2014 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM

POWER & MOBILITY (P&M) TECHNICAL SESSION
AUGUST 12-14, 2014 - NOVI, MICHIGAN

INTEGRATED POWER GENERATION FOR DIRECTED ENERGY APPLICATIONS

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ABSTRACT

The electrical power demands of military ground vehicles have grown rapidly over the years. New sensors, computers, communications equipment, and weapon systems demand increased levels of electrical power to employ their capabilities. To provide our War-fighters access to these new technologies, vehicle power initiatives are keeping pace by exploring efficient integrated next-generation mobile power solutions.

TARDEC's Advanced Propulsion with Onboard Vehicle Power (APOP) program and explorations into on-platform Directed Energy based systems demonstrate an ideal coupling of compliment technologies.

The advanced warfare capabilities of the future can be brought to our Warfighters through purposeful research and investment to ensure timely readiness. The TARDEC/GDLS APOP power generation effort is one such collaborative effort, and represents a potential breakthrough in next-generation power for military ground vehicles.

INTRODUCTION

The U.S. Military constantly invests in a broad array of new technical capabilities to better transport, protect, arm, and inform our Warfighters. The influx of new capabilities occurs at an astounding rate, and managing technology insertion into current platforms represents a unique and disciplined blend of Systems Engineering (SE) and technology development.

Ground combat vehicles can be fielded for decades. Because of this, upgrades to fielded platforms are commonplace taking the form of modernization programs. Modernization programs tend to have similar characteristics in that capability is always improved, but at the cost of diminished Space, Weight, and Power (SWAP) margins. Power generation capabilities can be reset to handle new and projected demand, but at a further hit to the available space and weight. This cycle may repeat itself several times as illustrated in Figure 1.

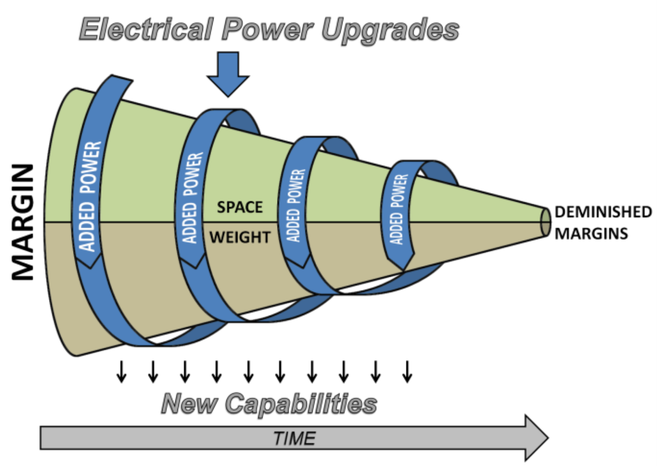

Figure 1 – Power growth cycle on a typical Modernization program

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Looking forward, there are several new technologies with significant electrical power demands on the horizon, specifically Directed Energy technologies. The magnitude of the power demands of these new technologies means that traditional modernization approaches won't be viable approaches anymore. Instead, industry and government scientists are pursuing a carefully synchronized strategy to mature new electrical power architectures along with new power generation subsystem technologies to help avoid the cycle of continually diminished system margins associated with traditional modernization programs.

TARDEC ADVANCED PROPULSION WITH ONBOARD VEHICLE POWER (APOP)

Integrated Starter Generator (ISG) based subsystems are a key solution path that aims to mitigate the electrical power gap. This is an area that both the United States Government (USG) and Original Equipment Manufacturers (OEM's) have committed funding and are applying purposeful research to advance the readiness. It incorporates a generator between the engine and transmission, presenting a manageable impact to integration. Electrical power generation capabilities can easily approach 4 to 5 times that of traditional alternator solutions, providing leap-ahead integration opportunities for the host platform. Retrofit to existing platforms is a key area of focus, and it is a strong candidate for new vehicle development programs. The ISG solution path for military ground vehicles addresses the electrical power gap. SIL testing of the ISG transmission system and power pack configuration can be seen in Figure 2 and Figure 3 respectively.

Figure 2 - ISG testing in a SIL at TARDEC

As part of TARDEC's APOP program, a ground combat vehicle integrated solution is being explored. The platform employs an integrated generator (IG) system to provide power generation capabilities well beyond that which is possible through alternator upgrades. This solution mounts directly to a production engine with the same axial length. This effort serves to demonstrate the technical readiness of a high-potential retrofit that provides significant power margin for the future. It also supports efforts to optimize efficiency through increased electrification and control of vehicle subsystems.

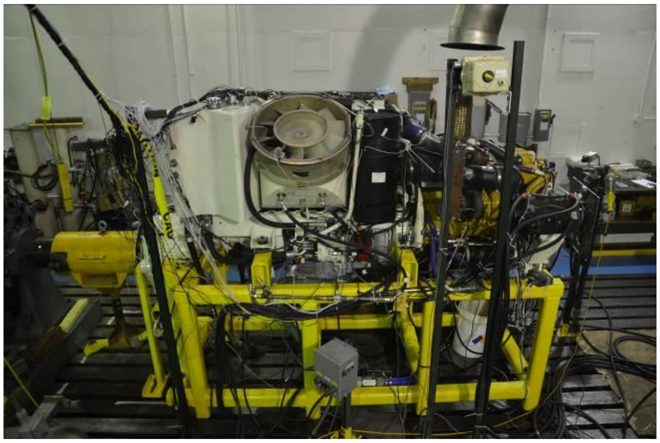

Figure 3 - Instrumented power pack setup in a SIL at TARDEC

INTEGRATED GENERATOR SYSTEM IMPACTS

Integration of an inline generator system has several impacts to the vehicle. The system requires space, weight, and power. However, some of the impacts can be managed at the vehicle system level. For comparison, a SWAP study was performed to look at the space and weight of upgrading a vehicle from a 16kW alternator to a 120kW IG with electrified auxiliaries. Its results are summarized in Table 1.

Description	Weight Delta (lb)	Volume Delta (L)
Current Generator Tech w/ electrified systems	+466	+220
Removal of hydraulics or local hydraulic supply + Li-Ion batteries.	+69	+151
Advanced power electronics + ISG starting capability	-227	9

Table 1: SWAP Summary

- The first approach, Current Generator Tech w/ electrified systems, assumes replacing the alternator with a 600V IG and 600-28V DC-DC converters. The main fan is changed from hydraulic to electric. The original Power Take Off (PTO) driven hydraulic pump for the auxiliary systems is moved to an electrically driven hydraulic pump. All of the electronics and electrical systems are based on fairly mature hardware.

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- The next approach, Removal of hydraulics or local hydraulic supply + Lithium-Ion batteries, makes further changes to the system, such as minimizing the hydraulic reservoir requirements and electrifying additional components, such as the Air Conditioning (A/C) system. Lithium-ion low voltage batteries are utilized to buy back space and weight.

- The final approach, advanced power electronics + ISG starting capability, includes some of the future power electronics that are in development by the Army. The technologies used in these electronics allow significant space, weight, and cooling savings.

The main point is that the technology and implementation of the integration have significantly different impacts on SWAP. The long term solution is actually lighter and nearly weight neutral compared to the baseline vehicle. The approach of the APOP project is to treat each of these approaches as steps along an evolutionary development timeline.

INLINE OR STANDALONE GENERATOR

Let's consider the issue from an efficiency standpoint. A system requiring large amounts of additional electrical power onboard the vehicle is planned. The options to power the system could be: use a generator in the vehicle driven by the main engine or install a standalone generator onboard the vehicle to power the system. Some analysis has been done to look at these two solutions based on vehicle/generator models and test data. The fuel efficiency of these two options is compared in Table 2. The vehicle with IG is more efficient than current standalone generators.

	Vehicle w/ IG (GPH)	GenSet (GPH)
30kW	1.3	2.6
60kW	2.3	4.7

Table 2: Fuel usage comparison for IG vs. standalone generator

ELECTRICAL POWER AND MOBILITY

Power has to come from somewhere in the vehicle system. In general, the main power source is the engine. The potential effects on mobility due to the increased electrical loading must be addressed.

This problem ties back to system efficiency and controls. By utilizing efficient electronics and electric machines, there can be significant system efficiency savings over hydraulic systems, accounting for some of the additional load. Also, when considering controls, management of the power is important to optimizing performance. The system controls models are currently under development for the APOP project and are taking these factors into consideration. The system will be checked against the vehicle performance requirements with the goal to not affect mobility.

Once these systems are installed in the vehicle, new capabilities are enabled by the significant additional power generation.

POWER GENERATION TO SUPPORT NEXT-GEN SYSTEMS

High Power and Directed Energy Systems are an emerging technology that is gaining notice for their applicability on the future battlefield. Specifically, High Energy Laser (HEL) systems provide an intriguing capability for Counter – Unmanned Aerial System (C-UAS) missions. As seen on the nightly news, the proliferation of drones is becoming more widespread in military operations for surveillance missions. Leveraging UAS technology for remote weapon operation or the delivery of explosive payloads is further cause for concern. The exceptionally low-cost capability benefit of a UAS and widespread availability changes the calculus for fielding expensive countermeasures. HEL solutions offer a compelling suite of capabilities to counter this threat for much lower dollars per shot than things like hand-held missile batteries. Due to the highly scalable nature of the technology, Counter-Rocket, Artillery, Mortar (C-RAM) and Counter-Cruise Missile (C-CM) applications are within reach. Currently under evaluation by the U.S. Army Space and Missile Defense Command (SMDC), they are demonstrating this potential and advancing the readiness of this technology on their HEL-MD program as shown in Figure 4 [1].

Figure 4 - U.S. Army Space and Missile Defense Command has demonstrated the defeat of a UAS & mortar rounds with a HEL [1]

Already a centerpiece of research and development within the U.S. Navy, such systems are targeted for fielding as early as this summer. A HEL weapon would train on the threat to blind the sensors, damage control or guidance electronics, or disrupt the propulsion system. Speed-of-light firing enables increased accuracy and decision-making time. Warfighter safety is enhanced through the elimination of stowed explosives. With the promise of pennies per shot, limitless ammunition, and a reduced logistical footprint, HEL technology could prove to be truly transformational for ground combat platforms.

After decades of development and maturation, High Energy Laser systems are poised to move from the lab to the battlefield. Leveraging the new power generation capability being explored under APOP with a rigorous systems engineering approach and coupled with close insight into customer expectations (SMDC vision), this will set the stage for future success on ground vehicle platforms.

ADDITIONAL CONSIDERATIONS

Another potential application for the power generation capabilities being explored under APOP is in contingency basing operations. Early in operations, where bases need to be setup quickly or are temporary, vehicles with inline generator technology can be used to power base operations by exporting power from the vehicle. This can be useful in locations where generators are not available or are hard to transport to. This vehicle to grid power export capability can be used at permanent bases to augment power generation, especially during peak power usage, which can save money. The exported power could also be used by other vehicles to power a failed vehicle's systems or save fuel by powering multiple vehicles from a single engine while idling during missions.

HEL systems can offer unique ancillary applications in addition to their typical offensive and defense uses. The wireless transmission of power to off-board assets has been demonstrated successfully; keeping a friendly UAS asset aloft for a significant time period [2]. This would have tremendous utility in a military environment in the case of surveillance or convoy operations. A graphical representation of the concept of operations is shown in Figure 5.

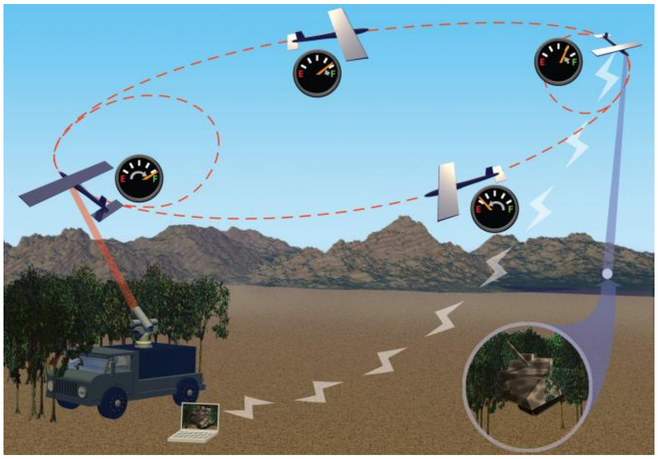

Figure 5 - Lasermotive and Lockheed Martin successfully demonstrated the capability to indefinitely extend a UAS flight time through the wireless transmission of power [2]

CONCLUSION / COLLABORATIVE FUTURE VISION

Leap-ahead capabilities in the area of power generation are critical in order to ensure our military has the ability to remain flexible, adaptable, and responsive to varying threats. As these threats continue to evolve, the need to observe, detect, identify, and neutralize them is as important as ever. The TARDEC APOP power generation initiative represents a potential breakthrough in next-generation power, particularly in the area of disrupting traditional space and weight tradeoffs associated with the modernization process. Explorations into High Energy Laser applications on a mobile, combat vehicle are looking to equip our warfighting force with solutions that ensure success when the time is right. Working in concert, these development efforts provide a strong compliment to one another's outcome. Through efforts such as these, the advanced warfare capabilities of the future can be brought to our Warfighters through purposeful research and investment to ensure timely readiness.

REFERENCES

[1] John H. Cummings, "Army vehicle-mounted laser successfully demonstrated against multiple targets", http://www.army.mil/article/116740/Army_vehicle_mounted_laser_successfully_demonstrated_against_multiple_targets/, 2013

[2] T. J. Nugent, J. T. Kare, "Laser Power for UAVs" White Paper, http://lasermotive.com/wp-content/uploads/2010/04/Wireless-Power-for-UAVs-March2010.pdf, 2010