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Derivation of Technical Requirements for New Uses of Electrified Tactical Vehicles

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Extended Abstract: Aligned with the U.S. Army's Climate Strategy and automotive trends, there is a push for military vehicle electrification and hybridization to cut carbon emissions and utilize technical advancements. While technically challenging, the electrification of tactical vehicles could provide a number of new capabilities to the warfighter. This study set out to identify operational and technical requirements for electrified tactical vehicles that would allow the warfighter to better leverage these new capabilities.

The study conducted a survey that identified soldiers' needs, wants, and desires regarding electrified tactical vehicles. The survey asked a range of questions related to the current tactical vehicles, concerns about tactical vehicles, and perceived opportunities through electrification. The survey was completed by 103 participants from various Army branches and units including the Army National Guard, Army Reserve, and active Army. Most respondents expressed that they are satisfied with current vehicles but had maintenance concerns, particularly with the more complex powertrains. Many respondents expressed concerns about operating and maintaining electrified tactical vehicles in the field, with experience with civilian electric vehicles correlating with fewer concerns. Common other concerns included vehicle durability, maintenance, and operating in austere conditions without recharging capabilities. However, soldiers also identified several operational scenarios where electric vehicles could be beneficial, such as silent movements, reconnaissance missions, urban operations, and providing power for command posts and bivouac sites. While most users preferred a range higher than 200 miles, they were willing to accept shorter ranges than diesel-powered vehicles, emphasizing the importance of signature management. Additionally, respondents favored opportunity charging, allowing vehicles to recharge whenever stationary and near a power source, including local grids or solar panels.

The survey allowed for the development of five use cases that are specific for an electrified tactical vehicle: silent overwatch, command post operations, silent approach, bivouac operations, and opportunity charging. Silent overwatch missions, crucial for reconnaissance and surveillance, could benefit from hybrid vehicles that can switch between electric and internal combustion engines, ensuring stealth while also enabling recharging during operation. Platoon command posts at patrol bases could utilize the large battery banks of electric vehicles to power essential equipment without relying on generators, enhancing operational planning capabilities. Electric vehicles also offer advantages for silent approach to objectives, maintaining stealth and reducing thermal signatures, particularly in dismounted movements over short distances. Supporting bivouac operations, electrified vehicles serve as mobile power sources, enhancing operational flexibility and reducing logistical burdens, with hybrid systems providing extended range and quieter operations. Opportunity charging, especially using solar blankets during stationary missions, presents a practical solution to replenish energy dissipated during initial movements or offset energy usage by onboard electronics, further enhancing the sustainability and effectiveness of tactical operations.

The use cases led to a set of operational requirements; however, the derivation of technical requirements from these operational requirements needed a better understanding of how the vehicles would be used in an operational setting. As such, the study then quantitatively analyzed geo-location data from tactical vehicles (n=460) at the National Training Center to capture real-world usage patterns. The analysis found that the vehicles are stationary for 93 percent of the day; however, the vehicles were on for 23 percent of the day, resulting in significant fuel consumption. The average vehicle had four movements per day, with the average duration being approximately 7 km. Further, the analysis found that the average vehicle used 180 MJ per day for locomotion. Meanwhile, a 300W solar blanket would only provide 7 MJ per day of energy to recharge the electrified vehicles battery pack.

These results were then combined with an extensive market research, which identified the state of technology for batteries, supercapacitors, motors, and alternators. This analysis looked at both the current state of the technology in addition to trends and future forecasts. The analysis found that current batteries are still too heavy to provide the desired range for electrified tactical vehicles. However, as the batteries continue to advance, they will be able to meet the desired durations. Additionally, alternators and other power electronics are currently bulky and require further improvement, especially to handle the high power loads associated with a heavy vehicle. Meanwhile, current motors that are used in commercial electric vehicles will work on an electrified tactical vehicle.

The market research and quantitative analysis were combined with the operational use cases to provide insight into the derivation of technical requirements. This derivation was captured using a model-based systems engineering approach. The background research was captured in a block definition diagram that provided traceability to the five use cases, which were individually captured in use case diagrams. The model tied the operational requirements to the relative use cases, and then decomposed them in a requirement diagram. If the final system design is able to meet these technical requirements, the users will be better able to leverage the new capabilities tied to electrifying a tactical vehicle.

Keywords: Military vehicles, Sustainability, Vehicle electrification, Requirement Derivation