustable and can be reconfigured to suit both small cars as well as trucks. The electric skateboard design has many advantages over the traditional chassis. First, as the batteries are located at the bottom, the centre of gravity is also lowered which helps in

TABLE I
COMPARISON OF DIFFERENT CONFIGURATION MODELS OF HMMWV [2]

Type	Mileage City (mpg)	Mileage Highway (mpg)	Hybridization Factor (HF)	0-60 mph (s)	Gradeability
Conventional	10.8	20.5	N/A	28.1	32.10%
Hybrid Parallel (Configuration 1)	10.8	21.9	10%	38.1	4.90% @ 55 mph
	12.9	23.8	30%	27.8	3.00% @ 55 mph
	15.6	26.2	50%	24.0	1.30% @ 55 mph
	21.3	35.8	70%	21.7	0.00% @ 55 mph
Hybrid Parallel (Configuration 2)	9.5	21.0	10%	34.8	5.70% @ 55 mph
	9.6	20.7	30%	21.1	4.90% @ 55 mph
	8.7	20.5	45%	N/A	4.20% @ 55 mph
Hybrid Series (Configuration 1)	14.3	21.8	10%	17.6	11.00% @ 20 mph
	13.7	28.4	30%	17.2	9.00% @ 20 mph
	19.8	40.2	50%	16.8	6.20% @ 20 mph
	33.1	66.9	70%	16.5	3.20% @ 20 mph
Hybrid Series (Configuration 2)	17.90	19.10	-20%	27.20	5.10% @ 20 mph
	18.10	18.90	-10%	26.80	5.10% @ 20 mph
	18.00	18.80	0%	26.60	5.00% @ 20 mph
	17.90	18.80	10%	26.50	4.90% @ 20 mph
	19.10	18.50	20%	26.40	4.90% @ 20 mph
ISA Configuration	14.40	29.00	0.17%	7.30	40.90% @ 9mph
	14.20	29.00	0.11%	8.20	41.80% @ 9mph
	14.10	29.00	0.02%	8.20	5.80% @ 9mph

handling and control of the vehicle. Secondly, this design also helps in providing additional space for the passengers and cargo.

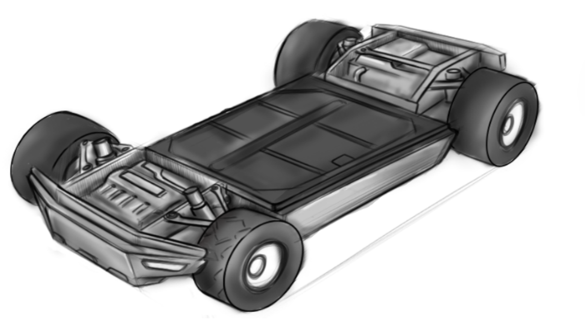

Fig. 3. Electric Skateboard Chassis Design for HMMWV.

Although there has been much advancement in using the skateboard design for compact cars, there are still many sectors which can be benefitted from such designs. The military transport vehicle HMMWV can be constructed using the electric skateboard chassis design. The design will help in converting a large fleet of vehicles to electric quickly. By just changing the chassis, the vehicle can be converted into electric.

Tomco's innovative solution for converting military HMMWV into electric makes use of the skateboard design [8]. The chassis of the conventional HMMWV can be replaced with that of an electric one by just attaching the body on top (Fig. 6). In this way, there will be no need to replace a ton of parts or equipment. The electric skateboard chassis will include all the required components like batteries, motor, steering, suspension etc.

For the battery, the design includes three variants (Fig. 4).

Fig. 4. Battery Designs.

The batteries are installed at the bottom so that the point of gravity is at the lowest and there is very little rolling effect when turning the vehicle at high speeds. As the gearbox, motor and the inverter are very closely placed, there is very little usage of high voltage wires.

V. ADVANTAGES OF TOMCO'S SOLUTION

Converting military vehicles like the HMMWV to electric using the electric skateboard design presents several benefits for manufacturing and military applications. The electric skateboard design makes use of a modular approach to vehicle design. By integrating the electric skateboard chassis, you can easily convert military vehicles into electric without the need for extensive modifications. This simplifies the conversion process, eliminating the need for drilling, procuring additional parts, or welding.

Converting to electric using the skateboard design eases the process, reducing downtime for military vehicles. The chassis can be easily swapped, enabling a quicker transition to electric without prolonged vehicle unavailability. Electric skateboard designs often use standardized components, facilitating easy replacements and maintenance. This can enhance the logistics

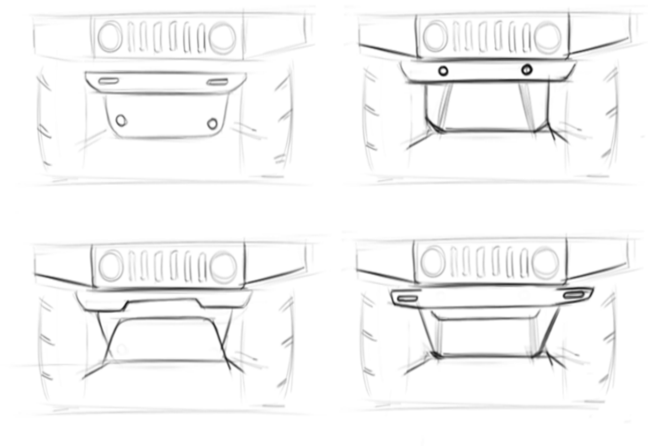

Fig. 5. Front Facial Designs for HMMWV.

chain for military fleets, ensuring availability of spare parts and reducing the complexity of repairs. Electric drivetrains offer high torque at low speeds, which is advantageous for off-road military applications. The electric skateboard design can enhance vehicle performance, providing better acceleration and climbing capabilities compared to traditional internal combustion engines. ICE vehicles have more moving parts than electric vehicles, resulting in reduced maintenance costs over the vehicle's lifespan. This can contribute to long-term cost savings for military fleets. Electric vehicles operate more quietly than traditional combustion engines, offering potential advantages in stealth and reduced thermal and acoustic signature during military operations. This can be crucial for tactical scenarios. The electric skateboard design allows for flexibility in adapting different body configurations on top of the chassis. This adaptability can accommodate various military vehicles like Family Medium Tactical Vehicle (FMTV) and Heavy Expanded Mobility Tactical Truck HEMMTT. Electric skateboard systems often come with customizable power management features. This allows military operators to optimize energy usage based on specific mission requirements, like extending operational range or mission duration.

Fig. 6. Upper Body and Chassis of HMMWV.

VI. Case Study

A. Israeli Industries Ltd. Electric Hummer

Israel Military Industries Ltd. (IMI) is working on making an electric version of the Hummer. This work is done at IMI's Slavin plant, which is known for developing and improving armored vehicles and tanks. The electric Hummer uses a strong battery-powered electric motor along with a diesel engine. The diesel engine acts like a generator, recharging the batteries when needed. This combination allows the Hummer to travel up to 450 kilometers with just one tank of diesel while on electric only power, its range is only a few dozen kilometers. The electric Hummer is great for silent military operations. It requires less maintenance, is more durable and has clean emissions. The acceleration of the vehicle is fast, and its speed can go over 120 km/h. Using a generator for self-recharging means it can move around independently without needing a special charging setup. IMI plans to convert around 200,000 ageing military Hummers to electric. There are reports that the Israel Defense Forces (IDF) might be interested in getting electric and hybrid vehicles for different uses. At the same time, the U.S. Army is looking for electric and hybrid vehicles for future battles [9].

B. Rivian Skateboard Design

The Rivian skateboard design features two compact electric motors mounted on each axle. The front unit delivers 415 hp and 413 lb-ft of torque, while the rear module outputs 420 hp and 495 lb-ft of torque. This arrangement provides a total power of 835 hp and 994 lb-ft, resulting in impressive acceleration and handling capabilities. Rivian's low-mounted battery packs make sure the vehicle stays stable. It also has an independent air suspension system that can lift the vehicle vertically up to 14.4 inches from a low of 7.9 inches providing 6.5 inches of adjustment [10].

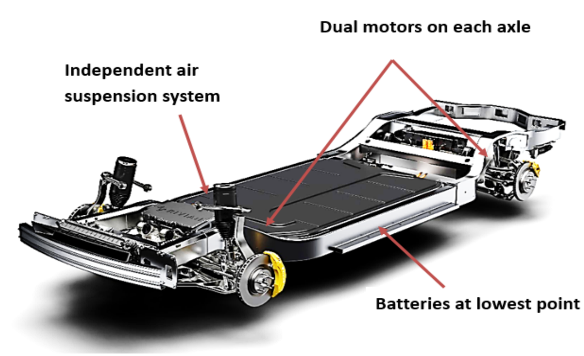

Fig. 7. Rivian Skateboard Design [10].

VII. Future Developments and Expansion

There have been many advancements in the field of electric vehicles, and as technology continues to evolve, the landscape of military mobility is also undergoing a transformative shift. In the area of electric military vehicles, Tomco stands at the forefront of innovation, redefining the concept of military mobility with cutting-edge designs. With a focus on sustainability, Tomco's design for electric military vehicles is a significant advancement in the pursuit of environmentally friendly and efficient solutions for military purposes. There are some areas of improvement in this regard which are mentioned below:

A. Advanced Battery Technology

Ongoing advancements in battery technology could lead to batteries with higher energy density, providing Tomco's electric military vehicles with increased range and endurance for extended missions. Improved fast-changing technologies could reduce downtime, allowing military vehicles to quickly recharge during breaks or mission pauses. The development of solid-state batteries may enhance safety, energy density, and lifespan, addressing some of the limitations associated with current lithium-ion batteries [11].

B. Drivetrain Efficiency

Continued improvements in electric motor efficiency can enhance the overall performance of Tomco's military vehicles, providing better torque, acceleration, and off-road capabilities. Advancements in regenerative braking systems could further improve energy efficiency [12].

C. Autonomy and AI Integration

The integration of advanced autonomous features and artificial intelligence can enhance the capabilities of Tomco's electric military vehicles. This includes unmanned operations, convoy support, and advanced situational awareness. Improved data connectivity and communication systems can enable real-time data sharing between Tomco's vehicles and command centers, improving coordination and decision-making during missions [13].

D. Stealth and Adaptability

Future designs may incorporate advanced stealth technologies, including reduced acoustic signatures, low-observable designs, and adaptive camouflage, enhancing the vehicles' ability to operate discreetly in various environments.

E. Cybersecurity and Electronic Warfare Integration

As electric military vehicles become more connected, robust cybersecurity measures will be crucial to protect against potential cyber threats. Integration of electronic warfare capabilities can provide Tomco's military vehicles with enhanced defense against electronic threats, as well as the ability to disrupt or disable enemy electronic systems [2][14].

F. Diverse Mission Profiles

Tomco can explore the development of specialized electric platforms tailored to specific military applications, such as reconnaissance, troop transport, logistics, surveillance, or electronic warfare. Electric platforms can be designed to adapt to various terrains, ensuring that Tomco's military vehicles are suitable for a wide range of operational environments [2][15].

G. Collaboration with Industry

Collaborating with the private sector can lead to the development of a diverse range of electric platforms. This collaboration may involve leveraging commercial electric vehicle technologies and adapting them for military use. Drawing inspiration from advancements in other industries, such as autonomous vehicles or renewable energy, can further expand the possibilities for Tomco's electric military platforms.

H. Economic and Environmental Considerations

Highlighting the life-cycle cost benefits of electric platforms, including reduced maintenance costs and energy efficiency, can make them more appealing for military procurement. Emphasizing the environmental benefits of electric military platforms aligns with global trends toward sustainability. This can contribute to the positive image of Tomco and its commitment to eco-friendly solutions.

VIII. Conclusion

In conclusion, the evolution of electric vehicles in the military sector, particularly the conversion of conventional military vehicles to electric, marks a significant stride towards efficiency, sustainability, and adaptability. From the historical conversion of the T-23 in 1943 to the recent advancements in hybrid electric vehicles (HEVs), the landscape has witnessed transformative changes. The benefits offered by HEVs, such as fuel efficiency, reduced moving parts, and low noise operation, make them a compelling choice for military applications. Tomco's innovative approach to military vehicle electrification makes use of the electric skateboard design. The modularity and simplicity of the electric skateboard chassis not only streamlines the conversion process but also addresses concerns related to maintenance, downtime, and adaptability. The ability to convert military vehicles like the HMMWV to electric without the need for extensive modifications like drilling or welding showcases the practicality and cost-effectiveness of Tomco's solution. The challenges, such as those related to cooling systems and initial costs, are acknowledged. The comparison with conventional HMMWV configurations and the case study of Israel Military Industries Ltd. illustrates the potential and feasibility of electric military vehicles. Looking ahead, the future developments and expansions proposed for Tomco's electric military vehicle solutions showcase a commitment to continuous improvement. Advanced battery technology, enhanced drivetrain efficiency, autonomy, stealth features, and adaptability are at the forefront of the promised advancements. As the world moves towards a more sustainable and technologically advanced future, Tomco's electric military vehicle solutions stand poised to play a pivotal role in shaping the next generation of military mobility. With a focus on performance, cost-effectiveness, and environmental responsibility, Tomco's vision aligns with the evolving needs of modern armed forces, ensuring a strategic and forward-looking approach to military vehicle design.

REFERENCES

[1] Khalil, Ghassan. ”Challenges of hybrid electric vehicles for military applications.” 2009 IEEE Vehicle Power and Propulsion Conference. IEEE, 2009.

[2] Antoniou, Antonis, et al. ”Modeling and simulation of various hybrid electric configurations of the high-mobility multipurpose wheeled vehicle (HMMWV).” 2005 IEEE Vehicle Power and Propulsion Conference. IEEE, 2005.

[3] Hodgson, J. W., et al. ”Design of a low production cost hybrid HMMWV.” 17th DASC. AIAA/IEEE/SAE. Digital Avionics Systems Conference. Proceedings (Cat. No. 98CH36267). Vol. 2. IEEE, 1998.

[4] “Hummer H1/HMMWV® Vehicle Duramax Conversion Kit - X-Treme Hummer Performance.” X, 28 July 2023, xhp.parts/product/h1-hummer-duramax-conversion-kit/. Accessed 11 Dec. 2023.

[5] “Classic Electric Restorations.” North American Electric Vehicles, northamericanev.com/. Accessed 09 Dec. 2023.

[6] “Custom M998 Hummer.” MATBOCK, www.matbock.com/products/custom-m998-hummer. Accessed 24 Dec. 2023.

[7] Nick. “GM Autonomy Concept.” Supercars.Net, 17 May 2016, www.supercars.net/blog/2002-gm-autonomy-concept/. Accessed 05 Dec. 2023.

[8] “Skateboard Platforms - E-Mobility Engineering.” E, 19 Oct. 2021, www.emobility-engineering.com/ev-skateboard-platforms/. Accessed 16 Nov. 2023.

[9] “IMI Developing Electric Hummer.” BDS Movement, 19 Sept. 2016, bdsmovement.net/news/imi-developing-electric-hummer. Accessed 12 Nov. 2023.

[10] Radu, Vlad. “Analyzing the ‘skateboard’ Architecture of the Rivian R1T and R1s.” Autoevolution, 25 Nov. 2020, www.autoevolution.com/news/analyzing-the-skateboard-architecture-of-the-rivian-r1t-and-r1s-152013.html. Accessed 12 Dec. 2023.

[11] Stott, Alexander R., et al. ”Cold impacts on vehicle electrical systems: developing a baseline for cold testing military vehicles.” (2023).

[12] Brudnak, Mark, et al. ”Motion Base simulation of a Hybrid-Electric HMMWV for fuel economy measurement.” SAE International Journal of Commercial Vehicles 1.2008-01-0775 (2008): 41-53. University Science, 1989.

[13] Filipi, Zoran, et al. “Engine-in-the-Loop Testing for Evaluating Hybrid Propulsion Concepts and Transient Emissions – HMMWV Case Study.” SAE Transactions, vol. 115, 2006, pp. 23–41. JSTOR, http://www.jstor.org/stable/44681888. Accessed 17 Nov. 2023.

[14] Kramer, Denise M., and Gordon G. Parker. ”Current state of military hybrid vehicle development.” International Journal of Electric and Hybrid Vehicles 3.4 (2011): 369-387.

[15] Fish, Scott, Troy Savoie, and Harold Vanicek. ”Modeling hybrid electric HMMWV power system performance.” IEEE transactions on magnetics 37.1 (2001): 480-484.