Picture credit: Drive System Designs

# WE ARE ELECTRIC

**Ben Chiswick** *outlines the importance of combatting barriers to electrification*

**The defence industry is impressively dynamic, prepared to swiftly react as needed but an understandable risk aversion leads to slow phasing in of new technologies and implementation of fundamental changes.**

The electrification of vehicle fleets is an inevitable change that is already taking hold in various transportation sectors and is now a focal point of discussion both industry and government wide. Though its adoption is not simple, the benefits are clear cut. Understanding the best path forward for where, when and how to electrify fleets despite existing barriers is critical to success. Drive System Design (DSD) has a comprehensive understanding of this industry shift and can help defence industry players define a timeline and next steps according to the vehicle's mission profile, electrification technologies available and the operational challenges and benefits it brings.

One of the key drivers for the adoption of electrification is to improve the efficiency of vehicles and reduce the fleet's reliability on fossil fuels. In 2017 the US Army purchased $947-million worth of fuel, and costs have sharply increased since then. The fully burdened cost, which includes the initial purchase price and the cost of transporting it to where it is needed, is significantly higher.

While reducing fuel consumption saves money, it also can improve personnel safety. In 2009, a US Army study found there was one casualty for every 39 fuel convoys in Iraq and one for every 24 fuel convoys in Afghanistan. Even small efficiency improvements would significantly reduce the number of fuel deliveries required and improve troop safety.

**Electrified vehicles lead to huge fuel savings**

On top of operational benefits, electrification also provides significant tactical opportunities. Every vehicle is now expected to do more – be more lethal or offer more protection – resulting in vehicles being equipped with additional surveillance and weapons systems, which require more power. An electrified vehicle would lead to huge fuel savings, since traditional internal combustion engine (ICE) powered vehicles spend a significant time idling to power these systems.

Powering auxiliary systems using an electrified powertrain will also provide opportunities to introduce next-generation weapons and surveillance systems that can use higher voltages. These can be fitted to traditional vehicles, but require support equipment, such as new DC/DC converters, which add weight and take up space. In vehicles with an electrified architecture, operating at higher voltage levels than current platforms, these systems can be integrated more easily.

There are inherent properties of an electric vehicle that offer significant benefits in theatre as well. For example, the EV propulsion systems are quiet and don't emit any exhaust gasses, aiding stealth efforts.

From a 'big picture' perspective, the sustainability value of adopting electrification should not be underestimated. This is why we continue to see environmentally friendly regulations enforced on a global scale.

While the benefits are extensive, there are still many issues at play combatting electrification. Perhaps the biggest barrier, and what will require the most change from an operational perspective, is the current fuel ecosystem. The vehicle infrastructure is set up around fossil-fuelled vehicles and would need to be completely rethought. There is not currently an infrastructure set up to charge a large fleet in remote operations, such as the desert, but getting JP8 to these areas is a well-established supply methodology. In the short term, the answer is to use the fuel that can be easily transported more intelligently using hybrid systems. This provides some of the benefits of electrification while mitigating the risk of step-change technology adoption.

Another common counterpoint to pure electrification is concern around redundancy and failure mechanisms. As ICE is the current accepted technology, the perception is that a traditional vehicle can limp home if it is damaged whereas an electric motor would leave the vehicle stranded. However, a parallel hybrid configuration that yields the benefits of a staged electrification introduction strategy can provide enhanced redundancy compared with conventional powertrains, if executed appropriately.

Another general perception is that there is no space for hybrid systems to be integrated in today's vehicles and making room would result in a compromise in the vehicle's survivability, lethality, mobility or size, weight, power and cost (SWAP-C). However, by taking a whole system approach to design, that can change. For example, when using a range extender engine, combining the power of an ICE and electric motor, peak performance including maximum torque and desired power can be achieved. As a result, a much smaller engine can be utilised, and this creates room to package the electric motor. Likewise, a hybrid vehicle will optimise the use of the energy onboard from both the fossil fuels and battery pack enabling the fuel tank to be reduced creating room for the electrified sub-systems. A good example is Cummins' development of an Advanced Combat Engine (ACE), a modular and scalable diesel engine solution that is capable of hybridisation, through a contract with the US Army.

Engineering consultancies like DSD are using this whole system approach, honed over years electrifying automotive, commercial vehicle and off-highway platforms, combined with specialist simulation tools to design electrified powertrains optimised for this scenario. We fully expect these perceptions will change as the technology becomes more widespread.

An often overlooked limitation to electrification is the thermal constraints of today's technologies. Thermally managing an electrified powertrain is not only important for performance, but critical to durability. The defence industry arguably presents the most challenging and diverse range of vehicle operating cycles and harsh environments that a powertrain engineer would need to design for. Whether it is required to climb the sand dunes in the Namibian desert or sit patiently waiting in the arctic, the range of temperatures the vehicle is subjected to is extreme. The necessity for armour, naturally representing a sealed or impenetrable layer around the vehicle, exacerbates these thermal challenges.

## REDUCING FUEL CONSUMPTION SAVES MONEY AND IMPROVES PERSONNEL SAFETY

Commonly available power electronics modules that DC-DC converters and inverters are built upon are generally rated to around 90°C, limited by inherent material properties. Many defence applications would require this to be at least 25 percent higher, to allow incumbent cooling circuits supporting the ICE power-pack to cool electrified sub-systems as well. When this is most often not viable, the difficult reality of separate cooling systems must be faced, along with the additional complexity and potential failure mechanisms that accompany the new systems. Solving these thermal problems is a near-term necessity, with high power electrical distribution and conversion systems already critical in supporting the increasing demands for different voltages and power requirements for a multitude of communication, protection and weapon systems, before electrified propulsion systems can even be considered.

Thermal modelling and simulation early in vehicle architecture development is essential to understand and mitigate the failure modes. Once the weak links are identified, design decisions from high-level cooling architecture changes right down to chip placement to alleviate junction temperature issues, can be taken.

Considering the barriers, moving directly to a purely electric vehicle fleet from what is currently in operation today simply isn't feasible. It would require a quantum leap in vehicle operation, fuelling infrastructure and retraining vast numbers of personnel, posing too much of a risk. Instead, a stepping-stone approach will be taken to progressively integrate electrification into the combat fleet, and this is likely to be guided by vehicle weight classes.

The defence industry is already looking to other sectors to leverage well-understood and proven technologies to take these first few bold steps. The automotive industry, whose adoption of electrification has been accelerated by legislation, is the current benchmark. This has naturally led to smaller vehicle platforms, such as the Humvee or the JLTV (Joint Light Tactical Vehicle), being good candidates for pure electrified architectures as they are wheeled and in a weight class that makes sense for hybrid architectures.

As vehicle weight classes increase, pure electrification becomes far from viable with current technology. The issue is battery power density; for example, to power a 70 tonne M1 Abrams tank the battery pack would weigh more than 12 tonnes and be around 350 cubic feet in volume – not so different to the overall package size of the existing Abrams powerpack. So pure electrification at this weight, and even at the 45-50 tonne IFV (Infantry Fighting Vehicle) class, is not yet practical, with a significant leap forward in battery technology needed to change this.

## VEHICLE AUTONOMY AND ELECTRIFICATION COMPLEMENT EACH OTHER VERY WELL

This horizon line where electrification becomes viable for larger weight classes will be continually changing in years to come, as battery and motor technologies rapidly advance. The matrix of vehicle types, applications, mission profiles and electrification technologies is too vast to rely on manual calculation, so simulation is playing a critical role in accurately pinpointing where this line is and plotting its movement as time and technology progresses.

Autonomy is arguably an even bigger trend in the defence industry than electrification. Its benefits in terms of removing troops from harm's way are clear and armies are already rolling out this technology. The US Army is developing the Optionally Manned Fighting Vehicle (OMFV), enabling Manned Unmanned Teaming (MUMT) whereby a lead vehicle is crewed while the other vehicles follow autonomously. In the lighter weight classes, it is also using Robotic Combat Vehicles (RCV) to carry equipment alongside troops and perform advanced reconnaissance tasks.

Autonomy and electrification complement each other very well and the move to autonomy could help accelerate electrification. For instance, removing personnel from the vehicle significantly shifts the design paradigm that exists between a vehicle's survivability, lethality and mobility. With no personnel on board, the survivability and armour can be compromised, liberating significant volume and weight allowance that can be utilised for battery packs and electrified sub-systems. Additionally, when platforms such as an RCV-L are considered expendable, even greater headroom for battery packs is available, not to mention the simplified thermal management systems that can be introduced in the absence of armour.

Fully maximising the benefits of autonomy requires a completely new vehicle architecture. Seats, steering controls, windows or air vents and even doors are no longer needed and this provides an opportunity to improve the design of the vehicle. So it is the perfect time to also optimise these new architectures for electrification too.

Developing an effective electrified technology deployment strategy isn't easy, but it is becoming increasingly necessary. We will continue to see more advanced electrification and autonomous technologies and infrastructure come to fruition that will provide sustainable and reliable growth for the electrified ecosystem. The trade-offs between mobility, survivability and lethality will continue to be at the forefront of the transition, with autonomy allowing the current trade-offs to be challenged, especially considering the potential for reduced personnel exposure and additional power for new, critical weapons and communication systems. In the short-term, a staged, system-level approach to electrification minimises risk and maximises platform capability. Marching toward hybridisation is the best first step ●

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