A WHITEPAPER FROM THE ARMY APPLICATIONS LABORATORY

POWERING AN ELECTRIC VEHICLE INFRASTRUCTURE FOR THE U.S. ARMY

Shared challenges point the way to shared solutions

ABSTRACT

The U.S. Army has a vehicle fleet that operates at an unrivaled scale. Yet this fleet is still wholly dependent on fossil fuels. That dependence creates serious risks for Soldiers, so the Army has begun to investigate and prototype electric replacements for legacy vehicles. But the transition to electric vehicles (EVs) will not be an easy one for the Army — it must still develop an infrastructure that can power them anywhere in the world.

Fortunately, the commercial market is working to solve some of the same EV issues that impact the Army. Widespread commercial adoption will also depend on a broadly available infrastructure that can provide fast recharging to alleviate range anxiety and meet user demands. The Army is encountering similar issues but on an industrial-scale where inconvenience isn't the concern as much as Soldier safety and mission success.

With similar challenges facing both the military and the commercial market, the Army and industry will both be served by joining forces to fast-track the development of flexible and scalable EV infrastructure technologies. The Power Transfer Cohort is the first step to making that a reality.

Using a proven model and an iterative design process, the Power Transfer Cohort can quickly advance new solutions for both the Army and companies developing EV-enabling technologies including remote access, rapid recharging, and legacy integration.

THE GROWING BUZZ AROUND ELECTRIC VEHICLES

For those who came of age in the decades before Y2K, the phrase, "It's electric!" triggers memories of a disco-style line dance set to the tune of "Electric Boogie." Fast-forward 30 years, and that phrase conjures up a completely different type of movement. From bikes to buses, scooters to SUVs, electric vehicles (EVs) are now on the move around the globe.

Worldwide EV sales topped 2.1 million in 2019, a 40 percent year-over-year increase, bringing the total number of EVs on the road to 7.2 million.[1] This increase is largely driven by a number of benefits that EVs have over vehicles with internal combustion engines, which hit roads in the United States more than a century ago.

Reduced costs

EVs are cheaper to fuel and maintain than their gasoline-powered counterparts, with a median annual fuel savings of more than $770 and a maintenance savings of more than $1,500 throughout the life of the vehicle.[2]

Environmentally friendly

EVs are also on the rise because they produce less global-warming pollution than conventional counterparts. In addition, they are less reliant on oil and offer the potential to cut U.S. oil use significantly throughout time.

Improved performance

Electric engines generate nearly instant torque, which means EVs can get out of the gate faster and offer smooth, responsive acceleration and deceleration. EVs also generally feature a lower center of gravity, which improves handling, responsiveness, and comfort.[3]

Theoretical convenience

EVs can be charged in homes, offices, or virtually anywhere there's a plug-in charging station. Cordless charging makes recharging as easy as parking, and

rechargers for EVs can get power from a variety of sources, including national grids, microgrids, and solar energy.

> What might be surprising is just how difficult it's been for both U.S. businesses and the U.S. Army to transition to EVs.

Between the environmental value and the upward market trend, it's no surprise that a growing number of U.S.-based businesses are investing in and developing EV-enabling technology — including traditional automobile manufacturers, technology firms, utility companies, and energy giants like Chevron Corporation.[4] Nor is it a surprise that, during the past five years, the U.S. Army has increasingly turned its attention to EV platforms as an alternative to its traditional gas-powered fleet. In 2020, the Army Futures Command (AFC) officially tasked its Futures and Concepts Center with developing a path forward to integrate EVs across the Army.[5]

What might be surprising is just how difficult it's been for both U.S. businesses and the U.S. Army to transition to EVs.

BREAKING DOWN THE EV INFRASTRUCTURE PROBLEM

Despite the progress that's been made in creating and refining EV platforms, the infrastructure necessary to power them is lagging behind. That delay results in an industrial-scale problem that hampers adoption of EVs in the private sector and also limits the Army's ability to incorporate EVs across its fleet.

The source of the delay can be traced to two primary culprits:

(1) A historical dependence on gasoline, and
(2) The absence of reliable power options.

1 https://www.iea.org/reports/global-ev-outlook-2020
2 https://www.ucsusa.org/resources/top-five-reasons-choose-electric-car
3 https://www.ucsusa.org/resources/top-five-reasons-choose-electric-car
4 https://www.forbes.com/sites/billroberson/2019/05/26/the-turning-electric-tide-chevron-announces-that-some-california-gas-stations-will-get-ev-chargers/?sh=779722701227
5 https://electrek.co/2020/04/23/the-military-develops-plan-to-use-evs-similar-to-tesla-semi-for-remote-missions/

GASOLINE CULTURE

In 2019, 143 billion gallons of gasoline were consumed in the U.S., an average of nearly 391 million gallons per day.[6] The Department of Defense (DoD) alone uses approximately 3.65 billion gallons of fuel annually — more than 10 million gallons each day — making it the largest single industrial consumer of fuel in the world.[7]

The staggering global scale of DoD fuel utilization is more than an environmental nightmare. The transport of fuel to the frontline creates a complex logistical trail that is both expensive and a prime target for attack. At the peak of the war in Afghanistan, one in every 24 fuel convoys suffered a casualty.[8]

Despite these threats, gasoline still appears to be a more reliable option for both consumers and the Army. Fuel stations are ubiquitous throughout most of the world. And, albeit imperfect, the Army has an approach to fossil fuel transport that is tested, familiar, and written into acquisition policy. Without a trusted, reliable infrastructure for EVs, the imperative to change loses ground.

RANGE ANXIETY

Consumers who gravitated to EVs sought the reduced costs, environmentally friendly operations, and improved performance that these new vehicles could deliver. The stumbling block has been realizing the promise of this theoretical convenience. While battery size and capacity issues are being addressed — to an extent — the infrastructure necessary to support practical use of EVs is still lacking.

Even today, as consumer EV sales increase and EV tractor-trailer fleets are eyed for future use,[9] the biggest worry remains where to plug in.[10] Urban areas have seen an increase in EV-charging stations, but the absence of power options in more rural areas remains pronounced.[11]

Many have dubbed this a chicken-and-egg problem: Consumers generally shy away from EV purchases without broadly deployed and easily accessible charging stations, but investments in charging stations don't make financial sense without a massive demand propelled by EV utilization.[12]

IMPACTS FOR INDUSTRY

- The slow adoption of EVs in the United States strains the return on investment for U.S-based companies working on EV-enabling technology. In the absence of the market demand, many companies are turning to foreign businesses and governments to develop and sell their EV technology.[1]
- There are only a limited number of municipalities with the resources, technical ability, or willingness to test and refine EV technology in a meaningful way. So U.S. businesses don't have many opportunities to validate their technology at scale, in remote areas, or across long distances.
- While some large organizations have received government funding to support electric vehicle research[2] — and U.S.-based investors are increasingly financing EV technology[3] — non-dilutive capital for research and development is limited. That imbalance leaves most small businesses at a disadvantage.

IMPACTS FOR THE ARMY

- Private sector spending has replaced federal spending as the primary source of R&D funding in the U.S.[4] That means the Army has under-invested in EV research and is behind both industry and some other countries.[5] This delay could create technological disadvantages in future conflicts.
- While the Army often sources technology from the commercial market, there is no existing commercial solution available to solve the Army's distinct needs for electric vehicles. And those companies that are most familiar with military technology are not typically the ones leading EV innovation.
- The Army continues to rely on fossil fuel to power its vehicles, which creates a continual and significant logistical challenge. Fuel must be moved from distribution points and delivered to locations around the world. This logistical tail is not only expensive but is also highly visible and, therefore, vulnerable.[6]

1 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales
2 https://fortune.com/2020/07/24/elon-musk-tesla-tweet-second-stimulus-package-government-subsidies-loan-great-recession/
3 https://www.reuters.com/article/us-autoshow-detroit-startups-electric-an/corporate-investors-pile-into-electric-vehicle-startups-idUSKCN1P52DC
4 https://ncses.nsf.gov/pubs/nsf19309
5 https://www.defensenews.com/land/2020/09/21/army-gives-green-light-to-shape-vehicle-electrification-requirements/
6 https://www.popularmechanics.com/military/a32255281/electric-jltv-army/

6 https://www.eia.gov/tools/faqs/faq.php?id=23&t=10#:~:text=In%202019%2C%20about%20142.71%20billion,9.31%20million%20barrels
7 https://fas.org/sgp/crs/natsec/R45832.pdf
8 https://www.google.com/url?q=https://apps.dtic.mil/dtic/tr/fulltext/u2/b356341.pdf&sa=D&source=editors&ust=1612466327302000&usg=AOvVaw1owpBqh0QVx6HEQwtlLKJE
9 https://www.nytimes.com/2020/03/19/business/electric-semi-trucks-big-rigs.html
10 https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2020/01/02/got-an-electric-car-great-where-do-you-plug-it-in
11 https://epm.ucdavis.edu/sites/g/files/dgvnsk296/files/inline-files/Preparing%20Rural%20America%20for%20the%20Electric%20Vehicle%20Revolution.pdf
12 https://www.bloomberg.com/news/articles/2020-06-23/electric-car-charging-stations-are-finally-about-to-take-off

This concern — a concept known as "range anxiety" — is not unfounded. Consumers fear being left stranded while running errands or picking up children from school. Or, worse, being left on the roadside while driving to the beach or mountains for recreational fun. In industrial-scale applications, this inconvenience compounds with supply chain disruptions.

Large vehicles, like tractor-trailer fleets, also bring the battery capacity issue to the fore. Most lithium-ion batteries cannot yet store enough energy to support extended journeys, and chargers can't power an EV as quickly as you can refuel a combustion engine.[13] No power means no movement, and that's a mobility dealbreaker — especially at an industrial scale.

For the Army, range anxiety takes on additional complexity and a dangerous level of criticality. These issues are driven by both the size of Army platforms and the environments in which the Army operates.

Building EV infrastructure for consumer and industrial users is a massive investment, with the potential for more than $111 billion in private and public investments required to establish the framework for widespread EV utilization.[14] But these investments will — in most circumstances — fund a fixed infrastructure. Charging stations will be built in one location and stay there.

An EV power infrastructure for the Army, on the other hand, has to be modular. Operational missions occur for a limited time — driven by humanitarian responses, disaster recovery activities, and other military missions — so charging stations in a fixed location won't meet the need. The Army needs a flexible, scalable EV

WHAT CAN COMMERCIAL BUSINESSES OFFER THE ARMY?

I

Companies in the EV infrastructure ecosystem have been thinking about and trying to solve these problems for a while. They can share that experience with the Army and back up their thinking with real-world evidence.

II

The iterative development models that are relatively new to the Army are standard practice for commercial innovators. These frameworks allow commercial solution providers to adjust and innovate more quickly.

III

The Army is open to new ideas, but its legacy investments, infrastructure, and practices don't align well to new EV infrastructure concepts. Commercial companies can bring a fresh perspective to the Army's EV challenges.

IV

Many commercial businesses have EV enabling technology with the potential to address part or all of the Army's power problem — or technology that can be translated to support this specific military use case.

WHAT CAN THE ARMY OFFER COMMERCIAL BUSINESSES?

I

The Army wants to electrify approximately 225,000 vehicles that operate in demanding environments. That presents an unmatched opportunity to test and prove that technology can work at scale and in extreme use cases.

II

With its expansive network of laboratories and experienced scientists, the Army can provide commercial EV infrastructure solvers with access to new perspectives as well as to R&D facilities across the country.

III

Commercial companies that partner with the Army can gain access to end users (Soldiers) who can provide valuable feedback to help inform solution design and who can help test technology in any condition.

IV

The Army has dedicated funding to solve high-priority problems, including this one. Through approved programs, qualified commercial businesses can access that funding without giving up a stake in their company.

13 https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf
14 https://www.bloomberg.com/news/articles/2020-06-23/electric-car-charging-stations-are-finally-about-to-take-off

infrastructure that can operate when and where it does. Without it, Soldiers are left in harm's way without a means to rapidly recharge their vehicles.

The Army cannot make the move to EVs if it could mean leaving Soldiers stranded as targets or impeding the success of operational missions.

SHARED CHALLENGES. SHARED SOLUTIONS.

While the Army's EV infrastructure gaps may pose more dire consequences than the impacts facing consumers and industry, the core challenges for each are interrelated. That means the solutions to those challenges share a common thread.

For that reason, though the scale and construction of final solutions may vary, the Army should partner with industry to address these four EV infrastructure needs in the most cost-effective way.

1. **Rapid recharging** – The Army and industry must both solve how to quickly charge and recharge numerous EV batteries at once in a safe, repeatable way.[15]
2. **Transportable power** – Both industry and the Army need a new EV infrastructure to support power import from and export to other EVs as well as non-EV systems.
3. **Flexible infrastructure** – Although the Army requires a higher degree of flexibility and portability, both industry and the Army need EV infrastructure assets that can scale.
4. **Infrastructure integration** – Both industry and the Army need to integrate EV infrastructure such that it can be complemented by and act as a complement to legacy infrastructure and systems.

Making the most of this shared problem set will require a new approach to concept development for the Army as well as the inclusion of some different industry players. The good news is that the shift from gas power to electric power presents a chance for the Army to work with a new generation of organizations that are trying to solve these same infrastructure issues.

The breadth and diversity of companies working in the EV infrastructure ecosystem are impressive. Beyond traditional manufacturers that may first come to mind, there are an even greater number of smaller companies in the mix.[16] From power electronics to EV supply equipment to distributed energy resources, hundreds of U.S. companies are trying to solve discrete but connected pieces of the EV infrastructure puzzle.

But solutions to these complex problems aren't likely to come from one source, even from the private sector. The answers — and the path forward for EV infrastructure in the United States — will come through active collaboration.

MILITARY AND INDUSTRY PARTNERSHIPS IN ACTION

The idea of public-private partnerships to address shared areas of need is not a new concept. Super glue. GPS. The Internet. All of these innovations can trace their roots back to the U.S. military.[17]

The novel ideas that came out of efforts like WWII and the Apollo missions — and that spurred economic growth for the nation — were grounded in a close, mutually-beneficial relationship between the federal government and the commercial world.[18] And the future of EV infrastructure in the United States may hinge on reinvigorating those partnerships of decades past.

As recently as 2020, the Army experienced the power of these partnerships with the private sector. One such example comes from the Long Range Precision Fires Cross Functional Team (LRPF) within the Army Futures Command (AFC).

15 https://www.myev.com/research/interesting-finds/is-dc-fast-charging-bad-for-your-electric-car
16 https://www.nytimes.com/2020/03/04/business/new-electric-car-companies.html
17 https://www.usatoday.com/story/money/2019/05/16/15-commercial-products-invented-by-the-military/39465501/
18 https://www.nasa.gov/sites/default/files/files/NASA_Partnership_Report_LR_20140429.pdf

Using a new cohort model, in partnership with the Army Applications Laboratory (AAL) and a team of contractors led by Alion Science and Technology Corporation, LRPF explored how best-in-class commercial technologies could address field artillery resupply challenges — and how the Army could quickly identify and incorporate those relevant technologies.

After just 12 weeks, the six companies in the Field Artillery Autonomous Resupply (FAAR) Cohort presented 14 different, interoperable solutions to help solve the Army's problem. LRPF elected to move forward with 50% of cohort participants and is currently planning to incorporate some of those technologies into new capabilities for 2023.

50%

of companies in the FAAR Cohort were selected to move forward with prototype development.

These collaborations aren't just good for the Army. The companies that participated in the FAAR Cohort gained new insight into the Army's technology roadmaps, helping to inform their future capabilities and investments.

Companies in the FAAR Cohort also learned how the Army's acquisition process works, which demystifies the path to working in an incredibly profitable market. And they gleaned new perspectives on how to translate their existing technologies for a military use case, which spurred ideas for similar modifications that could be made in the private sector.

While the EV challenge is different, the results speak for themselves. The government benefits from partnering with commercial innovators, and industry can benefit from partnering with the government — doubling the overall value for the country.

Failure to partner on this EV infrastructure challenge doesn't just mean missing out on an opportunity. It could also mean the Army lagging further behind in its efforts to modernize operational vehicles. The U.S. may continue to see a drain of intellectual property and small businesses to other countries, and American prestige in the vehicle industry will only continue to decrease.

And, of course, there is the impact on the environment. Without creating a viable EV power infrastructure, the Army will likely contribute significantly to DoD carbon emission for decades to come,[19] and American consumers will find fewer convincing reasons to make the switch to electric.

ESTABLISHING THE NEW POWER TRANSFER COHORT

The Army has realized the value in these partnerships and is creating specific programs to capitalize on them. Although its conventional approach to capability development involves the creation of a strict requirements document that prescribes exactly what a company should build or how it should solve a problem, that approach won't work for the EV infrastructure dilemma. Instead, the Army is presenting its EV infrastructure problems to the commercial market and inviting new thinkers to help solve them in an unconventional way.

To quickly explore the available and relevant commercial technologies on this topic, AAL is partnering with the Next Generation Combat Vehicle Cross Functional Team (NGCV) and the Ground Vehicle Systems Center (GVSC) within AFC on the Power Transfer Cohort.

Created and managed by AAL's Alion Science and Technology contractor team, the Power Transfer Cohort is designed for U.S.-based small businesses that are developing EV power charging and import/export technologies that may also apply to the military. The purpose of this intense, 8-week program is to identify and explore technologies that can help the Army move to EVs and use electric power in remote locations.

HOW THE COHORT WORKS

Step 1 — Identify and select top-tier, untapped commercial businesses working on EV-enabling technology.

Step 2 — Share insight on the specific business and technical challenges the Army is facing with EVs.

Step 3 — Introduce the Cohort to how these systems will be implemented and how current systems and end-users will use the technology.

Step 4 — Invite cohort participants to iterate on solution concepts with one another and with a cross-functional team of Army stakeholders.

Step 5 — Present solution concept designs from cohort members to senior Army leadership for the opportunity to move on to the next phase of development.

Step 6 — Move into a proof of technology phase of work with cohort companies that are selected based on their solution concept design.

Working within the constraints of social distancing due to the COVID-19 pandemic, the program will give cohort companies a glimpse into the field. These commercial companies will have an opportunity to measure and witness the Army's EV infrastructure problems firsthand through interactions with Soldiers and

19 https://watson.brown.edu/costsofwar/files/cow/imce/papers/2019/Pentagon%20Fuel%20Use,%20Climate%20Change%20and%20the%20Costs%20of%20War%20Final.pdf

VALUE FOR COHORT COMPANIES

Get paid for the EV-enabling research and development they already plan to do

Companies selected for the Cohort will receive $100,000 to showcase their technology directly to an Army leader and have the chance to apply it at an industrial scale with the Army as a client.

Partner with experts and end users in collaborative Solution Design Team

Member companies can inform their solution design by working alongside other commercial experts, military experts, and Army end users (Soldiers) to refine and develop new concepts as one team.

Help the largest industrial consumer of fuel in the world go electric

Companies in the Power Transfer Cohort will get insight into this major logistical challenge facing the Army as well as info on the related technology priorities to further inform their go-to-market strategy.

periods of collaboration alongside Army technologists and subject matter experts. By getting input from Army program managers, scientists and engineers, sustainment experts, combat vehicle leaders, and others, cohort participants will better understand the demands for their solutions and have the information required to adjust designs accordingly.

Through this carefully planned series of interactions, both sides can better understand the ways in which existing commercial technologies translate into the Army and how to apply that learning back into the private sector.

MOVING FORWARD

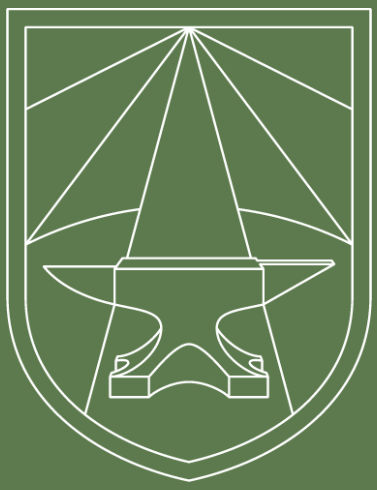
Momentum for EVs and EV infrastructure is only growing across industries, universities, and nations. Increased EV use will continue concurrent with smart grid technologies and will be a key component of future nano and micro grids. Wireless charging will likely become a more prevalent form of EV charging and soon be available at various locations, similar to the recent growth of WiFi hotspots.[20] Along with battery improvement, control algorithms will become more complex as the need increases for vehicles to communicate with chargers for optimized charging and to ensure loads are tailored to the EV. Although military demand for rapid recharging in austere locations is unique, it will be informed by commercial efforts with special attention given to fleet recharging and management, microgrid interoperability, and universal charging compatibility.[21][22]

In short, the EV movement is charging forward. The Army and industry may play distinct roles in the future of EV infrastructure, but they are trying to solve some of the same challenges. Rather than spinning their wheels on different paths in the same direction, they would both be served by joining forces to work together.

The Power Transfer Cohort offers an opportunity to do that while increasing the ROI for U.S. companies working on EV infrastructure technology. With this approach, we can help the Army and the nation's economy move forward, too.

Learn more at aal.army/cohortprogram.

20 https://www.marketwatch.com/press-release/wireless-ev-charging-market-forecast-to-reach-250-million-by-2025-2020-12-10
21 https://www.researchgate.net/publication/305828537_A_review_of_the_stage-of-the-art_charging_technologies_placement_methodologies_and_impacts_of_electric_vehicles
22 https://www.mdpi.com/1996-1073/10/8/1217



ABOUT THE ARMY APPLICATIONS LABORATORY

We're not a laboratory in the traditional sense of the word. As the U.S. Army's innovation unit, we don't make things — we make things possible. The Army Applications Laboratory (AAL) is fundamentally reshaping how the Army works with industry to reunite American innovation and national security. Together, we question *why* and deliver *what if.* Learn how we do it at aal.army.

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