White Paper

Driving Innovation: Propelling the U.S. Department of Defense's Acquisition of Hybrid-Electric Tactical Vehicles to Win the Wars of Tomorrow

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Driving Innovation: Propelling the U.S. Department of Defense's Acquisition of Hybrid-Electric Tactical Vehicles to Win the Wars of Tomorrow

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Table of Contents

Energy is the lifeblood of our warfighting capabilities.[2]

Adapt or perish, now as ever, is nature's inexorable imperative.[3]

I. INTRODUCTION

Imagine you are a theater or combatant commander responsible for the initial invasion of a highly contested, enemy-controlled territory as part of the United States action in a future large-scale combat operation (LSCO).[4] You have multiple division-size joint forces at your disposal to direct and continually resource in your ground-based push across thousands of square miles. Whether those units are airborne, armored, or otherwise, each relies on their vehicles to get them to their mission across the battlefield.[5]

Your operational ground fleet includes hundreds of thousands of vehicles of two types: "ground combat vehicles" (GCVs) (i.e., heavily armored, predominantly tracked platforms that perform a specific combat function, such as the Abrams tank, Bradley Fighting Vehicle, and Stryker)[6] and "tactical wheeled vehicles" (TWVs), ranging from light utility vehicles (such as the High Mobility Multipurpose Wheeled Vehicle (HMMWV), which comprise about half of the

[2] Memorandum from Commander, Int'l Sec. Assistance Force/U.S. Forces Afghanistan to the Soldiers, Sailors, Airmen, Marines, and Civilians of US Forces-Afghanistan, Supporting the Mission with Operational Energy para. 1 (7 June 2011).

[3] H.G. WELLS, THE MIND AT THE END OF ITS TETHER 19 (William Heinemann Ltd. ed., 1945).

[4] *See, e.g.*, *Combatant Commands*, U.S. DEP'T OF DEF., https://www.defense.gov/About/Combatant-Commands/ (last visited Apr. 11, 2024) (listing the various combatant commands).

[5] *See, e.g.*, *Operation Desert Storm: 24–28 February 1991*, U.S. ARMY CTR. FOR MIL. HIST., https://history.army.mil/html/bookshelves/resmat/desert-storm/images/army-art/Desert-Storm-Map.jpg (last visited Apr. 11, 2024) (providing a map of the arrayed forces in the Allied ground invasion of Iraq as part of Operation Desert Sabre, part of the larger Operation Desert Storm, on 24–28 February 1991).

[6] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-15-548, ARMY COMBAT VEHICLES: INDUSTRIAL BASE STUDY'S APPROACH MET RESEARCH STANDARDS 3, 4 (2015) [hereinafter GAO-15-548].

force's total operational vehicles)[7] to medium and heavy equipment transporters.[8] Your TWVs outnumber your GCVs ten-to-one and support the widest variety of combat operations by transporting warfighters, equipment, and materiels like munitions, water, and fuel.[9] Regardless of the vehicle type and purpose, however, they all have one common requirement—one critical vulnerability—their precarious reliance on a single, petroleum-based fuel source.[10]

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[7] *See* Daniel Goure, *The U.S. Army's All-But Forgotten Vehicle Fleet*, REAL CLEAR DEF. (Aug. 22, 2017), https://www.realcleardefense.com/articles/2017/08/22/the_us_armys_all-but_forgotten_vehicle_fleet_112116.html. With over 120,000 HMMWVs in use by all Services and across 50 countries, more HMMWVs have been produced than any other military vehicle since 1945 (nearly 300,000). Designed in the late 1970s to replace the famous World War II jeep, the HMMWV has since served as "the Army's proverbial workhorse" for over four decades. Whether "up-armored" or not, Army units use HMMWVs for a larger variety of roles than any other military vehicle: "troop/armament/cargo carrier, anti-tank missile carrier, medical transport, security vehicle and shelter carrier for command, control and communications elements." *Id*.

[8] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-21-460, TACTICAL WHEELED VEHICLES: ARMY SHOULD ROUTINELY UPDATE STRATEGY AND IMPROVE COMMUNICATION WITH INDUSTRY 3, 4 (2021) [hereinafter GAO-21-460]. The Army currently has in its fleet over 242,000 TWVs across light, medium, and heavy classes, including multiple variants on a common chassis. *Id*. at 3. This thesis distinguishes between "ground combat vehicles" (GCVs) (including generally tracked, but some wheeled, specific-function families of vehicles) and "tactical wheeled vehicles" (TWVs). *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-09-968R, DEFENSE ACQUISITIONS: DEPARTMENT OF DEFENSE NEEDS A UNIFIED STRATEGY FOR BALANCING INVESTMENTS IN TACTICAL WHEELED VEHICLES 1 (2009) ("Ground-based military operations generally make use of two broad categories of vehicles: combat vehicles designed for a specific fighting function and tactical vehicles designed primarily for use by forces in the field in connection with or in support of tactical operations."). This thesis refers to GCVs and TWVs collectively as "operational vehicles" to further distinguish them from Non-Tactical Vehicles (NTVs), the Service-owned, General Services Administration (GSA) leased, or long-term commercially leased vehicles in mainly non-deployed environments. *See* U.S. DEP'T OF THE ARMY, REG. 58-1, MANAGEMENT, ACQUISITION, AND USE OF MOTOR VEHICLES para. 1-1 (23 Mar. 2020) [hereinafter AR 58-1]; *see also* U.S. DEF. CONTRACT MANAGEMENT AGENCY, DCMA MANUAL 4101-05, ENTERPRISE NON-TACTICAL VEHICLES 21 (23 Feb. 2019) [hereinafter DCMA MANUAL 4101-05] (providing that NTVs include "[a]ny commercial NTV, trailer, material handling[,] or engineering equipment that carries passengers or cargo acquired for administrative, direct mission, or operational support of military functions. All DoD sedans, station wagons, carryalls, vans, and buses are considered 'nontactical.'").

[9] GAO-21-460, *supra* note 8, at 3; *see* GAO-15-548, *supra* note 6, at 3. For this reason, this thesis focuses on TWVs, of which ground-based forces like the U.S. Army and U.S. Marine Corps are the primary—but not only—users. Various publications that speak to Marine Corps leaders echo this shared vulnerability by all land-based forces. *See, e.g.*, Major Brian J. Donlon, Bringing a Tesla to War: Military Applications of Electric Vehicle Technology, U.S. Marine Corps Sch. of Adv. Warfighting 5 (May 1, 2017), https://apps.dtic.mil/sti/trecms/pdf/AD1178915.pdf ("The growing challenge of expeditionary energy consumption impacts fuel storage, distribution, and the vulnerability of bulk fuel to targeting. If Napoleon's Grand Armee 'marched on its stomach,' then today's Marine Corps 'fights on its gas tank.'").

[10] General (Ret.) Paul J. Kern et al., *An Albatross Around the US Military's Neck: The Single Fuel Concept and the Future of Expeditionary Energy*, MOD. WAR INST. OF WEST POINT (June 29, 2021), https://mwi.westpoint.edu/an-albatross-around-the-us-militarys-neck-the-single-fuel-concept-and-the-future-of-expeditionary-energy/; *see* Joel Schmitigal and Jill Bramer, *JP-8 and Other Military Fuels (2014 Update)*, U.S. ARMY TANK AUTO. RSCH., DEV., & ENG'G CTR. (TARDEC) 7 (June 17, 2014),

More modern examples specifically highlight the increasingly untenable vulnerability of the U.S. military's reliance on petroleum fuel as its single energy source to propel its war machines. For instance, during World War II (WWII), in the summer and fall of 1944, General George S. Patton was forced to repeatedly halt the advance of his Third Army because of a lack of gasoline resupply, leading some historians to argue that this fuel shortage delayed the end of WWII.[11] Nearly fifty years later, in February 1991, as part of Operation Desert Storm in the Gulf War, U.S. Army ground forces again almost outran their logistical support despite quickly penetrating the Iraqi defenses and destroying their resistance.[12] If the Iraqi Republican Guard had not surrendered so quickly, the U.S. Army would have been forced to cede the initiative and take a lengthy operational pause due to critical supply shortages, particularly in petroleum fuel.[13]

Most recently, after Russia invaded Ukraine in February 2022, most observers expected the operation to last no more than a few weeks based on Russia's apparent overwhelming advantage in terms of military size and capability.[14] However, experts say Russia's initial attack failed to

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https://apps.dtic.mil/dtic/tr/fulltext/u2/1011217.pdf; *see also infra* notes 89–**Error! Bookmark not defined.** and accompanying text (discussing the DoD's "single fuel concept").

[11] Dr. James Mancillas, Futures Integration Directorate, Futures Concept Ctr., Army Futures Command, White Paper: Electrification of U.S. Army Ground Force (An Evolutionary Revolution), CALSTART 2 (June 29, 2020), https://calstart.org/wp-content/uploads/2020/10/Vehicle_Electrification_Paper_29JUN20.pdf; *see* Greg Bailey, *The Red Ball Express – The Unknown Link in Winning World War Two?*, HIST. IS NOW MAG. (Aug. 15, 2015), http://www.historyisnowmagazine.com/blog/2015/8/12/the-red-ball-express-the-unknown-link-in-winning-world-war-two. *See generally* Roland G. Ruppenthal, *Pub. 7-2-1, The United States Army in World War II, Logistical Support of the Armies*, U.S. ARMY CTR. OF MIL. HIST. 499-510 (1953) (describing the critical POL fuel shortages from the Allied Forces' invasion on D-Day until winter 1944, which drastically slowed the advance of Patton's Third Army from France into Germany).

[12] *See* Major Gregory J. Hom, Charging Ahead: How the Army Can Learn from the Past to Prepare for Electric Vehicles in the Future 1 (May 1, 2020) (Monograph, Advanced Mil. Stud. Program, U.S. Army Command & Gen. Staff Coll.), https://apps.dtic.mil/sti/trecms/pdf/AD1159118.pdf.

[13] *Id.*; *see* Major Jason Carrico, Mitigating the Need for a Logistic Pause 17 (May 25, 2006) (Monograph, Advanced Mil. Stud. Program, U.S. Army Command & Gen. Staff Coll.), https://apps.dtic.mil/sti/pdfs/ADA450161.pdf.

[14] *See* BRADLEY MILLER ET AL., RAND CORP., RR-A2033-1, RUSSIAN LOGISTICS AND SUSTAINMENT FAILURES IN THE UKRAINE CONFLICT 10 (2023).

achieve its stated objectives and resulted in enormous Russian losses, largely "because of poor planning and lack of capacity in logistics and sustainment."[15] In particular, only one month into the operation, Russian forces abandoned hundreds of their stalled combat vehicles after running out of fuel in their infamous "40-mile-long" convoy on roads outside Kyiv.[16] These examples highlight the potential for disaster when armies over-rely on a single energy source to move to and across the battlefield.

In addition to lessons highlighting the dangers of armies' overreliance on a single tactic or energy source, the history of warfare also contains key moments where technological innovation revolutionized how armies fight and win.[17] From the advent of the longbow, gunpowder, artillery, machine guns, aircraft, and armored warships to more recent innovations like telegraphs, radios, and radar systems, these landmark developments armed those forces that first employed them with spectacular advantages on the battlefield.[18] Rapidly developing technology like unmanned

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[15] *See id.* As early as mid-March 2022, Russian forces dealt with shortages of everything from fuel to precision munitions. *Id.*; *see* Isabel Van Brugen, *Russia Suffering Shortages, Struggling to Sustain Troops: Pentagon*, NEWSWEEK (Mar. 28, 2022), https://www.newsweek.com/russia-ukraine-invasion-war-suffering-shortages-struggling-sustain-troops-pentagon-update-1689334.

[16] *See* Denys Davydenko et al., *Lessons for the West: Russia's Military Failures in Ukraine,* EUR. COUNCIL ON FOREIGN REL. (Aug. 11, 2022), https://ecfr.eu/article/lessons-for-the-west-russias-military-failures-in-ukraine/ ("A tank without fuel is of little use—as the Russians showed in the early days of their full-scale invasion, when they abandoned many vehicles and other equipment due to a lack of supplies. The episode revealed that the Russian military's logistics were so poorly organi[z]ed that many units simply could not reach their destinations."); Miller, *supra* note 14, at 10. For satellite imagery of Russia's apparent fuel-stalled 40-mile-long convoy, *see* Maxar Tech., *Aviation Week Names Maxar a 2022 Laureate Award Winner*, MAXAR BLOG (July 25, 2022), https://blog.maxar.com/for-a-better-world/2022/aviation-week-names-maxar-a-2022-laureate-award-winner; Eric Beech, *Russian Military Convoy North of Kyiv Stretches for 40 Miles – Maxar*, REUTERS (Mar. 2, 2022), https://www.reuters.com/world/europe/russian-military-convoy-north-kyiv-stretches-40-miles-maxar-2022-03-01/.

[17] *See* Larry Holzworth, *10 Innovations on the Battlefield Which Changed Warfare*, HIST. COLLECTION (May 23, 2018), https://historycollection.com/10-innovations-on-the-battlefield-which-changed-warfare. One scholar defines military innovation as "the process of creating a new capability—a new institutionalized technique of organized violence intended to convert a service's resources into success in future missions." Kendrick Kuo, Ph.D., *Dangerous Changes: When Military Innovation Harms Combat Effectiveness*, 47 INT'L SEC., no. 2, Fall 2022, at 48, 52.

[18] *See* Holzworth, *supra* note 17.

aerial vehicles (UAVs), cyber operations, artificial intelligence (AI), and satellite systems continue to have similarly far-ranging implications for future armed conflict.[19] Whether military entities or civilian industry lead the way in developing these types of innovations, their ultimate significance in determining military victories demonstrates that "fortune [generally] favors the bold."[20] That is, those who understand the need to remain at the frontier of innovation by prioritizing timely technological and tactical modernization are best equipped to consistently identify and gain advantages over adversaries.[21] This, in turn, enables those nations to triumph in future armed conflicts or outright avoid them through strategic deterrence by demonstrating their competitive advantage.[22]

Beyond developments in the means of warfare, the methods in which armies have historically moved on the battlefield likewise reflect leaders' need—despite their accompanying hesitance—to prioritize modernization.[23] Today, no one would reasonably question the soundness of the U.S.

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[19] *See* Eric Schmidt & Will Roper, *Ukraine Shows How Drones Are Changing Warfare*, TIME (Sept. 28, 2023), https://time.com/collection/time100-voices/6317661/eric-schmidt-drones-warfare-voices. "War spurs innovation. While peacetime stifles the speed of military advances, the unfolding battles in Ukraine continue to reveal a relentless pace of technological adaptation." *Id.*

[20] Historians attribute this saying's first use to the ancient Roman playwright Terence in 151 B.C. in his comedy play "Phormio." *See* Ammarsha Rewindra Ridwan, *Fortis Fortuna Adiuvat — Does Fortune Really Favors the Bold?* MEDIUM (Jan. 23, 2019), https://medium.com/@ammarsharewindra/fortis-fortuna-adiuvat-does-fortune-really-favors-the-bold-1297a3a92472. The original Latin, *Fortis Fortuna Adiuvat*, is still a popular motto of countless military units and U.S. Navy ships. *See id.*; Elisabeth Edwards, *Fortis Fortuna Adiuvat Meaning: Does Fortune Actually Favor the Bold?* WAR HIST. ONLINE (Aug. 12, 2022), https://www.warhistoryonline.com/ancient-history/fortis-fortuna-adiuvat.html.

[21] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-19-132, ARMY MODERNIZATION: STEPS NEEDED TO ENSURE ARMY FUTURES COMMAND FULLY APPLIES LEADING PRACTICES 1 (2019) [hereinafter GAO-19-132]. The Army uses the term "modernization" to refer to "initiative[s] to update its forces and equipment with improved capabilities." *See id.*

[22] *But see* Kuo, *supra* note 16, at 48, 49 (arguing against the assumption that innovation and enhanced military performance go hand-in-hand and claiming instead that historical examples reflect that innovation is more likely to weaken a military force's effectiveness when growing security commitments outstrip shrinking resources).

[23] *See* Hom, *supra* note 12, at 16.

Army's decision to transition from the horse to the motor vehicle.[24] However, from around 3500 B.C. to the early twentieth century A.D., armies around the world employed tactics and logistics that relied heavily on horses and other animals to support chariot and cavalry formations in battle as well as to transport troops, weapons, equipment, and supplies to sustain ground forces over many miles.[25] That ancient shift—from armies comprised solely of foot soldiers to those that widely incorporated horse-drawn and -mounted combat forces and those with animal-drawn logistic lines—became one of the most significant tactical and operational innovations in the history of warfare.[26] With over 5,000 years of proven benefits, it is not surprising that the Army's later shift from animal-powered locomotion to internal combustion engine (ICE) motors was more incremental than one might assume; the comparative advantages of vehicles were less obvious then than they are in hindsight today.[27]

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[24] *See id.* at 1, 16.

[25] *See id*.; Lauren Feldman, *Horses of War,* AM. COWBOY (May 27, 2022), https://americancowboy.com/people/history-archive/horses-war-23983.

[26] *See Riding into Battles,* AM. MUSEUM OF NAT. HIST., https://www.amnh.org/exhibitions/horse/how-we-shaped-horses-how-horses-shaped-us/warfare/riding-into-battles (last visited Apr. 11, 2024).

[2727] *See* Hom, *supra* note 12, at 16; *War Horse Facts*, THE BROOKE, https://www.thebrooke.org/get-involved/every-horse-remembered/war-horse-facts (last visited Apr. 11, 2024). In contrast to the Allied Forces near-total transition to motor vehicles, Germany continued to rely too heavily on horses for their logistics throughout WWII. John Perry, *Horses & The Mechanized Myth of the Eastern Front,* WARFARE HIST. NETWORK (May 2014), https://warfarehistorynetwork.com/article/horses-the-mechanized-myth-of-the-eastern-front. Despite the popular images and war propaganda showing the rapid mobility of Nazi Germany during WWII, from their overwhelming blitzkrieg strategy to their fierce Panzer tank attacks, in terms of their logistics, "the reality is that horses pulled two-thirds of the vehicles and supplied 80 percent of the German Army's motive power." Perry, *supra*. In fact, "[t]he use of horses in the German Army tripled by 1939 . . . [and the] German Army never considered completely replacing horses with motor vehicles," especially "when fuel and rubber shortages grew critical." Perry, *supra*. While German cavalry only played a minor role at the start of the Nazi invasion of the Soviet Union, the German Army continued its significant reliance on horse-drawn logistics most significantly—and to its ultimate detriment—on the eastern front of WWII:

> The German Army relied more on horse-drawn wagons to haul supplies, artillery, and for reconnaissance patrols during World War II *more* than in World War I. Up to 750,000 horses and mules served in Operation Barbarossa, the German invasion of the Soviet Union. The plan to invade England, Operation Sea Lion, involved more horses than vehicles: 57,000 to 34,000. Even Field Marshal Gerd von Rundstedt, commander of German Army Group South at the beginning of the campaign, admitted that the Germany Army in 1941 relied on divisions that moved by foot or horse-drawn vehicles. On the other hand, around 80 percent of Soviet

Since their first widespread battlefield use in World War I (WWI), motor vehicles drew many legitimate concerns.[28] Aside from countries' limited vehicle production capabilities at the start of the war, military vehicles were also still quite new and prone to faults, so armies continued to place greater trust in their hundreds of thousands of horses and mules.[29] Although their vulnerability to machine gun fire meant their use by cavalry was short-lived, "warhorses" continued to serve as the primary form of transportation for troops, weapons, and supplies on the WWI battlefield.[30] However, toward the war's end, WWI saw the development of motor-powered combat vehicles, especially primitive tanks and warplanes, first demonstrating their crucial tactical advantages.[31]

Even after this initial demonstration of the battlefield advantages of vehicles, the Army faced significant pushback—both from Congress and within its own ranks—against efforts to acquire motor vehicles in the interwar years before World War II (WWII).[32] It ultimately took the mounting threat of Adolf Hitler's actions in Europe and then- U.S. Army Chief of Staff General George Marshall's effective communication of his modernization vision (both up to Congress for

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> transportation was on wheels. The so-called German blitzkrieg soon slowed because horses trailed behind panzers and often clogged roads.

See Perry, *supra* (emphasis added). *See generally* Katherine McFarland, Warhorses Amongst War Machines: The German Army's Use of Horses and Cavalry Horses and Cavalry During World War II 405, (Spring 2021) (Senior Thesis, U. OF S.C.) (discussing in more depth the use of horses by the German Army during WWII).

[28] *See War Horse Facts*, *supra* note 27.

[29] *See id.*

[30] *Id.*; Livia Gershon, *An Uncertain Energy Transition a Century Ago*, JSTOR DAILY (June 5, 2023), https://daily.jstor.org/an-uncertain-energy-transition-a-century-ago.

[31] *See* Hom, *supra* note 12, at 16; Byan Sanbogi, *The Aircraft Engine: An Historical Perspective of Engine Development through World War I*, 8 J. AV./AEROSPACE EDUC. & RSCH. 3, 7 (1999), https://commons.erau.edu/cgi/viewcontent.cgi?article=1224&context=jaaer.

[32] *See* Hom, *supra* note 12, at 2, 5, 16.

funding and down to Army leaders for buy-in) for the Army to realize the warfighting advantages of motor vehicles in time for the U.S. entry into WWII.[33]

We are now at the next greatest moment of change in ground transportation on the battlefield with the advent of technology utilizing electricity and alternative, renewable energy sources to power our vehicles.[34] The potential warfighting advantages to be gained by developing and incorporating hybrid-electric (HE) TWVs into the U.S. Department of Defense's (DoD's) ground fleet are immense: from the *tactical* benefits of increased sprint speed, silent mobility, low thermal signature, and enhanced onboard electric systems capabilities to the *operational* benefits of improved logistics, formation endurance, and unit independence, to the *strategic* benefits of the nation's increased energy resilience, strengthened competitive advantage over adversaries, and relatively stabilized geopolitics.[35] As the single largest consumer of petroleum-based fuel in the world—only 35 *countries* consume more oil per year—DoD also has a particularly significant strategic incentive to reduce its increasingly vulnerable reliance on a single source of energy to keep its operational vehicles moving.[36]

In light of the warfighting imperative to modernize its ground fleet, DoD stands at a crossroads of innovation.[37] Concerningly, the People's Republic of China (PRC), which DoD sees

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[33] *See id.*; Sanbogi, *supra* note 31, at 7.

[34] *See* Hom, *supra* note 12, at 2, 5.

[35] *See* Mancillas, *supra* note 11, at 2.

[36] *See Daily Energy Report: A Look at US Military Energy Consumption*, OILPRICE (June 8, 2011) [hereinafter *Daily Energy Report*], https://oilprice.com/Energy/Energy-General/A-Look-At-US-Military-Energy-Consumption.html. For example, "Nigeria, with a population of more than 140 million, consumes as much energy as the U.S. military." *Id.*

[37] *See* Steve Blank, *The DoD is Getting its Innovation Act Together, But More Can Be Done*, DEF. NEWS (Jan. 5, 2024), https://www.defensenews.com/opinion/2024/01/05/the-dod-is-getting-its-innovation-act-together-but-more-can-be-done/.

as its greatest "pacing challenge,"[38] "develops and fields capabilities"—like HED for military vehicles—"as much as five to six times faster than the United States."[39] Nevertheless, despite the emerging global threat posed by the PRC, Russia, and other peer adversaries, DoD policymakers and Congress remain hesitant to fully commit to U.S. innovation in developing HE operational vehicles.[40] This is most evident in the persistent lack of a comprehensive DoD-wide or Army TWV strategy integrating HE vehicles into the ground fleet and in the insufficient appropriations for HE TWV or GCV acquisition programs.[41] As with the Army's horse-to-motor-vehicle

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[38] *See* U.S. SEC'Y OF DEF., U.S. DEP'T OF DEF., 2022 NATIONAL DEFENSE STRATEGY 1 (2022) [hereinafter 2022 NDS].

[39] Al Shaffer & John Whitley, *Modular Open System Architecture Allows Continuous Weapon Upgrades*, C4ISR NET (Nov. 28, 2023), https://www.c4isrnet.com/opinion/2023/11/28/modular-open-system-architecture-allows-continuous-weapon-upgrades.

[40] *See* RAPHAEL S. COHEN ET AL., RAND CORP., RR-2849/1-AF, THE FUTURE OF WARFARE IN 2030: PROJECT OVERVIEW AND CONCLUSIONS 35–43 (2020); U.S. DEP'T OF DEF., SUMMARY OF THE 2018 NATIONAL DEFENSE STRATEGY OF THE UNITED STATES OF AMERICA: SHARPENING THE AMERICAN MILITARY'S COMPETITIVE EDGE 2 (2018); SHUXEN CHEN & CHARLES WOLF, JR., RAND CORP., MR-1300-RC, CHINA, THE UNITED STATES, AND THE GLOBAL ECONOMY 25 (2001). The RAND Corporation describes the PRC and Russia as emerging threats in the following way:

> China has emerged as a powerful actor on the world stage, and Russia has re-emerged as a spoiler of U.S. interests. China has used its economic power to enhance its security and influence by exerting territorial control in the East China and South China seas, and these efforts threaten U.S. interests in the region. Russia also regained its military footing, fighting military campaigns in Crimea, Ukraine, and Syria while engaging in hybrid war activities in the Balkans. Moreover, both states have articulated foreign policy goals that are inimical to U.S. interests. Both states observed the U.S. military in action in the 21st century and have invested in military capabilities meant to exploit its weaknesses. It is now clear that Russia and China present peer-quality threats to U.S. interests in Europe and Asia.

JONATHAN P. WONG ET AL., RAND CORP., RR-A1670-1, IMPROVING DEFENSE ACQUISITIONS: INSIGHTS FROM THREE DECADES OF RAND RESEARCH 6 (2022).

[41] *See* Bryant Harris, *GOP Defense Bill Bars Pentagon from Enacting Biden's Climate Orders*, DEF. NEWS (Aug. 31, 2023), https://www.defensenews.com/congress/budget/2023/08/31/gop-defense-bill-bars-pentagon-from-enacting-bidens-climate-orders; Ashley Roque, *Army Readying Tactical Wheeled Vehicle Strategy Ahead of 2026 Budget Planning*, BREAKING DEF. (Mar. 2, 2023), https://breakingdefense.com/2023/03/army-readying-tactical-wheeled-vehicle-strategy-ahead-of-2026-budget-planning; *see also* Ray Alderman, *The Worldwide Market for Military Ground Combat Vehicles and Tanks*, MIL. EMBEDDED SYS. (June 29, 2023), https://militaryembedded.com/comms/vetronics/the-worldwide-market-for-military-ground-combat-vehicles-and-tanks (summarizing the U.S. military's combat and tactical vehicle fleet, as well as the amounts currently being appropriated for new vehicle acquisitions). An appropriation is a statutory authorization "to incur obligations and to . . . draw money from the Treasury to satisfy those obligations." U.S. GOV'T

transition, there remain significant political and cultural barriers to hybrid-electric drive (HED) modernization.[42] Further complicating these challenges, the federal government's ability to quickly mobilize the "defense industrial base" (DIB) to develop and produce the necessary vehicles in response to emerging wartime needs is also more complex than it was during the interwar years.[43]

The first major roadblock to HED modernization is policy-based, with deepening political polarization over climate change and environmental issues continuing to halt any federal spending measure that lawmakers perceive as even remotely related to climate policy goals.[44] Relatedly, Congress's increasing need to rely on continuing resolutions (CRs) in lieu of enacting timely DoD appropriations acts constantly delays critical funding for the Army's research and development (R&D) efforts to capitalize on industry's daily advances in HE propulsion.[45] However, the policy challenges to TWV electrification also include policymakers' higher prioritization of other DoD modernization efforts and their many valid—though increasingly moot—concerns regarding EVs in general (e.g., procurement costs, EV battery limitations and safety risks, and vulnerable sourcing of battery components from unfriendly nations).[46]

ACCOUNTABILITY OFF., GAO-16-464SP, PRINCIPLES OF FEDERAL APPROPRIATIONS LAW 2-3 (4th ed. 2016) [hereinafter GAO-16-464SP].

[42] *See* Hom, *supra* note 12, at 2, 4, 15, 16, 18, 17, 19.

[43] *See* Noah Robertson, *The Pentagon Wants Industry to Transform Again to Meet Demand. Can It?* DEF. NEWS (Feb. 20, 2024), https://www.defensenews.com/industry/2024/02/20/the-pentagon-wants-industry-to-transform-again-to-meet-demand-can-it.

[44] *See* Brian Kennedy & Alec Tyson, *How Republicans View Climate Change and Energy Issues*, PEW RSCH. CTR., (Mar. 1, 2024), https://www.pewresearch.org/short-reads/2024/03/01/how-republicans-view-climate-change-and-energy-issues.

[45] *See* Jeff Arkin, *What is a Continuing Resolution and How Does It Impact Government Operations?* U.S. GOV'T ACCOUNTABILITY OFF., GAO BLOG (Nov. 3, 2022), https://www.gao.gov/blog/what-continuing-resolution-and-how-does-it-impact-government-operations.

[46] *See* discussion *infra* Sections III.B. ("Critiques of the DoD's HED Modernization Efforts"), IV.B.2. ("The DoD's Low Prioritization of HED Modernization").

Even if leaders bypass this political gridlock, ongoing deficiencies in defense acquisition processes also pose formidable procedural barriers to HED modernization.[47] Despite constant attempts to reform these processes over the last four decades, lawmakers and DoD leaders continue to criticize defense acquisitions for being overly bureaucratic, unresponsive to user needs, and too slow to achieve timely innovation in warfighting capabilities.[48] Contemporary improvements to department-wide acquisition policies, such as DoD's creation of six streamlined pathways in the Adaptive Acquisitions Framework (AAF) in 2020, promised to deliver solutions.[49] Nevertheless, poor outcomes in several recent major defense acquisition programs (MDAPs) reveal enduring shortcomings in the interconnected DoD acquisition processes, especially in how they pursue the acquisition of "major weapon systems" (MWSs), like tactical or combat vehicles.[50]

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[47] *See* Robertson, *supra* note 43.

[48] *See* SHELBY S. OAKLEY, U.S. GOV'T ACCOUNTABILITY OFF., GAO-21-511T, DOD ACQUISITION REFORM: INCREASED FOCUS ON KNOWLEDGE NEEDED TO ACHIEVE INTENDED PERFORMANCE AND INNOVATION OUTCOMES 9, 14, 15 (2021) [hereinafter GAO-21-511T].

[49] U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-106059, WEAPON SYSTEMS ANNUAL ASSESSMENT, PROGRAMS ARE NOT CONSISTENTLY IMPLEMENTING PRACTICES THAT CAN HELP ACCELERATE ACQUISITIONS, REPORT TO CONGRESSIONAL COMMITTEES 6 (2023); *see* U.S. DEP'T OF DEF., INSTR. 5000.02, OPERATION OF THE ADAPTIVE ACQUISITION FRAMEWORK para. 1.3 (23 Jan. 2020) (C1, 8 June 2022) [hereinafter DODI 5000.02]. The purpose of the AAF is as follows:

> AAF supports the DAS with the objective of delivering effective, suitable, survivable, sustainable, and affordable solutions to the end user in a timely manner. To achieve those objectives, Milestone Decision Authorities (MDAs), other Decision Authorities (DAs), and Program Managers (PMs) have broad authority to plan and manage their programs consistent with sound business practice. The AAF acquisition pathways provide opportunities for MDAs/DAs and PMs to develop acquisition strategies and employ acquisition processes that match the characteristics of the capability being acquired.

DODI 5000.02, *supra* para. 1.3.

[50] *See* Scott F. Walter, *Augmenting the Adaptive Acquisition Framework with a Commercial Development Pathway*, DEF. ACQUISITION U., DAU PRESS 14 (May/June 2023), https://www.dau.edu/library/defense-atl/blog/AugmentingAdaptiveAcquisitionFramework; WONG ET AL., *supra* note 40, at 2, 21. "Major defense acquisition programs are those estimated to require eventual total research, development, test and evaluation expenditures of more than $365 million or procurement expenditures of more than $2.19 billion in fiscal year 2000 constant dollars." *See* MICHAEL J. SULLIVAN, U.S. GOV'T ACCOUNTABILITY OFF., GAO-10-155T, TESTIMONY BEFORE THE HOUSE ARMED SERVICES COMMITTEE, DEFENSE ACQUISITION REFORM PANEL, DEFENSE ACQUISITIONS, RAPID ACQUISITION OF MRAP VEHICLES 2 n.3 (2009) [hereinafter GAO-10-155T]. Although it is unlikely a TWV acquisition program would surpass these amounts to constitute an MDAP, this thesis also examines programs with larger budgets. The lessons for why those MDAPs failed may be just as

Congress and DoD policymakers must prioritize timely innovation and acquisition of HE tactical vehicles in order to secure the immense warfighting advantages of operational energy modernization—which will require maneuvering past climate-focused political gridlock and defense acquisitions procedural barriers that have so far stalled innovation—by taking a novel three-lane path to MWS acquisitions: (1) shifting the focus away from climate policy and publishing a comprehensive strategy that stresses the warfighting advantages of HE TWVs, (2) leveraging industry innovation in vehicle propulsion through two new AAF pathways and creative win-win contracting strategies, and (3) enforcing Modular Open Systems Approach (MOSA) contracting methods to "future-proof" the ground vehicle fleet.[51]

This thesis endeavors to demonstrate this national security imperative across four substantive parts.[52] Part II illustrates the opportunity for innovation, first surveying DoD's current ground vehicle fleet and its historical reliance on fossil fuels, then examining the mechanics of ground

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applicable, if not more so, to programs with smaller budget that are thus more likely to be cancelled when cost or schedule issues arise. The term "major weapon systems" in the Defense Acquisition System (DAS) generally refers to "aircraft, ships, submarines, and land vehicles that require a significant manufacturing investment for which typical acquisition cycles exceed ten years." WONG ET AL., *supra* note 40, at 20. As recently as June 2023, a comprehensive study by GAO concluded that the DoD "continues to face challenges quickly developing innovative new weapons [and vehicle platforms]. These challenges persist even with recent reforms to its acquisition process intended to help deliver systems to the warfighter in a timelier manner." U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-106059, HIGHLIGHTS: WEAPON SYSTEMS ANNUAL ASSESSMENT 1 (2023) [hereinafter GAO-23-106059].

[51] Crude oil and derivative petroleum products are called "fossil fuels" due to their chemical origin:

> [Crude oil and petroleum come from] mixtures of hydrocarbons formed from the remains of animals and plants (diatoms) that lived millions of years ago in a marine environment before dinosaurs existed. Over millions of years, the remains of these animals and plants were covered by layers of sand, silt, and rock. Heat and pressure from these layers turned the remains into what we now call crude oil or petroleum. The word petroleum means rock oil or oil from the earth.

Oil and Petroleum Products Explained, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/oil-and-petroleum-products/ (last visited Apr. 11, 2024). Coal and natural gas are the two other main types of fossil fuels that were "formed as a result of geologic processes acting on the remains of organic matter produced by photosynthesis." *See* Otto C. Kopp, *Fossil Fuel*, ENCYC. BRITANNICA, https://www.britannica.com/science/fossil-fuel (last visited Apr. 11, 2024).

[52] *See* Parts II–V, *infra* notes 64–996 and accompanying text.

vehicle propulsion and the future direction of the commercial vehicle industry.[53] Part II also explains how DoD typically acquires MWSs and, in particular, its tactical and combat vehicles.[54] Part III emphasizes the critical warfighting and political advantages of acquiring HE TWVs but also presents the criticisms against DoD's electrification efforts.[55] Part IV examines the barriers to HED innovation, first discussing DoD's current lines of effort (LOEs), then exploring both the political gridlock over DoD's perceived climate-focused efforts and the procedural challenges to timely acquiring HED capabilities for its massive tactical and combat vehicle fleets.[56] Finally, Part V proposes novel solutions to overcome those political and procedural obstacles, which Congress and DoD policymakers should pursue to best prepare for and deter future armed conflicts.[57]

As an initial point of clarification, this thesis broadly advocates for lawmakers and DoD senior leaders to prioritize sufficient funding and specific acquisition process reform to secure the warfighting advantages of HED.Although the other Services also use thousands of ground tactical and combat vehicles, because the Army is the largest user and the primary procurement authority for ground vehicle acquisitions, this thesis specifically calls on Army policymakers and stakeholders to lead the charge.[58] Second, this thesis does not advocate for the outright replacement of traditional ICE-powered vehicles but instead for a deliberate strategy to better

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[53] *See infra* notes 64–173 and accompanying text.

[54] *See infra* notes 174–**Error! Bookmark not defined.** and accompanying text.

[55] *See infra* notes 317–539 and accompanying text.

[56] *See infra* notes 540–820 and accompanying text.

[57] *See infra* notes **Error! Bookmark not defined.**–996 and accompanying text.

[58] *See* GAO-21-460, *supra* note 8, at 3; U.S. CONG. BUDGET OFF., PROJECTED ACQUISITION COSTS FOR THE ARMY'S GROUND COMBAT VEHICLES 1 (Apr. 2021) [hereinafter CBO, GCV ACQUISITIONS COSTS], https://www.cbo.gov/system/files/2021-03/57085-ground-combat-vehicles.pdf. This will require undertaking three critical tasks: (1) deliberately examining the Army's capability and logistics requirements, (2) developing and recommending a comprehensive strategy for integrating hybrid-electric TWVs across the joint force, and (3) communicating up to DoD leaders and Congress and down to subordinate Army units the necessity of these acquisitions. *See* Hom, *supra* note 12, at 16, 18.

engage the DIB to develop, contract for, and integrate HED technology into DoD's existing TWV—and eventually GCV—fleet.[59] Finally, although this thesis does not directly address DoD's procurement of HED for DoD's GCVs or its various sea- and aircraft, its main points of discussion may also apply to propel future electrification efforts of those larger MWS platforms.[60]

A former DoD official recently stated that the U.S. "is in a race against time to reestablish credible deterrence and contain further aggression before it turns into military conflicts. Timely adoption of new technology and fielding advanced equipment have become national security imperatives."[61] In the 2022 U.S. National Defense Strategy, DoD committed to "make reducing energy demand a priority" and to "seek to adopt more efficient and clean-energy technologies that reduce logistics requirements in contested or austere environments."[62] Accepting this mission, in 2022, the Army set its own ambitious goalpost for DoD's main ground forces: "[T]he Army will field purpose-built hybrid-drive tactical vehicles by 2035 and fully electric tactical vehicles by 2050."[63] It's time to get moving.

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[59] *See* Walker Mills & Ryan Wiechens, *The Lethality Case for Electric Military Vehicles*, MOD. WAR INST. OF WEST POINT (Dec. 1, 2022), https://mwi.westpoint.edu/the-lethality-case-for-electric-military-vehicles; Kern, *supra* note 10.

[60] *See* Jon Harper, *U.S. Military Wants Its Vehicles to Go Electric—With Detroit's Help*, NAT'L DEF. (Feb. 4, 2022), https://www.nationaldefensemagazine.org/articles/2022/2/4/military-wants-its--vehicles-to-go-electricwith-detroits-help. Following the TWV fleet, this thesis's analysis and recommendations perhaps next apply most immediately to the Army's HED modernization of GCVs, as well as to the Joint Force's (JF's) acquisition of smaller hybrid-electric sea- and air-craft for use by special-mission units, whose endurance, operability, lethality, and survivability will be enhanced dramatically by such modernization. *But see* 2022 NDS, *supra* note 38, at 20 (noting that operations by military aircraft, especially those owned by the U.S. Air Force, comprise over 60% of the DoD's total fuel consumption, presenting perhaps the most significant opportunity for reducing the DoD's fossil fuel reliance, if that is the only objective).

[61] John Whitley, *Three Reforms to Improve Defense Resource Management*, IBM CTR. FOR BUS. OF GOV'T 8, (June 9, 2022), https://www.businessofgovernment.org/sites/default/files/Three%20Reforms%20to%20 Improve%20Defense%20Resource%20Management.pdf.

[62] *See* 2022 NDS, *supra* note 3861, at 20.

[63] OFF. OF THE ASS'T SEC'Y OF THE ARMY FOR INSTALLATIONS, ENERGY, & ENV'T., U.S. DEP'T OF THE ARMY, 2022 UNITED STATES ARMY CLIMATE STRATEGY 11 (Feb. 2022) [hereinafter 2022 ACS].

II. The Opportunity for Innovation: DoD's Ground Tactical and Combat Vehicles

Before exploring whether and how DoD should modernize its war machines with HE propulsion, DoD must ensure that it *can* innovate in this area. With commercial advances in vehicle electric drive and DoD's historically vulnerable dependence on a single fuel source—oil—to keep its wheels moving, DoD's TWV fleet provides the most fertile ground to examine this need for HED technology.[64] However, before such an assessment, one must first understand DoD's land-based vehicle strength, its petroleum-reliant sustainment system, the various available propulsion alternatives, and how defense acquisition processes generally procure such vehicles.

A. The DoD's Current Ground Vehicle Fleet and Its Single Fuel Source "Achilles Heel"[65]

To gain an appreciation for the battlefield advantages of HED, military leaders and policymakers must first understand the DoD's current TWV fleet strength and how U.S. ground forces came to rely so heavily on a "single-fuel concept" (SFC).[66]

1. The DoD's Ground Vehicle Fleet

The DoD has the second-largest vehicle fleet in the Federal Government, behind only the U.S. Postal Office.[67] The DoD's ground vehicles generally fall into two broad categories: *non-tactical vehicles* (NTVs) and *operational vehicles*.[68] The DoD's approximately 180,000 NTVs include

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[64] *See* Kern et al., *supra* note 10.

[65] The term "Achilles heel" refers to "a fault or weakness that causes or could cause someone or something to fail." *Achilles' Heel*, THE BRITANNICA DICTIONARY, https://www.britannica.com/edictionary/Achilles-heel (last visited Apr. 11, 2024).

[66] *See id.*

[67] Jacob Finke & John Hess, *A Roadmap for the DoD's Adoption of Electric Military Vehicles*, AVASCENT (Apr. 1, 2021), https://www.avascent.com/news-insights/avascent-proving-ground/fast-followers-a-roadmap-for-the-dods-adoption-of-electric-military-vehicles.

[68] *See* AR 58-1, *supra* note 8 para. 1-1; DCMA MANUAL 4101-05, *supra* note 8, at 21. Although the terms "vehicles" and "motor vehicles" sometimes also refer to air and sea craft with a motor, for the purposes of this thesis, the terms refer to land-based wheeled and tracked vehicles. *See* AR 58-1, *supra* note 8, para. 1-1.

commercially available models of all civilian vehicle types, ranging from sedans to ambulances to buses, and are either individual-Service-owned, General Services Administration (GSA) -leased, or long-term commercially leased.[69] While DoD agencies and the individual Services use their NTVs for countless administrative or support purposes in non-deployed environments, such as on DoD installations and surrounding civilian jurisdictions, the DoD's operational vehicles are what truly carry the Services' warfighting missions.[70]

The DoD's ground-based military activities around the world generally use two kinds of operational vehicles: *ground combat vehicles* (GCVs), which are typically more heavily armored—and armed—and are designed for a specific fighting function, and *tactical wheeled vehicles* (TWVs), which are designed for multipurpose support functions.[71] Most of the DoD's approximately 20,000 GCVs move on tracks, including the Abrams tank and Bradley Fighting Vehicle, but some move on wheels, such as the Stryker.[72]

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[69] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105635, FEDERAL VEHICLE FLEETS: OBSERVATIONS ON THE TRANSITION TO ELECTRIC VEHICLES 1 n.1 (2022).

[70] *See* DCMA MANUAL 4101-05, *supra* note 8, at 21 (clarifying that NTVs include "[a]ny commercial NTV, trailer, material handling or engineering equipment that carries passengers or cargo acquired for administrative, direct mission, or operational support of military functions. All DoD sedans, station wagons, carryalls, vans, and buses are considered 'nontactical.'").

[71] *See* GAO-15-548, *supra* note 6, at 3; GAO-09-968R, *supra* note 8, at 1. Ground combat vehicles (GCVs) "are vehicles that are intended to conduct combat operations against enemy forces; they differ from other vehicles, such as trucks, that are used for logistical or transport purposes." CBO, GCV ACQUISITIONS COSTS, *supra* note 58, at 1. The Federal Government is not always consistent in how it categorizes the DoD's ground-based operational vehicles. *Compare* U.S. GOV'T ACCOUNTABILITY OFF., GAO-21-361, ARMY AND MARINE CORPS SHOULD TAKE ADDITIONAL ACTIONS TO MITIGATE AND PREVENT TRAINING ACCIDENTS 1 n.1 (2021) (using the term "tactical vehicles" to refer to both combat and tactical vehicles, from tanks to HMMWVs) *with* GAO-15-548, *supra* note 6, at 3 (distinguishing between combat vehicles and tactical vehicles). For clarity and consistency, this thesis categorizes all such vehicles as "operational vehicles" and distinguishes between GCVs and TWVs. *See* GAO-15-548, *supra* note 6, at 3.

[72] *See* GAO-15-548, *supra* note 6, at 3, 4. The Army currently has the following numbers of combat vehicles, with each class generally including various variants: 2,402 Abrams tanks, 4,042 Bradley Fighting Vehicles, 4,466 Strykers, 1,079 M109 Paladins (half of which are self-propelled howitzers with the other half as tracked ammunition carriers), 1,170 M88 Hercules, 5,218 M113 Armored Personnel Carriers, and 2,897 Armored Multi-Purpose Vehicles. *See id.* Most GCV types also have several variants to provide different armament capabilities, but each variant shares a common chassis. *See id.* For example, the Stryker Family of Vehicles include the following variants: M1126 Infantry Carrier Vehicle (ICV), M1127 Reconnaissance Vehicle (RV), M1128 Mobile Gun System (MGS), M1129 Stryker Mortar Carrier (MC), M1130 Commander's Vehicle (CV),

Tactical "trucks and utility vehicles, particularly those necessary to support field operations, are essential to the success of any modern military."[73] In contrast to GCVs, TWVs are wheeled vehicles designed to meet a much wider variety of needs to support critical combat operations, including "transporting soldiers and materiel such as munitions, armored vehicles, water, food, and fuel, on the battlefield."[74]

Not surprisingly, the Service with the most ground tactical vehicles is the Army, which currently has over 242,000 TWVs—more than ten times the number of its GCVs—across light, medium, and heavy classes, as well as more than 100,000 trailers of various sizes and purposes (e.g., open trailers, radar systems, and fuel-powered generators) that those TWVs tow.[75] More than 110,000 of the Army's fleet, or about half of all TWVs, are HMMWVs.[76] Still, other common TWVs include the Joint Light Tactical Vehicles (JLTVs), Family of Medium Tactical Vehicles (FMTVs) (totaling more than 60,000 vehicles, with many variants using a standard chassis), Mine Resistant Ambush Protected (MRAP) Vehicles, Heavy Expanded Mobility Tactical Trucks (HEMTTs), and other types of heavy transport trucks.[77] Aside from providing the logistical

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and M1131 Fire Support Vehicle (FSV), M1133 Medical Evacuation Vehicle (MEV), and Nuclear, Biological, Chemical, Reconnaissance Vehicle (NBCRV). *See Ground Combat Systems, Stryker Family of Vehicles*, U.S. ARMY PROGRAM EXEC. OFF. (archived Dec. 17, 2014), https://web.archive.org/web/20141217130120/http://www.peogcs.army.mil/ documents/SBCT.pdf.

[73] *Army Tactical Wheeled Vehicle Program Update and Review of Electrification: Hearing before the S. Comm. on Tactical Air & Land Forces of the H. Comm. on Armed Serv.*, 117th Cong. 2 (May 27, 2021) [hereinafter *TWV Hearing*] (opening statement of Rep. Donald Norcross, Chairman, S. Comm. on Tactical Air & Land Forces, H. Comm. on Armed Services).

[74] *See* GAO-21-460, *supra* note 8, at 3.

[75] GAO-21-460, *supra* note 8, at 3. Like combat vehicles, each class of TWV generally includes multiple variants built on a common chassis. *Id.* For example, the Army's Family of Medium Tactical Vehicles (FMTV) consists of 2.5- and 5-ton capacity trucks, each with the same chassis and includes cargo, tractor, van, wrecker, and dump truck variants. *Id.*

[76] *See id.*

[77] *See id.* at 3. The Army has approximately the following numbers of each TWV: JLTVs (8,806), FMTVs (67,879; various variants on a common chassis), Mine Resistant Ambush Protected (MRAP) Vehicles (8,466), Heavy Dump Trucks (1,037), Heavy Expanded Mobility Tactical Trucks (HEMTTs) (26,475), Palletized Load

sustainment for U.S. ground forces to fight, many of these vehicles also offer crucial combat functions, such as reconnaissance, convoy security, and transportation for vital weapon systems across the battlefield (e.g., M777 artillery cannons and air defense Patriot Missile Systems).[78] With their important battlefield mission and their immense numbers, TWVs typically comprise the most prominent visible footprint in the Joint Force's (JF's)[79] combat operations.[80]

It is also worth briefly noting DoD's current sea- and aircraft strength, especially in light of their comparatively higher fuel consumption—and, thus, their potential for similar HED modernization in the future.[81] Across all Services, the DoD currently has a total of over 13,000 military aircraft (ranging from fixed-wing transport and bomber planes to fighter jets and attack

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System (7,479), Heavy Equipment Transporter System (2,161), and Line Haul Tractor Truck (7,313). *See id.* The Marine Corps's ground forces use similar TWV variants, albeit at much lower quantities. *See id.* As an illustration of the variation among TWV types, the FMTV "includes Cargo, Tractor, Load Handling System (LHS), Wrecker, Expandable Van, Shop Van, and Dump variants with payloads ranging from 3-tons to 10-tons and associated companion trailers." *See* U.S. DEP'T OF ARMY, *Research, Development, Test & Evaluation, Army: RDT&E – Volume II, Budget Activity 5A, in* DEPARTMENT OF DEFENSE FISCAL YEAR (FY) 2024 BUDGET ESTIMATES: ARMY JUSTIFICATION BOOK VOLUME 3A OF 3 166 (2023) [hereinafter FY24 ARMY RDT&E BUDGET JUSTIFICATION]. The Army's FMTV trucks "perform over 55 percent of the Army's local haul, line haul, and unit resupply missions. [They] operate[] throughout theater as multi-purpose transportation vehicles in combat, combat support, and combat service support units." FY24 ARMY RDT&E BUDGET JUSTIFICATION, *supra*, at 166.

[78] *See, e.g.*, *HEMTT A4 Patriot Tractor*, OSHKOSH DEFENSE, https://oshkoshdefense.com/vehicles/heavy-tactical-vehicles/hemtt-a4/hemtt-a4-patriot-tractor-2/ (last visited Apr. 11, 2024) (noting the HEMTT's role as the primary mover for the Patriot surface-to-air missile (SAM) launcher system).

[79] The DoD uses the term "Joint Force" to refer to "[a] force composed of elements, assigned or attached, of two or more Military Departments operating under a single joint force commander." U.S. DEP'T OF DEF., DOD DICTIONARY OF MILITARY AND ASSOCIATED TERMS 116 (Nov. 2021).

[80] *See* GAO-21-460, *supra* note 8, at 3. This especially the case at forward operating bases (FOBs), combat outposts (COPs), command posts (CPs), tactical operations centers (TOCs), assembly areas (AAs), and rearm, refuel, and resupply points (R3Ps)*See generally* U.S. ARMY, FIELD MANUAL 1-02.1, OPERATIONAL TERMS (Mar. 2021) (describing operational terms like FOBs, COPs, CPs, TOCs, AAs, and R3Ps); U.S. ARMY, FIELD MANUAL 3-90-2 (RECONNAISSANCE, SECURITY, AND TACTICAL ENABLING TASKS (Mar. 2013) (using operational terms to reference placement of various ground force elements in combat operations). Although there is not consensus on certain operational terms across the JF, these terms are generally understood by all U.S. ground forces. *See* JOINT PUBL'N 3-0, JOINT OPERATIONS GL-1–5 (17 Jan 2017) (C1, 22 Oct. 2018).

[81] *See* Neta C. Crawford, *Pentagon Fuel Use, Climate Change, and the Costs of War*, WATSON INST. FOR INT'L & PUB. AFFAIRS, BROWN U. 8 (June 12, 2019).

helicopters)[82] and over 280 ships (including carriers, cruisers, destroyers, submarines, amphibious craft, littoral combat ships, and hospital ships).[83] Regardless of how an operational vehicle is categorized amongst DoD's massive ground, sea, and air fleets, one sustainment requirement that DoD leaders currently count on, for better or worse, is that they all typically run on a single fuel source: oil.[84]

2. The DoD's Vulnerable Single-Fuel Reliance

Energy has always been a critical source of vulnerability for the U.S. military.[85] In particular, a "traditional vulnerability of forward deployed ground forces over the last century is their reliance on liquid petroleum fuels."[86] Petroleum fuel is necessary not only to propel movement and maneuvering but also to power all sorts of weapon systems, communication networks, and electrical equipment (both onboard and external) in combat operations and austere

[82] *See* Niall McCarthy, *The World's Largest Military Aircraft Fleets*, STATISTA (Mar. 16, 2021), https://www.statista.com/chart/24431/active-number-of-military-aircraft-by-country.

[83] *See* U.S. NAVY, NAVY VESSELS, AMERICA'S NAVY, https://www.navy.com/vessels (last visited Apr. 11, 2024).

[84] *See* Finke & Hess, *supra* note 67; *Fuel Types*, ILL. U. AVIATION SUSTAINABILITY CTR., FED. AVIATION ADMIN., NAT'L ALT. JET FUELS DATABASE, https://altjetfuels.illinois.edu/fuel_types (last visited Apr. 11, 2024). Although the terms "oil" and "petroleum" are often used interchangeably, to understand the difference between crude oil and petroleum, the U.S. Energy Information Administration provides the following explanation:

> Crude oil is a mixture of hydrocarbons that exists as a liquid in underground geologic formations and remains a liquid when brought to the surface. Petroleum products are produced from the processing of crude oil and other liquids at petroleum refineries, from the extraction of liquid hydrocarbons at natural gas processing plants, and from the production of finished petroleum products at blending facilities. Petroleum is a broad category that includes both crude oil and petroleum products.

See Frequently Asked Questions (FAQs): What is the Difference between Crude Oil, Petroleum Products, and Petroleum? U.S. ENERGY INFO. ADMIN, https://www.eia.gov/tools/faqs/faq.php?id=40&t=6 (last visited Apr. 11, 2024).

[85] Mills & Wiechens, *supra* note 59.

[86] Mancillas, *supra* note 11, at 2.

environments.[87] Therefore, the amount and efficiency of petroleum fuel that ground forces can either carry or maintain constant access to is the single greatest determining factor for their warfighting effectiveness—and certainly, their survival.[88]

When DoD began shifting toward using a single fuel type in the late 1980s, military leaders saw it as a blessing.[89] After all, for decades prior and throughout the Korean and Vietnam Wars, they dealt with the logistics headache of a global force that used half a dozen different types and mixes of fuel for aircraft and ground vehicles.[90] Since the Cold War era, the "single fuel concept" (SFC) has historically provided "increased interoperability and simplified logistics for the procurement, storage, and transportation of fuel, especially on the battlefield."[91] As exalted in Army Regulation 70-12, the military's use of a single kerosene-based fuel "minimizes the number of liquid hydrocarbon fuels required to operate materiel and enhances fuel availability."[92] Although DoD now utilizes various specific fuel mixtures, including JP-8, JP-5, and F-24, these fuel types all fall under the SFC because they are all similarly structured petroleum-based hydrocarbon products derived from crude oil.[93]

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[87] *See id.*

[88] *Id.*

[89] Kern et al., *supra* note 10.

[90] *See id.*

[91] *Id.*

[92] *See* U.S. DEP'T OF THE ARMY, REG. 70-12, FUELS AND LUBRICANTS 12 (6 May 2022).

[93] *See supra* note 84 (discussing why the terms petroleum and oil are used interchangeably). Today, the DoD primarily uses a fuel mixture called "Jet Propulsion 8" (JP-8) to run its ground operational vehicles and aircraft. Kern et al., *supra* note 10. The use of specific variants under the SFC has since been further standardized with our NATO allies. *Id.* The DoD also still uses standard, commercial gasoline and diesel to power its NTVs. *See* OFF. OF THE UNDER SEC'Y OF DEF. FOR ACQ. & SUST., U.S. DEP'T OF DEF., U.S. DEPARTMENT OF DEFENSE OPERATIONAL ENERGY STRATEGY (May 2023) [hereinafter 2023 DOD OES]; *DLA Energy Products*, U.S. DEFENSE LOG. AGENCY, https://www.dla.mil/Energy/Products (last visited Apr. 11, 2024). This is a commercially available jet aviation fuel but "with military additives for improved lubrication and inhibition of static, icing, and corrosion." Kern et al., *supra* note 10. Unlike diesel and gasoline, which can only be used in their respective engine types, the main advantage of using JP-8 as the military's standard fuel is that it can be used in both diesel-powered ground equipment and turbine-engine aircraft. Kern et al., *supra* note 10. Although

Under the SFC policy, DoD has become "the world's largest institutional user of petroleum and, correspondingly, the single largest institutional producer of [GHGs] in the world."[94] Since 2001, DoD's energy needs consistently comprise between 77 and 80 percent of all U.S. federal government consumption.[95] Of this amount, petroleum-based fuels account for 80% of DoD's energy use, of which installation energy accounts for 30%[96] and operational energy (e.g., fueling its vehicles, ships, and aircraft worldwide) account for 70%.[97] In total, DoD now consumes more than 360,000 barrels of oil *each day*.[98] This massive oil requirement is not only due to DoD's sheer size, global footprint, and sustained operations but also thanks to the humorously low fuel

JP-8 is not perfectly matched for standard diesel engines, its chemical properties are close enough to diesel that its logistical efficiencies outweigh any performance drawbacks. *See* Kern et al., *supra* note 10. In 2012, however, all Services began switching to the cheaper and more commercially available "Fuel 24 (F-24)" fuel for U.S. operations (except in Alaska, where the lower freezing point of JP-8 remains necessary). *See* Kern et al., *supra* note 10. The military continues to use JP-8 overseas, along with two other fuel types, JP-5 (for ground vehicles) and F-76 (for Navy ships). Kern et al., *supra* note 10. The military uses JP-8 and JP-5 for its ground vehicles. However, JP-5 is preferred for use aboard ships due to its higher flash point temperature and the risk of onboard fire. Kern et al., *supra* note 10. Unlike the jet fuels, "Fuel 76 (F-76)" diesel fuel, which powers the diesel engines, gas turbines, and boilers aboard Navy ships, is formulated to remain stable and usable for several years. Kern et al., *supra* note 10.

[94] *See* Crawford, *supra* note 81, at 2.

[95] *Id.*

[96] *See id.* "Installation energy consists largely of traditional energy sources used to heat, cool, and provide electrical power to [DoD] buildings [around the world]. It also includes the fuel used by non-tactical vehicles housed at DoD installations. The Department spends over $4 billion a year on energy at fixed installations." *Environment and Energy Resilience: Installation Energy*, OFF. OF THE SEC'Y OF DEF., U.S. DEP'T OF DEF., https://www.acq.osd.mil/eie/eer/cr/ie/index.html (last visited Apr. 11, 2024).

[97] Crawford, *supra* note 94, at 4. Operational energy is defined as the energy "required for training, moving, and sustaining military forces and weapons platforms." *Operational Energy*, OFF. OF THE SEC'Y OF DEF., U.S. DEP'T OF DEF., https://www.acq.osd.mil/eie/OE/OE_index.html (last visited Apr. 11, 2024). Nita Crawford, a leading scholar on the costs of war, expounded on the research of the DoD's operational energy as follows:

> Most operational energy consumed is in the form of 'bulk fuel' purchases of jet (JP-8 and JP-5) and diesel fuel. Operational use varies, of course, depending on what the US military is doing in any particular year — its ongoing and occasional missions. When the US is engaged in war, as one would expect, consumption of jet and diesel fuels increase. Their ratio will depend on the types of operations the military is performing — whether the war or particular phase of the war is land or air intensive.

Crawford, *supra* note 81, at 4.

[98] *See Daily Energy Report*, *supra* note 36.

efficiencies of its TWVs and GCVs.[99] For example, the HMMWV, the Army's "proverbial workhorse" for over four decades, gets between four and eight miles per gallon of fuel, while the 70-ton Abrams tank gets around 0.6 miles per gallon.[100]

The SFC policy streamlined military logistics and proved invaluable throughout DoD's operations over the last four decades, from its Cold War posturing to its predominantly asymmetric warfare in Iraq and Afghanistan.[101] Nevertheless, during that same period, countless instances of U.S. ground forces nearly outrunning their logistics lines, fatal enemy attacks on fuel resupply convoys, and foreign countries shutting off oil supply during crucial overseas operations together emphasized to DoD leaders the untenable position of over-relying on a single fuel source.[102] Even so, the pervasive "SFC dogma" and "chicken-and-egg problem"—that is, the challenge of determining how best to time HED vehicle procurement versus standing up the advanced logistics infrastructure to support those vehicles' operational energy needs—maintains DoD's risky single-fuel reliance.[103]

B. How Vehicle Engines Work

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[99] *See* Crawford, *supra* note 81, at 4.

[100] Goure, *supra* note 7; *see* Crawford, *supra* note 81, at 4; *Military Specifications: M1 Abrams Main Battle Tank*, GLOB. SEC., https://www.globalsecurity.org/military/systems/ground/m1-specs.htm (last visited Apr. 11, 2024).

[101] *See* Crawford, *supra* note 81, at 4. "Asymmetric warfare" is defined as "warfare that is between opposing forces which differ greatly in military power and that typically involves the use of unconventional weapons and tactics (such as those associated with guerrilla warfare and terrorist attacks)." *Asymmetric Warfare*, MERRIAM-WEBSTER, https://www.merriam-webster.com/dictionary/asymmetric%20warfare (last visited Apr. 11, 2024).

[102] *See* Kern et al., *supra* note 10; Maurice E. Le Pera, *The Reality of the Single-Fuel Concept*, 37 ARMY LOGISTICIAN 2, PB 700-07-02, Mar.–Apr. 2005, at 40, 43, https://alu.army.mil/alog/2005/marapr05/pdf/alog_mar_apr_05.pdf. After driving the Army's all-electric prototype Infantry Squad Vehicle (e-ISV) during a demonstration at Fort Irwin in 2023, actor Robert Downey, Jr. prosed the following about human civilization's historical reliance on fossil fuels, which equally rings true for the DoD: "We got as far as we could go with our conspicuous consumption." *See* DOWNEY'S DREAM CARS, EPISODE 2 (HBO Max 2023).

[103] *See* Kern et al., *supra* note 10; Finke & Hess, *supra* note 67.

After gaining a glimpse into DoD's current TWV fleet and its petroleum fuel reliance, a basic understanding of the mechanics of vehicle propulsion is also necessary to appreciate HED's warfighting advantages for DoD's TWV fleet.[104]

Mankind has long experimented with machine-powered locomotion, from testing steam-powered automobiles in the late 1700s to Karl Benz developing what the world still knows as the modern vehicle in 1885.[105] Combining an ICE with an integrated chassis, Benz's three-wheeled vehicle was the first to enter mass consumer production in the early twentieth century.[106] Since then, the ICE became the core of most cars on the road today; it still remains the core of every single one of DoD's currently fielded operational vehicles.[107]

In a *traditional ICE*, whether powered by diesel, gasoline, or other crude-oil-derived petroleum mixture, fuel mixes with air as it is injected into the engine, and a piston compresses the mixture inside the engine's cylinders.[108] At a certain point, the fuel ignites or combusts, pushing the piston and turning the crankshaft, which connects to the vehicle's transmission, thus rotating the vehicle's wheels.[109] The piston then returns to its original position in the cylinder, expending the burnt gases

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[104] *Hybrid Electric Vehicles*, ALT. FUELS DATA CTR., U.S. DEP'T OF ENERGY [hereinafter *DoE HEVs*], https://afdc.energy.gov/vehicles/electric_basics_hev.html (last visited Apr. 11, 2024); *see* James Riswick, *What is a Hybrid Car and How Do They Work?*, CAR & DRIVER (Feb. 22, 2019), https://www.caranddriver.com/features/a26390899/what-is-hybrid-car/.

[105] *See* Beverly Braga, *Hybrid vs. Electric Cars: How They Work*, J.D. POWER (Sept. 4, 2020), https://www.jdpower.com/cars/shopping-guides/hybrid-vs-electric-cars-how-they-work.

[106] *See id.*

[107] *See id.*; Stephen Lee & Daniel Moore, *US Army's Electric Tanks on Hold as Battery Technology Develops*, BLOOMBERG L. (June 20, 2023), https://news.bloomberglaw.com/environment-and-energy/us-armys-electric-tanks-on-hold-as-battery-technology-develops.

[108] Ronan Glon, *The Difference Between Diesel- and Gasoline-Powered Cars*, DIGIT. TRENDS (Mar. 9, 2021), https://www.digitaltrends.com/cars/diesel-vs-gasoline-engines.

[109] *Id.* In essence, an ICE converts the fuel's potential chemical energy and oxygen into thermal energy, which the drivetrain converts into the vehicle's mechanical energy. *See* Heba Soffar, *The Energy Transformation Inside the Cars*, ONLINE SCIENCES (May 21, 2015), https://www.online-sciences.com/the-energy/the-energy-transformation-inside-the-cars.

from the engine through the tailpipe as exhaust.[110] This complete cycle repeats several times per second in each piston cylinder, propelling the vehicle.[111] The more cylinders an ICE has, the smoother it tends to run because the combustion events occur more rapidly.[112] However, the more cylinders an engine has—and thus, the larger the ICE is—, the more moving parts it has and the more complex and mechanically inefficient it becomes.[113]

Experts generally discuss an ICE's output in terms of its "horsepower," a measure of sustained power at higher speeds, and its "torque," a measure of twisting force on the driveline that makes the vehicle start moving faster.[114] Because they generally have much higher torque and durability than gasoline ICEs, diesel ICEs are the predominant engine type in the ground vehicles of DoD and our NATO partners.[115] In comparison to gasoline engines, the design of diesel engines—"big engines with big cylinders, large crankshafts, strong pistons, and multiple gears"—also involves fewer small, precise parts and more heavy-duty materials and fixed gears. This design limits movement and reduces "wear and tear" to support continuous operation, making these the obvious engine choice for military ground forces.[116]

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[110] *See* Glon, *supra* note 108.

[111] *Id.* For a visual depiction of the drive components in a gasoline ICE vehicle, see Appendix B-1.

[112] *See* Glon, *supra* note 108.

[113] *See id.*

[114] *See id.*

[115] *See* Trevor Anderson, *NATO Diesel: Military Vehicles, and the Single Fuel Concept,* DIESEL ARMY (Sept. 25, 2015), https://www.dieselarmy.com/features/history/diesel-on-the-ground-a-look-at-nato-fuels-and-vehicles. Diesel engines also have a much higher average life-expectancy of 250,000-300,000 miles due to their engine design and fuel type. *See Diesel vs. Gasoline: All You Need to Know*, TRUST AUTO [hereinafter *Diesel*, TRUST AUTO], https://www.trustauto.com/blog/diesel-vs-gasoline (last visited Apr. 11, 2024). However, with the DoD and many NATO countries now employing a single-fuel concept (i.e., using a fuel mixture that can be used in all engine types), many of the performance benefits and durability of diesel ICEs are degraded because they have been retrofitted to use a less-than-ideal fuel mixture. *See* Anderson, *supra*.

[116] *See Diesel*, TRUST AUTO, *supra* note 115.

In contrast, the basic design and function under the hood of an *all-electric vehicle* (AEV), also called a battery electric vehicle (BEV), could not be any more different than an ICE vehicle.[117] Electric vehicles have an electric motor instead of an ICE, and the vehicle works by using a large traction battery pack, usually comprised of multiple lithium-ion batteries (LIBs), to store the electrical energy to power the motor.[118] One must first charge the battery pack by plugging it into an electrical outlet or charging equipment, like an electric vehicle supply equipment (EVSE).[119] A power electronics controller (PEC) controls the flow of electrical energy from the battery pack to the motor based on how hard the driver pushes the accelerator pedal.[120] Before the motor can receive electrical energy from the battery pack, it goes through an inverter that converts the energy from a direct current (DC) to an alternating current (AC).[121] Similar to the repeating fuel ignitions inside an ICE cylinder, the repeating AC causes a magnetic rotor in the motor to spin and produce mechanical energy, which rotates the gears on the single-speed transmission.[122] As on an ICE, the

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[117] *How Do All-Electric Cars Work?* ALT. FUELS DATA CTR., U.S. DEP'T OF ENERGY [hereinafter *Electric Cars*, DOE], https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work (last visited Apr. 11, 2024).

[118] *Id.*; *see* EnergySage Staff, *How Do Batteries for Electric Cars Work?* ENERGYSAGE (Nov. 28, 2022), https://www.energysage.com/electric-vehicles/how-do-electric-car-batteries-work. Batteries produce electricity by using two different metals in a chemical substance called an electrolyte. *See Electricity Explained: Batteries, Circuits, and Transformers*, U.S. ENERGY INFO. ADMIN. [hereinafter *Electricity Explained*], https://www.eia.gov/energyexplained/electricity/batteries-circuits-and-transformers.php (last visited Apr. 11, 2024). Batteries consist of two electrical terminals (the cathode and the anode), separated by a conducive chemical material (electrolyte) through which the charge passes. *See Electricity Explained*, *supra*. "Electricity" is the term used to describe the energy of charged particles, which in a battery move from one side to another of a charged battery to produce energy. *See Electricity Explained*, *supra*. Electricity must have a complete path (or electrical circuit) before the electrons can move. *See Electricity Explained*, *supra*. Transformers can help to move that electricity over long distances. *See Electricity Explained*, *supra*; *DOE Explains...Batteries: How Lithium-ion Batteries Work*, OFF. OF SCIENCE, U.S. DEP'T OF ENERGY, https://www.energy.gov/science/doe-explainsbatteries (last visited Apr. 11, 2024).

[119] *See Electricity Explained*, *supra* note 118.

[120] *See* TEAM ACKODRIVE, *How Do Electric Cars Work?*, ACKODRIVE (June 9, 2022) [hereinafter TEAM ACKODRIVE, *Electric Cars*], https://ackodrive.com/car-guide/how-do-electric-cars-work/

[121] *Id.*

[122] *Id.* The rotating part, called the rotor, is connected to a single-speed transmission that sends power to the wheels. The fixed part, called the stator, has coils that act as magnets and pull the rotor along. Jill Scott, *How an*

transmission then transfers the mechanical energy to the wheels, propelling the vehicle forward.[123] At the point when an electric car slows down, however, the electric motor turns into an alternator, generating power from the car's movement that is then sent once more into the battery; this process is called "regenerative braking."[124] In general, the absence of an internal combustion event in an EV means that its battery pack delivers energy to the motor, and thus to the transmission and wheels, instantaneously.[125] This provides EVs much higher torque than their ICE-vehicle counterparts.[126] Of course, the lack of an ICE also means EVs have no exhaust pipes or GHG emissions from operating.[127]

In between the ICE and AEV is the *hybrid-electric vehicle* (HEV), which combines the respective benefits and minimizes the drawbacks of both traditional ICEs and AEVs by utilizing both an ICE and an electric motor.[128] Although HEVs still have an ICE and thus generally similar numbers of moving parts as traditional ICE vehicles, HEVs rely relatively less—sometimes dramatically less—on their ICEs to produce mechanical energy to propel the vehicle, putting less strain on those moving parts and reducing frequent maintenance needs.[129] Additionally, as HED technology

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Electric Motor Works in a Car, ELEC. MOTOR ENG'G, https://www.electricmotorengineering.com/an-electric-motor-works-car (last visited Apr. 11, 2024).

[123] *See* TEAM ACKODRIVE, *Electric Cars*, *supra* note 120.

[124] *See id.* For a visual depiction of the drive components in an AEV, see Appendix B-2.

[125] *See Electric Cars*, DOE, *supra* note 118.

[126] *See id.*

[127] *See id.*

[128] *See Understanding Hybrid Vehicles: The 4 Main Types*, MOTOR LEASE [hereinafter *Hybrid Vehicles*, MOTOR LEASE], https://motorlease.com/article/hybrid-vehicle-types (last visited Apr. 11, 2024).

[129] *Id.* For a visual depiction of the drive components in a full HEV, see Appendix B-3.

and efficiency continue to advance, the ICEs in HEVs continue to grow smaller and less complex, further reducing the number of wear-and-tear on their moving parts.[130]

There are three main types of HEVs: (1) mild hybrids, (2) full hybrids (including two main types of powertrains, parallel hybrids and series hybrids), and (3) plug-in hybrids.[131] In a mild hybrid vehicle, the typically 48-volt electric system cannot power the vehicle alone, but it can provide a slight boost to the vehicle's ICE, usually at acceleration from a dead stop, as well as help remove the burden of power-hungry systems like air conditioning from the ICE.[132] Mild hybrids also do not require plug-in charging because their batteries recharge from a combination of converted power from the ICE and energy recovered through regenerative braking.[133] In some ways, because batteries are increasingly powering the growing number of electric systems in newer traditional-ICE cars, "all new-production vehicles are at least 'mild-hybrid' vehicles."[134]

In contrast to a mild hybrid, the electric motor in a full hybrid vehicle is bigger and uses more batteries, so it can handle a far greater share of the workload.[135] In fact, most full hybrids can operate solely on electric power for long distances, especially if they stay at lower speeds.[136] Similar

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[130] *See* Jennifer Sensiba, *A Very Simply Hybrid that Rivals the Cleanliness of EVs is Possible*, CLEAN TECHNICA (Apr. 28, 2021), https://cleantechnica.com/2021/04/28/a-very-simple-hybrid-that-rivals-the-cleanliness-of-evs-is-possible.

[131] *See Hybrid Vehicles*, MOTOR LEASE, *supra* note 128; *see also* AR 58-1, *supra* note 8 para. 4-1 (defining the various types of AEVs, HEVs, and PHEVs).

[132] *See Hybrid Vehicles*, MOTOR LEASE, *supra* note 128

[133] *Id.*

[134] *DoE HEVs*, *supra* note 104; *see* Riswick, *supra* note 104.

[135] *See Hybrid Vehicles*, MOTOR LEASE, *supra* note 128.

[136] *See id.* "[A]dvances in battery technology have enabled some hybrids to achieve ranges of up to 600 miles on a single charge." Kern Campbell, *Hybrid Cars On Long Trips: Worth It For Long Distance Road Trips?*, DRIVEN WHEELS (Apr. 8, 2023), https://drivenwheels.com/hybrid-cars-on-long-trips-worth-it-for-long-distance-road-trips. In addition to battery type, the type of hybrid system in a HEV plays a role in the vehicle's range. Campbell, *supra*. "For instance, plug-in hybrids are capable of driving longer distances on electric power alone since they have a larger battery and can be charged externally." Campbell, *supra*. A third factor of driving range

to mild hybrids, full hybrids recharge their battery systems through energy from the ICE and regenerative braking.[137]

Full hybrids generally have one of two types of powertrains: parallel and series.[138] In parallel hybrids, the vehicle is powered in one of three ways: directly by the ICE, directly by the electric motor, or by both systems working together.[139] In a series hybrid, only the electric motor powers the wheels, with the ICE providing power for the electric motor, similar to a generator; that is, the energy passes in a "series."[140] Advances in HEVs also recently produced series-parallel hybrids, which combine the two methods by the vehicle's computer system "choosing the most efficient way to operate at any given time."[141]

As essentially "a half-way point" between a full hybrid vehicle and AEV, a *plug-in hybrid electric vehicle* (PHEV) runs solely on electric power from the electric traction motor until the battery is depleted; it then switches to using fuel that powers the ICE.[142] The battery pack, usually composed of LIBs, is recharged either by plugging in, regenerative braking, or using the ICE.[143] This combination of energy systems gives PHEVs a farther range than most AEVs, but it also requires

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of HEVs is the terrain and driving style. Campbell, *supra*. "For instance, if a driver accelerates aggressively or drives uphill frequently, the vehicle's battery may drain faster, reducing the range." Campbell, *supra*.

[137] *See Hybrid Vehicles*, MOTOR LEASE, *supra* note 128.

[138] *Id.*

[139] *Id.*

[140] *See id.*

[141] *Id.*

[142] *Id.*; *see* EnergySage Staff, *supra* note 118; *How Do Plug-In Hybrid Electric Cats Work?*, ALT. FUELS DATA CTR., U.S. DEP'T OF ENERGY [hereinafter *PHEVs*, DOE], https://afdc.energy.gov/vehicles/how-do-plug-in-hybrid-electric-cars-work (last visited Apr. 11, 2024).

[143] *See PHEVs*, DOE, *supra* note 142. For a visual depiction of the drive components in a PHEV, see Appendix B-4.

external charging similar to AEVs, which typically take hours to fully charge to achieve maximum fuel efficiency and range.[144]

Notwithstanding its current limitations, the battery technology of EVs is also evolving rapidly, with car manufacturers focusing on "achieving significant improvements in the energy density, cost competitiveness[,] and charging speeds of liquid electrolyte batteries."[145] There are four main types of batteries used in most variants of EVs: (1) lithium-ion, (2) nickel-metal hydride, (3) lead-acid, and (4) ultracapacitors.[146] One common feature each of these options share is that they all rely on a liquid electrolyte to facilitate the flow of charged particles ("ions") between the battery's two electrodes to generate the electric current sent to the motor.[147] However, major car manufacturers are increasingly achieving breakthroughs in solid-state batteries (SSBs), which instead use solid materials to facilitate this flow of charged particles.[148] There are also growing

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[144] *See Hybrid Vehicles*, MOTOR LEASE, *supra* note 128.

[145] *See, e.g.*, Laurie Winkless, *Could Solid-State Batteries Supercharge Electric Vehicles?*, FORBES (Nov. 14, 2023), https://www.forbes.com/sites/lauriewinkless/2023/11/14/could-solid-state-batteries-supercharge-electric-vehicles/?sh=3b2ef6bb592c (discussing Toyota's recent publication of its "battery technology roadmap" and its first mass productions of SSBs); *see also Toyota Sets Out Advanced Battery Technology Roadmap*, TOYOTA UK MEDIA (Sept. 14, 2023), https://media.toyota.co.uk/toyota-sets-out-advanced-battery-technology-roadmap/ (providing Toyota's aims for future AEV and HEV battery innovation).

[146] *See* EnergySage Staff, *supra* note 118. Of these, LIBs are the most common type of battery used in EVs partly because of their "high power-to-weight ratio, high energy efficiency, and good high-temperature performance." *Id.* In contrast, nickel-metal hydride batteries, which are more widely used in HEVs but are also in some AEVs, derive power only from fuel from the ICE rather than from an external plug-in source. *Id.* Their benefits include a longer life cycle than LIBs and lead-acid batteries as well as being safer and more abuse-tolerant. *Id.* However, they generally suffer from higher costs, self-discharge rates, and heat generation at high temperatures. *Id.* Lead-acid batteries are used in ICEs to power spark plugs or glow plugs and the vehicle's other electrical systems, but they generally only supplement other battery loads in EVs. *Id.* Although they are high-powered, inexpensive, safe, and reliable, "their short calendar life and poor cold-temperature performance make them difficult to use in [EVs]." *Id.* Finally, ultracapacitors are not traditional batteries but instead exist in EVs to "store polarized liquid between an electrode and an electrolyte. As the liquid's surface area increases, the capacity for energy storage also increases." *Id.* However, like lead-acid batteries, these are generally only supplemental "because they help electrochemical batteries level their load." *Id.*

[147] *See* Winkless, *supra* note 145.

[148] *Id.* Although they were historically complicated to produce, recent advances compounded the significant benefits SSBs provide. *Id.* For example, SSBs' materials can withstand both extremely low and high temperatures; their high heat resistance also means they can be safely charged much more quickly than LIBs. *Id.* Additionally, SSBs have higher energy densities, meaning they store more power for the same weight. *Id.*

alternative energy options in other vehicle types, like hydrogen fuel-cell vehicles (HFCVs), that present a plethora of opportunities for DoD's operational energy needs.[149]

In sum, the sheer number of breakthroughs and expanding options in electric battery technology and alternative energy sources demonstrate that DoD can no longer reasonably ignore the benefits HED modernization offers to propel its ground forces forward.[150] The swelling investment by commercial industry further illustrates this need.

C. Industry and Government Investment in HE Medium- and Heavy-Duty Work Vehicles; Leveraging Industry's Advances to Envision DoD's Future Ground Forces

Before exploring the game-changing battlefield advantages that these advances in HED technology offer military ground operations, it is promising to note that DoD is not entirely breaking new ground in its efforts to develop and acquire HED capabilities.[151] From the recent boom of commercial and government purchases of EVs to the continued commitment of

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[149] Similar to a series-HEV, a HFCV utilizes the same type of electric motor as an EV, but that motor is powered by a fuel-cell stack rather than by a large, heavy traction battery pack. *See* John Voelcker, *Hydrogen Fuel-Cell Vehicles: Everything You Need to Know*, CAR & DRIVER (Sept. 26, 2022), https://www.caranddriver.com/features/a41103863/hydrogen-cars-fcev. In the fuel-cell stack, "pure hydrogen [] passes through a membrane to combine with oxygen [] from the air, producing the electricity that turns the wheels plus water vapor." *Id.* Although the infrastructure to sustain HFCVs is still developing and there are some disadvantages, HFCVs offer similar benefits as EVs, but they achieve greater fuel efficiency, range, and durability and lower refueling time. *See* Tristan Perry, *21 Hydrogen Fuel Cell Car Advantages and Disadvantages*, GREEN CAR FUTURE (Apr. 28, 2022), https://www.greencarfuture.com/misc/hydrogen-advantages-and-disadvantages. They also fit into the current commercial gasoline infrastructure, furthering the promise that HFCVs offer. *See id.*

[150] *See* Casey Crownhart, *What's Next for Batteries*, MIT TECH. REV. (Jan. 4, 2023), https://www.technologyreview.com/2023/01/04/1066141/whats-next-for-batteries. The HEV market has even spurred advances in traditional ICEs. The ICEs in HEVs and traditional ICE-only vehicles typically still use crankshafts to open up intakes of fuel and air into the combustion cylinder. *See* CB Staff, *Koenigsegg's Free-Valve Tech Will Change The Game*, CAR BUZZ (Mar. 4, 2020), https://carbuzz.com/news/koenigseggs-free-valve-tech-will-change-the-game. However, newer vehicle models have begun to use larger cylinders and pneumatic free-valve technology that more efficiently pull in fuel and air, resulting in a smaller engine but faster RPMs and greater horsepower. *See* CB Staff, *supra*. Additionally, some companies are achieving breakthroughs in hub electric motor designs that achieve even greater energy efficiency and reduce batteries' energy density requirements. *See* EnergySage Staff, *supra* note 118.

[151] *See TWV Hearing*, *supra* note 73, at 21 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics).

longtime prime defense contractors to double down on their EV investments, there are several promising signs that DoD should look to when developing its own HED acquisition and integration strategies to avoid being left behind.[152]

The worldwide sales of light-duty EVs have already totaled 9.5 million AEVs and over four million PHEVs, comprising about one-fifth of all new car sales in 2023 and demonstrating the increasing viability of the technology and industry's capacity to support DoD's future needs.[153] Regarding DoD's heavier TWV requirements, corporate customers like Walmart, Amazon, United Parcel Service (UPS), and PepsiCo are also beginning to electrify their medium-duty (weighing 3.5 to 15 tons) and heavy-duty (weighing over 15 tons) freight and equipment transport vehicles.[154] In 2019, FedEx made the largest commercial AEV purchase to date, purchasing 1,000 medium-duty

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[152] *See* Sarah Sybert, *Army Futures Command to Develop Electric Powered Vehicles; LTG Eric Wesley Quoted*, EXECUTIVEGOV (Sept. 21, 2020), https://executivegov.com/2020/09/army-futures-command-to-develop-electric-powered-vehicles-ltg-eric-wesley-quoted. Lieutenant General (LTG) Eric Wesley, Former Deputy Commanding General of Army Futures Command (AFC) provided the following assessment:

> Let's be clear. We're behind. We're late to meet on this thing . . . If you look at all of the analysis, all of the various nations that we work with, they're all going to electric power with their automotive fleet, and right now, although we do [science and technology] and we've got some research and development going on and we can build prototypes, in terms of a transition plan, we are not there.

Id.

[153] *See* Nick Carey, *Global Electric Car Sales Rose 31% in 2023 - Rho Motion*, REUTERS (Jan. 10, 2024), https://www.reuters.com/business/autos-transportation/global-electric-car-sales-rose-31-2023-rho-motion-2024-01-11; Michelle Culver, *S&P Global Mobility Forecasts 88.3M Auto Sales in 2024*, S&P GLOBAL (Dec. 24, 2023), https://press.spglobal.com/2023-12-14-S-P-Global-Mobility-forecasts-88-3M-auto-sales-in-2024; *see also* Tom Krisher & Assoc. Press, *The EV Boom May Be Petering Out, But Americans are Buying Record Numbers of Hybrid Cars*, FORTUNE (Dec. 24, 2023), https://fortune.com/2023/12/24/record-sales-hybrid-electric-vehicles-cars-ford-toyota (noting that, although AEV sales are decreasing, HEV sales are increasing exponentially, with over one million sold in the U.S. annually); Neil King, *EVs Forecast to Account for Two Thirds of Global Light-Vehicle Sales in 2035*, EV-VOLUMES, https://www.ev-volumes.com/ (last visited Apr. 11, 2024) (finding that EVs accounted for 18 to 16 percent of all U.S. new car sales in 2023 and that EVs would account for two-thirds of all car sales by 2035).

[154] *See* Mancillas, *supra* note 11, at 7.

(6,000-lb cargo capacity) fully electric trucks.[155] Although these commercial trucks are unarmored and are typically not required to drive on anything more rugged than potholed highways, their similar weight and operational range requirements suggest that continued advancement will make such heavy, long-range HEVs competitive with the reliability and power of traditional ICE-powered TWVs.[156]

In addition to these corporate investments in HED, state and local governments are also accelerating the transition. At least 47 states and territories have instituted financial incentives for individual and business EV purchasers, with several states requiring all vehicles sold in the state to be EVs by a specific date.[157] Additionally, on the federal side, in 2022, the USPS, the largest institutional owner of light-duty vehicles, committed to investing over $6 billion to replace its approximately 140,000 vehicles with 100% AEVs.[158] As of 2023, in accordance with U.S. Executive Branch directives and "net-zero emissions" goals, DoD already purchased approximately 18,000 AEVs and HEVs to replace its light-duty NTVs and plans to purchase several thousand more each year.[159]

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[155] *Id.*; Seth Skydel, *FedEx Makes the Largest Commercial Electric Vehicle Purchase in the U.S., Continues the Zero-Emissions Trend*, FLEET EQUIP. MAG. (Jan. 14, 2019), https://www.fleetequipmentmag.com/fed-ex-largest-electric-truck-purchase-zero-emission/.

[156] Mancillas, *supra* note 11, at 7.

[157] See Austin Igleheart, *State Policies Promoting Hybrid and Electric Vehicles*, NAT'L CONF. OF STATE LEGISLATURES (last updated Aug. 23, 2023), https://www.ncsl.org/energy/state-policies-promoting-hybrid-and-electric-vehicles. For a regularly updated summary of relevant legislation on EVs among the states, see Igleheart, *supra*.

[158] Mancillas, *supra* note 11, at 7; *see* Michelle Lewis, *US Postal Service Commits to Buying 100% Electric Trucks by 2026*, ELECTREK (Dec. 20, 2022), https://electrek.co/2022/12/20/us-postal-service-commits-to-buying-100-electric-trucks-by-2026; *see also* Exec. Order No. 14057 of Dec. 8, 2021, Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability, 86 Fed Reg. 70935, 70936 (Dec. 13, 2021) [hereinafter EO 14057] (directing that "[e]ach agency's light-duty vehicle acquisitions shall be zero-emission vehicles by the end of fiscal year 2027"); Peter Johnson, *How Committed is the US Government to Electric? 9,500 EVs Are on Order This Year*, ELECTREK (Jul. 19, 2023), https://electrek.co/2023/07/19/us-government-9500-evs-2023/ (providing updates on USPS's purchases of EVs).

[159] David Shepardson, *US Government Agencies Target Purchasing 9,500 EVs in 2023*, REUTERS (Jul. 19, 2023), https://www.reuters.com/business/autos-transportation/us-government-agencies-target-purchasing-9500-

A final key trend in vehicle electrification is the committed investment by established vehicle manufacturers, including those that have long produced TWVs and GCVs for the DoD.[160] For example, various projections show the world's top automakers—U.S. manufacturers like GM and Ford, along with foreign manufacturers like Toyota and Mercedes—, "are planning to spend nearly *$1.2 trillion* through 2030 to develop and produce millions of electric vehicles, along with the batteries and raw materials to support that production over the next decade to develop and produce electric-powered vehicles."[161] According to similar analyses, "[a]utomakers have forecast plans to build 54 million [BEVs] in 2030, representing more than 50% of total vehicle production."[162] The rising prioritization of these investments and growing market share will certainly reduce sustainment costs for EVs and correspondingly escalate sustainment costs for legacy ICE vehicles.[163] Experts predict that electrified systems will increasingly become the market focus, while traditional ICE vehicle sales will become niche markets.[164] Continued development and investment in traditional ICE systems will thus become costlier and reliant on a shrinking

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evs-2023-2023-07-19; *see* U.S. DEP'T OF DEF., INSTR. 4500.36, ACQUISITION, MANAGEMENT, AND USE OF NON-TACTICAL VEHICLES (NTVS) para. 3-8 (1 Feb. 2023) [hereinafter DODI 4500.36]; U.S. DEP'T OF DEF., MANUAL 4500.36, ACQUISITION, MANAGEMENT, AND USE OF NON-TACTICAL VEHICLES (NTVS) MANUAL encl. 4, app. 5, para. 2.e. (7 Jul. 2015) (C1, 20 Dec. 2018) [hereinafter DODM 4500.36]; DCMA MANUAL 4101-05, *supra* note 8, at 21. *But see* U.S. DEP'T OF DEF., DIR. 5135.02, UNDER SECRETARY OF DEFENSE FOR ACQUISITION AND SUSTAINMENT (USD(A&S)) para. 4.bf. (15 Jul. 2020) [hereinafter DODD 5135.02] (delegating authority to the USD(A&S) to "[c]ertify, in accordance with Section 13212 of Title 42, U.S.C., that motor vehicles acquired and used for military purposes must be exempt from federal fleet alternative fuel vehicle acquisition requirements"). *See generally* U.S. DEP'T OF DEF., DIR. 4715.21, CLIMATE CHANGE ADAPTATION AND RESILIENCE (14 Jan. 2016) (establishing policy and assigning responsibilities "to provide the DoD with the resources necessary to assess and manage risks associated with the impacts of climate change").

[160] Mancillas, *supra* note 11, at 7.

[161] *See* Paul Lienert, *Exclusive: Automakers to Double Spending on EVs, Batteries to $1.2 Trillion by 2030*, REUTERS TECH. (Oct. 25, 2022) (emphasis added), https://www.reuters.com/technology/exclusive-automakers-double-spending-evs-batteries-12-trillion-by-2030-2022-10-21. Unfortunately, much of that investment will occur overseas. *See id.*

[162] *Id.*

[163] *See* Mancillas, *supra* note 11, at 7.

[164] *Id.*; *see* 2023 DOD OES, *supra* note 93, at 14.

manufacturing base, an unbearable risk for DoD if it ignores the many advantages of hybrid-electrification before it is too late.[165]

In light of these recent commercial advances and investment in HED innovation, DoD leaders and defense industry experts increasingly hail the possibilities for what the future DoD ground fleet might look like.[166] A comprehensive DoD acquisition strategy could involve procuring electrification kits to retrofit on its over 200,000 TWVs and GCVs, giving them at least mild-HED capabilities. Simultaneously, concerted DoD acquisition programs would develop and field thousands of new, purpose-built HE TWVs and GCVs to capitalize on the countless benefits of multiple energy sources while replacing its aging vehicle fleet over the next two decades.[167] For example, these new HE TWVs and GCVs could have smaller ICEs to support longer range, higher speed movements, as well as advanced electric motors and traction battery packs that utilize interchangeable or "swappable" high-energy-density batteries like SSBs for rapid replacement during a unit's combat operations.[168] These vehicles might also have external plug-in charging capabilities and solar paint for more expedient or on-the-move recharging capabilities.[169] All these additional power generation tools would further support the countless onboard electrical systems that increase users' lethality and survivability, such as those powering lighter reactive armor,

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[165] *See id.*

[166] *See* Josh Luckenbaugh, *JUST IN: All-Electric Army Vehicles Are Years away but Hybrids Are Rolling Out, Official Says*, NAT'L DEF. (Feb. 28, 2023), https://www.nationaldefensemagazine.org/articles/2023/2/28/ army-currently-focused-on-hybrid-rather-than-all-electric-vehicles-official-says.

[167] *See* Finke & Hess, *supra* note 67.

[168] *See id.*

[169] *See id.*; *U.S. Army Finds Growing Value in Paint Technology Center*, MATERIALS PERFORMANCE (Jul. 27, 2022), https://www.materialsperformance.com/news/2022/07/us-army-finds-growing-value-in-paint-technology-center; *see also* Troy Carter, *Army Invents New Business Opportunity: Smart Solar Controller for Vehicle Batteries*, TECH. LINK CTR. (Mar. 3, 2020), https://techlinkcenter.org/news/solar-can-save-the-us-army-17-million-in-vehicle-batteries (discussing the Army's patent-pending solar micro-panels to charge battery systems on legacy tactical and combat vehicles as well as the future possibility of companies licensing the technology for future innovation).

directed energy systems, and various counter-UAS, targeting, defense, and communication systems.[170] With less maintenance needs to keep each of these HEVs moving, the logistics workforce to maintain this sustainment infrastructure could rely on fewer but higher-skilled technicians.[171]

In sum, in light of increasing industry investment and technological advances, if DoD policymakers sufficiently prioritize and fund HED innovation for U.S. ground forces now, the most significant limitation on future TWV acquisition programs might simply be the imagination of those developing such technology.[172] Nevertheless, while engineering creativity in vehicle design merely provides a ceiling for future HE TWV acquisition programs, DoD's systems to procure those vehicles provide the remaining structure.[173]

D. How the DoD Acquires its Ground Vehicles

With an understanding of the DoD's current ground vehicle fleet and the increasing availability of innovative HED options, one must appreciate DoD's typical acquisition procedures to acquire such capabilities. This Section first presents the overarching framework and goals that guide the

[170] *See* Finke & Hess, *supra* note 67; Mancillas, *supra* note 11, at 7. "Enabling war-fighting capabilities such as Directed Energy Weapons [(DEW)] is a big deal. Every time we press the button on a missile, we send up $100,000 or more. A directed energy weapon shot is about $20. Re-arming the system [means simply] refueling the vehicle. In this era of UAVs, DEW flips the cost game and solves an ammo problem." E-mail from Dean McGrew, Dean McGrew, Branch Chief, Powertrain Electrification, GVSC, DEVCOM, AFC) to author (Mar. 15, 2024, 15:27 EDT) [hereinafter E-mail 1, McGrew] (on file with author).

[171] *See* Mancillas, *supra* note 11, at 7; *see also* Video Interview with Michael B. Smith, Operational Energy Capability Developer, Sustainment Capability Development Integration Directorate (CDID), Army Futures Command (AFC), Futures & Concepts Center (FCC) (Mar. 12, 2024) [hereinafter Video Interview, Smith] (notes on file with author) (discussing the sustainment advantages of HE TWVs and GCVs over legacy ICE vehicles, including their significantly lower maintenance requirements and refueling needs).

[172] *See* Finke & Hess, *supra* note 67.

[173] *See* E-mail from Dr. John Putrus, Branch Chief, Electrification, Joint Project Office–Joint Light Tactical Vehicle (JPO-JLTV), U.S. Army Program Executive Office, Combat Support & Combat Service Support (PEO-CS&CSS) (Mar. 19, 2024, 11:31 EDT) [hereinafter E-mail, Putrus] (on file with author).

Federal acquisition system.[174] Second, it examines the three interconnected systems in DoD acquisitions.[175] Third, it briefly discusses past reform efforts by DoD to improve the efficiency and performance of its MDAPs, culminating in the establishment of the AAF.[176] Fourth, it explores the specific acquisition approaches and contracting strategies that DoD typically employs in procuring its TWVs.[177]

1. Federal Acquisitions, Generally

Seeking to understand the DoD's acquisition processes first demands an appreciation for the broader goals of U.S. government procurement systems.[178] In his article, *Desiderata: Objectives for a System of Government Contract Law*, Professor Steven Schooner examines what he argues are the nine goals of government procurement systems: (1) competition; (2) integrity; (3) transparency; (4) efficiency; (5) customer satisfaction; (6) best value; (7) wealth distribution; (8) risk avoidance; and (9) uniformity.[179] Often used interchangeably with the term "procurement," the U.S. government "acquisition" system, in particular, constantly seeks to maximize three of those as overarching pillars: "system transparency; procurement integrity; and competition."[180]

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[174] *See infra* notes 178–192 and accompanying text.

[175] *See infra* notes 193–**Error! Bookmark not defined.** and accompanying text.

[176] *See infra* notes 220–230 and accompanying text.

[177] *See infra* notes 231–316 and accompanying text.

[178] *See* Steven Schooner, *Desiderata: Objectives for a System of Government Contract La*w, 11 PUB. PROCUREMENT L. REV. 103, 104 (2002).

[179] *Id.* For an elaboration of how the U.S. governments procurement system seeks to accomplish these goals, *see id.* The term "desiderata" is defined as "something desired as essential." *Deridata,* MERRIAM-WEBSTER DICTIONARY, https://www.merriam-webster.com/dictionary/desiderata (last visited Apr. 11, 2024)

[180] *See* Schooner, *supra* note 178, at 104. "While procurement implies a process of obtaining goods or services, the word also refers to a specific title and associated accounts within the annual National Defense Authorization Act (NDAA) and Department of Defense Appropriations Act." ALEXANDRA NEENAN, CONG. RSCH. SERV., IF10599, *Defense Primer: Procurement* 1 (2023) [hereinafter IF10599]; *see* HEIDI PETERS, CONG. RSCH. SERV., RL34026, *Defense Acquisitions: How DOD Acquires Weapon Systems and Recent Efforts to Reform the Process* 1 (2014). Although the DoD sometimes uses the terms "acquisition" and "procurement" interchangeably—as does this thesis, at times—to describe all contracting functions, the DoD now makes

Government acquisitions imply much more than the simple purchase of a product, system, or service.[181] For MWS procurement, the term also "encompasses the design, engineering, construction, testing, deployment, sustainment, and disposal of weapons or related items purchased from a contractor."[182] To achieve these goals for any new acquisition, federal acquisition leaders look to the Federal Acquisitions Regulation (FAR).[183] To empower the federal acquisitions workforce to effectively and innovatively contract on behalf of the U.S. government, the FAR's guiding principles provide four basic tenets that mirror those Schooner identifies in *Desiderata*: (1) Satisfy the customer in terms of cost, quality, and timeliness of the delivered product

distinctions. *See* Shari Ingerman, *Procurement vs. Acquisition: Top Differences for Government Leaders, Explained*, APPIAN (Apr. 27, 2023), https://appian.com/blog/acp/public-sector/procurement-vs-acquisition.html. Although Federal agencies predominantly used the word "procurement" until the late 1970s, the DoD and FAR councils clarified that "acquisitions" was the correct term and that procurement was a process within the DAS (including the two phases of "production & deployment" and "operations & support"). *See* Ingerman, *supra*; *see* FAR 2.101 (2024) ("*Acquisition* means the acquiring by contract with appropriated funds of supplies or services (including construction) by and for the use of the Federal Government through purchase or lease, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated. . . ."); *see also* FAR 2.101 (2024) (defining procurement as "see 'acquisition'"). In contrast to "acquisition," which the FAR considers to be the entire process from identification of a need through the contracting steps to fill that need, the Congressional Research Service considers a program entering "procurement" as follows:

> Programs that produce a major capability (e.g., an aircraft carrier or armored fighting vehicle) usually enter procurement after they receive Milestone C approval in the Defense Acquisition System. Prior to procurement, programs are considered to be in development and generally funded through Research, Development, Test and Evaluation (RDT&E) appropriations. Some programs will receive procurement funds before a formal Milestone C approval.

IF10599, *supra*, at 2; *see* FAR 2.101 (2024).

[181] *See Course 11, Tutorial 1, Department of Defense (DOD) Acquisition Basics*, AMERICA'S SEED FUND: SMALL BUSINESS INNOVATION RESEARCH (SBIR) & SMALL BUSINESS TECHNOLOGY TRANSFER (STTR), U.S. SMALL BUS. ADMIN. 11/1-1 [hereinafter SBIR, *Acquisition Basics*], https://www.sbir.gov/sites/all/themes/sbir/dawnbreaker/img/documents/Course11-Tutorial1.pdf (last visited Apr. 11, 2024).

[182] *Id.*

[183] *See Innovation and the FAR Guiding Principles*, Fed. Acquisition Inst. (Apr. 12, 2022), https://www.fai.gov/media-library/item/innovation-and-far-guiding-principles. "The vision for the Federal Acquisition System is to deliver on a timely basis the best value product or service to the customer, while maintaining the public's trust and fulfilling public policy objectives." FAR 1.1.02(a) (2024).

or service; (2) minimize administrative operating costs; (3) conduct business with integrity, fairness, and openness; and (4) fulfill public policy objectives.[184]

For example, as support of the first tenant, the FAR requires maximizing the use of commercial products and services and employing methods to promote competition among potential contractors.[185] Notwithstanding this preference to seek commercial products, acquiring MWSs typically requires developing unique items or components for which industry has no commercial markets.[186] The processes used to acquire these systems must therefore reflect the complexity and diversity of DoD's and its Services' unique warfighting needs.[187]

To meet the third tenet, FAR Part 6.102 "require[s], with certain limited exceptions . . . , that contracting officers shall promote and provide for full and open competition in soliciting offers and awarding Government contracts."[188] Full and open competition in federal contracting

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[184] *See* FAR 1.1.02(b) (2024).

[185] *See id.* Relatedly, the Competition in Contracting Act (CICA), implemented through FAR Part 6, "establishes a statutory preference for competition that shapes government procurement from acquisition planning, through market research, to developing specifications and publicizing." CONTRACT AND FISCAL L. DEP'T, THE JUDGE ADVOC. GEN.'S LEGAL CTR. & SCH., CONTRACT ATTORNEYS DESKBOOK para. 5-44 (2023). [hereinafter CONTRACT ATTORNEY'S DESKBOOK]; *see* Competition in Contracting Act (CICA) of 1984, Pub. L. No. 98-369, §§ 2701–2753, 98 Stat. 494, 1175–1203, 41 U.S.C. § 253(a)(1) (1984). *See generally* FAR 6 (2024) ("Competition Requirements").

[186] *See* WONG ET AL., *supra* note 40, at 20.

[187] *See id.*

[188] FAR 6.102 (2024); *see* FAR 6.101 (2024). The two exceptions to the FAR's requirement of full and open competition are described in FAR Subpart 6.2 ("full and open competition after exclusion of sources") and Subpart 6.3 ("other than full and open competition"). *See* FAR 6.2 (2024); FAR 6.3 (2024). The GAO provides the following explanation of the Federal government's requirement of full and open competition:

> The Competition in Contracting Act (CICA) of 1984 requires agencies to obtain full and open competition through the use of competitive procedures in their procurement activities unless otherwise authorized by law. Using competitive procedures to award contracts means that all prospective contractors are permitted to submit proposals. Agencies generally are required to perform acquisition planning and conduct market research to promote full and open competition. Generally, noncompetitive contracts must be supported by a written justification and approval document that addresses the specific exception to full and open competition that applies to the procurement. Each such document must contain sufficient facts and rationale to justify the use of the specific exception to competition. The allowable exceptions to full and open competition are identified in the Federal Acquisition Regulation (FAR). Exceptions include circumstances when only one source is capable of performing the requirement or when

specifically requires agencies to fairly, efficiently, and transparently engage would-be bidders using competitive procedures like sealed bidding, requests for proposals (RFPs), or a combination of the two.[189] Although contracting officers must generally use such competitive procedures to solicit offers and award contracts, "limited exceptions" may allow departure from this requirement if contracting officers can justify using "full and open competition after exclusion of sources" or "other than full and open competition."[190]

The unique mission and needs of DoD often necessitate its MWS acquisition programs resort to these limited exceptions.[191] Nevertheless, the sophisticated structure of DoD's three interwoven

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> an agency's need is of such unusual and compelling urgency that the government would be seriously injured unless the agency is permitted to limit the number of sources.

U.S. GOV'T ACCOUNTABILITY OFF., GAO-15-484R, DEFENSE CONTRACTING: DOD'S USE OF COMPETITIVE PROCEDURES 7 (2015); *see* 41 U.S.C. § 253(a)(1).

[189] *See* FAR 6.102. A combination of competitive procedures includes, for example, two-stepped sealed bidding, which involves "a combination of competitive procedures designed to obtain the benefits of sealed bidding when adequate specifications are not available." FAR 14.501 (2024). Step one involves the agency requesting and evaluating technical proposals from industry, and step two involves receiving and evaluating sealed bids from those who submitted acceptable technical proposals in step one. *See* FAR 14.501(a), (b) (2024).

[190] U.S. GOV'T ACCOUNTABILITY OFF., GAO-12-263, DEFENSE CONTRACTING: IMPROVED POLICIES AND TOOLS COULD HELP INCREASE COMPETITION ON DOD'S NATIONAL SECURITY EXCEPTION PROCUREMENTS 3 (2012) [hereinafter GAO-12-263]; *see* FAR 6.3. The FAR provides seven situations under the "other than full and open competition" exception: (1) only one responsible source and no other supplies or services will satisfy agency requirements; (2) unusual and compelling urgency; (3) industrial mobilization; engineering, developmental, or research capability; or expert services; (4) international agreement; (5) authorized or required by statute; (6) national security; and (7) public interest. *See* FAR 6.302 (2024); GAO-12-263, *supra* note 190, at 3. "The [CICA] established these seven exceptions to competition, which are often referred to as CICA exceptions, [and] Subpart 6.3 of the FAR implements the CICA exceptions." GAO-12-263, *supra* note 190, at 3 n.3; *see* 41 U.S.C. § 253(c); FAR 6.302 (2024).

[191] *See* GAO-12-263, *supra* note 190, at 3. Many MDAPs rely on the first exception, "full and open competition after exclusion of sources," due to the limited DIB and capacity for contractors to meet DoD's needs. *Id*.; *see* FAR 6.2 (2024). Additionally, the DoD often uses the other CICA exceptions and "is the largest user of the national security exception." *See* GAO-12-263, *supra* note 190, at 3. Like other Federal agencies, although it still "must promote competition to the maximum extent practicable," the DoD is also not required to use full and open competitive procedures "[f]or the acquisition of supplies and services, including construction, research and development, commercial products, and commercial services, the aggregate amount of which does not exceed the simplified acquisition threshold." *See* FAR 13.000 (2024); FAR 13.104 (2024).

acquisitions systems allows programs to still balance the overarching tenets of government procurement as they acquire systems to meet warfighters' needs.[192]

2. The Three DoD Acquisition Systems

With an appreciation for the broader principles and tenets of federal acquisitions, understanding the interconnected nature of the three systems of defense acquisitions becomes more intuitive. Any new MWS must proceed through three basic steps before its fielding to the warfighter: identifying the user's need or requirement, establishing a budget to fund a product or system to meet that requirement, and acquiring the product or system.[193] These steps correlatingly fall into three separate but intertwined systems.[194] These three systems "must work together, as an acquisition program won't begin unless there are identified warfighter needs, and can't start until there is money to support the initiative."[195] Understanding the immense, connected machine of defense acquisitions—including its main points of friction and inefficiency—demands examining each process on its own.

First, the Joint Capabilities Integration and Development System (JCIDS) is the initial needs-based process to identify warfighter requirements and evaluation criteria for future defense programs.[196] In contrast to previous DoD systems that focused purely on examining potential

[192] *See Acquisition Process Overview*, ACQNOTES, https://acqnotes.com/acqnote/acquisitions/acquisition-process-overview (last visited Apr. 11, 2024).

[193] *See id.*

[194] *See* SBIR, *Acquisition Basics*, *supra* note 181, at 11/1-2.

[195] *Id*.

[196] *See* SBIR, *Acquisition Basics*, *supra* note 181, at 11/1-2. The purpose of the JCIDS "is to enable the Joint Requirements Oversight Council (JROC) to execute its statutory duties to assess joint military capabilities, and identify, approve, and prioritize gaps in these capabilities, to meet applicable requirements in the National Defense Strategy (NDS)." U.S. DEP'T OF DEF., JOINT CHIEFS OF STAFF (JCS), MANUAL FOR THE OPERATIONS OF THE JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM (JCIDS) encl. A, para. 1 (30 Oct. 2021) [hereinafter JCIDS MANUAL].

threats to identify needs, the JCIDS provides a *capabilities-based* approach, which both analyzes the risks associated with future threats and considers current joint military capabilities gaps in the context of all the Services.[197] The JCIDS supports the NDS by enabling the Joint Requirements Oversight Council (JROC), which serves as the principal advisor on Joint Force (JF) requirements to the Chairman of the Joint Chiefs of Staff (CJCS), to identify major capability gaps and validate whether a DoD agency's proposed capability will fulfill those gaps.[198] The JROC must constantly stay abreast of "advances in technology and concepts of operation" to identify new capabilities and review the performance requirements of proposed joint military capabilities for the Services' acquisition programs.[199]

The exhaustive review and validation requirements of the JCIDS produces several key documents that acquisition programs need to move to each subsequent step.[200] If managed

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[197] CHAIRMAN, JOINT CHIEFS OF STAFF, INSTR. 5123.01I, CHARTER OF THE JOINT REQUIREMENTS OVERSIGHT COUNCIL AND IMPLEMENTATION OF THE JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM encl. A, para. 1 (30 Oct. 2021) [hereinafter CJCSI 5123.01I]. "The term 'joint military capabilities' means the collective capabilities across the JF, including both joint and force-specific capabilities that are available to conduct military operations." *Id*. at A-4. The DoD developed the JCIDS in the early 2000s to reduce the redundancies and insufficient analyses rampant across the previous regime of Service-specific methods of evaluating requirements and generating potential solutions. *See* SBIR, *Acquisition Basics*, *supra* note 181, at 11/1-2.

[198] *See* CJCSI 5123.01I, *supra* note 197, at A-1. A proposed capability may involve developing either a new physical system (materiel solution) or a new training or procedure (non-materiel solution). *See id.* To meet its broad requirements-generation mission, the JCIDS is under the leadership of the CJCS's J-8 (Force Structure, Resource, and Assessment Directorate) and the JROC, which serves as the CJCS's council to recommend approval or denial of joint capabilities acquisition programs. The JROC is composed of the Vice Chairman of the Joint Chiefs of Staff and an appointed General/Admiral from each of the five Services. *Id.* at A-3. Despite the centralized nature of leadership, the JCIDS's effectiveness to evaluate needs and develop capabilities relies on the expertise of various JROC advisors as well as continuous military input from combatant commanders, Service Chiefs, and Service-specific futures and concepts subordinate entities (e.g., Army Futures Command and similar Navy and Air Force entities). However, critical to the success of any acquisition program's development is user input from the ground up. *Id.*

[199] *See id.* at A-2. JCIDS also requires the JROC to assist the Chairman of the Joint Chiefs of Staff to establish and approve joint performance requirements to "[e]nsure interoperability, where appropriate, between and among joint military capabilities" as well as to identify alternatives to proposed acquisition programs. *Id*.

[200] *See id*. For example, to proceed to the first acquisition phase, Material Solutions Analysis, PMs must have an approved Initial Capabilities Document (ICD), which specifies one or more capabilities requirements (CRs), identifies "associated capability gaps that represent unacceptable operational risk if left unmitigated," and recommends materiel or non-materiel solutions. *Id*.

effectively, this otherwise lengthy process provides long-term benefits for an MWS acquisition program, such as eliminating the need to reroute requests for procuring related advanced technology if sought for the purpose of updating a previously approved system.[201] In sum, despite the cumbersome, bureaucratic nature of JCIDS, its deliberate systems ensure that DoD prioritizes filling joint warfighting capabilities gaps as efficiently, effectively, and input-driven as possible.[202]

Second, the Planning, Programming, Budgeting, and Execution System (PPBE) is a schedule-based process that "serves as a framework for [DoD] civilian and military leaders to decide which programs to fund based on strategic objectives and produces the [DoD's] portion of the President's annual budget request."[203] In other words, DoD uses the PPBE to "translate[] strategic guidance into resource allocation decisions [(i.e., budgeting)], resulting in *funding*."[204]

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[201] *See id.* at D-21.

[202] *See* JCIDS MANUAL, *supra* note 196, at A-1.

[203] BRENDAN MCGARRY, CONG. RSCH. SERV., R47178, *DOD Planning, Programming, Budgeting, and Execution (PPBE): Overview and Selected Issues for Congress* Summary (2022) [hereinafter R47178]. The major product of the first three phases is DoD's budget request, which is included in the President's Budget (PB) submitted to Congress at the beginning of each year for it to consider when allocating funds to DoD programs through the subsequent FY's NDAA and DoD Appropriations Act. *See Planning, Programming, Budgeting & Execution Process (PPBE)*, DEF. ACQUISITION U. [hereinafter DAU, *PPBE*], https://www.dau.edu/acquipedia-article/planning-programming-budgeting-execution-process-ppbe (last visited Apr. 11, 2024). Since its inception in 1961, the PPBE's ultimate mission is "to provide DoD components and various Combatant Commanders (COCOMs) with the optimal mix of forces, equipment, and support that are attainable within established fiscal constraints." *See* DAU, *PPBE*, *supra*.

[204] R47178, *supra* note 203, at 5; *see* U.S. DEP'T OF DEF., DIR. 7045.14, THE PLANNING, PROGRAMMING, BUDGETING, AND EXECUTION (PPBE) PROCESS para. 10.b. (Jan. 25, 2013) (C1, Aug. 29, 2017) [hereinafter DODD 7045.14]; SBIR, *Acquisition Basics*, *supra* note 181, at 11/1-2. The PPBE involves four separate but overlapping processes: Planning, Programming, Budgeting, and Execution. *See* R47178, *supra* note 203, at 1. The DoD intends the PPBE to serve as as "the annual resource allocation process for DoD within a quadrennial planning cycle." DODD 7045.14, *supra*, at para. 4.a. Although the Deputy Secretary of Defense (DEPSECDEF) oversees the PPBE process, there are numerous supporting players and decision-making bodies within OSD, the military departments, and defense agencies that keep the annual, four-part process moving. *See* R47178, *supra* note 203, at 2–3. Those in the OSD with key roles in the PPBE process include the Under Secretary of Defense for Policy, Director of the Cost Assessment and Program Evaluation, and Under Secretary of Defense (Comptroller). *See* R47178, *supra* note 203, at 2. Those in the military departments with key roles in the PPBE process include the CJCS, Service chiefs, commanders of the combatant commands, and the Chief of the National Guard Bureau. *See* R47178, *supra* note 203, at 2. "The CJCS's role is, in part, to advocate for solutions to department-wide requirements." *See* R47178, *supra* note 203, at 2–3. Congress also "authorizes and appropriates funding for [the DoD], the amount and timing of which can affect activities conducted in various

Largely in its same form since the Cold War, the PPBE is also the frequent target of calls for internal DoD and external congressional reform.[205] Some criticize the PPBE for its unreasonably long two-year planning timelines, which relies on an "'industrial-era' approach" that overly focuses on large, costly capital expenditures (e.g., aircraft carriers, strategic bombers, etc.) but creates "barriers for integrating advancements in [certain other] technology in a timely and effective manner."[206] Still, many others defend PPBE processes that provide DoD flexibility in amending its budget requests, submitting supplemental requests to Congress, and using existing or amended authorities provided by Congress to reprogram or transfer funds to respond to changing defense priorities.[207] This flexibility is key, given the PPBE's role in allocating funds to ultimately enable the acquisition and procurement of new warfighting capabilities like HED for TWVs.[208]

The third DoD acquisition process is the Defense Acquisition System (DAS).[209] Whereas the JCIDS is needs-driven and the PPBE is calendar-driven, the DAS is an *event-driven* process focusing on the research, development, procurement, and fielding of an item or system.[210] The DAS is the "process by which DoD manages the development and purchase of products and services,

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phases of the process. Congress also provides limited authority for DoD to transfer and reprogram funds, which can affect the activities typically conducted in the final phase of the process." R47178, *supra* note 203, at 3.

[205] *See* COMM'N ON PLAN., PROGRAMMING, BUDGETING, & EXECUTION REFORM, U.S. SENATE, INTERIM REPORT 2, 15 (Aug. 2023); Jerry McGinn, *How to Use the 'MRAP Mindset to Get US Industrial Base on a Wartime Footing*, BREAKING DEF. (Jan. 3, 2024), https://breakingdefense.com/2024/01/how-to-use-the-mrap-mindset-to-get-us-industrial-base-on-a-wartime-footing.

[206] R47178, *supra* note 203, at 18; *see* J. Michael McQuade et al., *Final Report of the Defense Innovation Board (DIB) Software Acquisition and Practices (SWAP) Study, Software Is Never Done: Refactoring the Acquisition Code for Competitive Advantage*, DEF. INNOVATION BD., U.S. DEP'T OF DEF. S134 (May 3, 2019), https://media.defense.gov/2019/Apr/30/2002124828/-1/-1/0/SWAP.REPORT.PDF.

[207] R47178, *supra* note 203, at Summary.

[208] *See id.*

[209] *See* U.S. DEP'T OF DEF., DIR. 5000.01, THE DEFENSE ACQUISITION SYSTEM para. 1.2 (Sept. 9, 2020) (C1 July 28, 2022) [hereinafter DODD 5000.01].

[210] *See* DAU, *PPBE*, *supra* note 203; R47178, *supra* note 203, at 5, 10.

resulting in *acquisition* (sometimes referred to as 'Little A' acquisition)."[211] Governed by DoD Instruction (DoDI) 5000.01, the DAS is divided into five phases, each of which interacts with the JCIDS to ensure the capabilities being developed continue to meet the need and with the PPBE to ensure continued funding for each phase of a program.[212] Moving from one phase to the next requires a program to meet certain milestones, produce key documents, and maintain communication with the other two acquisition processes.[213]

Although the interaction between these three defense acquisitions processes appears complex in theory, a hypothetical acquisition illustrates how these processes work in practice. Initially, the JCIDS process might involve a specific Army CDID, such as Sustainment CDID, interacting with ground formations to understand their users' changing needs for a novel capability like a purpose-built, HE FMTV.[214] After the appropriate PEO creates an ICD for the capability, the PPBE

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[211] *See* R47178, *supra* note 203, at 5. The purpose of DAS is elaborated in DODD 5000.01:

> The objective of the Defense Acquisition System (DAS) is to support the National Defense Strategy, through the development of a more lethal force based on U.S. technological innovation and a culture of performance that yields a decisive and sustained U.S. military advantage. The acquisition system will be designed to acquire products and services that satisfy user needs with measurable and timely improvements to mission capability, material readiness, and operational support, at a fair and reasonable price.

DoDD 5000.01, *supra* note 209, para. 1.2.

[212] SBIR, *Acquisition Basics*, *supra* note 181, at 11/1-2; *Defense Acquisition System Overview*, DEF. ACQUISITION U. (Sep. 3, 2021) [hereinafter DAU, *DAS Overview Video*], https://www.youtube.com/watch?v=EgkEGsIrcKQ. *See generally* DoDD 5000.01, *supra* note 209 (providing the purpose of the DAS).

[213] *See* SBIR, *Acquisition Basics*, *supra* note 181, at 11/1-2. Moving from one stage to the next might mean, for example, progressing from the second phase (initial R&D and competitive prototyping and demonstration of critical technologies) to the third phase (completing the build-to design, proving the design works through testing, and proving the design is manufacturable). For a more detailed discussion of the five phases and three milestones of the DAS, *see id.* The five phases of the DAS are: (1) Materiel Solution Analysis; (2) Technology Maturation and Risk Reduction; (3) Engineering and Manufacturing Development; (4) Production and Development; and (5) Operations and Support. Each of the first three phases has an accompanying milestone at the end that establishes documentation standards to move on to the next phase. *Id.* The phases are also generally grouped into three broader stages: Pre-systems Acquisition (phases one and two); Systems Acquisition (phases two and three); and Sustainment (phase 5). *See id.* For a comprehensive video explanation of the DAS, see DAU, *DAS Overview Video*, *supra* note 213.

[214] *See id.*; CONTRACT ATTORNEY'S DESKBOOK, *supra* note 185, at 5-32.

process requests and allocates funds to the respective program and specific project from the respective appropriation.[215] This triggers the Material Solution Analysis (MSA) phase to select the most promising technology that can meet the users' needs.[216] Interaction continues between DAS and JCIDS personnel throughout the phase to draft a Capability Development Document (CDD), as well as between DAS and PPBE personnel to secure funding for Milestone A.[217]

The three processes thus intertwine as they proceed through the three milestones and remaining phases of the DAS, including engaging in competitive prototyping and demonstrations of the vehicle, low rate initial production (LRIP), limited deployment, and, ultimately, full rate production (FRP) and fielding of the new vehicles across those ground forces in need.[218] As DoD

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[215] *See* DAU, *PPBE*, *supra* note 203; DAU, *DAS Overview Video*, *supra* note 213.

[216] *See* DAU, *PPBE*, *supra* note 203; DAU, *DAS Overview Video*, *supra* note 213.

[217] *See* DAU, *PPBE*, *supra* note 203; DAU, *DAS Overview Video*, *supra* note 213. At Milestone A, the JCIDS authority must validate the CDD, triggering the "Technology Maturation & Risk Reduction" phase to begin. The respective JCIDS and PPBE leaders then must review and approve the Development Request for Proposals Release Decision (DRFPRD), granting the PEO program manager permission to release an RFP from industry. Once published, RFPs typically cannot change significantly without creating greater risk of litigation, so DoD policymakers consider this the most crucial decision point for an acquisition program's long-term contracting strategy. *See* DAU, *DAS Overview Video*, *supra* note 213. In general, DoD acquisition leaders characterize the DRFPRD as the following:

> [T]he key decision in the overall life cycle of the program . . . because once [DAS] put[s] that out in writing in terms of your requirements for the program, it's going to go into a contract eventually. There's not a lot you can do to make major changes in that without major perturbations in your program, so it has a lot of momentum once you make this decision and put that request for proposals out on the street.

DAU, *DAS Overview Video*, *supra* note 213.

[218] *See* DAU, *DAS Overview Video*, *supra* note 213. The term LRIP refers to "[t]he first part of the Production and Deployment (P&D) phase[, which] is intended to result in completion of manufacturing development in order to ensure adequate and efficient manufacturing capability and to produce the minimum quantity necessary to" determine follow-on production needs and eventually conduct an FRP decision review. *See Major Capability Acquisition (MCA): Low Rate Initial Production (LRIP) and Limited Deployment*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/mca/lrip (last visited Apr. 11, 2024); *see also Major Capability Acquisition (MCA): Full Rate Production (FRP) Decision*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/mca/production-decision (last visited Apr. 11, 2024) (discussing the process of conducting a FRP decision review). The three processes carry on in this way through the remaining two milestones and three phases of the DAS. Even after all this, the "Operations and Sustainment" phase of the DAS (and its connected processes in the JCIDs and PPBE) continue to ensure sustainment of the vehicles and regular reassessment of the acquisition program's effectiveness

refined these processes over the last several decades, it also implemented several useful reforms to maintain clarity across an otherwise complicated acquisitions process.[219]

3. Historical DoD Acquisition System Reforms: Focusing on Procedure

Over the past four decades since the Cold War, following the subsequent decrease of DoD's budget and the shrinking of the DIB, Congress spent considerable attention, time, and resources to improve defense acquisition efficiency.[220] The focus of many of these efforts since 1986 was three-fold: (1) improving acquisitions processes; (2) seeking commercial products rather than building components with rigid military design specifications; and (3) minimizing MWS programs' schedule delays and cost overruns.[221] Although DoD made significant gains as to the first and second goals, it often fell short in meeting the third.[222]

Most of the major improvements in federal and DoD acquisitions over the last four decades can be traced to the Goldwater-Nichols Department of Defense Reorganization Act of 1986 ("Goldwater-Nichols Act"), which many consider "the most significant contribution to defense acquisition reform in modern history." [223] Notwithstanding its increase of bureaucratic processes,

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throughout the vehicles' life cycle, which is often decades for TWVs. *See* DAU, *DAS Overview Video*, *supra* note 213.

[219] *See* WONG ET AL., *supra* note 40, at 25.

[220] *See* Walter, *supra* note 50, at 15.

[221] WONG ET AL., *supra* note 40, at 25.

[222] *See id*.

[223] Major Dale P. Bond et al., The Goldwater-Nichols Act of 1986: 30 Years of Acquisition Reform I (Thesis, Acquisition Rsch. Program, Graduate Sch. of Bus. & Pub. Pol'y, Naval Postgraduate School), https://dair.nps.edu/bitstream/123456789/2192/1/NPS-AM-17-027.pdf; *see* Goldwater-Nichols Department of Defense Reorganization Act of 1986, Pub. L. No. 99-433, 100 Stat. 992, 993 (1986). The result of several extensive, President-directed assessments of DoD acquisitions, the Goldwater-Nichols Act continues to provide Congress and DoD policymakers inspiration for acquisitions improvement. Bond et al., *supra*, at 1–2; *see* § 3, 100 Stat. at 993. The underlying assessment that led to the act was focused on nine major areas formulated from the 1985 Blue Ribbon Commission on Defense Management ("Packard Commission"). Bond et al., *supra*, at 1–2; *see* EXEC. ORDER 12526, PRESIDENT'S BLUE RIBBON COMMISSION ON DEFENSE MANAGEMENT (July 15, 1985); David Packard, Chairman, President's Blue Ribbon Commission on Defense Management xi (June 1986) [hereinafter Blue-Ribbon Commission]. The commission and resulting reform measures in the act

the Goldwater-Nichols Act prompted several additional attempts at reforming the acquisition system in the subsequent twenty years.[224]

Despite those reforms, MDAPs' costs and schedule deficiencies continued to provoke congressional dissatisfaction, resulting in the Weapon System Acquisition Act of 2009 and multiple National Defense Authorization Acts' (NDAAs') reorganizations of DoD acquisitions leadership structure.[225] Recent congressional reform efforts implied "a stronger DoD and congressional interest in enabling greater adaptability, flexibility, and innovation to make the acquisition enterprise fit for addressing the challenges of peer competitors in an environment dominated by advancing commercial technologies."[226]

"included streamlining acquisition organization and procedures, using technology to reduce cost, balancing cost and performance, stabilizing programs (funding), using more commercial products where possible, increasing competition, clarifying the need for technical data rights, improving the acquisition workforce, and improving industrial mobilization" Bond et al., *supra*, at 2; *see* Blue Ribbon Commission, *supra*, at 52–71. The act targeted "big A" acquisition by considering all three components of defense acquisitions (e.g., requirements generation of JCIDs, budgeting and funding of PPBE, and acquisition of DAS), and it ultimately directed the establishment of the Office of the Under Secretary of Defense for Acquisition (USD(A)) and a similar structure of service component acquisition executives in authority over program executive officers (PEOs) and project managers (PMs). Bond et al., *supra*, at 1; *see* §§ 103, 104, 100 Stat. at 996. This reorganization of the acquisition enterprise shifted power from the military Services to centralized oversight and authority that involved more civilians, resulting in what some scholars characterize as "a division between a civilian-run acquisition process and a military-run requirement process that is 'inimical to the efficient and effective support of military forces and antithetical to the spirit of the legislation.'" WONG ET AL., *supra* note 40, at 25–26, *citing* CHARLES NEMFAKOS ET AL., RAND CORP., OP-308-NAVY, THE PERFECT STORM: THE GOLDWATER-NICHOLS ACT AND ITS EFFECT ON NAVY ACQUISITION xi (2009).

[224] *See* Walter, *supra* note 50, at 15, 16. Following the Goldwater-Nichols Act, in the 1990s, further reform efforts led to the codification of the defense acquisition processes into three DoD 5000-series documents, later incorporated into one DoDD and one DoDI, which placed stronger emphasis on rapid prototyping, tailoring processes, and providing greater discretion to PMs use commercial products and practices in fielding systems. *See id.* In the early-2000s, the OSD, GAO, and three Services conducted further studies, resulting in some improvements and better evaluation tools to monitor MDAP effectiveness.[224] *See id.*

[225] The Weapon System Acquisition Act of 2009 attempted to clarify DoD leadership channels to better track cost estimation, test and evaluation, systems engineering, and technological maturity for the largest MDAPs. WONG ET AL., *supra* note 40, at 25–26. Even still, by the mid-2010s, "[l]egislators and senior DOD leaders . . . again [sought] revolutionary acquisition reform, calling for a 'Goldwater-Nichols II' with significant restructuring and realignment of priorities." Bond et al., *supra* note 223, at i.

[226] WONG ET AL., *supra* note 40, at 25–26. The FY 2016 and FY 2017 NDAAs first manifested this intent to make DoD acquisition more adaptive and innovative by splitting the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics in two. *Id.* at 26; *see* U.S. DEP'T OF DEF., REPORT TO CONGRESS: RESTRUCTURING THE DEPARTMENT OF DEFENSE ACQUISITION, TECHNOLOGY AND LOGISTICS ORGANIZATION AND CHIEF MANAGEMENT OFFICER ORGANIZATION, IN RESPONSE TO SECTION 901 OF THE NATIONAL DEFENSE

The DoD also sought internal improvements to increase MDAPs' adaptability, flexibility, and innovation. Most significantly, in 2020, DoD adopted the Adaptive Acquisition Framework (AAF), which seeks "to enable the workforce to tailor strategies [based on each program's needs] to deliver better solutions faster."[227] To do so, the AAF clarified the six acquisition pathways that Congress previously authorized: Urgent Capability Acquisition (UCA); Middle Tier of Acquisition (MTA); Major Capability Acquisition (MCA); Software Acquisition; Defense Business Systems Acquisition; and Defense Acquisition of Services.[228] Acknowledging "that the goals of the acquisition system may vary depending on the weapon system or program," the AAF allows PMs to exercise greater judgment and particularized assessment by selecting the most efficient and

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AUTHORIZATION ACT FOR FISCAL YEAR 2017 (PUBLIC LAW 114 - 328) 3 (Aug. 2017). The resulting two new offices were the Office of the Under Secretary of Defense for Research and Engineering (focused on developing innovative technologies) and the Office of the Under Secretary of Defense for Acquisition and Sustainment (focused on delivering proven technology more efficiently). *See* WONG ET AL., *supra* note 40, at 25–26. Beneficial to commanders, this most recent reorganization shifted more power over the acquisition process into the hands of the military Services, undoing some of the centralization of the Goldwater-Nichols Act. WONG ET AL., *supra* note 40, at 26.

[227] ADAPTIVE ACQUISITION FRAMEWORK, DEF. ACQUISITION U., https://www.dau.edu/cop/pm/documents/adaptive-acquisition-framework (last visited Apr. 11, 2024).

[228] WONG ET AL., *supra* note 40, at 27; *see* U.S. DEP'T OF DEF., INSTR. 5000.02, OPERATION OF THE ADAPTIVE ACQUISITION FRAMEWORK para. 4.2 (Jan. 23, 2020) (C1, June 8, 2022) [hereinafter DODI 5000.02]; *see also* U.S. DEP'T OF THE ARMY, REG. 70-1, ARMY ADAPTIVE ACQUISITION FRAMEWORK (23 Jan. 2020) (C1, 28 Nov. 2023) (implementing the AAF for Army acquisition processes). For a visual representation of the six AAF pathways, see Appendix E-1. The AAF's purpose is as follows:

> The AAF supports the DAS with the objective of delivering effective, suitable, survivable, sustainable, and affordable solutions to the end user in a timely manner. To achieve those objectives, Milestone Decision Authorities (MDAs), other Decision Authorities (DAs), and Program Managers (PMs) have broad authority to plan and manage their programs consistent with sound business practice. The AAF acquisition pathways provide opportunities for MDAs/DAs and PMs to develop acquisition strategies and employ acquisition processes that match the characteristics of the capability being acquired.

DODI 5000.02, *supra*, para. 1.3. For example, Congress previously established the MTA pathway in the FY 2016 NDAA. *See* National Defense Authorization Act for Fiscal Year 2016, § 804, Pub L. 114-92, 129 Stat. 726, 882 (2015) ("Not later than 180 days after the date of the enactment of this Act, the Under Secretary of Defense for Acquisition, Technology, and Logistics, in consultation with the Comptroller of the Department of Defense and the Vice Chairman of the Joint Chiefs of Staff, shall establish guidance for a 'middle tier' of acquisition programs that are intended to be completed in a period of two to five years.").

effective pathway for each acquisition program.[229] For example, a UCA would prioritize speed over cost and performance, while an MCA would place greater value on performance and life cycle costs.[230] Despite the promise that the AAF and other reforms offer DoD acquisitions in the future, the effectiveness of MDAPs relies on acquisition leaders selecting the best acquisition approaches and contracting strategies for each program.[231] This is particularly true for DoD's acquisition of its operational vehicles.

4. Typical Acquisition Approaches, Contracting Strategies, and Contract Types Employed by DoD's Acquisition Programs for Operational Vehicles

Until the last decade, acquisition leaders frequently employed similar, cumbersome acquisition approaches and contracting strategies, regardless of the uniqueness of each MDAP.[232] However, recent procedural improvements, like the six AAF pathways and Congress's authorizations of non-FAR-based contracting instruments, helped leaders better tailor those program decisions to each individual MDAP.[233]

a. Acquisition Approaches

Prior to the AAF, MDAPs typically took acquisition approaches akin to the MCA pathway, requiring lengthy hurdles to proceed through each step and produce all potentially necessary

[229] WONG ET AL., *supra* note 40, at 27.

[230] *See id*.

[231] *See id.* at 28.

[232] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105008, MIDDLE-TIER DEFENSE ACQUISITIONS, RAPID PROTOTYPING AND FIELDING REQUIRES CHANGES TO OVERSIGHT AND DEVELOPMENT APPROACHES 1 (2023) [hereinafter GAO-23-105008].

[233] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-21-222, WEAPON SYSTEMS ANNUAL ASSESSMENT, UPDATED PROGRAM OVERSIGHT APPROACH NEEDED 10, 11 (2021).

products even if they were inapplicable to the respective program.[234] Defense acquisition policy, in essence, provided a massive checklist of different documentation requirements and decision points that might apply to a given MDAP but that PMs were expected to tailor to each MDAP.[235] "This created a culture of 'what don't I have to do' versus really thinking through what makes sense to do given the capability being developed. In many instances[, PMs] did things that were neither effective nor useful, but doing them was actually easier than tailoring them out."[236]

After the AAF streamlined and clarified necessary processes, MDAPs now generally follow acquisition pathways that are better tailored to their respective needs.[237] For example, rather than initiating as a bulky MCA program at the outset, Army MDAPs requiring novel capabilities are increasingly using the MTA pathway, which "facilitate[s] rapid prototyping and rapid fielding of capabilities within [two] to [five] years of a program's start."[238] The DoD "generally exempts MTA programs from its traditional acquisition and requirement development policies," allowing for more streamlined development and demonstration phases for innovative capabilities.[239]

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[234] *See* GAO-23-105008, *supra* note 232, at 10; *DoDI 5000.85 – Major Capability Acquisition.* The exception was the DoD's MRAP acquisition program in 2006. *See* GAO-10-155T, *supra* note 50, at 3. However, that program was an anomaly in DoD vehicle acquisitions because the DoD designated it as its highest priority at the time due to the significant number of casualties in Iraq and Afghanistan from improvised explosive devices (IEDs). *See* GAO-10-155T, *supra* note 50, at 3. The DoD "awarded a sole source indefinite delivery, indefinite quantity (IDIQ) contract and subsequently placed orders for the first 144 vehicles to respond to the urgent requirement while it conducted a competitive acquisition for the balance of the vehicles." *See* GAO-10-155T, *supra* note 50, at 2.

[235] *See* Matthew Howard, *Thinking Critically: Unleashing the Power of the Adaptive Acquisition Framework*, DEF. ACQUISITION U., https://www.dau.edu/datl/b/thinking-critically-unleashing-power (last visited Apr. 11, 2024).

[236] *Id*. (quoting Hon. Kevin Fahey, former Assistant Secretary of Defense for Acquisition (ASD(A)).

[237] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-20-579, NEXT GENERATION COMBAT VEHICLES: AS ARMY PRIORITIZES RAPID DEVELOPMENT, MORE ATTENTION NEEDED TO PROVIDE INSIGHT ON COST ESTIMATES AND SYSTEMS ENGINEERING RISKS 16 (2020) [hereinafter GAO-20-579]; GAO-21-460, *supra* note 8, at 26.

[238] *See* GAO-23-105008, *supra* note 232, at 1. *See generally* GAO-23-106059, *supra* note 50 (discussing updates from the DoD's 26 MDAPs, of which 19 were using the MTA pathway).

[239] *See id.* at 1, 2; GAO-20-579, *supra* note 237, at 11. Congress granted these exemptions "to reduce bureaucratic processes and could afford MTA programs greater capacity to innovate and deliver new capabilities with speed—themes consistent with leading principles for product development." *See* GAO-23-

In particular, TWV and GCV acquisition programs today most commonly initiate through the MTA pathway at the Rapid Prototyping (MTA-RP) phase.[240] After acquiring sufficient prototypes through competitive procedures or a non-FAR-based contracting instrument, the program then conducts demonstrations, experiments, and tests of the prototypes.[241] This allows the program leaders to better determine the requirements its contracting office and PMs must include in the purchase description (PD) and request for proposals (RFP).[242] The program then has three possible routes: (1) proceed to the MTA-Rapid Fielding (MTA-RF) phase, transitioning later to the MCA pathway at Milestone C,[243] (2) transition earlier to the MCA pathway at Milestone B, or

105008, *supra* note 232, at 1, 2; U.S. GOV'T ACCOUNTABILITY OFF., GAO-22-104513, AGENCY ACQUISITION POLICIES COULD BETTER IMPLEMENT KEY PRODUCT DEVELOPMENT PRINCIPLES 7, 8 (2022).

[240] *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 117, 250, 270; *see also* U.S. DEP'T OF DEF., DIR. 5000.80, OPERATION OF THE MIDDLE TIER OF ACQUISITION (MTA) para. 3.1 (Dec. 30, 2019) [hereinafter DODD 5000.80] (providing procedures to the MTA-RP path); Appendix E-1 (providing a diagram of the six AAF pathways). "The rapid prototyping path provides for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs." *Middle Tier of Acquisition (MTA) Rapid Prototyping*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/mta/prototyping (last visited Apr. 11, 2024). The MTA-RP path "relies on technologies that have not been demonstrated in an operational environment, to meet requirements due to the aggressive schedules for these programs." GAO-20-579, *supra* note 237, at 26. Containing MTA program development timelines to less than six years for supports the DoD's PPBE process and the need to balance requirements and technologies. *See* GAO-20-579, *supra* note 237, at 24.

[241] *See* E-mail from Steven Dawson, Assistant Program Executive Officer (APEO), Systems Engineering and Integration, Program Executive Office–Ground Combat Systems (PEO-GCS) (Mar. 12, 2024, 16:14 EDT) [hereinafter E-mail, Dawson] (on file with author). There are key differences between prototype demonstrations, experiments, and tests. For example, "[d]emonstrations are evaluations specifically designed to determine if a prototype can do what it was developed to do," and the desired outcome may be visibility of the PEO, warfighters, and vendors as well as "a 'ready to fight' capability for the warfighter." *MTA Rapid Prototyping Path: Test & Demonstrate*, DEF. ACQ. U. [hereinafter DAU, *Test & Demonstrate*], https://aaf.dau.edu/aaf/mta/prototyping/performance (last visited Apr. 11, 2024). In contrast, "[r]ather than simply demonstrating that a capability meets the need it was built to meet, experimentation stresses the technology to identify its full capability and limitations." DAU, *Test & Demonstrate*, *supra*.

[242] *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 117, 250, 270. A PD is a type of contract specification that describes "the essential physical characteristics and functions required to meet the government's requirements." CONTRACT ATTORNEY'S DESKBOOK, *supra* note 185, at 5-32; *see* Ralph C. Nash et al., THE GOVERNMENT CONTRACTS REFERENCE BOOK 468 (3d ed. 2007); FAR 11 (2024); DFARS 211 (2024). Other types of specifications include design, performance, and mixed specifications. *See id.* at 196, 432.

[243] *See* DODD 5000.80, *supra* note 240, para. 3.2.

(3) terminate or cancel the project or program.[244] After transitioning to the MCA pathway and achieving a Milestone C production decision, the program then typically conducts a new round of competitive procedures to solicit proposals and award a contract for LRIP of the vehicle system.[245] Finally, if applicable, the program conducts another round of competitive procedures to award a new production contract for FRP of the vehicle.[246] In general, the acquisition programs for different vehicles are segregated from start to finish, although different programs or projects may connect to a common R&D effort for a specific technological capability, like HED.[247] In sum, there are several possible acquisition approaches that DoD's vehicle programs typically pursue. Even more diverse, however, are the potential contracting strategies that are available to innovative MWS acquisition programs.

b. Contracting Strategies and Types

[244] *See* DAU, *DAS Overview Video*, *supra* note 213.

[245] *See id*. Occurring in the first part of the Production and Deployment (P&D) phase, the LRIP generally results in completion of manufacturing development to ensure adequate and efficient manufacturing capability and to produce the minimum quantity necessary to" conduct an FRP decision review (FRPDR). *See Low Rate Initial Production (LRIP) of Production and Deployment Phase*, DEF. ACQUISITION U., https://www.dau.edu/acquipedia -article/low-rate-initial-production-lrip-production-and-deployment-phase (last visited Apr. 11, 2024).

[246] *See* DAU, *DAS Overview Video*, *supra* note 213. Following the LRIP and "initial operational test and evaluation of representative production products," a FRPDR may result in an FRP of the system. See *Full-Rate Production Systems*, DEF. ACQUISITION U., https://www.dau.edu/acquipedia-article/full-rate-production-systems (last visited Apr. 11, 2024). Of note, the FRP or follow-on production contracts are not always awarded to the same vendor from the LRIP contract, as Oshkosh experienced in 2022 when the Army awarded a production contract for JLTVs to AM General over incumbent Oshkosh. *See In re* Oshkosh Defense, LLC, B-421506, 2023 CPD ¶ 2 (Comp. Gen. Dec. June 12, 2023).

[247] *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 117, 250, 270.

In addition to selecting the best acquisition approach, selecting the most appropriate contract strategy is another key decision for any MDAP.[248] This involves appropriately selecting both a primary contract strategy and a specific contract type.[249]

The options for a program's primary contracting strategy are widely varied, from utilizing formal negotiated contracts to more informal R&D agreements.[250] For the "[d]esign and development of . . . [MDAP] systems or subsystems . . . [that] support[] military combat utility such as . . . ground systems," the Defense Acquisitions University (DAU) recommends programs employ either contracting by negotiation,[251] indefinite delivery indefinite quantity contracts,[252] or prototyping through other transaction authority (OTA).[253] Nevertheless, for more minor projects that are part of a larger program, acquisitions leaders also rely on simplified acquisitions that do not require extensive competitive procedures when a purchase is under certain thresholds.[254] For

[248] *See Contracting Cone*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/contracting-cone (last visited Apr. 11, 2024).

[249] *See id*.

[250] *See id.* The primary strategy comes from the "contracting cone," which "outlines the full spectrum of available FAR and Non-FAR contract strategies." *Id.* The 11 FAR-based strategies include the following: Federal Supply Schedule (FAR Part 8.4); Commercial Items (FAR Part 12); Simplified Acquisitions (FAR Part 13); Negotiated Contracts (FAR Part 15); Indefinite Delivery Indefinite Quantity (IDIQ) (FAR Part 16.5); Letter Contracts (FAR Part 16.603); Agreements (FAR Part 16.7); Small Business Set-Asides (FAR Part 19); Broad Agency Announcements (BAAs) (FAR Part 35.016); SBIR/STTR Programs (15 U.S.C. § 638); and Commercial Solutions Opening (DFARS Part 212.2). *Id.* The Non-FAR strategies include the following three statutorily created instruments: Other Transactions (10 U.S.C. § 4021), Procurement for Experiments (10 U.S.C. § 4023), and R&D Agreements (15 U.S.C. §§ 3710a & 3715 and 32 C.F.R. Part 37). *Id.*

[251] *See* FAR 15 (2024).

[252] *See* FAR 16.5 (2024).

[253] *Contracting Cone: Major System Development*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/contracting-cone/scenarios/acquisition-program-development (last visited Apr. 11, 2024); *see* 10 U.S.C. § 2371b; *see also infra* notes 261–285 and accompanying text (discussing MDAPs' use of OTA agreements).

[254] *See* FAR 13 (2024). Simplified acquisition procedures are prescribed in FAR Part 13. *See* FAR 13.101 (2024). A simplified acquisition involves "the acquisition of supplies and services, including construction, research and development, commercial products, and commercial services, the aggregate amount of which does not exceed the simplified acquisition threshold," which is currently $250,000 for most types of acquisitions. *See* FAR 2.101 (2024); FAR 13.000 (2024).

example, for internal R&D and engineering projects, vehicle acquisition programs often rely on the micro-purchase threshold (MPT) to utilize their organization's Governmentwide commercial purchase card (GCPC) to more rapidly acquire supplies like components for vehicle hardware development.[255]

After acquisition leaders select the primary contracting strategy for a given MDAP, they must next determine the appropriate contract type.[256] Under FAR Part 16, there are six main types of contracts, each with various subtypes: (1) Fixed Price Contracts, (2) Cost-Reimbursement Contracts, (3) Incentive Contracts, (4) Indefinite-Delivery Contracts, (5) Time-and-Materials, Labor-Hour, and Letter Contracts, and (6) Agreements.[257] Most contract types are available for most FAR-based strategies, and an MDAP's primary contract strategy may involve using different contract types for various individual projects under the same program.[258] Despite its many options, DoD typically uses Firm Fixed Price (FFP) or Fixed Price Incentive (FPI) contracts in its operational vehicle acquisitions.[259] However, particularly in earlier R&D stages, DoD's TWV and GCV acquisition programs employ "both traditional contract types as well as more flexible approaches to enable rapid development of technology and designs."[260]

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[255] A "[m]icro-purchase is a method to procure supplies and services below the micro-purchase threshold. Government Purchase Card (GPC) is the preferred method to acquire requirements below the micro-purchase threshold" (MPT). *Simplified Acquisitions: Micro-Purchase*, DEF. ACQUISITION U. [hereinafter DAU, MPT], https://aaf.dau.edu/aaf/contracting-cone/simplified-acquisition-far-part-13/micro-purchase (last visited Apr. 11, 2024); *see* FAR 2.101 (2024); FAR 13.301 (2024); DFARS 213.301 (2024). In general, the current MPT is $10,000. FAR 2.01 (2024).

[256] *Contract Type Matrix*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/contracting-cone/contract-type-matrix (last visited Apr. 11, 2024); *see* FAR 16.1 (2024) ("Selecting Contract Types"); DFARS 216.1 (2024) ("Selecting Contract Types").

[257] *See* FAR 16 (2024).

[258] *See Contract Type Matrix*, *supra* note 256.

[259] *See* GAO-20-579, *supra* note 237, at 12; *see, e.g.*, FY24 Army RDT&E Budget Justification, *supra* note 77, at 141, 175, 254 (indicating a general trend of using FFP contracts for ISV and FMTV production awards).

[260] *See* GAO-20-579, *supra* note 237, at 11; GAO, TWVS, *supra* note 237, at 26.

c. Use of Other Transaction Authority (OTA) Agreements

Among the many available contract strategies and types, DoD increasingly utilizes non-FAR-based legal instruments like those under its OTA, a legal instrument and procurement authority under 10 U.S.C. § 4021, for its most innovative, cutting-edge R&D projects.[261] Although DoD only recently ramped up its use of OTA agreements ("OTs"), the National Aeronautics and Space Administration (NASA) has relied on them for more than 60 years.[262] Following the Soviet Union's successful launch of *Sputnik*, Congress recognized the misconception of the United States' technological superiority over its rivals. To improve the nation's strategic posture, Congress passed the "Space Act, " allowing NASA to use OTs to achieve rapid R&D advances and surpass peer adversaries in the "Space Race."[263] In the last decade, Congress again recognizes the "pressing need to maintain U.S. technological superiority, as well as military readiness, and find smart, quick, commercial/non[-]developmental solutions to" modernize DoD's MWSs and thoughtfully integrate novel capabilities.[264] Therefore, DoD seeks to leverage the R&D of nontraditional defense contractors (NDCs) that otherwise could not or choose not to do business with DoD because of its significant procedural requirements.[265]

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[261] *See* GAO, TWVS, *supra* note 237, at 27; *see also* DFARS 206.001-70 (2024) (providing an exception from DFARS competition requirements "for prototype projects for follow-on production contracts"). "Between 2016 and 2022, DoD took 15,000 OTA actions worth about $70 billion," while in FY 2022 alone, "the department took about 4,400 actions worth $10.7 billion." Anastasia Obis, *DoD Dispelling Lingering Myths About OTAs*, FED. NEWS NETWORK (Feb. 23, 2024), https://federalnewsnetwork.com/contracting/2024/02/dod-dispelling-lingering-myths-about-otas.

[262] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-20-84, DEFENSE ACQUISITIONS: DOD'S USE OF OTHER TRANSACTIONS FOR PROTOTYPE PROJECTS HAS INCREASED 8 (2019) [hereinafter GAO-20-84]; John Dobriansky & Dr. Patrick O'Farrell, *Other Transaction Authority: Acquisition Innovation for Mission-Critical Force Readiness,* CONT. MGMT. 51 (July 2018), https://acquisitioninnovation.darpa.mil/docs/Articles/Contract%20Management%20Dobriansky%20OTA.pdf.

[263] *See* Dobriansky & O'Farrell, *supra* note 262, at 51.

[264] *Id.*

[265] *Id*. at 52. Relevant statute defines nontraditional defense contractors (NDCs) as the following:

The federal government generally appreciates that industry "concerns related to intellectual property rights, the length of time it takes [DoD] to award a contract, and the need to establish a government-unique cost accounting system make [DoD] an unattractive customer for some companies."[266] In response, Congress promotes the use of OTA and other statutes that "permit federal agencies to enter into transactions *other than* procurement contracts, grants, or cooperative agreements."[267] Since the National Defense Authorization Act of Fiscal Year 2016 (FY16 NDAA), DoD entities may enter into OTs for three possible uses, including research, prototyping, and follow-on production purposes.[268] This presents a wide range of potential applications to "pursue commercial solutions to defense requirements" and propel rapid advances in technological innovation.[269] Further, Congress authorizes each Service to execute OTs up to $500 million with

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> [A]n entity that is not currently performing and has not performed, for at least the one-year period preceding the solicitation of sources by the Department of Defense for the procurement or transaction, any contract or subcontract for the Department of Defense that is subject to full coverage under the cost accounting standards prescribed pursuant to section 1502 of title 41 and the regulations implementing such section.

10 U.S.C. § 3014; *see* 10 U.S.C. § 4022(e)(2).

[266] U.S. GOV'T ACCOUNTABILITY OFF., GAO-22-105357, OTHER TRANSACTIONS AGREEMENTS: DOD CAN IMPROVE PLANNING FOR CONSORTIA AWARDS 5 (2022) [hereinafter GAO-22-105357]; *see* GAO-20-84, *supra* note 262, at 8.

[267] Dobriansky & O'Farrell, *supra* note 262, at 51; *see* Oracle Am., Inc., B-416061, 2018 CPD ¶ 180, at 1 n.1 (Comp. Gen. Dec. May 31, 2018).

[268] *See* 10 U.S.C. § 4021; National Defense Authorization Act of Fiscal Year 2016, Pub. L. No. 114-92, § 845, 129 Stat. 726, 915 (2015); *Other Transaction Authority (OTA)*, ACQNOTES (Feb. 7, 2024) [hereinafter ACQNOTES], https://acqnotes.com/acqnote/careerfields/other-transaction-authority-ota. For an explanation of Research OTs, Prototype OTs, and Production OTs, see OFF. OF THE UNDER SEC'Y OF DEFENSE FOR ACQ. & SUST., U.S. DEP'T OF DEF., OTHER TRANSACTIONS GUIDE 7 (July 2023) [hereinafter OT GUIDE]. While the DoD typically uses OTs to transact with technology companies for rapid R&D and prototyping purposes, programs also benefit from Congress's more recent expansion that authorizes follow-on production agreements under the OTA where the agency previously followed competitive procedures and provided notice of the follow-on production award as part of the initial OTA prototype award. ACQNOTES, *supra*; *see* 10 U.S.C. § 4021; National Defense Authorization Act of Fiscal Year 2016, Pub. L. No. 114-92, § 845, 129 Stat. 726, 915 (2015). An OT prototype "can generally be described as a physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item, or system." ACQNOTES, *supra* note 268.

[269] Dobriansky & O'Farrell, *supra* note 262, at 52; ACQNOTES, *supra* note 268; *see* 10 U.S.C. § 4021; National Defense Authorization Act of Fiscal Year 2016, Pub. L. No. 114-92, § 845, 129 Stat. 726, 915 (2015).

approval from their respective Service Acquisition Executive (SAE) and places no cap on the number of OTs each Service awards.[270] It is therefore not surprising, amidst the lengthy FAR-based acquisition process, that DoD increasingly looks to OTs to propel timely procurement of leading-edge battlefield capabilities.[271]

There are significant benefits to utilizing OTs.[272] First, they are exempt from the lengthy competition requirements and related controls under the FAR, its supplements, and various laws applicable to government procurement contracts.[273] Aside from streamlining internal DoD processes, this also reduces many of the typical barriers to entry into the defense market that smaller commercial firms and NDCs face, like audit requirements and mandatory accounting systems.[274] Relatedly, DoD is also able to leverage a broader pool of industry participants by awarding OTs not only to individual organizations but also to a consortium.[275] As illustrated in several MDAPs, effectively utilized OTs can also accelerate acquisition timelines substantially—generally cutting MWS acquisition timelines by 40%[276]—and enable more flexibility in contract

[270] ACQNOTES, *supra* note 268.

[271] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-21-8, ARMY MODERNIZATION: ARMY SHOULD IMPROVE USE OF ALTERNATIVE AGREEMENTS AND APPROACHES BY ENHANCING OVERSIGHT AND COMMUNICATION OF LESSONS LEARNED 10 (2020); Dobriansky & O'Farrell, *supra* note 262, at 51.

[272] *See* Dobriansky & O'Farrell, *supra* note 262, at 51.

[273] *Id.*; *see* GAO-20-84, *supra* note 262, at 2; OT GUIDE, *supra* note 268, at i; ACQNOTES, *supra* note 268.

[274] *See* Dobriansky & O'Farrell, *supra* note 262, at 52–53. The key aspects of OTAs that appeal to nonfederal entities include the following: "No "Changes" clause, [n]o disputes/claims, [n]o terminations for default or convenience, [n]o mandatory accounting systems, [n]o requirements to be CAS-compliant, [n]o audit requirements, [a]dvance payments are allowed, and [n]o requirements to flow down *FAR* clauses/provisions to subcontractors." *Id.* at 52–53; *see, e.g.*, FAR 242.75 (2024) (providing standards for mandatory contractor accounting systems and related controls).

[275] *See* GAO-22-105357, *supra* note 266, at 8. A consortium is "a group of members interested in a specific technology area or areas, which provides the government with a ready pool of stakeholders to innovate in that technology area." *Id.*

[276] *See* Dobriansky & O'Farrell, *supra* note 262, at 53.

types.[277] For example, the Army's MRAP acquisition program in 2006 utilized an OTA pathway, taking only 90 days to complete R&D and enter production, in contrast to "the typical 18- to 24-month FAR/Defense FAR Supplement (DFARS) acquisition life cycle, thus saving thousands of U.S. soldiers lives from the ravages of IEDs."[278]

Notwithstanding the benefits of OTs, there are several limitations.[279] First, under 10 U.S.C. § 4022(d)(1), agencies can generally only use prototype OTs under specific circumstances involving small businesses or NDCs.[280] Because of the unique nature of OTs, they are also generally subject to heightened scrutiny and oversight by independent government agencies and Congress.[281] This, in turn, causes DoD policymakers and acquisition leaders to inject additional internal procedures

[277] *See id.* at 52. One promising example of a current OT is the Fixed-Wing Utility Aircraft (FUA) Program. In that OTA, "U.S. Army Contracting Command, Redstone Arsenal (ACC-Redstone), in concert with the contracting professionals in Picatinny, New Jersey, have mapped out a way forward to solicit for prototypes of [COTS] aircraft with military modifications and then select through the evaluation of a fly off." *See id.* at 52.

[278] *See* Dobriansky & O'Farrell, *supra* note 262, at 52; McGinn, *supra* note 205. Although not in the realm of vehicle acquisitions, as recently as 2018, DoD awarded an OTA agreement with a $950 million ceiling to REAN Cloud, an NDC, for IT production cloud services. *See* Oracle Am., Inc., B-416061, 2018 CPD ¶ 180, at 1, 10 (Comp. Gen. Dec. May 31, 2018); Dobriansky & O'Farrell, *supra* note 262, at 52. Acquisition leaders executed the complex OTA award in 60% of the time they would have required "using traditional FAR/ DFARS-based acquisition methodologies." *See* Dobriansky & O'Farrell, *supra* note 262, at 52. *But see* Oracle Am., Inc., B-416061, 2018 CPD ¶ 180, at 1, 15 (Comp. Gen. Dec. May 31, 2018) (sustaining Oracle's bid protest against the Army's OTA follow-on production transaction with REAN because the Army did not comply with the statutory requirements "for the prototype OTA [to have provided] for the award of a follow-on production transaction and [for] the prototype project provided for in the prototype OTA [to have] been completed").

[279] *See* Dobriansky & O'Farrell, *supra* note 262, at 52, 53.

[280] INSPECTOR GEN., U.S. DEP'T OF DEF., NO. DODIG-2022-127, AUDIT OF DOD OTHER TRANSACTIONS AND THE USE OF NONTRADITIONAL CONTRACTORS AND RESOURCE SHARING 1 (Sept. 8, 2022); *see* 10 U.S. Code § 4022(d)(1). Agencies can only use Prototype OTs when one of the following four situations exists: (1) at least one NDC or nonprofit research institution participates to a significant extent; (2) all significant participants in the transaction are small businesses or NDCs; (3) sources other than the Federal government pay at least one-third of the total cost of the prototype project; or (4) the agency SAE determines in writing that exceptional circumstances justify the use of an OT. *See* 10 U.S.C. § 4022(d)(1). "The term 'small business' means a small business concern as defined under section 3 of the Small Business Act (15 U.S.C. 632)." 10 U.S.C. § 4022(e)(4).

[281] *See* ACQNOTES, *supra* note 268; GAO-20-84, *supra* note 262, at 2.

to reduce OTs' apparent lack of transparency and accountability.[282] Such risk aversion, coupled with the inexperience much of the federal acquisitions workforce still has with OTs, causes an instrument that Congress provided to enable more timely technological innovation to frequently become hampered by self-imposed delays, sometimes for several months.[283] Nevertheless, as their increasing use by MDAPs demonstrates, effectively utilized OTs provide an enduring and vital contracting instrument for innovative R&D and prototyping efforts.[284] Another flexible contracting strategy likewise promises significant benefits if policymakers and acquisition leaders similarly utilize it in MWS contracts.[285]

d. Use of MOSA Contracting Approaches

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[282] *See* Telephone Interview with Dean McGrew, Branch Chief, Powertrain Electrification, Ground Vehicle Systems Center (GVSC), U.S. Army Combat Capabilities Development Command (DEVCOM), Army Futures Command (AFC) (Mar. 29, 2024) [hereinafter Telephone Interview, McGrew].

[283] *See id.*

[284] *See* Dobriansky & O'Farrell, *supra* note 262, at 51. Efficiently authorizing and funding R&D and prototype projects also remains a constant challenge for MDAPs. *See Middle Tier of Acquisition (MTA): Cost & Funding*, DEF. ACQUISITION U., https://aaf.dau.edu/aaf/mta/prototyping/funding (last visited Apr. 11, 2024) [hereinafter *MTA Funding*]. While Procurement appropriations fund the LRIP and FRP of vehicle acquisition programs, securing funding during critical R&D phases is often the most problematic. *MTA Funding*, *supra*. Often, the PPBE process is what "makes it difficult for prototyping projects to obtain necessary [RDT&E] funding when it's needed," especially because it "takes nearly two years from the time a funding need is identified to the time funding is available." *MTA Funding*, *supra*. Acknowledging the risks these delays pose to timely modernization, "Congress provided authorities and funded some accounts outside of acquisition programs that can be tapped into for prototyping projects." *See MTA Funding*, *supra*. For example, along with establishing the MTA pathway in the National Defense Authorization Act of Fiscal Year 2016, Congress also created the Rapid Prototyping Fund "to provide funds, in addition to other funds that may be available for acquisition programs under the [MTA-RP] pathway." *See* National Defense Authorization Act of Fiscal Year 2016, Pub. L. No. 114-92, § 804(d), 129 Stat. 726, 882, 883 (2015); OFF. OF THE UNDER SEC'Y OF DEFENSE FOR RSCH. & ENG'G, U.S. DEP'T OF DEF., PROTOTYPING GUIDEBOOK 7 (Oct. 2022) [hereinafter PROTOTYPING GUIDEBOOK]. Congress also recently granted special authorities to allow Services to use funds from the same FY to "leverage an emergent technological advancement" or rapidly respond "to an emerging threat." *See* National Defense Authorization Act of Fiscal Year 2024, Pub. L. No. 118-31, § 229(a), 137 Stat. 136, 200 (2023) [hereinafter NDAA FY24]; *see also* 10 U.S.C. § 3601 ("Procedures for urgent acquisition and deployment of capabilities needed in response to urgent operational needs or vital national security interest").

[285] *See* Interview with Major David Marold, Associate Professor, Contract and Fiscal Law Department, The Judge Advocate General's Legal Center and School (Feb. 7, 2024) [hereinafter Interview, Marold]; Interview with Major Matthew Bryan, Associate Professor, Contract and Fiscal Law Department, The Judge Advocate General's Legal Center and School (Feb. 7, 2024) [hereinafter Interview, Bryan].

Another increasing congressional focus area for improving the effectiveness of MDAPs' contracting strategies is the use of a modular open systems approach (MOSA).[286] A traditional acquisition program for a MWS "focuses on tightly integrated or closed systems with connections . . . between parts of a platform, e.g., radar, fire control, computers, etc., that are custom-designed and unique to the platform, with the intellectual property behind that integration owned by original manufacturer."[287] In contrast, programs that employ MOSA standards include "standardized connections between major parts of a system that allows users to easily remove and replace major components, subsystems[,] and software[, enabling] regular technological upgrades of specific components without wholesales change to the platform."[288]

Incorporating MOSA into an MDAP requires using a mixture of engineering and business practices to design an MWS with highly cohesive, clearly-defined system interfaces that link loosely coupled, modular components.[289] By functionally deconstructing the MWS into modular components and interfaces, MOSA contracting allows for long-term refresh of an existing system by plugging in new, improved components from many independent suppliers to "evolve to

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[286] *See* OFF. OF THE UNDER SEC'Y OF DEF. FOR RSCH. & ENG'G, U.S. DEP'T OF DEF., MODULAR OPEN SYSTEMS APPROACH (MOSA) REFERENCE FRAMEWORKS IN DEFENSE ACQUISITION PROGRAMS 2 (May 2020) [hereinafter OUSD(R&E) MOSA FRAMEWORKS]. The GAO summarizes the DoD's MOSA as follows:

> [The DoD's MOSA] is to design systems with highly cohesive, loosely coupled, and severable modules that can be competed separately and acquired from independent vendors. This approach allows the department to acquire warfighting capabilities, including systems, subsystems, software components, and services, with more flexibility and competition. MOSA implies the use of modular open systems architecture, a structure in which system interfaces share common, widely accepted standards, with which conformance can be verified.

U.S. GOV'T ACCOUNTABILITY OFF., GAO-22-104752, DEFENSE ACQUISITIONS: DOD SHOULD TAKE ADDITIONAL ACTIONS TO IMPROVE HOW IT APPROACHES INTELLECTUAL PROPERTY 26 n.52 (2021) [hereinafter GAO-22-104752].

[287] Shaffer & Whitley, *supra* note 39.

[288] *Id*.

[289] *See* GAO-23-106059, *supra* note 50, at 22; GAO-22-104752, *supra* note 286, at 26 n.52.

respond to changing 'technology, threat, or interoperability need.'"[290] In doing so, an open system approach allows DoD greater flexibility, speed, and competition in acquiring warfighting capabilities.[291]

As an important clarification, employing MOSA does not necessitate that *all* possible system interfaces—for example, all hardware connections between an HEV's ICE and its traction battery pack, batteries and onboard electrical systems, etc.—employ open standards for the complete system to be characterized as "open."[292] Instead, MOSA requirements exist on a spectrum, encouraging acquisition leaders and engineers to identify and validate standardization for those "key interfaces between the modules that are likely to change, may frequently fail or need to be replaced, or are needed for interoperability."[293]

Notwithstanding the immense benefits of MOSA contracting strategies, DoD's vehicle acquisitions programs for legacy TWVs and GCVs typically *do not* require such open systems.[294] This is partly because it is difficult to inject MOSA standards into an existing program, in which PEOs and contractors have already invested considerable R&D effort.[295] "[T]he approach is best implemented at the start of product design because this is where initial modularity, key interface, and data ownership decisions are made and would result in costly redesign if implemented later."[296]

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[290] *See* OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 2 (citing National Defense Authorization Act of Fiscal Year 2017, Pub. L. No. 114-328, § 2446(a), 130 Stat. 200, 2252 (2016)); GAO-23-106059, *supra* note 50, at 22; U.S. GOV'T ACCOUNTABILITY OFF., GAO-13-651, DOD EFFORTS TO ADOPT OPEN SYSTEMS FOR ITS UNMANNED AIRCRAFT SYSTEMS HAVE PROGRESSED SLOWLY 1 (2013) [hereinafter GAO-13-651].

[291] *See* GAO-23-106059, *supra* note 50, at 24.

[292] *See id.*; 10 U.S.C. § 4401(b) (2024).

[293] *See* GAO-23-106059, *supra* note 50, at 24; 10 U.S.C. § 4401(b) (2024).

[294] *See* GAO-13-651, *supra* note 290, at 6.

[295] *See* Telephone Interview, McGrew, *supra* note 282.

[296] *See* GAO-13-651, *supra* note 290, at 6.

A second reason for the lack of MOSA standards in most ground vehicle acquisitions is that MOSA typically demands that programs acquire from the MWS manufacturer the intellectual property (IP) and data rights—at a minimum, to the standardized, open-system interfaces—because such rights are key to enabling future tech refresh, repair, and upgrades.[297] "The [DoD's] license rights to a contractor's [technical data and IP] generally depend upon the extent to which the [DoD] funded the development of the technology, whether the technology is commercial or noncommercial, and any negotiations for mutually agreeable 'special' license agreements."[298] This poses a challenge to contracting and negotiation for many TWV acquisition programs, which often rely on "commercial [vehicles] being adapted to military application."[299] In such cases, prime defense contractors have a significant financial incentive to protect their investments by retaining IP and data rights not only to secure future DoD production and sustainment contracts for the vehicle but also to preserve commercial marketability of dual-use technologies.[300] Nevertheless, like requiring MOSA, contracting for IP and data rights exists on a spectrum, and there are various rights categories that dictate to what extent contracts give up such rights in MWS initial development contracts.[301]

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[297] *See id*. "'Data Rights' is a shorthand way to refer to the Government's license rights in two major categories of valuable intellectual property: [(1)] Technical Data (TD) includes any recorded information of a scientific or technical nature (e.g., product design or maintenance data, and computer software documentation (CSD))[; and (2)] Computer software (CS) includes executable code, source code, code listings, design details, processes, flow charts, and related material." Open Systems Architecture–Data Rights Team, *Understanding and Leveraging Data Rights in DoD Acquisitions*, U.S. DEP'T OF DEF. 1 (Oct. 2014) [hereinafter Data Rights Team], https://www.dau.edu/sites/default/files/Migrated/CopDocuments/Data%20Rights%20Focus%20Sheet%20final.pdf.

[298] *See* Data Rights Team, *supra* note 298, at 1.

[299] *See* E-mail from Steven Roberts, Project Lead, Integration, U.S. Army Program Executive Office, Combat Support & Combat Service Support (PEO–CS&CSS) (Mar. 19, 2024, 17:15 EDT) [hereinafter E-mail, Roberts] (on file with author).

[300] *See id*.

[301] *See* Data Rights Team, *supra* note 298, at 2 (providing a chart of possible data rights categories and applications as well as a list of "Data Rights and Intellectual Property Strategy Resources").

Despite the rarity of MOSA in DoD's vehicle acquisition contracts, American consumers have enjoyed the benefits of open systems in commercial products for decades.[302] "Many consumer products, including U.S. appliances, personal computers, and smartphones, are considered to be open systems because they use widely available hardware and software standards at key interfaces."[303] For example, most American household appliances share a common open system design that uses a particular wall socket standard, allowing them to plug into any power outlet without raising customer concern over whether a specific product brand will be compatible in their homes.[304] This provides customers more options to meet their needs and helps maintain low prices by promoting market competition.[305]

Like commercial industries, DoD is no stranger to the benefits of open system architectures.[306] Although DoD has employed MOSA for over 20 years, Congress only recently formalized the

[302] *See* GAO-23-106059, *supra* note 50, at 24. For example, in 1981, International Business Machines (IBM) Corporation released its first personal computer (PC), which employed an open system design using existing components or COTS parts for its processor, software, and floppy drives. *See* GAO-13-651, *supra* note 290, at 7. Openly publishing its hardware and software specifications, IBM allowed other manufacturers to develop compatible products to interface with its PCs. *See* GAO-13-651, *supra* note 290, at 8, 9. This in turn spurred immense competition, advanced technological innovation, reduced consumer costs, and increased alternatives for those products. *See* GAO-13-651, *supra* note 290, at 8, 9; *IBM*, ENCYC. BRITANNICA, https://www.britannica.com/topic/International-Business-Machines-Corporation (last visited Apr. 11, 2024). While not protecting its IP may have opened the door for other PC companies to copy its design and gain a considerable market share, the open architecture of IBM's PC design also enabled it to be first to get to market and helped secure the company's lasting success and impact. *See* Michael Miller, *Why the IBM PC Had an Open Architecture*, PCMAG (Aug. 12, 2021), https://www.pcmag.com/news/why-the-ibm-pc-had-an-open-architecture; Michael Miller, *The Original IBM PC: Lessons Learned*, PCMAG (Nov. 22, 2022), https://www.pcmag.com/news/the-ibm-pc-at-40-lessons-learned.

[303] *See* GAO-23-106059, *supra* note 50, at 24.

[304] *See id.*

[305] *See id*. Further demonstrating the power of open systems in consumer products, in the mid-1990s, a group of computer companies joined efforts to develop the now widely used Universal Serial Bus (USB) interface standard "to reduce the number of different connectors, such as parallel and serial ports, that were required to allow various components to work together." *See* GAO-13-651, *supra* note 290, at 9.

[306] *See* OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 2.

requirement for MDAPs to use MOSA to improve its acquisitions of MWSs in 2017.[307] Specifically, 10 U.S.C. § 4401(a) requires any MDAP "that receives Milestone A or Milestone B approval after January 1, 2019 . . . be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability."[308] As a result, DoD guidance now provides that "modular contracting is the preferred approach to acquire major software information technology systems."[309] Since these statutory requirements, DoD has pursued open systems in many of its hardware and software procurements.[310]

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[307] *See id.*

[308] *See* 10 U.S.C. § 4401(a). A MOSA means any of the following:

> [A]n integrated business and technical strategy that—
>
> (A) employs a modular design that uses major system interfaces between a major system platform and a major system component, between major system components, or between major system platforms;
>
> (B) is subjected to verification to ensure major system interfaces . . . comply with, if available and suitable, widely supported and consensus-based standards. . . .
>
> (C) uses a system architecture that allows severable major system components at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation while yielding [significant cost, schedule, technological upgrade, interoperability, and sustainment benefits]; and
>
> (D) complies with the technical data rights set forth in [10 U.S.C. § 2320].

See 10 U.S.C. § 4401(b)(1).

[309] GAO-23-106059, *supra* note 50, at 47; *see* OFF. OF THE UNDER SEC'Y OF DEF. FOR RSCH. & ENG'G, U.S. DEP'T OF DEF., CONTRACTING CONSIDERATIONS FOR AGILE SOLUTIONS: KEY AGILE CONCEPTS AND SAMPLE WORK STATEMENT LANGUAGE 1 (Nov. 2019); *see also* 41 U.S.C. § 2308 ("Modular Contracting for Information Technology"); FAR 39.103 (2024) ("Consistent with the agency's information technology architecture, agencies should, to the maximum extent practicable, use modular contracting to acquire major systems . . . of information technology. Agencies may also use modular contracting to acquire non-major systems of information technology."); U.S. DEP'T OF DEF., INSTR. 5000.87, OPERATION OF THE SOFTWARE ACQUISITION PATHWAY (2020) [hereinafter DODI 5000.87] (identifying modular contracting as one of the key elements of an acquisition strategy in the Software Acquisition Pathway guidance).

[310] For example, "[t]he transition of the Aegis Combat System to an open architecture is an example of employing [COTS] infrastructure and achieving faster upgrade cycles for hardware and even more so for software." *See* Gregory Sanders & Alexander Holderness, *Readiness for Open Systems: How Prepared Are the Pentagon and the Defense Industry to Coordinate?*, CTR. FOR STRATEGIC & INT'L STUD. 1 (Nov. 15, 2021),

The U.S. Navy implemented MOSA standards in recent acquisition programs for UAS systems, Virginia class of destroyers, and submarine radar systems.[311] Additionally, many consider the Air Force's B-21 bomber acquisition program "a positive example of employing an open mission architecture, where past Northrup Grumman investments and clear government priorities have kept requirements stable during development."[312] Key to the effectiveness of MOSA contracting was that, "[a]s the project enter[ed] the prototype stage, the Air Force . . . acquired key IP and data rights and expects that the open architecture will allow them to integrate new systems quicker and employ continuous, rather than block, upgrades."[313]

Acquisition programs for DoD's operational vehicles are likewise interested in incorporating MOSA into their designs and contracts.[314] However, for TWVs, "the interfaces between modules, the overall system, and the modules themselves are often proprietary with the [IP] and data rights owned by the manufacturer or integrator."[315] Therefore, the use of MOSA in TWV and GCV acquisition programs remains exceedingly rare.[316] Nevertheless, the benefits of tools like OTs and

https://www.csis.org/analysis/readiness-open-systems-how-prepared-are-pentagon-and-defense-industry-coordinate.

[311] *See* GAO-13-651, *supra* note 290, at 9–11; Nickolas Guertin & Douglass C. Schmidt, *Emerging Opportunities in Modularity and Open Systems Architectures – First in a Series*, SEI BLOG, SOFTWARE ENG'G INST. (Oct. 15, 2018), https://insights.sei.cmu. edu/blog/emerging-opportunities-in-modularity-and-open-systemsarchitectures-first-in-a-series*; see also* Sanders & Holderness, *supra* note 310, at 19 (discussing "the Navy Program Executive Office for Submarines early open system success story that sacrificed legacy approaches to allow for the use of commercial processors and greatly sped technology insertion"). For an analysis of each MDAP's effectiveness, see GAO-13-651, *supra* note 290, at 9–11.

[312] *See* Sanders & Holderness, *supra* note 310, at 4 n.12. "General Timothy Ray[, former commander of the Air Force Global Strike Command,] commented that the B-21 will be able to integrate JASSM-ER in 10 percent the time it took to integrate the system on B-2." *Id.*

[313] *Id.* at 4.

[314] *See* E-mail, Putrus, *supra* note 173.

[315] *See* Sanders & Holderness, *supra* note 310, at 1.

[316] *See* GAO-13-651, *supra* note 290, at 9–11. *But see* GAO-21-460, *supra* note 8, at 27 (noting that, in 2021, Army acquisition leaders claimed they planned to implement MOSA into designs for the CTT and e-ISV). *See*

MOSA in vehicle development contracts will become clearer as DoD leaders increasingly appreciate the need to acquire innovative HE TWVs.

III. The Need for Innovation: The DoD's Incentives to Hybrid-Electrify its TWV Fleet

The DoD's acquisition of HE tactical vehicles is no longer a distant goal but an operational imperative. In the 2022 U.S. National Defense Strategy, DoD committed itself to prioritizing reducing its operational energy demands by seeking technologies that more cleanly and efficiently reduce its logistics requirements in contested or austere environments.[317] Therefore, DoD leaders must examine ways for their vehicles to utilize clean-energy fuel sources to best enhance the nation's energy resilience and competition to both ward off and prepare for future armed conflicts.

With Executive Order (EO) 14057's ambitious goals of reducing U.S. greenhouse gas (GHG) emissions (i.e., requiring all Federal agencies to achieve net-zero carbon emissions by 2050, including a 65% reduction by 2030 and 100% zero-emission vehicle acquisitions by 2035), one might assume DoD's impetus to electrify its TWV and GCV fleet is environmentally focused.[318] On the contrary, the most crucial motivations for DoD innovation include the need to reduce its

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generally OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 20-24 (discussing MOSA strategies and effectiveness in various DoD software and hardware acquisition programs).

[317] *See* 2022 NDS, *supra* note 3862, at 10.

[318] EXEC. ORDER 14057, CATALYZING CLEAN ENERGY INDUSTRIES AND JOBS THROUGH FEDERAL SUSTAINABILITY (Dec. 8, 2021) [hereinafter EO 14057]; *see also* Alejandro de la Garza, *To Take Climate Change Seriously, the U.S. Military Needs to Shrink*, TIME (Feb. 17, 2022), https://time.com/6148778/us-military-climate-change. One reporter commented on the irony of believing the DoD's HED modernization efforts were to produce environmentally friendly vehicles:

> To be clear, even a hybrid-electric Bradley is about as friendly to the environment as it is to anyone on the wrong end of its Bushmaster chain gun—the electric upgrade could push fuel economy close to 0.9 m.p.g., from 0.75 before. But the improvement could amount to substantial fuel savings—and accompanying emissions reductions—across all U.S. forces, especially if BAE is able to apply its hybrid technology to other armored vehicles, as the company hopes.

See de la Garza, *supra*.

increasingly vulnerable reliance on fossil fuels and the concrete warfighting advantages such modernized vehicles will enable.[319] Ultimately, amidst the polarizing nature of climate and energy policy at the local, national, and international levels, these warfighting advantages will win the day over changing political landscapes. [320] Nevertheless, skeptical politicians and critics of electrification initiatives point to legitimate concerns that policymakers and military leaders must first address before driving forward with electrification efforts.[321]

A. Gaining an Edge in Great Power Competition: Military and Political Advantages of Incorporating HED Vehicles on the Battlefield

The DoD should begin pursuing in earnest the capabilities that electric power offers for its military combat and tactical vehicles. However, rather than pursue all-electric drive for its vehicles or attempt to electrify its heavier GCVs before the technology proves itself on the battlefield, leaders should first prioritize acquiring HED technology for its TWV fleet.[322] Doing so would best capitalize on HED's many military and political advantages—both important aims to achieve in "great power competition"[323]—while adequately recognizing the valid concerns of a complete

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[319] *See* Mills & Wiechens, *supra* note 59.

[320] *See* Interview, Marold, *supra* note 285.

[321] Mills & Wiechens, *supra* note 59.

[322] *See id.*

[323] *See* RONALD O'ROURKE, CONG. RSCH. SERV., R43838, GREAT POWER COMPETITION: IMPLICATIONS FOR DEFENSE 1 (2024) [hereinafter R43838]. Great power competition (GPC) or "strategic competition" involves the following:

> The emergence over the past decade of intensified U.S. competition with the People's Republic of China (PRC or China) and the Russian Federation (Russia). . . [The concept of GPC] has profoundly changed the conversation about U.S. defense issues from what it was during the post–Cold War era: Counterterrorist operations and U.S. military operations in the Middle East—which had been more at the center of discussions of U.S. defense issues following the terrorist attacks of September 11, 2001—are now a less prominent (but still present) element in the conversation, and the conversation now focuses more on the following elements, all of which relate largely to China and/or Russia. The issue for Congress is how U.S. defense planning and budgeting should respond to GPC, and whether to approve, reject, or modify the Biden Administration's defense strategy and proposed funding levels, plans, and programs for

electric transition.[324] Members of Congress and DoD senior leaders may find it most helpful to employ the doctrinal levels of warfare (tactical, operational, and strategic) and their corresponding levels of political science analysis (individual, state, and international system) to fully appreciate the need for TWV innovation.[325]

1. Military Advantages

The concept of levels of warfare has long provided history students and military leaders a useful lens through which to analyze a specific military aim, such as hybrid-electrification of TWVs.[326] These "three levels of warfare—strategic, operational, and tactical—link tactical actions to achievement of national objectives."[327] Although there are no finite boundaries between these three levels, Joint Publication (JP) 1, *Doctrine for the Armed Forces of the United States*, establishes the general scope of each level to allow one to assess where an individual objective, mission, or task

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> addressing GPC. Congress's decisions on these issues could have significant implications for U.S. defense capabilities and funding requirements and the U.S. defense industrial base.

Id.

[324] *See id.*

[325] *See* Dr. Andrew S. Harvey, *The Levels of War as Levels of Analysis*, MIL. REV.75, 75, 76 (Nov.-Dec. 2021); *see also* JOINT CHIEFS OF STAFF, JOINT PUB. 1, DOCTRINE FOR THE ARMED FORCES OF THE UNITED STATES I-7–I-8 (12 July 2017) [hereinafter JP 1] (discussing the three levels of warfare in doctrinal terms).

[326] *See* Harvey, *supra* note 325, at 75, 76.

[327] *See* JP 1, *supra* note 325, at I-7–I-8. Finding inspiration from historical minds like Carl von Clausewitz and Aleksandr A. Svechin, current U.S. doctrine regarding levels of war exists in both Joint Publication (JP) 1, *Doctrine for the Armed Forces of the United States* and JP 3-0, *Joint Campaigns and Operations*:

> The three levels of warfare—strategic, operational, and tactical—link tactical actions to achievement of national objectives. There are no finite limits or boundaries between these levels, but they help commanders design and synchronize operations, allocate resources, and assign tasks to the appropriate command. The strategic, operational, or tactical purpose of employment depends on the nature of the objective, mission, or task.

See id.; JOINT CHIEFS OF STAFF, JOINT PUB. 3-0, JOINT CAMPAIGNS AND OPERATIONS I-10–I-11 (18 June 2022) [hereinafter JP 3-0]. For a helpful diagram of the three levels, see Harvey, *supra* note 325, at 76.

fits into DoD's activities around the globe.[328] Multiple levels of warfare may be relevant to a single action or task—that is, one military objective can be important for many different reasons and at various levels of analysis.[329] Although it may seem intuitive to tie the level of warfare to the military authorities hierarchy (e.g., "echelons of command, size of units, types of equipment[,]" or approval authorities for weapons use), it is the *nature* of the objective, mission, or task—not its mission authority—that determines at which level(s) an objective or action lies.[330]

a. Tactical Advantages – Increasing Ground Forces' Survivability and Lethality

The tactical level of warfare involves "the employment and ordered arrangement of forces" and the short-term "maneuver of combat elements in relation to each other and the enemy to achieve combat objectives."[331] The Army's objective of electrification of the TWV fleet would provide land forces in Multi-Domain Operations (MDO) at the tactical level with "immediate benefits that contribute directly to enhanced lethality" and survivability.[332] Most significantly, the

[328] *See* JP 1, *supra* note 325, at 1.

[329] Mills & Wiechens, *supra* note 59.

[330] *See* Harvey, *supra* note 325, at 77 Fig.1; *see also* JP 3-0, *supra* note 327, at, I-12 ("Echelon of command, size of units, types of equipment, and types and location of forces or components may often be associated with a particular level, but the strategic, operational, or tactical purpose of their employment depends on the nature of their task, mission, or objective.").

[331] *See* JP 1, *supra* note 325, at I-8; Harvey, *supra* note 325, at 80.

[332] *See* Mills & Wiechens, *supra* note 59. According to Army doctrine, "Multi-Domain Operations [MDO] are the combined arms employment of joint and Army capabilities to create and exploit relative advantages that achieve objectives, defeat enemy forces, and consolidate gains on behalf of joint force commanders." U.S. DEP'T OF ARMY, FIELD MANUAL 3-0, OPERATIONS 1-2 (Oct. 2022) [hereinafter FM 3-0]. As MDO concepts explain, "[e]mploying Army and joint capabilities makes use of all available combat power from each domain to accomplish missions at least cost." FM 3-0, *supra*, at 1-2. *See generally* ANDREW FEICKERT, CONG. RSCH. SERV., IF11409, DEFENSE PRIMER: ARMY MULTI-DOMAIN OPERATIONS (MDO) (2024) (elaborating on the Army's MDO concept). In a statement before the U.S. House of Representatives, Committee on Armed Services, Subcommittee on Tactical Air and Land Forces, senior Army officials who are spearheading HED modernization initiatives summarized the benefits of TWV electrification as follows:

> Electrification provides land forces in Multi-Domain Operations (MDO) the ability to operate at longer distances without refueling and provides extended silent-watch capability. In additional the combination of silent mobility, reduced thermal signature, and improved sprint speeds will allow greatly improved convergence of lethal and nonlethal effects. Finally,

tactical advantages of HE TWVs over legacy TWVs with traditional drivetrains powered only by ICEs include their higher fuel efficiency and sprint speed, lower acoustic and thermal signatures, and their power-generating ability for other onboard tactical electrical systems.[333]

Because of their battery-powered drivetrains, EVs and series-hybrid vehicles can instantly deliver high torque and rapid acceleration, enabling drastically faster "sprint speeds" that can "save lives and provide decisive lethality" on the battlefield.[334] Studies by Army Futures Command (AFC) over the past decade demonstrated that increasing a vehicle's sprint ability can improve vehicle and Soldier survivability because it reduces exposure time while driving from one position of cover to another.[335] According to these studies, "a five percent increase in a vehicle's acceleration can result in a 10 percent decrease in vehicle strikes."[336] As commercial EV and HEV

> electrification provides the on-board electrical power and energy storage required for the sensors and mission payloads envisioned for land forces in MDO.

TWV Hearing, *supra* note 73, at 32 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics, and Mr. Michael Cadieux, Director, GVSC, DEVCOM).

[333] *See* Mancillas, *supra* note 11, at 4, 5.

[334] *Id.* at 4; *see TWV Hearing*, *supra* note 73, at 5 (statement of Mr. Michael Cadieux, Director, GVSC, DEVCOM); Mills & Wiechens, *supra* note 59. While involving an AEV, a commercial example highlights the sprint speed advantage:

> [T]he Tesla S P90D, a mass produced and mass marketed, four door all-wheel drive sedan, delivering 762 HP and 713 lb-ft of torque, [is] able to accelerate from 0 to 60 miles per hour in an astonishing 2.4 seconds. A comparable ICE vehicle, the Lexus 500 LS, has a similar price, weight, and all-wheel drive, delivering 416 HP, 442 lb-ft, and 0-60 mph in 4.6 seconds.

Mancillas, *supra* note 11, at 2; *see Model S*, TESLA, https://www.tesla.com/models (last visited Apr. 11, 2024); *Model 500 LS Performance*, LEXUS, https://www.lexus.com/models/LS/specifications/ls-500-awd#engine (last visited Apr. 11, 2024).

[335] Mancillas, *supra* note 11, at 4.

[336] *See* Mancillas, *supra* note 11, at 4; R.J. Hart & Richard Gerth, *The Influence of Ground Combat Vehicle Weight on Automotive Performance, Terrain Traversability, Combat Effectiveness, and Operation Energy*, 2018 NDIA GROUND VEHICLE SYS. ENG'G & TECH. SYMP. 7 (9 Aug. 2018).

technology improves, acceleration and sprint speed performance will likely only improve, emphasizing the need to procure such vehicles for MDOs.[337]

In addition to their high sprint speed, the ability of electric powered vehicles to operate "silently"—that is, with significantly reduced acoustics and thermal signatures—further strengthens their lethality and survivability at the tactical level.[338] These types of vehicles can "idle," occupy a stationary overwatch position, and drive slowly with extraordinary stealth, giving an obvious advantage to reconnaissance or special operations units.[339] In fact, one Army study found that electrification reduces vehicle audible signatures by a factor of five (5:1 reduction), while reducing thermal signatures by a factor of ten (10:1 reduction).[340] Relatedly, the reduction or elimination of visible exhaust emissions from HE TWVs also reduces their visibility to enemy surveillance, thus further enhancing survivability of these vehicles.[341] With the Russia-Ukraine War currently at a stalemate because of the equally matched abilities of both armies to constantly

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[337] *See* Keith Barry, *Why Hybrid Vehicles Are a Smart Choice Right Now*, CONSUMER REPS. (Mar. 2, 2023), https://www.consumerreports.org/cars/hybrids-evs/why-hybrid-vehicles-are-a-smart-choice-right-now-a2736240282.

[338] *See* Mancillas, *supra* note 11, at 4; *TWV Hearing*, *supra* note 73, at 5 (statement of Mr. Michael Cadieux, Director, GVSC, DEVCOM); Video, *What Silent Electric Vehicles Could Bring to Battlefield Tactics*, FORCES NEWS, YOUTUBE.COM (Jan. 30, 2023), https://www.youtube.com/watch?v=ZeComMjybM4.

[339] OFF. OF THE UNDER SEC'Y OF DEF. FOR ACQ. & SUST., U.S. DEP'T OF DEF., DOD PLAN TO REDUCE GREENHOUSE GAS EMISSIONS 11, 13 (2022) [hereinafter DOD, REDUCING GHG]; *see* Mancillas, *supra* note 11, at 4, 56; Mills & Wiechens, *supra* note 59; Brett Tingley, *Oshkosh Reveals New Hybrid-Electric Variant Of The Military's Light Tactical Vehicle*, THE DRIVE (Jan. 25, 2022), https://www.thedrive.com/the-war-zone/44014/new-ejltv-hybrid-electric-variant-of-militarys-light-tactical-vehicle-revealed.

[340] *See* Mancillas, *supra* note 11, at 4.

[341] *See TWV Hearing*, *supra* note 73, at 4 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics); *see also* Marcus Weisgerber, *Hybrid-Electric Troop Transports Are Moving Toward the Battlefield*, DEF. ONE (Oct. 14, 2022), https://www.defenseone.com/technology/2022/10/hybrid-electric-troop-transports-are-moving-toward-battlefield/378460 ("It's got a really low IR signature,' Stephen duMont, the president of GM Defense [and former Apache helicopter pilot], said of the all-electric Infantry Squad Vehicles at this week's conference. 'There's no hot engine. There's no hot exhaust pipe. There's no hot hood. Those are the things that tend to give you contrast when you're targeting.'").

observe one another's maneuvers, any tactical advantage that allows one element to move quietly on the modern battlefield is invaluable.[342]

The third key tactical advantage of HE TWVs is their high onboard electricity storage and generation ability.[343] This provides those vehicles an efficient power supply to enable advanced sensors, integrated communications networks, and other future mission payloads—warfighting capabilities like directed energy weapons (DEW), counter-small unmanned aerial vehicles (C-sUAS), and reactive armor systems[344]—that require the high-instantaneous power output made possible by large batteries.[345] Large batteries and efficient energy generation also enables exportable power generation and distribution, a crucial benefit in light of existing ICE-powered

[342] *See* Valerii Zaluzhnyi, *Modern Positional Warfare and How to Win in It*, ECONOMIST (Nov. 2, 2023), https://infographics.economist.com/2023/ExternalContent/ZALUZHNYI_FULL_VERSION.pdf. The Army recently conducted demonstrations of legacy ICE-powered JLTVs with retrofitted anti-idle Tactical Vehicle Electrification Kits (TVEKs), making those vehicles partly HE. An unexpected tactical advantage of the vehicle's near-silent operations was the dramatically increased situational awareness of Soldiers in the vehicle, who no longer had to listen over loud, idling ICEs when the vehicle was static. *See* E-mail 1, McGrew, *supra* note 170.

[343] *See* E-mail from Keith Jadus, Director for Ground Systems, Office of the Deputy Assistant Secretary of the Army (Research & Technology), ASA(ALT), to author (Jan. 29, 2024, 09:55 EST) [hereinafter E-mail, Jadus] (on file with author).

[344] *See* Telephone Interview with Keith Jadus, Director for Ground Systems, Office of the Deputy Assistant Secretary of the Army (Research & Technology), ASA(ALT) (Jan. 26, 2024) [hereinafter Telephone Interview, Jadus]; E-mail, Roberts, *supra* note 299; E-mail 1, McGrew, *supra* note 170; *see, e.g.*, U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105868, DIRECTED ENERGY WEAPONS: DOD SHOULD FOCUS ON TRANSITION PLANNING 1 (2023) [hereinafter GAO-23-105868] ("Unlike kinetic weapons, [like] bullets and missiles that generally rely on physical impact to attack a target, DEWs use concentrated electromagnetic energy to deliver destructive or disruptive effects to targets at the speed of light. In addition, DEWs have potentially significant advantages over kinetic weapons, including lower per-use cost."); *C-UAS Directed Energy*, BLUE HALO, https://bluehalo.com/c-uas-autonomous-systems/c-uas-directed-energy (last visited Apr. 11, 2024) (presenting the LOCUST Laser Weapon System (LWS), an integrated radar and high-energy, AI laser system to identify and take down sUAS like enemy drones); Michael Smith, *"Electric armour" Vaporises Anti-Tank Grenades and Shells*, TELEGRAPH UK. (Aug. 19, 2002) (discussing early developments of electric reactive armor for tanks to stop anti-tank grenades), https://web.archive.org/web/20020822234931/http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2002/08/19/nmod19.xml.

[345] *See TWV Hearing*, *supra* note 73, at 5 (statement of Mr. Michael Cadieux, Director, GVSC, DEVCOM); Mills & Wiechens, *supra* note 59; E-mail 1, McGrew, *supra* note 170.

vehicles often struggling to supply enough electrical power for the ever-increasing small-unit mission requirements like drones, radios, tablets, lasers, computers, and sensors.[346]

The anticipated tactical advantages of increased sprint speed, silent mobility, and enhanced electric power supply are not merely theoretical. As demonstrated in a Tactical Vehicle Electrification Kit (TVEK) study from November 2019, the Army has already successfully proven the benefits of a HE modification kit for the M977 Cargo Heavy Expended Mobility Tactical Truck (HEMTT) and JLTV.[347] The retrofit modification "achieved operational fuel savings of 15-25 percent, with 56 percent reduced overall engine run time, and positive Return on Investment (ROI) in under 24 months."[348] Additionally, the TVEK provided "twice the silent watch capability, triple the power generation capability, import/export power capability, and 600[-]volt Direct Current (DC) bus for future capability expansion."[349]

More recent demonstrations by Army units at the National Training Center (NTC) employed Vehicle Integrated Power Kits (VIPKs), similar retrofitted anti-idle electrification kits for heavier

[346] Mills & Wiechens, *supra* note 59.

[347] Mancillas, *supra* note 11, at 5. The TVEK is an "anti-idle system [that] automatically cuts engine power to the JLTV during periods of extended idling, not only reducing fuel but also extending silent watch, which is a clear advantage for warfighters who don't want to give away their positions by turning on the vehicle engine unnecessarily." Jerome Aliotta, *Anti-Idle Technology Reduces Fuel, Extends Silent Watch,* U.S. ARMY (Mar. 29, 2022), https://www.army.mil/article/255156/anti_idle_technology_reduces_fuel_extends_silent_watch; *see also supra* notes 552–557 and accompanying text (discussing the fuels savings from the Army's testing of TVEKs installed in JLTVs). During military operations, tactical and combat vehicles typically spend just as much, if not more, time stationary as they do on the move. However, even while the vehicle is stationary, their ICEs must continue running "in order to power the essential onboard electronics, as well as the heating and cooling systems in the crew compartments. This results in significant fuel consumption while the vehicle idles." *See* David Vergun, *Prototype Aims to Reduce Fuel Use, Improve Tactical Vehicle Performance*, U.S. DEP'T OF DEF. (Nov. 24, 2021), https://www.defense.gov/News/News-Stories/Article/Article/2853649/prototype-aims-to-reduce-fuel-use-improve-tactical-vehicle-performance.

[348] Mancillas, *supra* note 11, at 5.

[349] *Id.* at 5; *see* Weisgerber, *supra* note 341. "Silent watch" refers to the ability to run electronics and sensors inside a tactical or combat vehicle while the engine is turned off. Weisgerber, *supra* note 341.

TWVs.[350] These demonstrations hinted at the immense tactical advantages of HE capabilities for tactical operations centers (TOCs) on the battlefield, as well.[351] Providing *ten times* the electrical power production of traditional ICE-powered TWVs and reducing static fuel use by over 35%, these HE retrofits *eliminated* the need for towed trailers for external power generation, significantly reducing the length of convoys and footprints of TOCs—and thus, their targetability by the enemy.[352] Additionally, with onboard electrical power generation capabilities, Soldiers were able to set up and tear down vehicle microgrids to power TOC and CP operations in less than three minutes, a huge advantage for these typically large, slow-displacing targets on the battlefield. [353] As the TVEK and TPIK were merely modifying retrofits, experts estimate the similar tactical gains from procuring more of these kits and eventually developing purpose-built HE TWVs and GCVs will be astronomical.[354]

Aside from these proven tactical advantages, investing in HE TWV innovation will also likely yield exponential performance benefits over time from revolutionized vehicle designs and configurations.[355] For example, "[t]he use of hub motors or electric assist axles, and conformable batteries" would dramatically affect design considerations of TWVs and GCVs by no longer

[350] *See* E-mail 1, McGrew, *supra* note 170.

[351] *See id*.

[352] *See id*.

[353] *See id*. One unit's commander expressed disbelief as he watched these electrification kits revolutionize land-based C2 operations, changing his CP from a complicated system relying on six loud, fuel-guzzling, exhaust-emitting towed generator trailers to a single, near-silent electrified TWV that powered the unit's electrical C2 systems. *See* Telephone Interview, McGrew, *supra* note 282; E-mail 1, McGrew, *supra* note 170.

[354] *See* Mancillas, *supra* note 11, at 5. *See generally infra* notes 232–315 (examining the DoD acquisitions process for military vehicles).

[355] Mancillas, *supra* note 11, at 5.

needing to design vehicles around heavy, bulky engines and transmissions.[356] Such evolutions in vehicle drivetrain configuration may in turn alter vehicles' shape and profile, how and where equipment and personnel can be distributed, armor requirements, and armament requirements.[357] Further, design and configuration improvements coupled with increased electricity output capability may allow for remote diagnostics, updates, and predictive maintenance not yet possible today.[358] In sum, the potential tactical benefits achievable through HE TWV innovation may ultimately prove limitless.

b. Operational Advantages – Achieving Greater Operational Independence and Endurance; Reducing Logistical Burdens (Fuel Resupply and Maintenance Requirements)

The operational level "links strategy and tactics by establishing operational objectives needed to achieve the military end states and strategic objectives. It sequences tactical actions to achieve objectives."[359] Hybrid-electric-powered vehicles enable military commanders to address two crucial operational challenges on the modern battlefield: energy logistics and formation endurance.[360] Expediently modernizing the force by incorporating more flexible HED across the

[356] *Id*.; *see* Roger Kaza, *The Engines of our Ingenuity, No. 2714: Hub Motors*, CULLEN COLL. OF ENG'G, U. OF HOUSTON (Mar. 26, 2024), https://engines.egr.uh.edu/episode/2714.

[357] Mancillas, *supra* note 11, at 5.

[358] *Id*.

[359] *See* JP 1, *supra* note 325, at I-8. "The focus . . . is on the planning and execution of operations using operational art: the cognitive approach by commanders and staffs—supported by their skill, knowledge, experience, creativity, and judgment—to develop strategies, campaigns, and operations to organize and employ military forces by integrating ends, ways, and means." *Id*.

[360] *See* Mancillas, *supra* note 11, at 2; Hom, *supra* note 12, at 1, 3. Energy logistics refers to the coordination of supplying armed forces with operational energy, the "energy required for training, moving, and sustaining military forces and weapons platforms for military operations." *See* 10 U.S. Code § 2924(4); 2023 DoD OES, *supra* note 93, at 6. "The term [operational energy] includes energy used by tactical power systems and generators and weapons platforms." 10 U.S. Code § 2924(4). Operational endurance is "[t]he length of time that an army unit can continuously engage in operations without resupply." National Academies of Sciences, Engineering, and Medicine, *Electrification of the Army's Light Combat Vehicle Fleet: Proceedings of a Workshop – In Brief*, THE NAT'L ACADS. PRESS 2 n.5 (2023) [hereinafter Nat'l Academies, *Electrification*], https://doi.org/10.17226/26886.

operational ground vehicle fleet would reduce the logistic burdens of constant fueling and maintenance operations that have historically slowed down and crippled military vehicle formations.[361] This relief would, in turn, provide land-based formations the capability to move farther and longer without relying on constant fuel resupply.

Fuel and mobility drive all decisive actions.[362] Therefore, adversaries often exploit this weakness, attacking petroleum refineries, pipelines, and fuel convoys.[363] For example, during the Vietnam War, Viet Cong and North Vietnamese forces frequently attacked U.S. Army fuel and other resupply convoys with company-sized ambushes, resulting in thousands of U.S. casualties.[364] This vulnerability becomes even more dangerous in modern warfare; during the recent conflicts in Iraq and Afghanistan, near-constant enemy attacks on U.S. fuel resupply convoys accounted for *more than one-quarter of all U.S. casualties*.[365]

With the depth of the battlefield expanding exponentially in recent years, further intensifying land forces' logistical burdens, DoD has a significant incentive to abandon its "single fuel

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[361] Hom, *supra* note 12, at 3.

[362] *See id*.

[363] *Id*.; *see* Richa Syal, *"Gushing Oil and Roaring Fires": 30 Years On Kuwait is Still Scarred by Catastrophic Pollution*, THE GUARDIAN (Dec. 11, 2021), https://www.theguardian.com/environment/2021/dec/11/the-sound-of-roaring-fires-is-still-in-my-memory-30-years-on-from-kuwaits-oil-blazes; Thom Shanker & David Sanger, *U.S. Suspects Iran Was Behind a Wave of Cyberattacks*, N.Y. TIMES (Oct. 13, 2012), https://www.nytimes.com/2012/10/14/world/middleeast/us-suspects-iranians-were-behind-a-wave-of-cyberattacks.html.

[364] https://transportation.army.mil/history/unit_history/124tb.html

[365] James Conca, *U.S. Military Eyes Mini Nuclear Reactors to Reduce Convoy Casualties*, FORBES (Mar. 12, 2019), https://www.forbes.com/sites/jamesconca/2019/03/12/our-military-wants-small-nukes-to-reduce-convoycasualties/#329cbe43ba2b; David Eady et al., *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys, Final Technical Report*, U.S. ARMY ENVT'L POL.INST. 9 (Sept. 2009). Although some reports found that enemy attacks on fuel convoys accounted for up to half of all U.S. casualties in Iraq and Afghanistan, others found they accounted for one in eight U.S. casualties. *See* Mancillas, *supra* note 11, at 2; *Pentagon Could Save Lives by Cutting Fuel Use – Study*, REUTERS (Nov. 10. 2009), https://www.reuters.com/article/rbssAerospaceDefense/idUSN1028357920091110.

concept."[366] After two decades of executing predominantly counterinsurgency operations in the Middle East, where fuel was more easily accessible, even senior military leaders may take for granted the ability to easily acquire and resupply their units with fuel to keep moving.[367] However, when U.S. ground forces eventually face a LSCO again, the emergence of anti-access/area denial (A2/AD) weapons and surveillance systems designed to counter operational reach—from longer-range missiles to drone reconnaissance assets—will further degrade the ability of U.S. ground forces to stockpile needed supplies and transition to the offense.[368] Operations requiring widely dispersed forces "will quickly overtax current fuel distribution methods."[369]

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[366] *See* Kern, *supra* note 10.

[367] *See id*. The nature of future armed conflict foreshadows the logistical concerns over fueling operations and the SFC:

> What started as a way to streamline the logistics for US armored units in Europe now threatens to constrain operational energy innovation at a critical time for the US military. The US military is relying on innovative new operating concepts like Multi-Domain Operations and Expeditionary Advanced Base Operations (EABO) to counter aggression by China and Russia, but the concepts for operational energy are stuck in the Cold War. Distributed operations, seen as a critical piece to all of the services' emerging operating concepts, will strain logistics networks in new ways, especially with regard to fuel and operational energy.

Id.

[368] Hom, *supra* note 12, at 1. Anti-access/area denial (A2AD) is a strategy or operation that is intended to control an adversary's movement to or maneuverability within an area. In particular, anti-access is "[a]ction intended to slow deployment of friendly forces into a theater or cause forces to operate from distances farther from the locus of conflict than they would otherwise prefer. A2 affects movement to a theater." In contrast, area denial is "[a]ction intended to impede friendly operations within areas where an enemy cannot or will not prevent access. AD affects maneuver within a theater." U.S. DEPT OF DEF., DEPARTMENT OF DEFENSE AUTHORIZATION FOR APPROPRIATIONS FOR FISCAL YEAR 2012 AND THE FUTURE YEARS DEFENSE PROGRAM 522 (2011). "In the absence of dominant U.S. power projection capabilities, the integrity of U.S. alliances and security partnerships could be called into question, reducing U.S. security and influence and increasing the possibility of conflict." U.S. DEPT OF DEF., QUADRENNIAL DEFENSE REPORT ix (Feb. 2010) [hereinafter QDR 2010]. "Prudence demands that the Department prepare for possible future adversaries likely to possess and employ some degree of anti-access capability—the ability to blunt or deny U.S. power projection—across all domains." QDR 2010, *supra*, at 9.

[369] Hom, *supra* note 12, at 1.

Recent studies by the U.S. Army's Combined Arms Center (ACAC) identified line-haul and tactical fuel distribution as a critical gap in the Army's warfighting capabilities,[370] finding that the Army cannot currently sustain itself at the operational level in LSCOs without external support or stockpiles of petroleum-based fuel.[371] Other Services are similarly concerned, with recent Marine Corps wargaming in the Pacific identifying sustainment (particularly fuel sustainment) as their leading operational constraint.[372] This danger is exacerbated by warnings from the PRC's military leaders that they intend to contest U.S. maritime operations and specifically target U.S. logistics vessels.[373]

Providing a means to begin filling this critical operational independence gap, the fuel-saving benefits from incorporating HED technology into the TWV fleet would better meet MDO concepts, which rely on the JF's ability to conduct dispersed and independent operations effectively.[374] As one 2022 RAND survey noted, "[t]he increased quality, volume, and geographic breadth of [Russian and Chinese] combat capabilities could be addressed by improving the mobility and supportability of U.S. platforms."[375] Electrification of TWVs, in concert with organic

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[370] *Id.* "In a contested environment, balancing the risk of resupplying forward elements while potentially exposing their positions becomes increasingly dangerous." *Id.*

[371] *See id.*

[372] *See* Kern, *supra* note 10. General David H. Berger, Commandant of the U.S. Marine Corps, provided a chilling assessment of the Corps' ability to support logistical sustainment in the U.S. Navy's "Force Design 2030": "I am not confident that we have identified the additional structure required to provide the tactical maneuver and logistical sustainment needed to execute [Distributed Maritime Operations], [Littoral Operations in a Contested Environment], and EABO in contested littoral environments against our pacing threat." *See* U.S. DEP'T OF THE NAVY, FORCE DESIGN 2030 10 (2020).

[373] *See* Mills & Wiechens, *supra* note 59; Kern et al., Albatross, *supra* note 10; Christopher Woody, *In a War with China, the US Navy's Warships Might Not Be the First Target*, BUS. INSIDER (June 5, 2020), https://www.businessinsider.com/in-war-china-us-logistics-fleet-would-be-major-target-2020-6.

[374] Mancillas, *supra* note 11, at 2, 3. "Key tenets of the MDO concept are calibrated force posture, multi-domain formations, and convergence; inherent in these tenets is the conduct of dispersed operations with the ability to operate independently. These operational tenets require the energy independence that electrification promises." *Id.* at 2.

[375] WONG ET AL., *supra* note 40, at 13;

persistent power generation capabilities, would "dramatically increase the amount of time units can sustain operations without external logistical support."[376] For example, one projection by an Army capabilities directorate found that TWV electrification could reduce fuel demand in LSCOs by almost 50 percent.[377] Such "localized" energy logistics—that is, the use of power generation systems that are organic to deployed forces to either partially or entirely "refuel" their vehicles—would substantially untether U.S. ground forces from logistics vulnerabilities, thereby reducing the targetability and predictability of crucial supply lines in our global operations of all types.[378] Another study by the AFC Ground Vehicle Systems Center (GVSC) demonstrated that simply incorporating anti-idle technology in TWVs and GCVs "extend[s] the operational duration from 3 to 5 days to outlast the adversary."[379] The advantages of a *several-day increase* in operational

[376] *Id.* at 3.

[377] *Id.*

[378] *Id.* In 2003, Marine Corps General John Mattis, then the Commander of U.S. Central Command, said that U.S. ground forces needed to be "unleashed from the tether of fuel." Crawford, *supra* note 81, at 3. In 2011, when asked to elaborate by Congressman Adam Smith during a House Armed Services Subcommittee hearing, Mattis explained:

> On the fuel, it is a significant Achilles heel for us when you have to haul the amounts of fuel that we have to haul around the battlefield for the generators and for the vehicles. We are working with DARPA [Defense Advanced Research Projects Agency], we are working with a number of civilian organizations to try and find solutions. There are efforts under way to make more expeditionary bases which would actually generate some of their own energy requirements using, for example, solar power. In many of these places, there is a lot of sunshine. If we can get expeditionary capability to capture that and then basically recharge our batteries. I mean, it is an amazingly complex effort to maintain the fuel lines. And it also gives the enemy an ability to choose the time and place of attacking us. We are engaged with Science and Technology, we are engaged with DARPA, and we are looking at very pragmatic ways of doing this. We are also looking at what we can do to actually change how we distribute fuel, to reduce the enemy's opportunities to come after us.

Hearing on National Defense Authorization Act for Fiscal Year 2012, Hearing before the S. Comm. on Tactical Air & Land Forces of the H. Comm. on Armed Serv., 112th Cong. 173 (Mar. 3, 2011); *see* Crawford, *supra* note 81, at 4.

[379] *See* Nat'l Academies, *Electrification*, *supra* note 396, at 2. *See* E-mail 1, McGrew, *supra* note 170. More recent demonstrations by Army units at the National Training Center at Fort Irwin during Project Convergence Capstone (PCC-4) further demonstrated this operational endurance that the reduced fuel consumption from anti-idle kits provides. *See* Telephone Interview, McGrew, *supra* note 282; E-mail 1, McGrew, *supra* note 170. Demonstrations of the Vehicle Integrated Power Kits (VIPK), a similar retrofitted anti-idle electrification kit but for heavier TWVs, showed immense tactical and operational advantages of hybrid-electrifying the TWV fleet,

endurance on the battlefield are not to be understated. These fuel savings also mean freeing up existing, limited fuel supplies on ships and forward operating bases to be used for aircraft, tanks, and other heavy combat platforms.[380]

The capacity for EVs to push energy production and sustainment capabilities down to the lowest tactical level would also negate the effectiveness of enemy A2/AD capabilities.[381] Given the DoD's enduring strategy and defense posture, which focuses on deterring and "defeating adversaries across the range of military operations, including adversaries equipped with sophisticated [A2/AD] capabilities," localized energy production capability thus supports DoD operations across MDOs.[382]

As a final benefit for increasing operational independence and endurance, energy-source flexibility—that is, the ability for HE TWVs to use energy through a wider number of possible sources—better enables units to seek sourcing of energy not only from planned resupply points but also from prepositioned power nodes for recharging across an area of operations (AO) or tapping into host-nation electric infrastructures.[383] In particular, the benefit of being able to tap into regional sources of electricity during overseas operations will likely only increase from the continuing boom of overseas investment in renewable power generation and EV production,

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including "[t]en times the electrical power production[,] 30[%] mission fuel reduction[,] eliminat[ing] the need for a towed trailer[,] 25% mobility fuel use reduction," and rapid deployment and displacement of a vehicle microgrid for CPs. *See* E-mail 1, McGrew, *supra* note 170.

[380] Commander Michael Knickerbocker, *Military EVs are a Necessary Awakening – Not 'Wokeness,'* THE HILL (Apr. 27, 2022), https://thehill.com/opinion/national-security/3469206-military-evs-are-a-necessary-awakening-not-wokeness.

[381] Mancillas, *supra* note 11, at 3.

[382] QDR 2010, *supra* note 368, at 32.

[383] *Id*.

especially among our allies around the world.[384] This potential for increased interoperability is "vital to U.S. international and intra-service relationships" and will "reduce the costs of warfighting, increase burden-sharing, improve operational effectiveness, and enable future coalition or joint service operations."[385]

In addition to providing greater operational independence, HE TWVs would reduce the prevalence of vulnerable logistics lines in a LSCO, primarily because of their reduced fuel consumption and lower maintenance requirements. Smaller, simpler ICEs in HEVs (and drastically fewer moving parts in AEVs) produce increased drivetrain efficiency, resulting in much lower fuel consumption.[386] This ability to operate at longer distances without refueling means they can operate more independently without resupply.[387]

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[384] *See Massive Expansion of Renewable Power Opens Door to Achieving Global Tripling Goal Set at COP28*, INT'L ENERGY AGENCY (Jan. 11, 2024) [hereinafter *IEA Report*], https://www.iea.org/news/massive-expansion-of-renewable-power-opens-door-to-achieving-global-tripling-goal-set-at-cop28. For example:

> [U]nder current policies and market conditions, global renewable capacity is already on course to increase by two-and-a-half times by 2030 . . . Solar PV and onshore wind deployment through 2028 is expected to more than double in the United States, the European Union, India and Brazil, compared with the last five years. Prices for solar PV modules in 2023 declined by almost 50% year-on-year, with cost reductions and fast deployment set to continue. This is because global manufacturing capacity is forecast to reach 1100 GW by the end of 2024, significantly exceeding demand.

Id.

[385] WONG ET AL., *supra* note 40, at 17; ERIC LARSON ET AL., RAND CORP., MR-1603-AF, INTEROPERABILITY OF U.S. AND NATO ALLIED AIR FORCES: SUPPORTING DATA AND CASE STUDIES 5 (2004). Interoperability is defined as the "ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them to operate effectively together." WONG ET AL., *supra* note 40, at 17. "When the services and allied nations have joint acquisition programs, such as the Joint Strike Fighter program, this allows for interoperability and more-diverse missions." WONG ET AL., *supra* note 40, at 17.

[386] Mills & Wiechens, *supra* note 59; *see* Teahupoo, *Why Hybrids Require Less Maintenance*, STREET DIRECTORY, https://www.streetdirectory.com/travel_guide/22650/car_accidents/why_hybrids_require_less_maintenance.html (last visited Apr. 11, 2024).

[387] *See TWV Hearing*, *supra* note 73, at 5 (statement of Mr. Michael Cadieux, Director, GVSC, DEVCOM).

Fewer moving parts and more efficient drivetrains in AEVs and HEVs also generally mean significantly less maintenance requirements.[388] In fact, studies show that "hybrids, on average, have 26 percent fewer problems than their ICE counterparts."[389] Reduced maintenance and repair requirements provide three crucial operational benefits.[390] First, of interest to commanders at all levels, lower vehicle maintenance requirements reduce strain on operational budgets in garrison and deployed environments.[391] Second, lower maintenance requirements also mean a reduced need for operations to continually plan for resource-heavy logistics packages (LOGPACs).[392] Finally, lower maintenance requirements mean less time offline for both vehicles and their crews.[393] This also reduces the need for mechanics to constantly repair ICE motors with thousands of moving parts, further relieving strain on personnel time and energy.[394] This reduction in maintenance requirements—and eventually on training requirements, as maintenance on these vehicles becomes more straightforward with greater HED innovation—thus allows DoD leaders to allocate more personnel to warfighting rather than support operations, a vital benefit given the worsening difficulties in military recruiting and retention.[395] In sum, the operational advantages of

[388] Mancillas, *supra* note 11, at 6–7; *see* Teahupoo, *supra* note 386.

[389] *See* AutoGuide.com Staff, *Hybrids Soar Over ICE Vehicles in Reliability, PHEVs and EVs Falter*, AUTOGUIDE (Nov. 30, 2023), https://www.autoguide.com/auto/featured-articles/hybrids-soar-over-ice-vehicles-in-reliable-phevs-and-evs-falter-44608540.

[390] Mancillas, *supra* note 11, at 6-7; *see* Teahupoo, *supra* note 386.

[391] Mancillas, *supra* note 11, at 6–7.

[392] *Id.* at 6–7.

[393] *See id.* at 6–7.

[394] *See id.* at 6–7.

[395] *See id.* at 6–7; *see also* Terrance Bell, *JLTV Instruction Fully Integrated into Wheeled Vehicle Mechanic Course*, U.S. ARMY (Apr. 5, 2022), https://www.army.mil/article/255386/jltv_instruction_fully_integrated_into_wheeled_vehicle_mechanic_course (noting that the 91B10 Wheeled Vehicle Mechanic Advanced Individual Training course trains more than 5000 Soldiers annually on maintenance of all TWV types).

HE TWVs, especially in terms of their logistic and maintenance benefits, make them among the greatest "force-multiplying" acquisition opportunities for DoD.[396]

c. Strategic Advantages – Reducing Vulnerable Fossil Fuel Reliance, "Future-Proofing" the Tactical Vehicle Fleet to Remain Competitive, and Combatting Climate Change as a National Security Threat

The strategic level involves "employing the instruments of national power in a synchronized and integrated fashion to achieve theater and multinational objectives."[397] At this level, it is important to note the mission of DoD is "to provide the military forces needed to deter war and to protect the security of the United States."[398] Similarly, as the primary land-based Service, the mission of the U.S. Army is "to deploy, fight, and win our nation's wars by providing ready, prompt, and sustained land dominance as part of the joint force of all U.S. military."[399] Meeting these nested missions and ensuring national security at the highest, strategic level requires U.S. ground forces constantly remain competitive against potential adversaries by simultaneously considering shifting geopolitical conditions, evolving technological capabilities, and dwindling natural resources.[400] Nevertheless, despite the historic might of the U.S. military, even its strongest,

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[396] *See* Knickerbocker, *supra* note 380 ("Manpower and money are not in limitless supply. Electric vehicles buy back time, money[,] and manpower."); *see also* Anthony Capaccio, *Nearly 40% of US Attack Submarines Are Out of Commission for Repairs*, BLOOMBERG (July 11, 2023), https://www.bloomberg.com/news/articles/2023-07-11/us-navy-attack-submarine-readiness-almost-40-out-of-commission-for-repairs (discussing how some of the most crucial submarine assets in the Navy are offline 40% of the time due to maintenance of their engines).

[397] *See* JP 1, *supra* note 325, at I-7; *see also Strategic*, OXFORD ENGLISH DICTIONARY, https://www.oxfordlearnersdictionaries.com/definition/english/strategic (last visited Apr. 11, 2024) (defining "strategic" as "relating to, or characterized by the identification of long-term or overall aims and interests and the means of achieving them; designed, planned or conceived to serve a particular purpose or achieve a particular objective"). One of the most significant instruments of national power is a state's military strength, composition, and technologies. *See* CHAIRMAN, JOINT CHIEFS OF STAFF, JOINT DOCTRINE NOTE 2-19, STRATEGY II-2 (10 Dec. 2019).

[398] *See About*, U.S. DEP'T OF DEF. https://www.defense.gov/about (last visited Apr. 11, 2024).

[399] *See Purpose-Legacy*, U.S. ARMY, https://www.goarmy.com/explore-the-army/purpose-legacy.htm (last visited Apr. 11, 2024).

[400] *See id.*

most precise instruments of national power are at risk of dulling by the DoD's continued overreliance on a single fuel source.[401] Prioritizing the acquisition of HED capabilities for its TWVs, however, may provide a timely whetstone to sharpen the strategic readiness of DoD ground forces through three key benefits: reducing the military's increasingly untenable dependence on oil around the globe; strengthening the U.S. military position relative to its strategic competitors by making it more energy-resilient; and reducing GHG emissions to combat the national security threat posed by climate change.[402]

The DoD's reliance on fossil fuels cannot be overstated. The DoD is the largest institutional consumer of petroleum fuels on the planet, using more than four billion gallons of fuel each year.[403] Since 2001, DoD has consistently accounted for between 77 and 80 percent of *all* energy consumption by the U.S. government; to be sure, DoD annually consumes more fuel than most countries.[404] Not surprisingly, its fuel bill is immense, with the Defense Logistics Agency (DLA) spending over $10 billion on bulk fuel in one FY.[405] Additionally, Congress must regularly resource

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[401] *See Daily Energy Report*, *supra* note 36.

[402] A whetstone is "a stone that is used to make tools, knives[,] and weapons sharp." *Whetstone*, OXFORD ENGLISH LEARNERS DICTIONARY, https://www.oxfordlearnersdictionaries.com/definition/english/whetstone (last visited Apr. 11, 2024). Military "readiness" is "a term regularly applied to the United States' ability to produce, deploy, and sustain military forces that will perform successfully in combat." G. JAMES HERRERA, CONG. RSCH. SERV., R46559, THE FUNDAMENTALS OF MILITARY READINESS 1 (2020) [hereinafter R46559]. "The DOD—including its predecessors the Departments of War and Navy—and Congress have used the word 'readiness' since at least the 1830s to discuss the state of military personnel, training, equipment, and other related activities. *See* R46559, *supra*, at 1.

[403] Mills & Wiechens, *supra* note 59.

[404] Crawford, *supra* note 81, at 4, 5.

[405] U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105531, DOD BULK FUEL: IMPROVED MANAGEMENT OVER TRANSACTIONS COULD LEAD TO MORE RELIABLE FINANCIAL REPORTING 1 (2023) [hereinafter GAO-23-105531]; *see* Mills & Wiechens, *supra* note 59. Although most of the DLA's "customers" are the military Services, it also sells the bulk fuel it purchases to non-DoD entities (e.g., foreign governments and other federal government entities). *See* GAO DoD Bulk Fuel, *supra* note 405. Nevertheless, this amount (over $10 billion in FY22) is staggering, especially considering that it has only increased since the drawdown in Iraq and withdrawal from Afghanistan in preceding years. *See* GAO-23-105531, *supra*, at 1. The known costs of fuel pose one danger; the volatility of prices from geopolitical factors poses another. For example, from the start of the Iraq war in 2003 until the surge in 2007, U.S. military fuel consumption slipped by about 10 percent, but costs more than doubled due to surging oil prices in the same period (i.e., although fuel consumption decreased

DoD with more fuel than budgeted, often amounting to billions of dollars in supplemental DoD appropriations each year.[406] In the Persian Gulf alone, DoD expends billions of dollars and countless other resources and manhours annually to constantly secure oil shipping lanes that are vital to U.S. economic and security interests.[407] Furthering these financial costs of DoD's fuel dependence, the ongoing Russia-Ukraine conflict, as well as commitments by the Organization of the Petroleum Exporting Countries (OPEC) to reduce petroleum production, will hold fuel prices high for the foreseeable future.[408]

Estimates by Army leaders place the cost of fuel in deployed and austere environments especially high; in Afghanistan and Iraq, the price of delivering fuel to remote outposts cost as much as $1,000 per gallon, not to mention the cost in Service members' lives from enemy attacks on fuel resupply convoys.[409] These costs will only increase in LSCOs, with an armored division estimated to consume up to half a million gallons of fuel daily.[410] For example, a 2017 RAND Corporation report identified that both the PRC and Russia could effectively launch an "interdiction campaign" to restrict the flow of battlefield necessities like fuel to U.S. forces at a

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from about 145 billion barrels in 2003 to 132 billion barrels in 2007, fuel costs increased from $5.2 billion in 2003 to $12.6 billion in 2007). *US Military Fuel Spending*, REUTERS (Mar. 20, 2008), https://www.reuters.com/article/idUSN20416568.

[406] Mills & Wiechens, *supra* note 59.

[407] *See* Dr. Edward J. Marolda, *The United States Navy and the Persian Gulf*, NAVAL HIST. & HERITAGE COMMAND ("Maintaining political stability and the free flow of oil to the global economy have been the overarching objectives of U.S. foreign policy in the Persian Gulf for almost half a century. The U.S. Navy has been one of the primary instruments of that policy, in both peace and war."); Mark Delucchi, *The Cost of Protecting Oil in the Persian Gulf*, RESOURCES (Jan. 16, 2012), https://www.resources.org/common-resources/the-cost-of-protecting-oil-in-the-persian-gulf-1 (estimating that "the long-run variable costs of defending all interests in the Persian Gulf in peacetime are on the order of $30 billion to $75 billion per year—a substantial fraction of the roughly $300 billion per year spent by DOD during peacetime.").

[408] Mills & Wiechens, *supra* note 59.

[409] *Id*.

[410] *See id.*

strategic level in a LSCO.[411] The DoD's continued dependency on a single fuel source to keep its wheels running—a demand that continues to rise over recent decades despite massive advances in vehicle HED technology in the same period—thus presents an increasingly apparent "Achilles Heel" to potential adversaries in future armed conflicts.[412]

This strategic vulnerability is highlighted by recent historical examples of how access to oil can itself serve as a strategic weapon, from the burning of oil fields to the targeting of oil tankers and refineries to the cutting off of key fuel resupply routes. First, highlighting the strategic and political symbolism of oil, as Iraqi forces pulled out of Kuwait in 1991 during the First Gulf War, they deliberately set more than 700 oil wells ablaze, blackening skies for hundreds of miles and pouring a staggering 11 million barrels (over 240 million gallons) of crude oil into the Persian Gulf.[413] Decades later, in 2016, retreating Islamic State of Iraq and Syria (ISIS) militants employed the same tactic, setting fire to oil fields as they fled from Mosul.[414] In 2021, a fatal Iranian drone strike hit the bridge of the MT Mercer Street, an Israeli-linked oil tanker, off the coast of Oman in the Arabian Sea while it was bound for the United Arab Emirates.[415] Also, in 2021, the Iran-

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[411] Kern et al., Albatross, *supra* note 10; *see* DAVID OCHMANEK ET AL., RAND CORP., RR1782-1, U.S. MILITARY CAPABILITIES AND FORCES FOR A DANGEROUS WORLD: RETHINKING THE U.S. APPROACH TO FORCE PLANNING 123 (2017).

[412] Kern et al., Albatross, *supra* note 10.

[413] *See* Syal, *supra* note 363; Michael Castellani & Andrew Stuhl, *The Gulf War Oil Spill: A Man-Made Disaster*, ENV'T & SOC'Y (2018), http://www.environmentandsociety.org/tools/keywords/gulf-war-oil-spill-man-made-disaster. Iraqi forces apparently did so to prevent U.S. forces from using the oil or attempting beach landings. "Subsequent analysis estimated that [burning] released 133 million tonnes of carbon dioxide into the air. That is more than a year's worth of CO2 emissions for a medium-sized country such as the Philippines, Belgium or Nigeria." Megan Darby, *Photos Reveal Iraq Oil Fields Burning Behind ISIS Retreat*, CLIMATE CHANGE NEWS (Aug. 23, 2017), https://www.climatechangenews.com/2017/08/23/photos-reveal-iraq-oil-fires-burning-behind-isis-retreat.

[414] *See* Darby, *supra* note 413; Brad Plumer & Yochi Draezen, *In Iraq, the Environment Itself Has Once Again Become a Weapon of War*, VOX (Nov. 1, 2016), https://www.vox.com/2016/11/1/13481682/isis-mosul-oil-fires-sulfur.

[415] *See* Jon Gambrell, *US, UK and Israel Blame Iran for Ship Attack; Tehran Denies*, ASSOC. PRESS (Aug. 1, 2021), https://apnews.com/article/middle-east-business-iran-persian-gulf-tensions-419efc522acbd213a79696c9876af6dc. The tanker was crewed by members from the United Kingdom and

aligned Houthis conducted an air attack on an oil refinery in Saudi Arabia, the world's top oil exporter.[416] Nine years prior, another suspected-Iranian attack targeted Saudi Aramco, the world's largest oil company, through cyberspace via a virus that crippled computers across the Saudi oil industry.[417] Finally, demonstrating the risks to operational fuel access across international borders, in 2010, in response to a U.S. airstrike that mistakenly killed or wounded several Pakistani soldiers, Pakistan closed a key border crossing into Afghanistan, keeping critical fuel trucks bound for NATO convoys idling on the other side of the border.[418]

In light of these historical examples of adversaries' attacks on vulnerable oil supplies, U.S. ground forces must wean off their dependence on foreign oil. This is especially true in critical theaters like Europe, where before Russia's invasion of Ukraine, DoD's bases and military operations consistently used the energy equivalent of nearly half a million barrels of Russian oil

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Romania; Israeli, U.S., British, and Romanian officials blamed the "unlawful and callous attack" on Iran, who denied involvement. *Id.*

[416] *See* Lisa Barrington, *Drone Strike on Riyadh Oil Refinery Claimed by Houthis Causes Fire*, REUTERS (Mar. 19, 2021), https://www.reuters.com/article/saudi-security-yemen-int/drone-strike-on-riyadh-oil-refinery-claimed-by-houthis-causes-fire-idUSKBN2BB19Q.

[417] *See* Shanker & Sanger, *supra* note 363. Then-U.S. Secretary of Defense Leon Panetta called the cyberattack "probably the most destructive attack that the private sector has seen to date." *Id.* United States officials suspected Iran because Saudi Arabia is Iran's main rival in the Middle East and is among the Arab states that argued privately for the toughest United Nations actions against Iran. Aramco, the Saudi state oil company, bolstered supplies to customers who could longer obtain oil from Iran because of Western sanctions. *Id.*

[418] Karen Bulliard & Karen DeYoung, *Pakistan Keeps Afghan Border Crossing Closed to NATO Convoys*, WASH. POST (Oct. 7, 2010), https://www.washingtonpost.com/wp-dyn/content/article/2010/10/06/AR2010100600358.html; *see* Mills & Wiechens, *supra* note 59; Crawford, *supra* note 81, at 4. A related strategic vulnerability comes from the frequent need for U.S. forces in combat to resupply fuel demands across international borders:

> Between 2008 and 2014, [U.S.] convoys were attacked en route through Pakistan to NATO bases in Afghanistan 485 times, causing 167 deaths and 450 injuries. As the then Secretary of the Navy Ray Mabus said, "[f]ossil fuel is the No. 1 thing we import to Afghanistan . . ."

Crawford, *supra* note 81, at 4; *see* Elisabeth Rosenthal, *U.S. Military Orders Less Dependence on Fossil Fuels*, N.Y. TIMES (Oct. 4, 2010), https://www.nytimes.com/2010/10/05/science/earth/05fossil.html.

per year.[419] The DoD should not only prepare for but expect that adversaries will target and potentially cut off its petroleum fuel supply in future LSCOs. Seeking to untether itself from its monstrous petroleum fuel requirements by transitioning to HE TWVs is, therefore, a necessary step to ensure DoD can reallocate limited resources to effectively project force across the globe.[420]

In addition to the strategic benefit of reducing its vulnerable fossil fuel reliance, DoD should also seek to acquire HE TWVs because of the "future-proof" promise they offer to strengthen the relative position of U.S. ground forces amongst strategic competitors on the global stage. The 2018 U.S. National Defense Strategy (NDS) forecasted "a global security environment in which the reemergence of long-term, strategic competition is the central challenge." [421] "This

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[419] Mills & Wiechens, *supra* note 59; *see* Alexander S. Gard-Murray & Theodore J. Shanks, *Mapping U.S. Military Dependence on Russian Fossil Fuels*, WATSON INST. FOR INT'L & PUB. AFFAIRS, BROWN U. (Apr. 28, 2022), https://watson.brown.edu/climatesolutionslab/research/2022/mapping-us-military-dependence-russian-fossil-fuels. One study by Brown University highlights this untenable security risk:

> The U.S. military's dependence on fossil fuels has created a crucial security threat for its European bases. American taxpayers could inadvertently be helping to fund the Russian war effort to the tune of a million dollars a week. We estimate that before Russia's invasion of Ukraine, U.S. bases in Europe relied on Russian fossil fuels to meet 30% of their annual energy needs. This means that American forces in Europe have been buying the energy equivalent of nearly half a million barrels of oil from Russia every year. In light of Russia's pending cutoffs of gas to European countries, the Department of Defense's dependence on fossil fuels represents a serious threat to American and Western European security. Until the U.S. invests in sustainable energy sources and base electrification, these threats will continue.

Gard-Murray & Shanks, *supra*.

[420] *See id.* Fortunately, in its 2023 Operational Energy Strategy, the DoD acknowledged this strategic imperative for innovation:

> Foremost, the [DoD] needs to reduce operational energy demand to reduce risks and enhance military effectiveness in contested environments. . . For ground vehicles, the [DoD] will focus on maturing electrification technologies that save fuel and support flexible ground-based power, beginning with anti-idle capabilities, progressing to hybrid-electric and then all-electric drivetrains, while enhancing vehicle electrical production and the ability to import and export power.

See 2023 DoD OES, *supra* note 93, at 6.

[421] *See* U.S. SEC'Y OF DEF., U.S. DEP'T OF DEFENSE, 2018 NATIONAL DEFENSE STRATEGY 20 (2018) [hereinafter 2018 NDS]. The term "strategic competition" refers to "active rivalry between states that perceive their fundamental interests under threat by the opposing party." Lieutenant Colonel (Ret.) Scott McDonald, *Strategic Competition?* J. OF INDO-PACIFIC AFF. 5 (Winter 2020).

environment requires our military to regain its competitive advantages by becoming more lethal, resilient, agile, and ready across a range of potential contingencies and geographies." [422] Predominantly emphasizing U.S. strategic competition with adversaries like the PRC and Russia, the 2022 National Security Strategy (NSS) cautions that "[t]he PRC has expanded and modernized nearly every aspect of the PLA, with a focus on offsetting U.S. military advantages."[423] In response, the U.S. government recently recognized its need to, among other things, "modernize and strengthen [its] military so it is equipped for the era of strategic competition with major powers, while maintaining the capability to disrupt the terrorist threat to the homeland."[424]

In part to reduce its own vulnerable fossil fuel reliance, the PRC has begun investing heavily in HE military vehicles to improve its ground forces' mobility, stealth, and sustainability. For example, at a military expo in September 2023, the PRC unveiled its military's new HE "Lynx"

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[422] OFF. OF THE SEC'Y OF DEF., U.S. DEP'T OF DEF., DOD POLICY ON LANDMINES 1 (2020). Current U.S. national security strategy recognizes the immense strategic threat posed by the PRC:

> The most comprehensive and serious challenge to U.S. national security is the PRC's coercive and increasingly aggressive endeavor to refashion the Indo-Pacific region and the international system to suit its interests and authoritarian preferences. The PRC is the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military, and technological power to do it . . . The PRC is therefore the [DoD's] pacing challenge.

WHITE HOUSE, 2022 NATIONAL SECURITY STRATEGY, U.S. OFF. OF THE EXEC. 4 (October 2022), [hereinafter "2022 NSS"]; *see* McDonald, *supra* note 421, at 8.

[423] *See* 2022 NSS, *supra* note 422, at 4; 2022 NDS, *supra* note 38, at 20. Other sources recognize the strategic threats posed by Russia and the PRC to U.S. interests elsewhere in the world:

> [P]eer threats have begun to reassert themselves. China has emerged as a powerful actor on the world stage, and Russia has re-emerged as a spoiler of U.S. interests. . . Both states observed the U.S. military in action in the 21st century and have invested in military capabilities meant to exploit its weaknesses. It is now clear that Russia and China present peer-quality threats to U.S. interests in Europe and Asia.

WONG ET AL., *supra* note 40, at 6; *see* RAPHAEL S. COHEN ET AL., RAND CORP., RR-2849/1-AF, THE FUTURE OF WARFARE IN 2030 35–43 (2020).

[424] 2022 NSS, *supra* note 422, at 11; *see* R43838, *supra* note 323, at 2.

assault vehicle, for the first time incorporating electric propulsion into its combat vehicle fleet.[425] The PRC also continues to demonstrate a strong commitment to revolutionizing EV technologies in its civilian vehicle industry. With the inherently intertwined nature of the PRC's commercial industry and government, coupled with its recently published "military-civil fusion" (MCF) strategy of driving military innovation through fusion with civilian innovation, DoD's strategy must develop ways for U.S. ground forces to remain strategically competitive with such PRC initiatives.[426]

Hybrid-electrification is where the commercial vehicle industry is already going, so it will become increasingly challenging (and costly) for DoD to pay a premium for fuel, replacement parts, and maintenance services for its legacy ICE vehicles.[427] For example, although DoD is

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[425] *See China Unveils First Lynx Hybrid 6x6 All-Terrain Assault Vehicle*, ARMY RECOGNITION (Sept. 19, 2023), https://armyrecognition.com/defense_news_september_2023_global_security_army_industry/china_unveils_first_lynx_hybrid_6x6_all-terrain_assault_vehicle.html (last visited Apr. 11, 2024). The PLA's "Lynx" is similar in configuration and purpose to the DoD's Stryker, but with six wheels instead of eight. *See id.* The PRC also recently tested a hybrid gasoline-electric powered heavy-load missile transport truck (HTF5700HEV), similar to U.S. TWV variants, designed to carry intercontinental ballistic missiles. *See Chinese Prototype of 12x12 Missile Carrier on Hybrid Powertrain*, ARMY RECOGNITION (Sept. 14, 2020) [hereinafter *Chinese Hybrid Missile Carrier*], https://www.armyrecognition.com/weapons_defence_industry_military_technology_uk/chinese_prototype_of_12x12_icbm_carrier_on_hybrid_powertrain.html. Other modernization efforts by the People's Liberation Army (PLA) to reduce its fossil fuel reliance and logistic burdens while projecting force farther and longer include developing HE propulsion technology for its VN-17 Armored Personnel Carrier and ZBD-03 Infantry Fighting Vehicle (both similar to the U.S. Bradley Fighting Vehicle) as well as its ZFB-05 Utility Vehicle (similar to the U.S. HMMWV). *See Chinese Hybrid Missile Carrier*, *supra*.

[426] *See* Elsa Kania et al., *How Should the U.S. Respond to China's Military-Civil Fusion Strategy?* CHINA FILE (May 22, 2021), https://www.chinafile.com/conversation/how-should-us-respond-chinas-military-civil-fusion-strategy; Michael Horowitz & Lauren Kahn, *DoD's 2021 China Military Power Report: How Advances in AI and Emerging Technologies Will Shape China's Military*, COUNCIL ON FOREIGN RELS. (Nov. 4, 2021). *But see* Anja Manuel & Kathleen Hicks, *Can China's Military Win the Tech War?*, FOREIGN AFFS. (July 29, 2020), https://www.foreignaffairs.com/articles/united-states/2020-07-29/can-chinas-military-win-tech-war (cautioning against a U.S. strategy that tries to emulate PRC's inefficient government-driven approach to innovation, and instead to focus on what the U.S. does best in promoting research and development).

[427] *See* Mills & Wiechens, *supra* note 59. "The auto industry in Detroit and elsewhere has been moving toward hybrid and electric engines for years, proof that the technology has matured enough to be profitable." Travis Tritten, *Electric Military Vehicles Are Part of Biden Climate Agenda, Pentagon Says*, MILITARY (Nov. 9, 2021), https://www.military.com/daily-news/2021/11/09/electric-military-vehicles-are-part-of-biden-climate-agenda-pentagon-says.html. Indeed, "nearly all major manufacturers in the world plan to partly shift to hybrid and electric, or at least roll out new models." Tritt, *supra*. Some companies are further ahead in corporate strategic shifts to electrification, as illustrated by General Motors's plan to "eliminate gasoline models by 2035." Tritt, *supra*.

historically "an unpredictable partner for industry and often chang[ing] its mind about what it wants,' all of the U.S. prime defense contractors believe 'that industry views electrification as a persistent macro trend and will move into this area regardless of DoD support.'"[428] Modernization will therefore enhance DoD's military readiness and energy resilience, despite the uncertainty of ever-evolving battery technologies and shifting commercial markets.[429] Prioritizing the development and procurement of series-hybrid-electric power train designs, in particular, would likely leverage this advantage, regardless of the direction of future technological innovation.[430] In contrast to other vehicle architectures, the petroleum fuel tanks and onboard generators of series-hybrid-electric motors can be configured to run on different fuel sources (such as hydrogen, synthetic fuels from carbon dioxide, etc.) or even replaced with other power generation systems (like fuel cells).[431] Nevertheless, "there is no 'one-size-fits-all' solution for electrification: the Army will need flexibility, exportable power, and a full range of capabilities"; fortunately, seeking HED innovation best provides this potential.[432]

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[428] *See* Nat'l Academies, *Electrification*, *supra* note 396, at 3 (quoting Scott Hall, General Dynamics Land Systems (GDLS)). One RAND study in 2022 cautioned the future impact of vulnerable supply chains on the DoD's weapons systems:

> Globalization and advancing technologies make it more difficult to reliably produce complex military equipment at scale. Diminishing manufacturing sources result from the fact that DoD is a small-volume customer compared with the commercial market and that, eventually, because DoD systems become obsolete, only a small number of producers or even a single producer is left. Therefore, for some of its parts or subsystems, DoD ends up in a predicament in which it has to simply accept what the producer makes.

WONG ET AL., *supra* note 40, at 16.

[429] Mills & Wiechens, *supra* note 59; *see* de la Garza, *supra* note 318; Crawford, *supra* note 81, at 4.

[430] Mills & Wiechens, *supra* note 59.

[431] *See id.*

[432] *See* Nat'l Academies, *Electrification*, *supra* note 396, at 3 (quoting Michael Foster).

Finally, although reducing fuel dependence and gaining more "future-proof" capabilities already provides DoD with more than enough strategic incentives to acquire HED for its TWVs, the lower GHG emissions from HEVs also meet the 2022 NDS's requirement for the DoD to seek cleaner technologies to reduce its significant emissions and help curb the national security risk posed by climate change.[433]

Amidst changing political views, DoD has been unwavering in its treatment of climate change as a national security threat for decades.[434] For example, DoD leaders consistently acknowledge the challenges that climate-change-related natural disasters—such as severe flooding, storms, and drought—pose to military operations worldwide.[435] They also recognize that these impacts of climate change and the related dangers from global warming events, like famine from crop failure and severe storms, often further aggravate political disputes and lead to armed conflict, especially in already geopolitically unstable regions.[436] Finally, DoD leaders increasingly point to the national security dangers posed by warming and rising seas, such as the Russian navy's increased maritime

[433] *See* 2022 NDS, *supra* note 38, at 20. Global observations and scientific consensus now emphasize that the GHGs emitted by human activities are the primary driver of climate change and the planet's warming. *See* AM. ASS'N FOR THE ADVANCEMENT OF SCI., OPEN LETTER TO MEMBERS OF THE SENATE, STATEMENT ON CLIMATE CHANGE FROM 18 SCIENTIFIC ASSOCIATIONS 1 (2009) ("Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver.").

[434] *See* Curtis Cranston, *The U.S. Military's Environmental Protection Efforts: Unexpected Eco-Friendly Solutions to Land Management Problems*, 60 B.C.L. REV. 1023, 1029, 1046 (2019); Sarah E. Light, *Valuing National Security: Climate Change, the Military*, and Society, 61 UCLA L. REV. 1772, 1799 (2014); *see also* Sarah E. Light, *The Military-Environmental Complex*, 55 B.C. L. REV. 879, 893, 918 (2014) (noting that the DoD's energy operations recognize that climate change, caused partly by the military's significant use of fossil fuels, may increase the likelihood of geopolitical instability and future armed conflict). "The U.S. military has actually been talking about climate change for a long time, even as the issue has fallen in and out of political favor." *See* de la Garza, *supra* note 318.

[435] *See* U.S. DEP'T OF DEF., QUADRENNIAL DEFENSE REVIEW 2014 8 (2014) [hereinafter 2014 QDR]; Cranston, *supra* note 434, at 1046; Light, *supra* note 434, at 886.

[436] *See* Light, *supra* note 434, at 886.

access to previously frozen (but newly opened) shipping lanes in the Arctic Ocean, the flooding of coastal DoD bases, and the desertification of inland DoD bases worldwide.[437]

Recent prioritization of climate change response by the President, DoD, and Department of the Army further indicates the urgency of the threat.[438] In December 2021, President Joe Biden issued EO 14057 and the accompanying *Federal Sustainability Plan*, setting a range of goals to reduce GHG emissions across federal procurement and operations.[439] A key goal of EO 14057 is for Executive Branch agencies to transition their fleets to zero-emission vehicles (ZEVs).[440] The EO specifically requires all acquisitions of light-duty vehicles (e.g., sedans, smaller sport utility vehicles, and smaller pick-up trucks) to be ZEVs by the end of FY 2027 and requires *all* vehicle acquisitions (including medium- and heavy-duty vehicles) to be ZEVs by 2035. The EO "affects approximately 380,000 vehicles within Federal fleets as they become subject to replacement, and represents a significant transformation in the Federal government's approach to vehicle procurement."[441] To

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[437] Cranston, *supra* note 434, at 1046; *see* Andrew Revkin, *Defense Secretary Cites Climate Change as National Security Challenge*, PROREPUBLICA (Mar. 14, 2017), https://www.propublica.org/article/trumps-defense-secretary-cites-climate-changenational-security-challenge [https://perma.cc/XTM2-53GK]. *See generally* OFF. OF THE UNDER SEC'Y OF DEF. FOR ACQ., TECH., & LOGISTICS, U.S. DEP'T OF DEF., CLIMATE-RELATED RISK TO DOD INFRASTRUCTURE INITIAL VULNERABILITY ASSESSMENT SURVEY (SLVAS) REPORT (2018), https://climateandsecurity.files.wordpress.com/2018/01/tab-bslvas-report-1-24-2018.pdf [https://perma.cc/U7M9-CR3T] (surveying the negative impacts that DoD installations experienced from extreme weather events and assessing various threats posed by climate change to those installations' operations and security).

[438] *See* Emily E. Bobenrieth, *The Judge Advocate's Guide to Advising in Domestic Climate Crises Operations*, ARMY LAW. 5, 6 (publication forthcoming, 2024).

[439] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105350, FEDERAL FLEETS: ZERO-EMISSION VEHICLE IMPLEMENTATION 1 (2023) [hereinafter GAO-23-105350].

[440] *Id.* "A ZEV is any vehicle that, when operating, produces zero tailpipe exhaust emissions of certain pollutants or greenhouse gases, such as an electric vehicle." *Id.* Nevertheless, EO 14057 "only applies to acquisitions by executive agencies, as defined by 5 U.S.C. § 105, excluding independent regulatory agencies, as defined in 44 U.S.C. § 3502(5)." *Id*. at n.1; EO 14057, *supra* note 159, § 602(b). The Military Departments' tactical vehicles are thus excepted from these requirements. *See id*.; 5 U.S.C. § 105; 44 U.S.C. § 3502(5).

[441] GAO-23-105350, *supra* note 439, at 1. For example, GAO reported in 2022 that Federal agencies subject to the Order replaced or acquired about 45,000 vehicles in fiscal year 2021, and of those, about 260 were considered zero-emission. *Id.*; *see* GAO-23-105635, *supra* note 69, at 1 n.1.

date, Federal agencies have acquired more than 50,000 HEV or AEVs and installed hundreds of charging stations of various types on Federal installations around the world.[442] The DoD is executing this charge accordingly, already procuring thousands of AE and HE NTVs.[443]

Executive Order 14057 allowed agency heads to exempt from these mandatory ZEV procurement requirements "any vehicle, vessel, aircraft, or non-road equipment that is used in combat support, combat service support, military tactical or relief operations."[444] Nevertheless, the 2022 NSS, 2022 NDS, and 2022 Army Climate Strategy (ACS) all recognize that climate change poses a significant national security threat and, thus, DoD must reduce the GHG emissions of its military operations worldwide.[445] The 2022 NSS calls climate change the "greatest and potentially existential [problem] for all nations[,]"[446] framing it as "a top-tier threat on par with near-peer adversaries and competitors."[447] Additionally, the 2022 NDS evaluates climate change as a threat to DoD's readiness, installations, and capabilities.[448]

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[442] *See* WHITE HOUSE, FACT SHEET: BIDEN-HARRIS ADMINISTRATION ANNOUNCES NEW PRIVATE AND PUBLIC SECTOR INVESTMENTS FOR AFFORDABLE ELECTRIC VEHICLES *(2023)*. *See generally* MELISSA DIAZ & CORRIE CLARK, CONG. RSCH. SERV., R47675, FEDERAL POLICIES TO EXPAND ELECTRIC VEHICLE CHARGING INFRASTRUCTURE (2023) (discussing the Federal government's plan to build or leverage the necessary electrical infrastructure and charging stations for these ZEVs).

[443] American media often comments on the Army's rising budget in part to meet these procurement requirements. As one article commented, "[t]he focus on electrifying the Army's fleet is reflected in its expanding budget. In fiscal 2022, the Army spent $47.8 million on EV NTVs, but that figure ballooned to $78.4 million in fiscal 2023. The Army has asked for $270.6 million in fiscal 2024" for further EV NTV procurement. *See* Lee & Moore, *supra* note 107. Such articles also tie these efforts to the Army's efforts to electrify its TWVs and GCVs. *See id.* ("For now, the Army is focused on developing hybrid combat vehicles, which it thinks are "attainable, useful, and can reduce our sustainment footprint.").

[444] *See* EO 14057, *supra* note 159, § 602(b).

[445] *See* 2022 NSS, *supra* note 422, at 9; 2022 NDS, *supra* note 38, at 20; 2022 ACS, *supra* note 63, at 11.

[446] *See* 2022 NSS, *supra* note 422, at 9; 2022 NDS, *supra* note 38, at 20; 2022 ACS, *supra* note 63, at 11.

[447] Bobenreith, *supra* note 438, at 6; Erin Sikorsky, *A Central Role for Climate Change in the New U.S. National Security Strategy*, LAWFARE (Nov. 1, 2022), https://www.lawfareblog.com/central-role-climate-change-new-us-national-security-strategy.

[448] 2022 NDS, *supra* note 38, at 6; *see* Bobenreith, *supra* note 438, at 6.

Regardless of potential future shifts in political prioritization, DoD must continue to recognize that climate change poses a significant national security threat.[449] Mark Nevitt, a leading scholar at the intersection of environmental law and national security law, submits that climate change acts as both a "threat accelerant" and a "catalyst for conflict."[450] As a threat accelerant, climate change increases the frequency and intensity of extreme weather events "while threatening nations' territorial integrity and sovereignty through rising sea levels." As a catalyst for conflict, it leads to competition for scarce resources, internal displacement within nations, and climate refugees across national borders.[451] The types of conflicts it exacerbates are the same as those to which DoD often must respond.

As the world's single greatest institutional GHG polluter, DoD has a significant incentive to reduce its harmful emissions where possible to curb the rate of these climate change impacts.[452] Although there are no studies examining the potential climate impacts of DoD's HED modernization, seeking procurement of more fuel-efficient and potentially cleaner energy would likely reduce DoD's vehicle emissions that would otherwise further contribute to climate change and increase national security risks.[453]

2. Political Advantages

Just as DoD leaders would apply the three levels of warfare lens, those in Congress would assess the proposed acquisition of HE TWVs in terms of the *political* benefits. Their proper lens

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[449] *see* Bobenreith, *supra* note 438, at 6.

[450] *See* Mark P. Nevitt, *On Environmental Law, Climate Change, & National Security Law*, 44 HARVARD ENV'T L. REV. 321 (2020).

[451] *Id.* at 325, 345.

[452] *See* Crawford, *supra* note 81, at 2, 4; Alexander Nazaryan, *The U.S. Department of Defense is One of the World's Biggest Polluters*, NEWSWEEK (July 17, 2014), http://www.newsweek.com/2014/07/25/us-department-defence-one-worlds-biggest-polluters-259456.html.

[453] *See* Mills & Wiechens, *supra* note 59.

must, therefore, be the three levels of government action under international relations and political science theory: (1) the individual, (2) the state, and (3) the international system.[454] As Kenneth N. Waltz first proposed in his books, *Man, the State, and War* and *Theory of International Politics*, these three levels of analysis see use by policymakers and political science theorists in assessing the reasons for a state's action, such as the application of a major instrument of national power.[455] Although generally backward-looking, this assessment also provides U.S. policymakers with a helpful tool to assess the benefits of future state action.[456]

At the *individual* level of analysis, HED in the TWV fleet provides American lawmakers the opportunity to better equip ground forces and enhance their survivability. Because the majority of the U.S. population shares this aim to protect Service members in an armed conflict, lawmakers should generally support spending measures for this initiative.[457]

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[454] David J. Singer, *The Level-of-Analysis Problem in International Relations*, 14 WORLD POLS. 1, 77, 80–84 (1961); *see* KENNETH N. WALTZ, THEORY OF INTERNATIONAL POLITICS 3 (Addison-Wesley, 1979) [hereinafter WALTZ, THEORY]; GRAHAM ALLISON, ESSENCE OF DECISION: EXPLAINING THE CUBAN MISSILE CRISIS 21 (1st ed. 1971); KENNETH N. WALTZ, MAN, THE STATE, AND WAR: A THEORETICAL ANALYSIS 56 (Columbia University Press 1959) [hereinafter WALTZ, MAN, STATE, & WAR].

[455] Harvey, *supra* note 325, at 79. *See generally* WALTZ, THEORY, *supra* note 454 (elaborating on this theory of analysis); WALTZ, MAN, STATE, & WAR, *supra* note 454 (introducing this theory of analysis). One scholar expounded on these three levels of political action analysis as follows:

> These three levels allow a scholar to investigate phenomena from very different perspectives. For example, if the *individual* level of analysis is selected, then the research would focus on what the individual decision-maker does in terms of policy and why he or she made that decision. If the *state* level of analysis is chosen, then the focus would be on the internal workings of the state and how bureaucracies and groups make decisions (e.g., Graham Allison's work on the Cuban Missile Crisis). If the *international* system is chosen, then the research would focus on the structure of the system and the interactions between actors in the system (e.g., looking at the structure of alliances and treaties before World War I).

Harvey, *supra* note 325, at 79 (emphasis added).

[456] *See* Harvey, *supra* note 325, at 79.

[457] *See id.*; Gard-Murray & Shanks, *supra* note 419.

At the *state* level, despite significant initial procurement costs of acquiring HE TWVs, this investment should be more cost-effective for the U.S. in meeting a national aim in the long run. First, it will best protect national security interests by better equipping its ground forces with more lethal capabilities, which may in turn apply to propulsion of its heavier GCVs, aircraft, and sea-craft.[458] In terms of financial incentives for the nation, HE TWVs would typically have longer and less costly life cycles, a key benefit for a government with a limited federal budget.[459] Investing in HED innovation and alternative energy sources may also yield benefits for other federal agencies and the national economy by creating more domestic jobs and opportunities for contracting with U.S. companies.[460] Likewise, decreasing DoD's fuel consumption would free up a limited fuel supply to be allocated elsewhere in the federal government as well as reduce the nation's need to contribute so many resources to securing brittle oil supply chains worldwide.[461] Further, appropriating sufficient funds for HE TWV development also allows the federal government to honor its commitment to the American people to strengthening military readiness by seeking innovation and reducing the nation's vulnerable fossil fuel reliance.[462]

Finally, at the *international system* level, advances in novel capabilities and untethering from the single-fuel concept better ensure the security of our allied partners.[463] Modernization with HED capabilities would deter U.S. current and future adversaries that recognize their armed forces'

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[458] *See* Mills & Wiechens, *supra* note 59; Mancillas, *supra* note 11, at 6-7; Teahupoo, *supra* note 386.

[459] *See* Mills & Wiechens, *supra* note 59; Mancillas, *supra* note 11, at 6-7; Teahupoo, *supra* note 386

[460] *See* LUKE NICASTRO & HEIDI PETERS, CONG. RSCH. SERV., IF10548, DEFENSE PRIMER: U.S. DEFENSE INDUSTRIAL BASE 1 (2023) [hereinafter IF10548].

[461] *See* Delucchi, *supra* note 407.

[462] *See* 2022 NSS, *supra* note 422, at 11; 2022 NDS, *supra* note 38, at 20; *see also* UNITED NATIONS, PARIS AGREEMENT, art. 10, para. 1 (2015) (requiring signatories to make efforts to reduce GHG emissions).

[463] *See IEA Report*, *supra* note 384.

comparative disadvantage on the battlefield.[464] Additionally, leading the electrification charge demonstrates to our allies our intent to meet our commitments to international aimed at curbing the effects of climate change and mitigating future geopolitical instability.[465] It also creates more opportunities to share development costs and increase interoperability through foreign military sales.[466]

B. Critiques of DoD's HED Modernization Efforts

Despite the many advantages of HE tactical vehicles, there are several potential criticisms of such HED modernization efforts. These critiques generally fall within one of seven main areas: (1) the technological limitations and costs of current EV technology; (2) the sourcing of EV battery materials and components; (3) the safety risks associated with EVs; (4) the perceived inability of the federal government to pivot agilely between energy sources; (5) the apparent climate-focused political motivations of electrification; (6) DoD's current challenges in procuring electricity for its installations; and (7) the broader concerns over DoD's rashness in pursuing innovation at all costs. These valid critiques are expressed not only by taxpayers but also by various DoD leaders and members of Congress.[467] Nevertheless, such skeptics must also appreciate the counterpoints to

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[464] *See* Whitley, *supra* note 61.

[465] *See id*.; 2022 NSS, *supra* note 422, at 11; 2022 NDS, *supra* note 38, at 20; David Vergun¸*Climate Change Has National Security Implications, DOD Official Says*, U.S. DEP'T OF DEF. (July 26, 2021), https://www.defense.gov/News/News-Stories/Article/Article/2707739/climate-change-has-national-security-implications-dod-official-says/.

[466] *See IEA Report*, *supra* note 384.

[467] *See generally TWV Hearing*, *supra* note 73 (illustrating various representatives' concerns through their questions of Army acquisition leaders regarding TWV electrification efforts). One media statement by a Republican congressman is illustrative of his party's main concerns:

> 'I have serious concerns about supply chains and logistics to support eco-friendly military vehicles,' said Rep. Michael Waltz (R-Fla.) . . . One concern is that the US relies heavily on China and other countries for many of the minerals required to build batteries, 'and should we find ourselves in a conflict with the Chinese Communist Party, we will be cut off from these supply chains,' Waltz said. Another worry is that 'there aren't charging stations in the middle of foreign deserts or mountain ranges,' he said. 'Thirdly, I have questions in terms of

these critiques to recognize the greater risk they would bear in *not* deliberately and timely acquiring HED capabilities for our ground vehicle fleet.

1. Technological Limitations and Costs of Current EV Batteries

Perhaps the most salient concerns in electrifying the DoD's tactical vehicles involve the current limitations of EV technology to meet the DoD's hefty power and endurance requirements. Central to such skepticism is the perceived insufficient energy density of the LIBs commonly used in battery traction packs of EVs.[468]

Potential commercial customers most often worry about EVs' driving range, which is determined by the battery energy densities, or the amount of energy stored per unit volume of weight.[469] With limited space and weight in EVs, batteries with higher energy densities can drive vehicles longer distances. Although LIBs' battery density is one of the highest among modern battery technology, it is still significantly less—nearly 50 times less—than that of the same weight of gasoline or diesel (or military JP- 8 and F-24).[470] Therefore, many heavy batteries are necessary

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> interoperability without allies. Bottom line is, we should be focused on the most lethal fighting vehicles and not the most eco-friendly. I guarantee you that lethality will be the focus of our adversaries.'

Lee & Moore, *supra* note 107 (quoting Rep. Michael Waltz (R-Fla.), Chairman, Armed Services' Readiness S. Comm., Armed Services Comm., U.S. House of Representatives).

[468] *See* Lee & Moore, *supra* note 107.

[469] *See* Jie Deng et al., *Electric Vehicles Batteries: Requirements and Challenges*, 4 JOULE 509, 511 (2020), https://www.sciencedirect.com/science/article/pii/S254243512030043X#bib1; *see* Michael Woodward et al., *New market. New entrants. New challenges. Battery Electric Vehicles*, DELOITTE UK (2019), https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-battery-electric-vehicles.pdf. Because energy density is the amount of energy per weight, a higher density means more energy for the same amount of weight. *See* Deng et al., *supra*. Generally, LIBs have energy densities of only 0.5-1.0 MJ/kg while crude oil-derived fuels (e.g., jet propulsion, diesel, gasoline, and kerosene) have energy densities between 41.9 and 46.3 MJ/kg. *See Energy Density of Some Combustibles*, THE GEOGRAPHY OF TRANSP. SYS., https://transportgeography.org/contents/chapter4/transportation-and-energy/combustibles-energy-content (last visited Apr. 11, 2024).

[470] *See* Vikram Mittal, *Hybridization of US Army Combat Vehicles*, SAE INT'L 2 (Mar. 29, 2022) https://doi.org/10.4271/2022-01-0371; Andrew Eversden, *Army Electric Vehicle Goals 'Pretty Darn Achievable,' But Challenges Remain*, BREAKING DEF. (Mar. 2, 2022),

to enable most EVs today to reach an average maximum driving range of just 200 to 300 miles.[471] The heavier a vehicle is, the more energy it takes to move it and, thus, the more batteries it requires, further compounding the energy density problem. The larger and more batteries a vehicle requires, the longer the charging time to reach the maximum recharge of its batteries.[472] Dean McGrew, branch chief for powertrain electrification at the Army's GVSC, highlights what this problem means for potentially electrifying its heavy, armored combat vehicle fleet: "[t]o charge a 50-ton tracked combat vehicle inside the Army's preferred envelope of 15 minutes, [S]oldiers would need a 17-megawatt charging station—more than 20 times bigger than the largest mobile generator the Army currently has." [473] In addition to the inability of current commercial electrification technologies to meet DoD's heaviest GCVs' high energy density requirements, they also do not yet meet the Army's unique environmental and cooling needs, like the need to operate in extremely hot or cold temperatures.[474] These technological challenges are one reason why "not a single all-electric [or HE] fighting vehicle is currently deployed in the field, with the Defense Department

https://breakingdefense.com/2022/03/army-electric-vehicle-goals-pretty-darn-achievable-but-challenges-remain.

[471] *See* Deng et al., *supra* note 469.

[472] *See id*. "Most current EVs take hours to fully charge. . . . This works fine when charging overnight or charging during work, for example, but it becomes inconvenient when driving a long distance that requires frequent recharging[,]" such as during military operations. *Id.*

[473] *See* Lee & Moore, *supra* note 107. Ultimately, the energy requirements to fuel such an imaginary Army generator to charge an electric combat vehicle would negate any fuel-savings benefit of the combat vehicle itself, worsening the Army's fossil fuel reliance: "The hourly fuel consumption of a 17-megawatt generator would require in excess of 1200 gallons of diesel per hour. That compares to around 60 gallons per hour over cross country terrain for a 60-ton diesel-powered tank, with a 10-minute refueling time." IER, *Electric Vehicles Make No Sense on the Battlefield*, INT. FOR ENERGY RSCH. (June 22, 2023), https://www.instituteforenergyresearch.org/uncategorized/electric-vehicles-make-no-sense-on-the-battlefield/.

[474] *See* Telephone Interview, Jadus, *supra* note 344; *See* Keith Jadus, Off. of Asst. Sec'y of Army (Acquisition, Logistics & Tech.), *Army Hybridization & Electrification Strategy* 6 (Nov. 30, 2023) [hereinafter *Army HE Strategy*, Jadus Presentation] (unpublished PowerPoint presentation) (on file with author). *But see* E-mail 1, McGrew, *supra* note 170 (noting that each retrofitted anti-idle TVEK "includes an arctic kit (fuel[-]fired heating). . . [, so each] vehicle is cold climate ready," which would be a requirement on purpose-built HE TWVs).

[simply] hoping intense interest in scaling up batteries for consumer and utility sectors will lead to breakthroughs for the battlefield."[475]

Fortunately, there appears to be no shortage of seemingly daily breakthroughs by industry in commercial EV battery technology. For example, research labs and car manufacturers constantly test different materials and metal combinations to achieve the highest energy density for EV batteries.[476] Additionally, other groundbreaking developments—like Toyota's recently unveiled "solid-state battery with a staggering range of 1,200 kilometers and a charging time of just ten minutes," a game-changer for future EV innovation—serve as constant reminders that society's collective imagination is often its principal technological limitation.[477] Still, because such commercial advances equally help our competitors' efforts to power their militaries' ground forces,

[475] *See* Lee & Moore, *supra* note 107; Yasmin Tadjdeh, *Electric Vehicles for the Military Still a Pipedream*, NAT'L DEF. (Oct. 6, 2021), https://www.nationaldefensemagazine.org/articles/2021/10/6/electric-vehicles-for-the-military-still-a-pipedream. As the then-head of the AFC's Next Generation Combat Vehicle (NGCV) team, Lieutenant General (LTG) Richard Coffman told media, "Ideally, we would be able to go to a full electric vehicle, but currently the technology does not exist to generate, store, and distribute power in a tactically relevant amount of time for the frontline troops." He noted that, although "[e]lectrification may be possible for support vehicles in the rear, . . . 'as far as large, heavy vehicles that can take a punch and throw a punch, the amount of batteries required to do that over great distances—and the ability to charge quickly—is a challenge for us.'" *See* Lee & Moore, *supra* note 107 (quoting LTG Coffman, current Deputy Commanding General, AFC).

[476] *See, e.g.*, Deng et al., *supra* note 469 (discussing industry breakthroughs). One research team's findings from examining other battery options for EVs is reflective of industry's current position:

> New designs, such as Li-Sulfur, Li-Air, or Mg-ion batteries, have been explored. Although they have higher theoretical energy densities than LIBs have, they suffer from other issues, such as safety (due to dendrite formation) or poor cyclability, which prevent their application in EVs. In addition, battery packs in EVs include not only cells but also other components like busbars, thermal components, and battery management systems. Accounting for this added hardware further reduces the overall pack-level energy densities. Thus, improving both cell design and pack efficiency is critical to increasing energy densities of EV batteries.

See Deng et al., *supra* note 469.

[477] *See* Winkless, *supra* note 145; *2024: The Year of Revolutionary EV Battery*, CARDINO, https://www.cardino.de/en/blog-posts/solid-state-battery-ev (last visited Apr. 11, 2024).

DoD would be wiser to lead innovation earlier rather than merely participating as a "fast follower" of industry.[478]

When examining EV technology's current limitations, it is also worth emphasizing that DoD should prioritize hybrid-electrification—particularly through series-parallel hybrid or similar drivetrain architectures[479]—of its TWV fleet (and eventually, its GCV fleet), rather than complete electrification.[480] Although AE drive would maximize the tactical and operational benefits of such modernization, it may ultimately create a similar vulnerability as DoD's current fossil fuel reliance if the fleet transitions to a logistics infrastructure solely dependent on electricity to power its operational vehicles (i.e., trading in one addiction to a single energy source for another). Ensuring DoD's ground forces achieve and maintain energy resilience and agility, rather than simply innovation for its own sake, must remain a priority in its vehicle modernization efforts.[481]

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[478] *See TWV Hearing*, *supra* note 73, at 8, 21 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics). However, "the Army cannot afford to wait for the perfect solution; it must collaborate with the government customer on adapting emerging technologies and move toward point solutions." *See* Nat'l Academies, *Electrification*, *supra* note 396, at 11 (summarizing statements of Rick Kewley, GM Defense).

[479] *See infra* note 141 and accompanying text (discussing series-parallel hybrids).

[480] One dialogue with a leader in the Army's electrification efforts provided a vital clarification:

> Dr. Peter Schihl, senior research scientist for ground vehicle propulsion and mobility at the Ground Vehicle Systems Center, said conversations about electric vehicles can sometimes become 'convoluted' because combat vehicles, tactical trucks and specialty vehicles often get lumped together. . . 'Those are all different sectors across the spectrum, and it gets more difficult [to do electrification] the heavier' the platform is, he said. . . 'Sometimes people extend across the spectrum and say, 'Hey, we're going to have an electric tank' — and that's not the intent."

Tadjdeh, *supra* note 475.

[481] *See* Kuo, *supra* note 16, at 48, 49, 52; IER, *supra* note 473; Crawford, *supra* note 81, at 4. *see also* JURASSIC PARK (Universal Pictures 1993) ("Your scientists were so preoccupied with whether or not they could, they didn't stop to think if they should."). Energy resilience is "the ability to anticipate, prepare for, and adapt to changing conditions—and withstand, respond to, and recover rapidly from power [and energy] disruptions." *See* Hon. Alex Beehler, Assistant Sec'y of the Army (Installations, Energy, & Env't, *Army Installations Test Energy Resilience*, NAVAL POSTGRADUATE SCH. (2020), https://nps.edu/web/eag/army-installations-test-energy-resilience. Similarly, energy agility involves the ability to leverage and pivot between different energy sources "to *maintain* critical mission functions even *during* unexpected disruptions." *See Hearing on National Defense Authorization Act for Fiscal Year 2017, Hearing before the S. Comm. on Tactical Air & Land Forces of the H.*

Related to current technological limitations, DoD's second most concerning factor in the feasibility of adopting HE TWVs is their cost.[482] On average, commercial EVs are certainly still more expensive than traditional ICE cars.[483] Therefore, critics may argue that the initial acquisition costs of procuring HE TWVs are unreasonable, especially in light of an already ballooning DoD budget each FY.[484] However, closer inspection using the DAS's "Life Cycle Cost (LCC) Model" will likely reveal that cost, too, is another factor in favor of HED modernization in the long run.[485]

The DoD employs the LCC to enable decision-makers to conduct a cost-benefit analysis in any new MWS acquisition.[486] The categories of the LCC include R&D, investment, operating and support (O&S), and disposal.[487] The most considerable costs for an acquisition program are the investment and O&S costs.[488] Regarding investment costs, the price of batteries is generally still the most significant driver of prices for any EV or HEV.[489] Fortunately, although "sticker shock" has historically dissuaded most would-be commercial AEV and HEV buyers, the prices of these

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Comm. on Armed Serv., 114th Cong. 658 (Apr. 12, 2016) (prepared statement of Hon. Miranda A.A. Ballentine, Ass't Sec'y of the Air Force for Installations, Env't, & Energy) (emphasis added).

[482] *See* Mancillas, *supra* note 11, at 6.

[483] *See* Finke & Hess, *supra* note 67.

[484] Mancillas, *supra* note 11, at 6.

[485] *See* Ellen Barber, *Introduction to Cost Analysis*, DEF. ACQUISITION U. B-3 (Feb. 2011), https://www.dau.edu/sites/default/files/Migrated/CopDocuments/B3%20Intro%20to%20Cost%20Analysis%20Feb%2011%20rev%20c.pdf.

[486] *Id.* at B-4. "Major defense acquisition programs are those estimated to require eventual total research, development, test and evaluation expenditures of more than $365 million or procurement expenditures of more than $2.19 billion in fiscal year 2000 constant dollars." *See* GAO-10-155T, *supra* note 50, at 2 n.3.

[487] Barber, *supra* note 485, at B-4, B-5; *see* U.S. DEP'T OF DEF., INSTR. 5000.73, COST ANALYSIS GUIDANCE AND PROCEDURES, para. 3.1 (13 Mar. 2020). For ground systems acquisition programs, the typical cost distributions are 4% R&D, 33% Investment, and 63% O&D/Disposal. *See Life Cycle Cost (LCC)*, DEF. ACQ. U. [hereinafter *LCC*, DAU], https://www.dau.edu/acquipedia-article/life-cycle-cost-lcc (last visited Apr. 11, 2024).

[488] *See LCC*, DAU, *supra* note 487.

[489] *See* Barber, *supra* note 485, at B-4, B-5.

vehicles have dropped dramatically over the last decade, predominantly due to decreases in LIB cost, a promising indication for future HE TWV prices.[490] Additionally, the reduced maintenance and repair requirements of HEVs—especially when weighed against the sustainment costs of legacy ICE systems that experts predict will increase substantially in the future—indicate these investment and O&S costs may weigh in favor of HE TWV procurements.[491] Reflecting this prediction, recent demonstrations of JLTVs with retrofitted anti-idle TVEKs also showed a 24-month increase in those vehicles' estimated life cycles due to the decreased fuel and maintenance requirements from hybrid-electrification.[492]

Other significant procurement costs of transitioning U.S. ground forces from an ICE-only TWV fleet to one incorporating HE vehicles are also relevant.[493] For example, the Army's considerable time and financial costs of training Soldiers on the additional maintenance and logistics requirements of this new "hybrid fleet" will no doubt strain the already undermanned workforce for some time.[494] However, the long-term benefits of decreased maintenance and sustainment demands and the growing potential to recruit a workforce with HEV expertise as

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[490] *See* Brandon Vigliarolo, *Forget the Climate: Steep Prices the Biggest Reason EV Sales Aren't Higher*, THE REGISTER (Jan. 5, 2023), https://www.theregister.com/2023/01/05/ev_deloitte_price/; Mancillas, *supra* note 11, at 6. Sticker shock is "the shock at seeing just how much something new, usually an automobile, costs as determined by looking at the price tag or sticker." *Idioms, Sticker Shock*, THE FREE DICTIONARY, https://idioms.thefreedictionary.com/sticker+shock (last visited Apr. 11, 2024). Over the last 14 years, the average price for LIB traction packs fell nearly 90%, with a continuing steady decline predicted until at least 2030 "due to improvements in technology and economies of scale." *See* Dan Gearino, *Battery Prices Are Falling Again, and That's a Good Thing*, INSIDE CLIMATE NEWS (Nov. 30, 2023), https://insideclimatenews.org/news/30112023/inside-clean-energy-battery-prices-are-falling; Mancillas, *supra* note 11, at 6; Logan Goldie-Scot, Head of Energy Storage, *A Behind the Scenes Take on Lithium-ion Battery Prices*, BLOOMBERG NEF (Mar. 5, 2019), https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices.

[491] *See* Barber, *supra* note 485, at B-4, B-5; Mancillas, *supra* note 11, at 7.

[492] *See* E-mail 1, McGrew, *supra* note 170.

[493] *See* Barber, *supra* note 485, at B-4; *see also* Kuo, *supra* note 16 (cautioning against military innovation when it would cause overextension of already limited resources).

[494] *See* Barber, *supra* note 485, at B-5.

commercial EVs sales rise indicates that technical cost-benefit analyses weigh in favor of HED modernization.[495]

2. Strategic Concerns: Foreign Supply Chain Risks of EV Battery Materials and Components

There are also significant concerns over the sourcing of crucial EV battery components from foreign countries.[496] Batteries for EVs are overwhelmingly manufactured outside the U.S. and rely on lithium, cobalt, and other raw materials that are likewise primarily mined and refined in a select number of other countries, several of which are hostile to the U.S., like the PRC.[497] Cybersecurity is also a serious risk if the U.S. lacks control over software development that goes into products like tactical vehicles' onboard computer systems.[498]

The limited sources of key materials and components for EVs creates a fragile supply chain during peacetime and could cut off the DIB from necessary materials when DoD needs them

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[495] *See id.*; John Blyler, *Automotive Technicians Must Train for Hybrids and EVs*, DESIGN NEWS (Mar. 17, 2021), https://www.designnews.com/electric-vehicles/automotive-technicians-must-train-for-hybrids-and-evs. Technical colleges are increasingly offering certificates and degrees to become a hybrid and electric vehicle mechanic. *See, e.g.*, *Want to Become a Hybrid and Electric Vehicle Mechanic? Industry Changes to Watch in 2022*, AUTO. TRAINING CTRS., https://www.autotrainingcentre.com/blog/hybrid-electric-vehicle-mechanic-industry-watch-2022/ (last visited Apr. 11, 2024) (discussing trends in commercial EV market and increasing opportunities for mechanics with EV maintenance skills).

[496] *See* Steven P. Bucci, *America's National Security Is Dependent on Critical Rare Earth Minerals—and Worse, on China*, THE HERITAGE FOUND. (Nov. 8, 2022) https://www.heritage.org/defense/commentary/americas-national-security-dependent-critical-rare-earth-minerals-and-worse; Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380.

[497] *See* Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380. *See* 2023 DoD OES, *supra* note 93, at 8. "In alignment with the Department of Defense Lithium Battery Strategy 2022-2030, stringent testing and certification governing the use of batteries—particularly lithium-ion batteries—on land, air, and sea platforms pose a challenge to implementing new capabilities and concepts." 2023 DoD OES, *supra* note 93360, at 8. "Advanced batteries are the single-greatest cost and a bottleneck for electric platforms due to supply chain and integration issues . . . From raw materials to assembly, the commercial supply chain is heavily reliant on adversarial nations – and defense integration of new batteries is slow, cumbersome and costly." Halimah Najieb-Locke et al., *Collaboration and Standardization Are Key to DOD's Battery Strategy, Meeting U.S. Energy Objectives*, U.S. DEP'T OF DEF. (June 5, 2023) (quoting Andrew Higier, director of the energy portfolio at the Defense Innovation Unit).

[498] *See* Nat'l Academies, *Electrification*, *supra* note 396, at 5.

most at the onset of a major armed conflict.[499] Therefore, DoD cannot rely on foreign sources for critical HE TWV components. Even so, although prime defense contractors in the U.S. might sufficiently meet the military's needs, commercial EV markets would also compete with DoD for limited supplies for those key battery components, possibly further increasing demand and prices for DoD.[500]

Fortunately, the number of U.S. manufacturers of EV batteries, hardware, and software is growing, as are efforts to expand domestic sources of lithium.[501] If the federal government can further encourage these lines of effort through effective policymaking and expenditures, the electrification of DoD's TWV fleet could strengthen the symbiotic relationship between the nation's security and economy.[502]

3. Operational and Tactical Concerns: Ground Forces' Survivability and Vehicle and Sustainer Crews' Safety Risks

Despite the many warfighting benefits of HED modernization, there are also potential operational disadvantages of AEVs and HEVs in a modern LSCO, including their possibly higher

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[499] *See* Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380.

[500] *See* Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380.

[501] Patrick Whittle, *U.S. Seeks New Lithium Sources as Demand for Clean Energy Grows*, PBS NEWS HOUR (Mar. 28, 2022), https://www.pbs.org/newshour/economy/u-s-seeks-new-lithium-sources-as-demand-for-clean-energy-grows; *see* Mills & Wiechens, *supra* note 59; Nat'l Academies, *Electrification*, *supra* note 396, at 5. "For the first time, . . . the dynamic is changing as the U.S. government aggressively funds battery research and shores up its supply chains. [For example, see] the $2 billion allocated for 21 companies working on battery materials processing in 2022. The United States . . . is beginning to create its own battery manufacturing ecosystem that will drive advances in next-generation rechargeable batteries." Nat'l Academies, *Electrification*, *supra* note 396, at 6. *See also* Bryant Harris, *GOP Defense Bill Bars Pentagon From Enacting Biden's Climate Orders*, DEF. NEWS (Aug. 31, 2023), https://www.defensenews.com/congress/budget/2023/08/31/gop-defense-bill-bars-pentagon-from-enacting-bidens-climate-orders (summarizing the release of the U.S. nonpublic strategy on LIBs in February 2023 by Undersecretary of Defense for Acquisition and Sustainment, Bill LaPlante; this strategy seeks to "increase[e] the mining and production needed to produce [LIBs] within the U.S. and friendly countries.").

[502] *See* Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380.

electromagnetic signatures, the cybersecurity risks of remote diagnostics, and the safety concerns of LIBs.

The higher electrical energy of HE TWVs would potentially "generate considerable electromagnetic fields to which an enemy could adapt sensory equipment."[503] This electromagnetic (EM) footprint, if coupled with a logistics system that requires lengthy recharging of batteries, could place a massive target on brigade- and division-level field sustainment centers, TOCs, R3Ps, and AAs, not unlike the danger that JP-8 storage and refueling points currently pose on the battlefield.[504] However, recent testing of TVEK-retrofitted vehicles confirmed that the design of such HE systems does not create any greater external EM field than legacy ICE vehicles.[505] Additionally, studies of commercial vehicles consistently show that HEVs and AEVs do not pose a risk to users from EM exposure.[506] Nevertheless, because of the potential danger to individual Service members as technology advances and onboard electric systems increase, DoD acquisition programs should keep vehicles' EM output a factor in developing requirements.[507]

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[503] IER, *supra* note 473; *see* Krzysztof Gryz et al., *Complex Electromagnetic Issues Associated with the Use of Electric Vehicles in Urban Transportation*, NAT'L LIB. MED., PUBMED CENT. (Feb. 22, 2022), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8914635.

[504] *Id. But see* notes 351–352 and accompanying text (discussing the proven advantages in eliminating the need for so many towed generators for external electrical production).

[505] *See* Telephone Interview, McGrew, *supra* note 282. Of note, most of the external EM field of TWVs and GCVs is *intentional* in the form of radio and electronic communication systems. *Id.*

[506] *See* Joaquin Machado, *Electromagnetic Exposure in Hybrid and Electric Vehicles (EV): How Safe Are You?*, LINKEDIN (Jan. 8, 2021), https://www.linkedin.com/pulse/electromagnetic-exposure-hybrid-electric-vehicles-ev-how-machado. "According to the official position of organizations such as the ICNRIP (International Commission of Non-Ionizing Radiation Protection), hybrid and electric vehicles do not represent any risk [so] governments do not ask for electromagnetic fields and exposure to be measured inside these cars, and therefore extensive studies in the field of electrosmog measurements and the associated health risks of these vehicle's emissions have not been conducted." *Id.*; *see Electric Cars: No Risk for Human Health*, EUR. COMM'N, CORDIS (Feb. 23, 2015), https://cordis.europa.eu/article/id/156586-electric-cars-no-risk-for-human-health (summarizing testing results showing that there is little difference between magnetic field exposure from EVs and those with ICEs under International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards).

[507] *See also infra* note 844 and accompanying text (discussing lack of GHG emission standards in draft PDs for HE TWVs).

Second, HEVs generally rely on more advanced computer systems to "tell" the drivetrain and propulsion system which type of energy to use at any given time.[508] If these systems interact with remote diagnostic systems that connected to a cyber network, adversaries might be able to hack into those same systems, stopping warfighters on the battlefield.[509] Therefore, HE TWV acquisition programs must mitigate that risk by considering software cybersecurity at the earliest stages of design, in accordance with recent DoD policy.[510]

Third, at the individual Service member level, lawmakers also express concern that the use and transport of LIBs present serious safety risks to vehicle crews and sustainers, such as from overheating or exploding, leaking chemicals, and short-circuiting.[511] Although DoD certainly cannot ignore these risks, much of the research on LIBs' safety relies on outdated, irrelevant data that DoD would need to reexamine in light of recent battery advances.[512] Additionally, these dangers are generally no more severe than those posed by the transport and use of petroleum-

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[508] *See Hybrid Vehicles*, MOTOR LEASE, *supra* note 128.

[509] *See id.*; Mancillas, *supra* note 11, at 5.

[510] *See* GAO-23-106059, *supra* note 50, at 44; *see, e.g.*, U.S. DEP'T OF DEF., INSTR. 5000.82, REQUIREMENTS FOR THE ACQUISITION OF DIGITAL CAPABILITIES para. 3.5 (June 1, 2023) (requiring consideration of cybersecurity survivability in acquiring capabilities that are digital in nature); U.S. DEP'T OF DEF., INSTR. 8500.01, CYBERSECURITY para. 3.a.(2) (Mar. 14, 2014) (C1, Oct. 7, 2019) ("Risks associated with vulnerabilities inherent in IT, global sourcing and distribution, and adversary threats to DoD use of cyberspace must be considered in DoD employment of capabilities to achieve objectives in military, intelligence, and business operations.").

[511] *See TWV Hearing*, *supra* note 73, at 15, 16 (statement of Rep. Anthony Brown (D-MD), Member, S. Comm. on Tactical Air & Land Forces, H. Comm. on Armed Services). Although LIBs are generally safe, they contain highly flammable liquid electrolytes that can catch fire or explode if they become damaged or overheated, such as from rapid recharging or sustained use in extremely high temperature environments. *See The Disadvantages of Lithium-Ion Batteries for Electric Cars*, ENERGY5 (Dec. 3, 2023), https://energy5.com/the-disadvantages-of-lithium-ion-batteries-for-electric-cars [hereinafter *LIB Disadvantages*]. Additionally, if a LIB case is punctured and the electrolyte leaks out, it may cause skin burns or respiratory problems. *See LIB Disadvantages*, *supra*. Finally, damage to LIBs or faulty wiring can cause them to short-circuit, resulting in fire or explosion. *See LIB Disadvantages*, *supra*.

[512] Knickerbocker, *supra* note 380.

based fuels.[513] These risks can also be mitigated by the effective logistics and safety protocols the Services already employ in transporting a large number of LIBs for use by ground, air, and sea forces in their electronic systems.[514] Nevertheless, to reduce these dangers, DoD acquisition programs should explore alternatives to current LIBs, like SSBs, hydrogen fuel-cells, or more durable LIBs.[515]

4. Perceived Federal Government Inefficiencies in Energy Sector Innovation

Critics also claim that the federal government's massive size and unwieldy bureaucratic procurement requirements make it ill-suited to drive energy innovation efficiently.[516] Even proponents of HED modernization generally still only argue that DoD should remain a "fast follower" of the commercial industry in adopting such technology.[517] Harsher skeptics, however, decry the seeming inability of the federal government and DoD to shift to new, emerging technologies in the energy sector.[518] Although relevant to the broader concept of the DIB weaknesses and barriers to MWS acquisitions, these concerns more specifically underscore the perception that the federal government is generally ineffective—compared to civilian markets—at pursuing innovative solutions to enduring problems.

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[513] Neil Winton, *Electric Car Fire Risks Look Exaggerated, But More Data Required For Definitive Verdict*, FORBES (Mar. 2, 2022), https://www.forbes.com/sites/neilwinton/2022/03/02/electric-car-fire-risks-look-exaggerated-but-more-data-required-for-definitive-verdict.

[514] *See* Mills & Wiechens, *supra* note 59.

[515] *See LIB Disadvantages*, *supra* note 511; *see also supra* notes 148–**Error! Bookmark not defined.** (discussing SSBs).

[516] *See* Brent Heard et al., *Beyond A Single Stimulus: How to Leverage the Federal Government to Advance Clean Energy Innovation?*, NAT'L LIB. MED., PUBMED CENT. 1 (June 17, 2022), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9127172.

[517] *See* Finke & Hess, *supra* note 67; *TWV Hearing*, *supra* note 73, at 8, 21 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics).

[518] *See* Finke & Hess, *supra* note 67; Jen Judson, *Is the Army Warming Up to Electric Vehicles in its Fleet?*, DEF. NEWS (July 12, 2021), https://www.defensenews.com/land/2021/07/12/is-the-army-warming-up-to-electric-vehicles-in-its-fleet.

Nevertheless, the federal government has already proven itself to be an effective leader of change in other areas of timely innovation, not only for technology like radios, cell phones, and the internet, but also specifically in the energy sector.[519] For example, the GSA is a pioneer in working with industry to develop battery storage and battery management solutions for its federal buildings that "have no upfront cost because they're financed with the utility cost savings they'll deliver."[520] Even more impactful was the Army's leading role propelling commercial efforts to develop advanced automobile technology at the start of WWII (e.g., large ICEs to power armored vehicles, technology that later found use in commercial trucks), not to mention its innovation in nuclear energy toward the end of the war that has since found use to power regions.[521] Indeed, federal contracting has brought about some of the world's greatest clean-energy innovations through focused investment, from nuclear power plants to hydroelectric dams.[522] Notwithstanding the valid concerns over the federal government pulling too far ahead of industry, at the risk of untenable future costs and maintenance if industry moves in a different direction, DoD should remember its vital—and historic—role as a leader of technological innovation.

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[519] *See* Joe Mariani et al., *Revisiting the Government's Role in Catalyzing Modern Innovation*, DELOITTE INSIGHTS (July 20, 2023), https://www2.deloitte.com/us/en/insights/industry/public-sector/role-of-government-in-innovation.html.

[520] *See* U.S. Gov't Serv. Admin., *How GSA is Using Innovative Energy Storage Technologies Today to Power the Government with 100 Percent Carbon Pollution-Free Electricity by 2030*, GSA BLOG (Feb. 28, 2022), https://www.gsa.gov/blog/2022/02/28/how-gsa-is-using-innovative-energy-storage-technologies-today-to-power-the-government-with-100-percent-carbon-pollutionfree-electricity-by-2030.

[521] *See Innovating for Victory*, THE NAT'L WWII MUS., https://www.nationalww2museum.org/war/articles/innovating-victory (last visited Apr. 11, 2024).

[522] *See* Dorothy Robyn, *Mission, Money, and Process Makeover: How Federal Procurement Can Catalyze Clean Energy Investment and Innovation*, INFO. TECH. & INNOV. FOUND. 24 (15 Aug. 2022), https://itif.org/publications/2022/08/15/mission-money-and-process-makeover-how-federal-procurement-can-catalyze-clean-energy-investment-and-innovation/; *see, e.g.*, U.S. DEP'T OF ENERGY, AMERICA'S STRATEGY TO SECURE THE SUPPLY CHAIN FOR A ROBUST CLEAN ENERGY TRANSITION, U.S. DEPARTMENT OF ENERGY RESPONSE TO EXECUTIVE ORDER 14017, "AMERICA'S SUPPLY CHAINS" 8 (24 Feb. 2022), https://www.energy.gov/policy/articles/americas-strategy-secure-supply-chain-robust-clean-energy-transition ("The United States has the largest commercial nuclear power fleet in the world, which generates the largest source of carbon-free electricity in the country and supports approximately half a million jobs.").

5. Apparent Political Motivations of Modernization; Over-Focus on Climate Policy

As with other proposed federal spending measures, critics of DoD efforts to electrify its TWV and GCV fleet "decry them as politically motivated and overly focused on climate change, which they argue should not factor into planning to meet the military's core mission."[523] For example, skeptics argue that this is just another example of military "wokeness" intended to use DoD and its Service members as tools to experiment and advance environmental and social agendas.[524]

However, these critiques ignore the overwhelming warfighting advantages and the rising financial incentives of electrification.[525] Innovation in propelling U.S. ground forces on the battlefield is far from a politically motivated mission but a critical national security and cost-saving imperative to benefit American warfighters and taxpayers alike. Additionally, DoD and Army leaders remain unequivocal that they would pursue such electrification initiatives only if and for as long as such efforts support their combat mission and would not do so if such measures run counter to that mission.[526]

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[523] *See* Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380.

[524] Knickerbocker, *supra* note 380; *see If the Military Loses Focus, Who Will Want to Join It?*, WSJ OPINION (Feb. 18, 2022), https://www.wsj.com/articles/us-military-army-woke-identity-politics-climate-change-pentagon-11645135333 ("Young Americans don't enlist to be climate-change warriors or fight for identity politics.").

[525] *See* Mills & Wiechens, *supra* note 59; Knickerbocker, *supra* note 380.

[526] *See* de la Garza, *supra* note 318. The following dialogue reflects DoD leadership's focus on its key mission:

> In some sense, it's a good thing that some of those green technologies are a win-win for fighting ability and the climate. But it also shows that the military isn't interested in emissions reductions that run counter to its broader aims. Jack Surash—who serves under the unwieldy title of 'senior official performing the duties of assistant Army secretary for installations, energy, and environment'—has hinted as much. 'Climate change and its effects obviously pose a very serious threat,' he said, speaking at the annual meeting of the Association of the U.S. Army in October. 'But I want to stress that … climate change does not alter the Army's overall mission, which is to deploy, fight, and win.' Joe Bryan, senior climate adviser to the Secretary of Defense and the Defense Department's chief sustainability officer, was more blunt. 'DOD's mission is to provide the military forces needed to deter war and ensure our nation's security . . . 'We will never compromise on that.'

6. Installation Energy Limitations: Challenges in Recharging in Garrison

The DoD also faces criticism in how it procures clean energy for both its installations and its global operations, which has the potential to stall HE TWV acquisitions.[527] If DoD ultimately seeks to acquire HE TWVs and GCVs with plug-in charging capabilities, it will be severely crippled if it cannot reliably procure the electrical energy necessary to recharge its operational vehicles on its installations or in field environments.[528] One potential solution for installation energy involves building more microgrids on installations, an initiative in which DoD is already invested.[529] However, installations already face challenges in electrical energy procurement and self-generation in terms of inaccurate budgeting, patchwork energy regulatory regimes across the country and world, and shortsighted civil engineering.[530] As the ongoing procurement of AE NTVs demonstrates, adding to installations' mounting electrical energy challenges by acquiring "electricity-guzzling" PHEV TWVs and GCVs may be the wrong answer.[531] This additional

See id.

[527] *See* Robyn, *supra* note 522, at 27.

[528] *See* Video Interview, Smith, *supra* note 171.

[529] *See id.*; Stephen Curtis & Peter Rocha, *Microgrids for the 21st Century: The Case for a Defense Energy Architecture*, JOINT FORCE Q., 1st Q., 2024, at 22, 28.

[530] Jonathan Ahl, *The Military is Converting to Electric Vehicles on Bases, but Charging Them Remains a Challenge*, WUSF (Apr. 15, 2023, 2:00 PM) https://www.wusf.org/transportation/2023-04-15/the-military-is-converting-to-electric-vehicles-on-bases-but-charging-them-remains-a-challenge; E-mail from Emily Medlyn, Regulatory Law Attorney, U.S. Army Environmental Law Division (Mar. 12., 2024); Interview with Kyle Smith, Regulatory Law Attorney, U.S. Army Environmental Law Division (Feb. 23, 2024).

[531] *See* Ahl, *supra* note 530."Electricity-guzzling" is a modification of the term "gas-guzzling," which refers to traditional ICE operational vehicles. *See* Eric Rosenberg, *Can Electric Cars Replace Gas Guzzlers?* INVESTOPEDIA (July 31, 2022), https://www.investopedia.com/articles/personal-finance/051515/can-electric-cars-replace-gas-guzzlers.asp; *see also Military Specifications: M1 Abrams Main Battle Tank*, GLOB. SEC., https://www.globalsecurity.org/military/systems/ground/m1-specs.htm (last visited Apr. 11, 2024) (noting the M1 Abrams tank's fuel efficiency of 0.6 miles per gallon of fuel).

burden of using limited resources is another useful point in considering whether HED modernization is truly worth the cost and how best to assess program requirements.[532]

7. Dangerous Changes: The Potential for HED Innovation to Harm Combat Effectiveness

Although not a unique criticism against efforts to acquire HE TWVs, DoD leaders and policymakers should always examine whether a contemplated military innovation would, in fact, harm combat effectiveness and therefore consider foregoing its procurement despite its allure.[533] Dr. Kendrick Kuo, a leading scholar on the dangers of military innovation, offers that "innovation is more likely to weaken a [S]ervice's effectiveness when growing security commitments outstrip shrinking resources" and thus cautions "against over relying on military innovation to bridge wide commitment-resource gaps."[534] Therefore, before DoD commits to procuring innovative HED for its TWVs and GCVs, it must first assess whether such capabilities will overtax its already limited resources, such as its constrained budgets and warfighters' and sustainers' time and energy to train on and maintain these new systems.[535] Fortunately, the Services are well-suited to this type of comprehensive assessment and strategy development as long as DoD policymakers clearly define the mission and intent.[536]

Relatedly, similar to the misperception of TWV electrification efforts as DoD seeking to deploy "electric tanks" or "bring[] Teslas to war," critics often mischaracterize the drive for HED capabilities in the tactical fleet as a proposal to completely *replace* ICEs and fossil fuels as an energy

[532] *See* Kuo, *supra* note 16, at 48.

[533] *See id.* at 48, 49.

[534] *See id.*

[535] *See id.*

[536] *See id*.

source.[537] Instead, innovation requires incorporating new technology thoughtfully into existing doctrine and sustainment systems to enhance, not hinder, ground forces' warfighting capabilities.[538] After developing a comprehensive strategy for HE TWV acquisition and integration into the ground fleet, DoD leaders must communicate in all directions its driving focus that superior lethality, survivability, and energy-agility is simply smart warfighting.[539] Clearly defining and expressing this vision will prove vital to overcoming the formidable political and procedural barriers to HED modernization.

IV. The Barriers to Innovation: Political and Procedural Challenges to DoD's HE TWV Acquisition Efforts

The Army, in particular, is vigorously pursuing multiple LOEs to modernize its ground vehicles through HED.[540] Nevertheless, these efforts remain slow-moving due to inadequate prioritization by senior leaders and funding by Congress, leaving U.S. land-based forces in an increasingly vulnerable position in future LSCOs.[541] Most significantly, the road to innovation is mired by two persistent challenges: political gridlock over spending measures that have a perceived

[537] *Compare* Lee & Moore, *supra* note 107 (using the term "electric tanks" in a negative light to refer to the Army's HED modernization efforts that appear to not yet be technologically feasible) *with* Donlon, *supra* note 9, at 9 (using the term "bringing a Tesla to war" in a positive light to refer to DoD's longtime enthusiasm for electrifying its tactical vehicles).

[538] *See* Telephone Interview, McGrew, *supra* note 282.

[539] *See* Hom, *supra* note 12, at 3.

[540] *See* E-mail, Putrus, *supra* note 173.

[541] *See* Video Interview with Will Rogers, Senior Climate Advisor, U.S. Army (Apr. 4, 2024) [hereinafter Video Interview, Rogers]; Telephone Interview with Lieutenant Colonel Brian Lohnes, Deputy Legal Counsel, Office of the Chairman of the Joint Chiefs of Staff (Mar. 29, 2024) [hereinafter Telephone Interview, Lohnes]; Telephone Interview, Jadus, *supra* note 344; Telephone Interview, McGrew, *supra* note 282.

nexus to climate change policy and procedural shortfalls in the defense acquisition systems that hinder timely and effective R&D efforts.

A. Current Efforts to Electrify the DoD's Operational Vehicle Fleet

As early as 2001, long before President Biden's climate-focused EO 14057, the U.S. Army recognized the potential battlefield advantages of electrifying its tactical and combat vehicle fleet.[542] These advantages had little to do with reducing the GHG emissions of the Army's front-line war machines.[543] Driven by this long-time recognition of the benefits of HED in combat and reenergized by the modernization directives in recent years' strategy documents, leaders set three overarching vehicle electrification objectives in the 2022 ACS: (1) "Moderniz[ing] existing Army platforms by adding mature electrification technologies"; (2) "[f]ield[ing] purpose-built hybrid-drive tactical vehicles by 2035 and fully electric tactical vehicles by 2050"; and (3) "[d]evelop[ing] the charging capability to meet the needs of fully electric tactical vehicles by 2050."[544] Nevertheless,

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[542] *See* Reed Blakemore & Tate Nurkin, *Power Projection: Accelerating the Electrification of US Military Ground Vehicles*, ATL. COUNCIL 1 (Nov. 2022); Brace Huffman, *Innovation Shaping Future Battlespace*, U.S. ARMY (Feb. 4, 2021), https://www.army.mil/article/243015/innovation_shaping_future_battlespace; Luckenbaugh, *supra* note 166.

[543] *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, McGrew, *supra* note 282; Fabian Villalobos & Joshua Simulcik, *Do Generals Dream of Electric Tanks?*, THE HILL (Aug. 7, 2023, 6:30 PM), https://thehill.com/opinion/congress-blog/4142583-do-generals-dream-of-electric-tanks.While the Army has several ongoing R&D and prototype competitions for specific AE and HE TWV and GCV programs, the Marine Corps is currently only conducting more general R&D into HE engine development. *See* Department of Defense Appropriations Act, 2024, H.R. 4365, 118th Cong. 95B (2023); U.S. DEP'T OF NAVY, *Research, Development, Test & Evaluation, Marine Corps RDT&E, in* DEPARTMENT OF DEFENSE FISCAL YEAR (FY) 2024 BUDGET ESTIMATES, NAVY JUSTIFICATION BOOK, VOLUME 1 OF 1 124 (Mar. 2023); Megan Eckstein, *GM Defense Tackling Battlefield Power for Marines Through DIU Effort*, DEF. NEWS (July 19, 2023), https://www.defensenews.com/industry/techwatch/2023/07/19/gm-defense-tackling-battlefield-power-for-marines-through-diu-effort. However, the Marine Corps is likewise examining electrification of its Infantry Squad Vehicles (ISVs) and other expeditionary vehicles, and it previously developed an HE Expeditionary Modular Autonomous Vehicle (EMAV) prototype that inspired the Army to develop a similar vehicle in 2021. *See* Huffman, *supra* note 542; Finke & Hess, *supra* note 67. The Army's prototype Robotic Combat Vehicle – Light (RCV-L) employs a hybrid-diesel generator that allows for silent watch capabilities and reduces visibility to enemy surveillance. *See* Finke & Hess, *supra* note 67.

[544] *See supra* notes 437–446 and accompanying text (discussing the 2022 NSS, NDS, and ACS requirements; *infra* notes 612–613 and accompanying text (discussing the 2023 DoD OES). The Army's overall

these modernization goalposts do not yet exist in broader Army or DoD strategy documents outside the climate or energy realms.[545]

In anticipation of the 2022 ACS goals and in an effort to achieve the warfighting advantages of HED, in December 2021, the Army Acquisition Executive (AAE) approved a Tactical and Combat Vehicle Electrification (TaCV-E) initial capabilities document (ICD).[546] This TaCV-E ICD aims to incorporate electrification advancements into both existing and future vehicles.[547] One of the acquisition leaders executing this vision is Brigadier General Luke Peterson, Program Executive Officer for combat support and combat service support (PEO–CS&CSS), who explained in 2023 that the Army's plan for tactical vehicle electrification involves an overlapping "three-phase operation," involving modifying legacy ICE vehicles, acquiring purpose-built HE TWVs and GCVs, and developing the mobile recharging platforms to sustain such HED systems in combat operations.[548]

In the first phase, the Army seeks to retrofit its over 250,000 legacy TWVs with anti-idle systems like the JLTV's TVEKs.[549] Leading DoD's efforts in this phase is Dean McGrew, branch

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modernization priorities include development of the NGCV, which relies on the nested operational energy science and technology (S&T) needs as follows: "Increased energy for onboard capabilities and silent operation; Platform Rapid Recharge; Parallel Hybrid-Electric Tech; and Battery Technologies for Resilient Supply Chain." *See Army HE Strategy*, Jadus Presentation, *supra* note 474, at 4; Telephone Interview, Jadus, *supra* note 344. For a more detailed explanation of the Army's TWV and GCV electrification objectives and timelines, see *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2, 5, 6, 7.

[545] *See Army HE Strategy*, Jadus Presentation, *supra* note 474544, at 4. *But see* E-mail, Roberts, *supra* note 299 (discussing the TaCV-E ICD, which is not yet approved for public distribution).

[546] *See* E-mail, Roberts, *supra* note 299; *see also* Appendix F (referencing the role of the TaCV-E ICD).

[547] *See* Telephone Interview, Jadus, *supra* note 344; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2.

[548] *See* Josh Luckenbaugh, *Army to Develop Electric Scout Vehicle in Pursuit of Fuel Savings*, NAT'L DEF. (Apr. 7. 2023), https://www.nationaldefensemagazine.org/articles/2023/4/7/army-to-develop-electric-scout-vehicle-in-pursuit-of-fuel-savings; *see* Telephone Interview, Jadus, *supra* note 344; Appendix F.

[549] *See* E-mail 1, McGrew, *supra* note 170; Appendix F (showing Army acquisition programs' proposed hybrid-electrification timeline).

chief of powertrain electrification at the GVSC, DEVCOM–AFC, who emphasizes the immense battlefield advantages over adversaries that HED modification kits like TVEKs offer U.S. ground forces.[550] These kits automatically cut ICE power to the vehicle during periods of extended idling, relying instead on energy from LIBs.[551] The TVEKs have already demonstrated their potentially massive return-on-investment, not only reducing operational fuel use of those outfitted units by up to 30% but also extending silent watch, all while powering the vehicles' crucial onboard electric systems.[552] As of 2024, the Army has installed approximately 4,000 prototype TVEKs into JLTVs and is conducting aggressive testing of the kits with ground units at the NTC at Fort Irwin.[553]

In 2023, acquisition leaders sought to double-down on TVEKs' proven benefits by releasing requests for information (RFIs) from industry, mainly to inform future draft RFPs for LRIP.[554] Nevertheless, recent budget cuts by Congress in 2024 placed this phase of the Army's TWV electrification plan in doubt.[555] The sudden halt of TVEK funding is increasingly concerning in light of the Army's continuing receipt of thousands of more legacy JLTVs to field across the

[550] *See* E-mail 1, McGrew, *supra* note 170.

[551] *See* Aliotta, *supra* note 347.

[552] *See* E-mail, Roberts, *supra* note 299; Aliotta, *supra* note 347. The Army plans to field TVEKs to 12 percent of its JLTVs, seven percent of its FMTVs, and five percent of its HTVs by Fiscal Year (FY) 2027. *See* Aliotta, *supra* note 347. As the Army expounded in a public release, a 2022 demonstration of TVEK-installed JLTVs indicated that the kits could enable a "20 percent fuel savings and 50 percent less engine run time" and required only "a two-minute vehicle [ICE] runtime to charge the system, enabling six minutes of silent (engine-off) operation[;] full-field operations are expected to retain this ratio with a full hour of engine-off operation with 20 minutes of engine-on charging time." *See* Aliotta, *supra* note 347. Dean McGrew, Branch Chief for Powertrain Electrification notes that "[t]his increases the amount of time for silent watch by twofold." *See* Aliotta, *supra* note 347.

[553] *See TWV Hearing*, *supra* note 73, at 47 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics); Telephone Interview, Jadus, *supra* note 344; Aliotta, *supra* note 347; E-mail 1, McGrew, *supra* note 170; *see also supra* notes 217–19 and accompanying text (summarizing various studies' findings of TVEK benefits).

[554] *See* Luckenbaugh, *supra* note 548.

[555] *See infra* notes 656–663 and accompanying text (discussing Congress's markups of the FY 2024 NDAA and DoD Appropriations Act).

various Services.[556] It is also detrimental in that it reduces the ability of Army acquisition program engineers and JCIDS stakeholders to better understand the JF's HED requirements and reduce risk for future acquisition programs.[557]

The Army's second HED initiative is its acquisitions programs to field purpose-built HE operational vehicles, which is also the one most in danger of budget cuts.[558] As part of this LOE, the Army has already received prototypes and began demonstrations of various TWV and GCV platforms, including the AE Infantry Squad Vehicle (ISV),[559] e-LRV,[560] HE JLTV,[561] and Bradley HE Vehicle (BHEV).[562] Although associated program offices are largely employing the MTA pathway to rapidly develop and prototype these new capabilities, Milestone C and LRIP of such vehicles is still years away.[563]

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[556] *See In re* Oshkosh Defense, LLC, 2023 CPD ¶ 2; ANDREW FEICKERT, CONG. RSCH. SERV., IF11729, JOINT LIGHT TACTICAL VEHICLE (JLTV) 1, 2 (2024) [hereinafter IF11729]; Ashley Roque, *AM General Wins Army's JLTV Recompete, Deal Valued Up to $8.6 Billion*, BREAKING DEF. (Feb. 9, 2023), https://breakingdefense.com/2023/02/am-general-wins-armys-jltv-recompete-contract-valued-up-to-7-3-billion. Although the Marine Corps and Air Force also employ JLTVs, the Army is the primary procurement authority. *See* IF11729, *supra*.

[557] *See* Luckenbaugh, *supra* note 548 (quoting Steve Roberts) ("Everything we learn [from the TVEK] informs hybrid electric, informs . . . [other areas of operational] electrification. . . And then the risk decreases as we move along that continuum as well."); *accord* E-mail, Roberts, *supra* note 299 (discussing the same); *see also* E-mail 1, McGrew, *supra* note 170 (emphasizing the vital role of getting user input for new HED capabilities like TVEKs and purpose-built HE operational vehicles).

[558] *See* Telephone Interview, Jadus, *supra* note 344; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2. Specifically, the Army aims to develop HED components and higher energy density storage and generation capabilities for various TWVs and GCVs by FY27 as well as to test HED in select TWVs by FY27. *See* Telephone Interview, Jadus, *supra* note 344; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2.

[559] *See* Huffman, *supra* note 542; Finke & Hess, *supra* note 67. DOWNEY'S DREAM CARS, EPISODE 1: THOR'S THUMPER (HBO Max 2023) [hereinafter DOWNEY'S DREAM CARS]. In January 2023, actor Robert Downey, Jr. joined the Commanding General of Fort Irwin and the president of GM Defense in test driving the ISV, applauding the innovation and capability. *See* DOWNEY'S DREAM CARS, *supra*.

[560] *See* Telephone Interview, Jadus, *supra* note 344.

[561] *See* E-mail, Putrus, *supra* note 173; E-mail, Roberts, *supra* note 299.

[562] *See* E-mail, Dawson, *supra* note 241.

[563] *See* Telephone Interview, Jadus, *supra* note 344; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2, 7; *see also* E-mail, Dawson (differentiating between prototyping, testing, evaluations, and demonstrations).

Aside from these MTA programs aimed at acquiring full-system HE TWVs and GCVs, the Army is also starting to buck the traditional approach of MWS acquisition programs that rely heavily on external R&D, opting instead for more in-house development. For example, lead engineers in AFC and ASA(ALT) are increasingly stretching small program budgets to focus greater attention on internal R&D into HED capabilities, especially for key system components and interfaces.[564] Leading some R&D efforts internally, rather than relying purely on outsourced innovation, has already shown significant promise for modernization as well as the Army's ability to attract industry attention for future HE TWV and GCV programs.[565] For example, in 2020, the GVSC team developed the "Zeus 200 kW silicon carbide inverter," a DC/AC starter/generator inverter that enables high-power vehicle applications in an ultra-compact container at high operating temperatures.[566] Businesses are now able to license from the Army the technical data package for the Zeus, allowing the inverter—a key component in HEVs—to pay for itself and reduce future costs of HE TWV acquisitions.[567] Acquisition leaders refer to the Zeus inverter

[564] *See* Telephone Interview, McGrew, *supra* note 282.

[565] *See id.*

[566] *See id.*; *Zeus 200 kW Silicon Carbide Inverter*, TECHLINK, https://techlinkcenter.org/technologies/zeus-200-kw-silicon-carbide-inverter/4da28d60-cca7-4d79-981a-eb37c0339a48 (last visited Apr. 11, 2024). The GVSC explains the Zeus's purpose and potential as follows:

> The Zeus Inverter development is part of GVSC's electrification efforts to control new motors, generators, and import/ export power for vehicles. Whereas the automotive industry is electrifying vehicles mainly for fuel efficiency, the military is focused on enabling new capabilities such as silent mobility, energy weapons, vehicle to grid capability, extended mission duration, autonomy, and mobile command and control.

Alexander Soles, *Zeus 200 Advanced SiC Inverter*, GVSC, DEVCOM, U.S. ARMY FUTURES COMMAND (Sept. 2023), https://www.usarmygvsc.com/wp-content/uploads/2023/09/Zeus-200-Datasheet-V3_3.pdf.

[567] *See* Telephone Interview, McGrew, *supra* note 282.

development and licensing scheme as a "new best practice" for DoD vehicle acquisition programs.[568]

In addition to internal R&D efforts to achieve HED innovation, DoD and Army acquisition leaders remain in constant communication with industry regarding technology advances, especially in battery capabilities.[569] In February 2024, Army Contracting Command–Warren (ACC-Warren) released a market survey regarding "a projected new production effort of a light tactical wheeled [HEV] with the intent to gain industry feedback on the technical performance requirements . . .[to be] developed."[570] In addition to HED, Army R&D efforts are also exploring AE options for its lighter vehicles, like the AE light reconnaissance vehicle (e-LRV), indicating the game-changing potential of such capabilities for units with reconnaissance or kinetic mission sets that demand fast, quiet operations.[571] Although the Marine Corps intentionally remains closely behind the Army in such initiatives, its mission as a global expeditionary force means it too pursues similar R&D efforts for purpose-built HE tactical vehicles.[572]

As for the third phase of its TaCV-E plan, the Army still has significant ground to cover to develop an effective field recharging station for sustaining a fleet of HE operational vehicles.[573]

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[568] *See id*.

[569] *See* E-mail, Putrus, *supra* note 173.

[570] *See* FRANCIS SENGER, U.S. ARMY CONTRACTING COMMAND – DETROIT ARSENAL, JOINT PROGRAM OFFICE JOINT LIGHT TACTICAL VEHICLE (JPO JLTV) HYBRID ELECTRIC VEHICLE (HEV) MARKET SURVEY (Feb. 2024), https://sam.gov/opp/41ba85cbbbef4599bd382a4e16638988/view#contact; E-mail, Putrus, *supra* note 173.

[571] *See* SAM MANZELLA, U.S. ARMY CONTRACTING COMMAND – DETROIT ARSENAL, SPECIAL NOTICE –DRAFT RPP ELRV AND INTENTION OF SOLICITATION (Jul. 1, 2023), https://sam.gov/opp/bd8fe73aa1dd4c678d9fd f290f561a7c/view; Ashley Roque, *Army greenlights Electric Light Reconnaissance Vehicle Prototype Buy in 2024*, BREAKING DEF. (Feb. 28, 2023), https://breakingdefense.com /2023/02/army-greenlights-electric-light-reconnaissance-vehicle-prototype-buy-in-2024.

[572] *See* H.R. 4365, 118th Cong. ln. 19 (2023).

[573] *See* Hope Hodge Seck, *DIU Wants to Cure Services' Electric Vehicle Range Anxiety*, NAT'L DEF. (Mar. 7, 2024), https://www.nationaldefensemagazine.org/articles/2024/3/7/diu-wants-to-cure-services-electric-vehicle-range-anxiety. The Army seeks to ultimately meet the energy demand of a fully electric tactical fleet by 2050 by conducting Operational Energy Analysis for charging solutions (wired and wireless), "demonstrating" a

Acquisition leaders are particularly mindful of ground-based unit commanders' "range anxiety"—that is, their "fear of running out of charge with no nearby power supply."[574] Given some programs' intent to develop HEVs with plug-in recharging capabilities, this fear is especially warranted.[575] Fortunately, although the form of such a range extender still remains in early market research stages, acquisition leaders aim to deliver a mobile recharging station compatible with the JLTV and similar platforms that will reduce commanders' anxiety.[576] Even so, with political gridlock already threatening the future funding of the first two phases of the Army's TaCV-E efforts, accomplishing this third phase by 2050 is anything but certain.[577]

While promising, the Army's hybrid-electrification efforts are moving slowly, especially in light of the rapid advances in EV technology in the commercial sector.[578] One self-imposed reason is that DoD's current acquisition strategy requires its Services to remain only "fast followers" behind industry innovation in HED.[579] Of course, this leaves its ground forces vulnerably tied to the "tether of fuel" until, presumably, there exists sufficient industry interest and investment in a given vehicle drive technology (e.g., adequate battery energy density for heavy vehicles, faster mobile

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prototype Army Universal Tactical Power Architecture capability, and "prototyping" a standalone charger by FY26. *See* Telephone Interview, Jadus, *supra* note 344; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2.

[574] *See* Seck, *supra* note 573.

[575] *See* Video Interview, Smith, *supra* note 171.

[576] Although Dean McGrew admitted that the Army is "really kicking the can on these huge megawatt charging stations down the road quite a ways," acquisition leaders "are investing quite a bit into fast mobile charging capability." *See* Seck, *supra* note 573.

[577] *See* Telephone Interview, Jadus, *supra* note 344; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 2.

[578] *See supra* notes 153–159 (discussing commercial investment in EV technological advances).

[579] *See TWV Hearing*, *supra* note 73, at 8, 21 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics).

recharging options, etc.).[580] However, under GPC concepts, the purpose of DoD efforts to modernize in MWSs is not merely to *keep up with* peer adversaries but to maintain a competitive edge *over them* to deter and prepare for future wars; this is especially true in the context of MDO and LSCOs.[581] Notwithstanding some internal hesitance, timely ground vehicle HED modernization is stalled more so because of two broader issues: the increasingly polarized nature of DoD's limited budget and systemic performance shortfalls in DoD's acquisition procedures.[582]

B. Political Gridlock: Policy Challenges to Long-Term Funding of HE TWV Acquisitions

With an understanding of DoD's fledgling efforts to hybrid-electrify its ground vehicles, one can appreciate how easy even minor roadblocks can block timely innovation. Still, the policy-based barriers in the way of timely HED modernization are substantial, thwarting sufficient funding at the very onset of acquisition programs.[583] One political barrier, the increasing prevalence of Continuing Resolutions (CRs), is a threat to all MWS modernization efforts.[584] However, the other two key political challenges, DoD's low prioritization of HED innovation and congressional

[580] *See Crawford, supra note 81, at 3; see also supra* notes 469–475 and accompanying text (discussing concerns over current EV batteries' technical limitations).

[581] *See* R43838, *supra* note 323, at 1. The Army is not the only Service facing challenges in procuring HE propulsion capabilities; even with higher budgets for ship and aircraft modernization, the Navy and Air Force may be much farther away from fielding effective HED for its platforms. *See* SHELBY OAKLEY, U.S. GOV'T ACCOUNTABILITY OFF, GAO-21-79R, ARLEIGH BURKE CLASS DESTROYERS: OBSERVATIONS ON THE NAVY'S HYBRID ELECTRIC DRIVE PROGRAM 6, 7 (2020). *But see Beta Electric Aircraft Completes First Deployment with US Air Force*, AEROSPACE TESTING INT'L (Jan. 30, 2024) (discussing recent successful tests by Beta Technologies with the Air Force of the Alia CX300 electric aircraft and the Alia eVTOL aircraft, which have flight ranges of several hundred miles and can recharge in one hour).

[582] *See TWV Hearing*, *supra* note 73, at 8, 21 (statement of Timothy Goddette, Deputy Assistant Secretary of the Army for Acquisition Policy and Logistics); Telephone Interview, Lohnes, *supra* note 541; Luckenbaugh, *supra* note 166.

[583] *See* Telephone Interview, Lohnes, *supra* note 541.

[584] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-21-541, DEFENSE BUDGET: DOD HAS ADOPTED PRACTICES TO MANAGE WITHIN THE CONSTRAINTS OF CONTINUING RESOLUTIONS 13 (2021).

polarization over perceived climate-focused acquisitions, are especially ubiquitous in TWV acquisitions.[585]

1. Continuing Resolutions as a Barrier to DoD Innovation

The most significant barrier to timely HED innovation—and indeed, to R&D efforts for all new MDAPs—is Congress's increasing use of CRs to fund federal government agencies.[586] Congress has enacted one or more CRs in all but three of the last 47 fiscal years (FYs) since 1947.[587] Over the last two decades, in particular, Congress relied on more CRs each year and for longer durations, thrice using CRs to fund the federal government for an entire FY.[588]

The damage by this growing prevalence of CRs is immense, constantly threatening U.S. national security and military readiness.[589] Although CRs help avoid costly federal government

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[585] *See* Telephone Interview, McGrew, *supra* note 282.

[586] *See* Arkin, *supra* note 45. The Congressional Research Service describes CRs as follows:

> The program activities of most federal agencies are generally funded on an annual basis through the enactment of regular appropriations acts. When those annual appropriations acts are not enacted by the beginning of the fiscal year (October 1), one or more continuing appropriations acts (commonly known as continuing resolutions or CRs) may be enacted to provide temporary funding to continue certain programs and activities until action on the regular appropriations acts is completed.

JAMES SATURNO ET AL., CONG. RSCH. SERV., R46595, CONTINUING RESOLUTIONS: OVERVIEW OF COMPONENTS AND PRACTICES Summary (2023) [hereinafter R46595].

[587] *See* R46595, *supra* note 586, at 1.

[588] *See id.*; *see also Continuing Resolutions Are Stopgap Measures— ut Now We Average Five A Year*, PETER G. PETERSON FOUND. (Mar. 3, 2024), https://www.pgpf.org/blog/2024/03/continuing-resolutions-were-designed-to-be-stopgap-measures-but-now-we-average-five-a-year (providing a table showing numbers and durations of CRs since 1998). Congress did not approve the FY 2024 DoD Appropriations Act until March 2024, again relying on multiple CRs for six months. *See* H.R. 4365, 118th Cong. (2023).

[589] Jim Garamone, *DOD Officials Say Service Members, Families Pay Price of Continuing Resolutions*, U.S. DEP'T OF DEF. (Jan. 12, 2022), https://www.defense.gov/News/News-Stories/Article/Article/2897977/dod-officials-say-service-members-families-pay-price-of-continuing-resolutions. In recent requests for greater authority to initiate MTA-RP programs, the DoD stated that "'the current practice of waiting for new-start prototype approval until the next budget cycle is hobbling the department's ability to compete with China, particularly given the routine practice of extended continuing resolutions in which new-start reprogrammings are not allowed.'" Tony Bertuca, *Lawmakers Grant DOD's Request for Early Prototyping Authority*, INSIDE DEF. (Dec. 7, 2023) (quoting Frank Kendall, U.S. Secretary of the Air Force), https://insidedefense.com/insider/lawmakers-grant-dods-request-early-prototyping-authority.

shutdowns, they freeze spending at the previous FY's levels.[590] This prevents any "new starts" on contracts or programs and restricts production rates to those permitted in the previous FY.[591] This "new start" prohibition is especially harmful to MDAPs, which primarily rely on RDT&E and Procurement appropriations, both of which are multi-year amounts that rely on reliable year-to-year funding to develop and procure novel capabilities.[592] As the DoD Comptroller told Congress during a CR in FY 2022, CRs make the U.S. militarily less competitive than its strategic adversaries like the PRC and Russia because there is "significant funding that's misaligned, trapped[,] or frozen in the wrong places and unusable because we don't have the tools or flexibility to realign funds."[593] When combined with "the straight loss of purchasing power under a CR," the impacts of unusable or misaligned funds each year are disastrous for Procurement and RDT&E accounts, sometimes increasing individual acquisition program rates two- or threefold.[594] The ultimate consequence is

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[590] *See* Arkin, *supra* note 45.

[591] *See id*.

[592] *See* GAO-21-541, *supra* note 584, at 13-14 (finding that, "[w]hile these [new start] restrictions have the potential to cause delays and cost increases to major defense acquisition programs, our analysis of selected acquisition programs did not find any instances where this occurred").

[593] *See* Garmone, *supra* note 589 (quoting Michael McCord, Comptroller, U.S. Department of Defense). In short-term CRs, Congress typically does not permit the DoD to reprogram funds, or reallocate previously appropriated funds between authorized programs to reflect shifting needs or priorities. *See id.*; *Vital Signs 2023*, NAT'L DEF. INDUS. ASS'N 17 (Feb. 10, 2023) [hereinafter *Vital Signs*], ndia_vitalsigns2023_final_v3.pdf. As for the strategic threat that CRs post to national security, Mr. McCord said the following:

> Our competitors, China and Russia in particular, use all the pieces on the chessboard to compete with us. . . We're competing on the diplomatic front, the economic front, the military front, innovation and technology. If we take this competition seriously[,] . . . then we cannot afford to continue acting this way. Time is money, and year-after-year, we're giving away time in these lengthy CRs. We do not have such an insurmountable edge on our competitors that we can afford to keep doing this.

Garmone, *supra* note 589 (quoting Michael McCord, Comptroller, U.S. Department of Defense). Former Deputy Secretary of Defense David L. Norquist expressed a similar sentiment in a 2019 hearing before Congress: "The CR stop-gap measures are wasteful to the taxpayer. They . . . damage the gains our military has made in readiness and modernization." *Hearing on Department of Defense Audit, Hearing before the S. Comm. on Readiness & Mgmt. Support of the S. Comm. on Armed Serv.*, 117th Cong. 12 (Nov. 20, 2021) (statement of Hon. David L. Norquist, U.S. Deputy Secretary of Defense).

[594] *See* Garmone, *supra* note 589.

that "the parts of the budget most crucial to re-orient DoD to prepare for, deter, and—if necessary—respond to peer conflict are the accounts most vulnerable to being cut or squeezed during budget instability: [R&D] for emerging technologies, as well as procurement and sustainment of current and next generation major platforms."[595]

Another negative impact comes from limiting language Congress has included in CRs since 2010, restricting DoD from initiating "multi-year procurements using advance procurement funding for economic quantity procurements."[596] As exceptions to the DoD's preferred "full funding policy," or the preference to fully fund in one FY the total cost of all end-items of a major procurement or construction, multi-year contracts and advance procurement authorities are vital for DoD to be able fund its largest procurements that require long lead components.[597] These types of contracting mechanisms are vital to many MDAPs "by protecting the production schedule and maintaining a workforce with critical skills during the production phase."[598] The inability to use these contracting tools during CRs means that MDAPs must often rely on previous FYs'

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[595] *See Vital Signs*, *supra* note 593, at 17.

[596] *See* GAO-21-541, *supra* note 584, at 9. The Defense FAR Supplement (DFARS) defines "advance procurement" as follows:

> [A]n exception to the full funding policy that allows acquisition of long lead time items (advance long lead acquisition) or economic order quantities (EOQ) of items (advance EOQ acquisition) in a fiscal year in advance of that in which the related end item is to be acquired. Advance procurements may include materials, parts, components, and effort that must be funded in advance to maintain a planned production schedule.

DFARS 217.103 (2024); *see also* DFARS 217.172 (2024) (providing agency requirements and restrictions when entering into multi-year contracts for supplies, including weapon systems, and "[a]dvance procurement of components, parts, and materials necessary to manufacture a weapon system"). "Advance procurement of long lead components is an exception to the DoD "full funding" policy and must be part of the President's budget request." *Advance Procurement*, DEF. ACQUISITION U., https://www.dau.edu/acquipedia-article/advance-procurement [hereinafter *Advance Procurement*] (last visited Apr. 11, 2024).

[597] *See* GAO-21-541, *supra* note 584, at 9.

[598] *See Advance Procurement*, *supra* note 596; *see, e.g.*, CONF. REPORT TO ACCOMPANY H.R. 2670, NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2024 § 123 (2024) [hereinafter FY 2024 NDAA CONFERENCE REPORT], https://www.cong ress.gov/118/crpt/hrpt301/CRPT-118hrpt301.pdf (granting multi-year procurement authority for Virginia class submarine program).

production rates while paying premiums for aging MWSs—like legacy TWVs—to slowly trickle to ground forces readying for war.[599] Unfortunately, even if CRs become less common, DoD policymakers' hesitance to prioritize sufficient funding for HED modernization in its budget requests further stall critical innovation.

2. The DoD's Low Prioritization of HED Modernization

For the majority of DoD's annual budget requests, there are typically very few polarizing issues, so bipartisan support ensures funding for much of DoD's budget in NDAAs and DoD appropriations acts each year.[600] However, even if Congress more consistently appropriates funds on time, that funding is only as good as DoD's budget requests.[601] That is, if the DoD does not first prioritize its need for funding to fill a critical capability requirement gap, Congress can only do so much to fund innovation.[602]

In light of the typically broad congressional support for DoD's budget requests, DoD leaders' low prioritization of HED modernization funding poses an especially visible and self-imposed barrier to timely innovation.[603] This lack of attention thus signals to industry that DoD investment in those initiatives will remain diminutive in the near future, exacerbating DoD's future challenges in acquiring responsive and affordable products.[604]

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[599] *See Vital Signs*, *supra* note 593, at 17.

[600] *See Senate Approves Final FY24 Funding Package in Overwhelming 74-24 Vote*, U.S. SENATE SUB. COMM. ON APPROP. (Mar. 23, 2024), https://www.appropriations.senate.gov/news/majority/senate-approves-final-fy24-funding-package-in-overwhelming-74-24-vote; Video Interview, Rogers, *supra* note 541; Telephone Interview, Lohnes, *supra* note 541.

[601] *See* Telephone Interview, Lohnes, *supra* note 541.

[602] *See id.*; Telephone Interview, McGrew, *supra* note 282.

[603] *See* Telephone Interview, Lohnes, *supra* note 541.

[604] *See* Telephone Interview, Jadus, *supra* note 344; Telephone Interview, McGrew, *supra* note 282; E-mail, Putrus, *supra* note 173.

a. The DoD's Communicated Priorities

Explicit prioritization in a capability requirement by DoD leaders and Congress is the key driver of industry's investment in warfighting innovation; simply put, industry will not invest resources and supplies where there is no significant demand.[605] For example, when DoD made the acquisition of MRAPs its "number one priority" in 2005, industry responded immediately and effectively, with multiple companies contracting to deliver thousands of responsive capabilities within months rather than years.[606] Currently, defense strategies that explicitly prioritize air and sea power modernization efforts over ground vehicle innovation most clearly demonstrate to industry DoD's priorities for the foreseeable future.[607]

The remarks of U.S. Secretary of Defense (SECDEF) Lloyd J. Austin III on the President's FY 2025 Defense Budget most recently illustrated to the public DoD's modernization efforts.[608] Tying the budget to the 2022 NDS and capability requirements from ongoing global conflicts and other emerging threats, the statement reflects similar sentiments by DoD in recent years.[609] In it, the SECDEF summarized the broad modernization priorities as follows: "$61.2 billion for airpower to continue developing, modernizing, and procuring lethal air forces; $48.1 billion for sea power, including new construction of six battle force fleet ships; and $13.0 billion for land power, supporting the modernization of Army and Marine Corps combat equipment."[610] Tellingly,

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[605] *See* Telephone Interview, Jadus, *supra* note 344.

[606] *See* GAO-10-155T, *supra* note 50, at 3.

[607] *See, e.g.*, 2023 DoD OES, *supra* note 93360, at 6 (prioritizing operational modernization for aircraft and ships above ground vehicles).

[608] *See* OFF. OF THE SEC'Y OF DEF., U.S. DEP'T OF DEF., STATEMENT BY SECRETARY OF DEFENSE LLOYD J. AUSTIN III ON THE PRESIDENT'S FISCAL YEAR 2025 DEFENSE BUDGET (Mar. 11, 2024) [hereinafter SECDEF AUSTIN ON FY25 BUDGET].

[609] *See id.*

[610] *Id*.

while he mentioned specific air and sea platforms—from the Columbia-class ballistic missile submarine to the B-21 bomber—there was no reference to ground vehicles.[611] The 2023 DoD Operational Energy Strategy (OES) more explicitly communicated the hierarchy of DoD's modernization priorities in relation to fuel demand reduction.[612] While noting DoD's "focus on . . . reducing operational energy demand of *all* current platforms and acquisition programs," the OES settled that, "[i]n the near-term, . . . [efforts] will be weighted significantly to the largest single users of energy, including mobility aircraft (airlift and aerial refueling) and ships, followed by ground vehicles."[613] Congress's actual DoD appropriations also unequivocally communicate these priorities.

Because actions generally speak louder than words, DoD's budgets for its MDAPs provide industry the clearest indication of focus areas for military investment. The prime defense contractors appreciate that "budgets are a grounded signal of government priorities and, thus, of what reward is available for ['capturing the stag['] and what opportunities may exist for future hunts."[614] In total, DoD's FY 2024 funding request for its MWS acquisitions, including both

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[611] *See id*. The SECDEF's statement mentioned funding for the ground-based Sentinel program, an air and missile defense radar system, but did not mention specific ground vehicle platforms. *See id*.; *see also Sentinel-A-4*, LOCKHEED MARTIN, https://www.lockheedmartin.com/en-us/products/sentinel-a4.html (last visited Apr. 11, 2024) ("Sentinel A4 is a high-performance replacement of the legacy Sentinel A3 (AN/MPQ-64A3) air and missile defense radar that will provide significant improvements to the existing Sentinel capability against cruise missiles, unmanned aerial systems, rotary wing and fixed wing threats.").

[612] *See* 2023 DoD OES, *supra* note 93, at 6.

[613] *See* 2023 DoD OES, *supra* note 93, at 6. "For ground vehicles, the Department will focus on maturing electrification technologies that save fuel and support flexible ground-based power, beginning with anti-idle capabilities, progressing to hybrid-electric and then all-electric drivetrains, while enhancing vehicle electrical production and the ability to import and export power." *Id*.

[614] *See* Sanders & Holderness, *supra* note 310, at 6. Economists and social scientists use the "stag hunt" model to illustrate how industry invests resources across competing markets, either cooperating to "hunt a stag" to achieve greater overall success or working independently to "hunt a hare," which involves less risk but also less reward. The chances of success and the size of the reward determines whether industry will decide to "hunt the stag"—that is, whether companies will cooperate to some extent in order to have a better chance of capturing greater reward. *See id.*; Laura Ahlstrom, *Stag Hunt*, INOMICS (July 13, 2023), https://inomics.com/terms/stag-hunt-1537413.

Procurement and RDT&E accounts, amounted to $315 billion, allocating $170 billion to Procurement and $145 billion to RDT&E.[615] With the exception of those HED acquisition programs discussed below, Congress largely authorized and appropriated DoD's investment funding request in full,[616] with $61.1 billion for "Aircraft and Related Systems" (19% of the request) and $48.1 billion for "Shipbuilding and Maritime Systems" (15% of the request).[617] In contrast, the budget for all of DoD's "Ground Systems" acquisitions totaled only $13.9 billion (5% of the investment budget request), with over 80% of that amount allocated to procure existing legacy GCVs and TWVs.[618] The DoD budgeted less than $3 billion of RDT&E funds for modernization of all its ground systems, compared to over $24.1 billion of RDT&E funds to support the Air Force and Navy's modernization programs for air and sea platforms.[619] Although DoD's TWVs comprise over half of its entire air-, sea-, and land-based vehicle fleet, DoD budgeted less than *$103 million* RTD&E funds—only 0.03% of the total budget request for MWS acquisitions—to support HE TWV modernization programs.[620]

b. Reasons for DoD Under-Prioritization

There are three key reasons for DoD's relatively low funding of ground vehicle HED innovation. The most obvious reason is that DoD's budget is not unlimited. Leaders and

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[615] *See* OFF. OF THE UNDER SEC'Y OF DEF. (COMPTROLLER)/CHIEF FIN. OFFICER, PROGRAM ACQUISITION COST BY WEAPON SYSTEM, U.S. DEPARTMENT OF DEFENSE FISCAL YEAR 2024 BUDGET REQUEST i (Mar. 2023) [hereinafter OUSD, PROGRAM ACQUISITION COSTS]; *see also* IF10599, *supra* note 180, at 1 (discussing the difference between Procurement and RDT&E accounts in DoD appropriations).

[616] *See generally* Department of Defense Appropriations Act, 2024, H.R. 4365, 118th Cong. (2023) (approving in full or increased amount more than 90% of other RDT&E and Procurement lines of appropriation).

[617] *See* OUSD, PROGRAM ACQUISITION COSTS, *supra* note 615, at i, iv, x.

[618] *See id. at* i, iv, vi.

[619] *See id.*

[620] *See id.* at i, iv, vi, 3-1, 3-2, 3-7, 3-8;

policymakers must constantly make decisions as to which MWSs—from aircraft platforms to ships to air defense artillery systems—they must focus limited DoD funds to best "posture us to deter aggression against the United States, or our allies and partners, while also preparing us to prevail in conflict if necessary."[621] The main explanation for DoD not requesting more for HED innovation is thus that it currently prioritizes other modernization programs higher, based on valid global threat assessments.[622] Furthermore, although many DoD leaders now appreciate the strategic imperative of reducing DoD's vulnerable fossil fuel reliance, the higher fuel consumption of the fleet's most "gas-guzzling" war machines—its ships and aircraft—suggests that those platforms should be a higher priority for immediate operational energy modernization.[623]

The other two explanations for DoD's under-prioritization of ground vehicle HED modernization involve biases among DoD leaders and policymakers.[624] First, DoD leaders have now relied for decades on the SFC and enjoyed virtually continuous access to petroleum-based fuels during the recent asymmetric conflicts in the Middle East.[625] In those settings, DoD leaders also generally did not worry about enemies who had significant thermal imaging or advanced targeting capabilities or ones who could challenge U.S. access to oil.[626] These advantages fortified individual leaders' fuel reliance, deepening their biases against changing logistics systems and seeking operational energy innovation.[627]

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[621] *See* SECDEF AUSTIN ON FY25 BUDGET, *supra* note 608.

[622] *See* 2023 DoD OES, *supra* note 93, at 6.

[623] *See id.*

[624] *See* Kern et al., *supra* note 10; Crawford, *supra* note 81, at 4.

[625] *See* Kern et al., *supra* note 10.

[626] *See id*.

[627] *See* Telephone Interview, Jadus, *supra* note 344; SECDEF AUSTIN ON FY25 BUDGET, *supra* note 608; *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 6; 2022 NDS, *supra* note 38, at 20.

Second, DoD leaders have historically focused on investments in certain types of MWS platforms that now expose risk of diminished relevance in future MDO and LSCOs.[628] For example, the Air Force's F-35 Lightning II Joint Strike Fighter program is the DoD's most expensive MDAP in history, by billions of dollars.[629] However, the Russia-Ukraine War indicates that the value of fighter jets should be questioned in a LSCO against a peer adversary with advanced air defense systems and swarming UAS capabilities.[630] Nevertheless, the DoD continues to budget significantly more for fighter jet acquisition programs than all of its ground vehicle acquisition programs combined.[631]

The relatively de minimis levels of DoD investment in ground vehicle modernization programs worsen the already low industry participation in advancing DoD's HED acquisition efforts.[632] Nevertheless, the number of new HED R&D programs across the Services continues to grow, reflecting the increasing demand of requiring activities (RAs) for these capabilities.[633] With sufficient funding for these programs to at least demonstrate to the JF the immense

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[628] *See* Dan Grazier, *Has the Pentagon Learned from the F-35 Debacle?*, PROJECT ON GOV'T OVERSIGHT (June 8, 2023), https://www.pogo.org/analysis/has-the-pentagon-learned-from-the-f-35-debacle.

[629] *See* U.S. GOV'T ACCOUNTABILITY OFF., GAO-24-107177, F-35 JOINT STRIKE FIGHTER: MORE ACTIONS NEEDED TO EXPLAIN COST GROWTH AND SUPPORT ENGINE MODERNIZATION DECISION Highlights (2024) [hereinafter GAO-24-107177].; MICHAEL J. SULLIVAN, U.S. GOV'T ACCOUNTABILITY OFF., GAO-17-690R, F-35 JOINT STRIKE FIGHTER: DOD'S PROPOSED FOLLOW-ON MODERNIZATION ACQUISITION STRATEGY REFLECTS AN INCREMENTAL APPROACH ALTHOUGH PLANS ARE NOT YET FINALIZED 1 (2017) [hereinafter GAO-17-690R].

[630] *See* Grazier, *supra* note 628.

[631] *See id.* (claiming that the consistently high funding prioritization by Congress for fighter jet acquisitions an example of "political engineering," or the motivation of lawmakers to seek acquisition programs that require many different manufacturing plants, thereby increasing opportunities for businesses in their districts to capture production subcontracts).

[632] *See In re* Oshkosh Defense, LLC, 2023 CPD ¶ 2 (noting that only two companies bid for JLTV production contract).

[633] *See* Telephone Interview, Jadus, *supra* note 344.

warfighting advantages that HED offers ground forces, more DoD senior leaders will no doubt soon emphasize the need for TWVs and GCVs with HE capabilities.[634]

c. Lack of an Updated TWV Strategy

Despite the increasing warfighter demand for HE operational vehicles and AFC's TaCV-E ICD, the lack of a broader Army TWV strategy leaves ongoing HED acquisition programs apparently isolated and disconnected.[635] The Army last issued a formal TWV strategy in 2010 and an accompanying management plan in 2014 to provide guidance in how it intended to update the ground fleet's size and composition.[636] In accordance with Government Accountability Office (GAO) recommendations, Army leaders planned to release an updated TWV strategy in 2022 to "encompass an enterprise-wide view of the TWV fleet and synchronize the plans and actions of Army agencies involved in TWV requirements, procurement, integration, sustainment, and management."[637] Such a strategy would also "inform the selection of capabilities, fleet acquisition, management plans, and the development of Army funding requests."[638] Nevertheless, the Army has yet to release an updated TWV strategy to guide those broader acquisitions strategies.[639] This has left acquisition leaders with unclear guidance to communicate to industry.[640]

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[634] *See* GAO-21-460, *supra* note 8, at 8, 12, 13.

[635] *See id.* at 8.

[636] *See id.*; OFF. OF VICE CHIEF OF STAFF, U.S. DEP'T OF ARMY, THE ARMY TACTICAL WHEELED VEHICLE (TWV) STRATEGY (2010) [hereinafter 2010 TWV STRATEGY], https://apps.dtic.mil/sti/pdfs/ADA540698.pdf; Brigadier General John P. Sullivan & Scott Davis, Managing to the Army Tactical Wheeled Vehicle Strategy (6 May 2914) [hereinafter 2014 TWV Plan], https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2014/tactical/SessionII2Sullivan.pdf.

[637] *See* GAO-21-460, *supra* note 8, at 8.

[638] *Id*.

[639] *See id*. at 2; E-mail, Roberts, *supra* note 299.

[640] *See* E-mail, Roberts, *supra* note 299.

Without a clear, accepted modernization strategy at the highest levels to guide long-term acquisition approaches and contracting strategies, there exists a "pattern of the increasing risk of the Army's management of [TWVs] over the last few years by cutting modernization and productions funding to generate more money for the higher priority weapons programs."[641] This lack of an updated TWV strategy creates a lack of shared understanding of DoD's vision for its future ground force vehicle fleet.[642] This confusion is felt not only by DoD leaders and sustainers but also by industry.[643] For any MDAP, "cutting plans and funding for development and procurement programs creates vendor uncertainty and a lack of predictability over time. Doing so also increases unit costs and risks for loss of industrial capacity, capability, and resilience."[644]

Although the Army only budgeted a handful of relatively inexpensive TWV HED modernization programs, totaling approximately $103 million in RDT&E funds for FY 2024, Congress cut even those funds in *half* in the FY 2024 NDAA and DoD Appropriations Act.[645] Without a comprehensive TWV strategy to communicate the Army's vision, the remaining narrative—that is, the widespread misconception that climate change policies motivate DoD's

[641] GAO-21-460, *supra* note 8, at 8.

[642] Stew Magnuson, *Army Doing Poor Job Communicating its Tactical Wheeled Vehicle Needs*, NAT'L DEF. (July 15, 2021), https://www.nationaldefensemagazine.org/articles/2021/7/15/just-in-report-army-doing-poor-job-communicating-its-tactical-wheeled-vehicle-needs; *see* GAO-21-460, *supra* note 8, at 8.

[643] *See* Magnuson, *supra* note 642.

[644] *See TWV Hearing*, *supra* note 73, at 3 (statement of Rep. Don Bacon (R-NE), Member, S. Comm. on Tactical Air & Land Forces, H. Comm. on Armed Services).

[645] *See* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; H.R. 4365, 118th Cong. 95B (2023); KAY GRANGER, H. COMM. ON APPROPRIATIONS, EXPLANATORY STATEMENT REGARDING H.R. 2882, FURTHER CONSOLIDATED APPROPRIATIONS ACT, 2024, DIVISION A – DEPARTMENT OF DEFENSE APPROPRIATIONS ACT, 2024 (2024) [hereinafter GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT], https://docs.house.gov/billsthisweek/20240318/Division%20A%20Defense.PDF.

budding HED acquisition efforts—continues to fuel political gridlock over such spending in Congress.[646]

3. Partisan Divide Over Perceived Climate-Related Spending

As in other areas of DoD spending, authorizations and appropriations in past years hinted at lasting, bipartisan support for HED acquisition efforts to modernize DoD's ground fleet.[647] Nevertheless, amidst industry's near-daily advances in battery technology that make HED more technologically feasible and lethal in combat, Congress is scaling back support for such acquisitions.[648] Recent congressional debate over NDAAs and appropriation bills, as well as lawmakers' personal statements to media, reveal that efforts to electrify DoD's ground fleet now face similar levels of political polarization as other highly divisive issues before Congress.[649] The primary reason for this divide is the perception that Executive Branch climate policy goals are driving DoD's HED modernization efforts.[650]

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[646] *See id*.

[647] *See* National Defense Authorization Act for Fiscal Year 2023, § 4201, Pub. L. 117 Stat. 2395, 3126 (2022) (authorizing over $5 million specifically for "[c]ombat vehicle hybrid-electric transmissions"). *But see* S. B. 117-2, § 4201, 19 (2022) https://www.armed-services.senate.gov/imo/media/doc/fy23_ndaa_bill_text2.pdf (hinting at the greater polarization of the issue of HED in the House of Representatives; the Senate's previous version of the bill authorized higher funding for the same "[c]ombat vehicle hybrid-electric transmissions" line than Congress ultimately authorized and appropriated).

[648] *See* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; Telephone Interview, Jadus, *supra* note 344.

[649] *See* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141.

[650] *See* Maxine Joselow & Vanessa Montalbano, *House Republicans Target the Pentagon's Use of Electric Vehicles*, WASH. POST (July 10, 2023), https://www.washingtonpost.com/politics /2023/07/10/house-republicans-target-pentagon-use-electric-vehicles; FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249.

"Political polarization is a barrier to enacting policy solutions to global issues[, especially] in the context of one of the most pressing modern issues: climate change."[651] Congress is historically split along party lines over spending bills related to the environment, climate change mitigation, and renewable energy investment, with Democrats generally more supportive and Republicans less supportive of such measures.[652] Therefore, not surprisingly, in 2019 and 2020, Congress was largely split over supporting budget requests to implement President Biden's EO 14057 to replace the federal government's NTV fleet with newly procured ZEVs.[653] In contrast, Congress demonstrated initial bipartisan support for DoD's RDT&E budget requests focused on electrifying its operational vehicles, approving over $100 million for such programs.[654]

Despite initial funding for HED modernization, Congress reversed course in the FY 2024 NDAA and DoD Appropriations Act.[655] Although it overwhelmingly approved the Army's other

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[651] Jennifer C. Cole et al., *Social Psychological Perspectives on Political Polarization: Insights and Implications for Climate Change*, PSYARXIV 2 (Feb. 6, 2023), doi:10.31234/osf.io/xz6wk. Political issue polarization is defined as "opposing stances on political issues between political parties." *Id.* at 5.

[652] *See Are Our Efforts to Address Climate Change Doomed Due to Partisan Politics?*, UCLA LUSKIN CTR. FOR INNOVATION (Sept. 7, 2023), https://innovation.luskin.ucla.edu/2023/09/07/are-our-efforts-to-address-climate-change-doomed-due-to-partisan-politics; Ivy Main, *Is There a Partisan Divide on Climate? Not Among Young People*, VA. MERCURY (June 13, 2023, 12:04 AM), https://virginiamercury.com/2023/06/13/is-there-a-partisan-divide-on-climate-not-among-young-people. Although the relationship between campaign donations and congressmen's voting records is complex and not necessarily causal. *See* Pranav Goel et al., *Donor Activity is Associated with US Legislators' Attention to Political Issues*, PLOS ONE 2 (Sept. 20, 2023), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10511130/pdf/pone.0291169.pdf. That is, it is just as likely that certain political party campaigns are more likely to receive donations from certain industries because their ideals and priorities align, rather than the alternate explanation that politicians vote a certain way because of which industries donated to their campaigns. *See* Goel et al., *supra*. Nevertheless, it is worth noting that 88.4% of political campaign donors from environmental industry and 73.2% of renewable energy industry donors gave to Democrat candidates. *See* https://www.opensecrets.org/elections-overview/most-partisan-industries. Meanwhile, 82.6% of oil and gas industry donors and 75.4% of automotive industry donors gave to Republican candidates. *See* Goel et al., *supra*.

[653] *See* Jory Heckman, *'Nowhere to go But Up.' Biden's Zero-Emission Federal Fleet Hits Roadblocks*, FED. NEWS NETWORK (June 11, 2021), https://federalnewsnetwork.com/facilities-construction/2021/06/nowhere-to-go-but-up-bidens-zero-emission-federal-fleet-hits-roadblocks.

[654] *See* Jadus email; Dean McGrew email; Joselow & Montalbano, *supra* note 650.

[655] FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249; H.R. 4365, 118th Cong. (2023).

budget requests for legacy TWV and GCV acquisitions, totaling more than $3 billion in RDT&E and Procurement funding, Congress cut nearly all of the Army's $70 million RDT&E budget requests for HED programs.[656] Pointing simply to "incomplete development goals," these cuts largely defunded the Army's R&D efforts into purpose-built HE light- and medium-duty TWVs and stalled crucial additional purchases of retrofit anti-idle TVEKs.[657]

Closer inspection of the Army's budget request accompanying the FY 2024 DoD Appropriations Act reveals the key difference between these two slashed RDT&E programs and those that Congress fully funded.[658] In particular, Congress cut from the Army's FMTV modernization program $25 million, the exact amount the Army specifically requested "to continue the development, test, and integration of *Climate Change initiatives* such as Tactical Vehicle Anti-Idle Retrofit Kit [(TVEK)], On Board Vehicle Power, Hybrid Propulsion, Predictive Logistics (PL) development *and other technologies associated with combatting climate change for the Tactical Wheeled Vehicle fleet*."[659] Likewise, Congress cut from the light tactical vehicle (LTV) modernization

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[656] FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1441; FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249; H.R. 4365, 118th Cong. (2023); H.R. 4365, 118th Cong. (2023); *see also* Appendix H (providing relevant screenshots from the Conference Report's cuts in the FY24 NDAA); Appendix I (providing relevant screenshots of the House Armed Forces Committee's cuts in the FY 2024 DoD Appropriations Act).

[657] *See* Jadus email 2; McGrew email 2; Roberts email 2; *see* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249; H.R. 4365, 118th Cong. (2023); H.R. 4365, 118th Cong. (2023). For innovation of new technology and capabilities (like advanced HED and batteries in TWVs and GCVs), the NDAA authorizes funding for RDT&E in Title XLII. The NDAA typically authorizes procurement funding for DoD weapons acquisition programs—including the purchase of new and modifications to existing ground combat and tactical vehicles—in Division A, Title XLI. *See* BRENDAN MCGARRY, CONG. RSCH. SERV., FY2023 NATIONAL DEFENSE AUTHORIZATION ACT: OVERVIEW OF FUNDING AUTHORIZATIONS 12, 16 (2023). Although DAAs do not define the phrase "incomplete development goals," it historically denotes where the voting and accompanying remarks demonstrate general disapproval of the intended purpose of the request. *See* Telephone Interview, Jadus, *supra* note 344; Telephone Interview, Lohnes, *supra* note 541.

[658] *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249.

[659] *See* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645, at 200, 94FJ; H.R. 4365, 118th Cong. (2023); FY24 Army RDT&E Budget Justification, *supra* note 77, at 173 (emphasis added). This program totaled approximately $28 million in requested funds and included allocations for development of FMTV anti-idle kits, other HED capabilities, and "*fund the development of other technologies associated with the [sic] combatting*

program over $43 million, the exact amount of program increase from the previous FY's request, which the Army intended to "initiate design, development and testing for prototype HMMWV HEV solutions."[660] Demonstrating Congress's aversion to climate-motivated DoD spending, the program's description for this slashed amount stated that "HMMWV HEV funding supports the Army's Climate Strategy . . . to modernize existing platforms by adding electrification technologies."[661] As these were the only RDT&E vehicle programs that leaders explicitly tied to the Army's climate policy goals, the perceived nexus undoubtedly motivated Congress's budget cuts.[662] Confirming this finding, in the ultimate FY 2024 DoD Appropriations Act, Congress

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climate change, power and battery modernization strategies[,] and the support of artic [sic] strategies for the Tactical Wheeled Vehicle fleet." *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 174, 175. The program's acquisition strategy further noted that it "will continually monitor emerging technologies and capabilities and leverage existing partnerships within the science and technology centers as well as through industry market research and partnerships *in order to support the Army's Climate Change strategy*." *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 176 (emphasis added).

[660] *See* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; FY24 Army RDT&E Budget Justification, *supra* note 77, at 249; GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645, at 200, 94FJ. The DoD's budget request even led with the battlefield advantages of HED for its TWVs but unfortunately—and fatally—also highlighted the potential climate change benefits:

> A HMMWV Hybrid Electric Vehicle (HEV) mitigates a gap in Large-Scale Combat Operations to employ semi-independent maneuver in a Multi-Domain Operational (MDO) environment. A HMMWV HEV will seek to improve and provide new capabilities such as silent mobility, extended silent watch, reduced fuel consumption, increased automotive performance, increased on-board vehicle power (Direct Current), available export power (Alternating Current), integrated charging, potential Vehicle-To-Grid (V2G)[,] *and reduced greenhouse gas emissions.* HMMWV HEV funding *supports the Army's Climate Strategy (Line of Effort 2.1) to modernize existing platforms by adding electrification technologies*.

See FY24 Army RDT&E Budget Justification, *supra* note 77, at 248–49 (emphasis added). Ultimately, that final tie-in to climate goals was enough to dissuade bipartisan congressional support for innovation, with Representative Ken Calvert calling such spending measures "overreach by the Biden Administration on climate change." *See Calvert Remarks During Floor Consideration of H.R. 4365, The Department of Defense Appropriations Act*, HOUSE APPROPRIATIONS REPUBLICANS (Sept. 27, 2023), https://appropriations.house.gov/news/statements/calvert-remarks-during-floor-consideration-hr-4365-defense-appropriations-act.

[661] *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 248, 249; *see also* H.R. 4365, 118th Cong. (2023) (decreasing RDT&E and Procurement funding for JLTV programs by over $300 million across the Services due to production phasing and "[u]njustified unit cost growth").

[662] *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, Lohnes, *supra* note 541; FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249; FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141; GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645, at 200, 94FJ; *see also* E-mail, Roberts, *supra* note 299 (confirming that the warfighting advantages from HED are what actually drove these budget requests and that the Army will utilize whatever

authorized RDT&E funding for the Army's and other Services' various HE propulsion R&D programs, including $30 million for the Air Force's HE propulsion technology development, which budget requests did not tie to climate policy.[663]

The statements of members of Congress in recent years, both in congressional sessions and interviews with media outlets, further reflect that their wariness to fund HED acquisitions relates more to the perceived climate nexus than any concerns about technical limitations or competing modernization priorities.[664] The 2022 ACS elicited many such split responses, especially because it clearly tied the Army's operational energy initiatives to Executive climate policy goals, setting the stage for more severe political polarization. [665]

Demonstrating that misperception as to DoD's HED motivations exists on both sides of the aisle, Democrats generally supported the Army's operational energy goals as "another important

limited funds are available from Congress to continue acquiring TVEKs and conducting R&D for HE TWVs); Telephone Interview, Jadus, *supra* note 344 (confirming the same); Dean McGrew (confirming the same). Further highlighting the uniquely contentious nature of HEV acquisitions, Congress approved full funding for similar RDT&E programs into alternative fuel sources for operational vehicles whose budget requests did not include language referencing climate policy. *See, e.g.*, GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645, at 95F (authorizing $10 million for R&D projects exploring hydrogen fuel cell and battery technology for the NGCV to improve its silent watch capabilities).

[663] *See* H.R. 4365, 118th Cong. line 119 (2023). Congress approved the following RDT&E funding for the other Services' HE R&D programs: $30 million for the Air Force's HE propulsion tech development (Line 19), $9.8 million for the Marine Corps' HE engine development (Line 9), $5 million for the Space Force's in-orbit electrical propulsion (Line 17), and $5 million for the Navy's "high temperature superconducting main propulsion electric motor technology" (Line 48). Additionally, Congress appropriated $5 million for the NGCV program line involving modular electric motors (Line 44). *See* GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645.

[664] *See* GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645.

[665] *See* 2022 ACS, *supra* note 63, at 11; John Donnelly, *New Army Climate Strategy Splits the Parties*, ROLL CALL (Feb. 8, 2022, 6:58 PM), https://rollcall.com/2022/02/08/new-army-climate-strategy-splits-the-parties. The climate strategy set ambitious energy objectives including the procurement of 100 percent carbon-free energy on all of the Service's 130 worldwide installations by 2030, deployment of all-electric tactical vehicles by 2050, and requirements for Army training exercises and simulations to consider climate change risks and threats by 2028. *See* 2022 ACS, *supra* note 63, at 11; Donnelly, *supra* note 665. This marriage between Army climate goals, operational energy, and HED modernization has stuck; HE TWV acquisition programs' progress is regularly briefed at Pentagon operational energy and climate change meetings. *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, Jadus, *supra* note 344.

step" in responding to and mitigating the global effects of climate change, the "existential threat of our time."[666] In contrast, several Republicans in the U.S. House of Representatives and U.S. Senate viewed initiatives in the 2022 ACS as "a waste of Department resources," "a distraction at best" that jeopardizes the "combat readiness and training of soldiers and equipment," and just another way for President Biden "to turn the Army into a climate change task force."[667] Senator James M. Inhofe (R-OK), the top Republican on the Senate Armed Services Committee, perhaps best summarized his party's response to the 2022 ACS: "This new proposal seems like another effort from the Biden administration to focus our military on everything except its primary mission: defending our country . . . The Army's top priority should be securing the capabilities needed to operate and win in contested environments, not adhering to arbitrary bureaucratic deadlines."[668] These arguments, suggesting that the Army's warfighting mission serves the reason *not* to support HED capabilities on the battlefield, indicates a fundamental misunderstanding—albeit a justified one in light of DoD's so-far unclear message—over the Army's impetus for such HED innovation.[669]

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[666] *See* Donnelly, *supra* note 665 (quoting Rep. Adam Smith (D-WA, Chairman, House Armed Services Committee) and Rep. Donald Norcross (D-NJ, Chairman, Tactical Air and Land Forces Subcommittee)).

[667] *See* Joselow & Montalbano, *supra* note 650 (quoting Rep. Mike D. Rogers (R-AL, top Republican on the House Armed Services Committee), Sen. Tom Cotton (R-AR, top Republican on the Tactical Air and Land Forces Subcommittee in the Senate Armed Services Committee), and Senator James M. Inhofe (R-OK, former top Republican on the Senate Armed Services Committee). Senator Cotton elaborated, "[t]ime and money spent indulging Democrats' political goals is time and money lost in the fight against America's enemies — and our enemies know it." *See* Donnelly, *supra* note 665. Representative Paul A. Gozar (R-AZ) also cautioned: "The military is no place to experiment with untested technology. . . The combat readiness and training of soldiers and equipment is jeopardized by the compelled use of electric vehicles." *See* Joselow & Montalbano, *supra* note 650.

[668] *See* Donnelly, *supra* note 665.

[669] *See id.* This inaccurate perception of climate policy impetus driving HED modernization has grown more severe in part due the DoD's ongoing procurement of thousands of ZEVs to replace its NTV fleet and construction of EV charging stations on installations. In the case of those acquisitions, climate policy *is* the primary motivator. *See See* EO 14057, *supra* note 159, § 602(b); Video Interview, Rogers, *supra* note 541. Subsequent DOD documents that tied ZEV NTV procurement efforts to HE TWV initiatives also cemented this inconvenient marriage. *See DoD Plan to Reduce Greenhouse Gas Emissions*, U.S. DEP'T OF DEF. 6 (Apr. 2023),

Along with these polarized media statements regarding the Army's HE acquisition efforts, several House Republicans formally opposed such programs through proposed amendments to the FY 2024 NDAA.[670] For example, one amendment sought to prohibit *any* DoD funding for RDT&E to be obligated or expended "for projects involving electric vehicles, electric vehicle charging, or photovoltaic technology."[671] Another amendment sought to prevent DoD invoking the Defense Production Act to encourage production of EVs, EV batteries, EV charging infrastructure, or critical minerals used in EVs.[672] Although the conference only accepted a handful of such limitations on DoD's electrification efforts,[673] Congress's subsequent markups of the FY 2024 DAA illustrate that political opposition to what appears as DoD climate-related spending will endure.[674]

Despite this apparent nexus between an MDAP's mention of climate policy and current congressional defunding of such programs, there are other reasonable explanations for Congress's

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https://media.defense.gov/2023/Jun/16/2003243454/-1/-1/1/2023-DOD-PLAN-TO-REDUCE-GREENHOUSE-GAS-EMISSIONS.PDF.

[670] *See* Donnelly, *supra* note 665.

[671] *See H.R. 2670 – National Defense Authorization Act for Fiscal Year 2024*, COMM. ON RULES, https://rules.house.gov/bill/118/hr-2670 (last visited Apr. 11, 2024) (listing Rep. Perry's amendment as number 500).

[672] *See id.* While relating to NTVs rather than TWVs, a third amendment proposed a requirement for the DoD to terminate any contracts for electric NTVs. *See id.* (listing Rep. Boeber's amendment as number 73). Similarly, a fourth amendment sought to allow one DoD installation to continue using nonelectric NTVs, specifically noting that military operations are never bound to use electric vehicles. *See id.* (listing Rep. Gosar's amendment as number 66).

[673] *See, e.g.*, FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 318 (prohibiting SECDEF from requiring certain contractors to reveal GHG emissions); *id.* at § 319 (requiring DoD installations to finalize infrastructure plans before employing EV NTVs).

[674] *See* Telephone Interview, Jadus, *supra* note 344; GRANGER, MARKUPS OF FY 2024 DOD APPROPRIATIONS ACT, *supra* note 645, at 200, 94FJ. A markup is "[t]he process by which congressional committees and subcommittees debate, amend, and rewrite proposed legislation." *Glossary*, U.S. SENATE, https://www.senate.gov/about/research-tools/glossary.htm (last visited Apr. 11, 2024) (search "markup"). *See generally* VALERIE HEITSHUSEN & BRENDAN MCGARRY, CONG. RSCH. SERV., IF10515, DEFENSE PRIMER: THE NDAA PROCESS 1 (2024) [hereinafter IF10515] (providing an overview of the NDAA and markup process).

waning support for HE TWV acquisitions.[675] Many lawmakers and DoD policymakers share valid concerns over EV batteries' current technological limitations, safety risks, and supply chain vulnerabilities, preferring instead to hold off funding until industry makes greater advances.[676] Further weakening political support for such acquisitions is the constant need for Congress and DoD policymakers to balance an already tight defense budget, especially in light of what they view—right or wrong—as greater modernization priorities for DoD.[677] Nevertheless, even if Congress and DoD leadership can navigate past these policy-based challenges to HE TWV acquisitions, these programs remain at risk of stalling due to the procedural challenges that historically plague DoD's acquisitions of tactical vehicles.[678]

C. Procedural Roadblocks: Defense Acquisition Challenges to Hybrid-Electrifying DoD's TWV Fleet

Even if HED acquisition programs maneuver past the polarized political environment and competing DoD modernization priorities that currently block HE TWV acquisitions, there are persistent challenges in DoD acquisitions processes that nevertheless will continue to hinder such innovation.[679] Despite recent reforms, these processes still frequently result in poor performance

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[675] *See* FY24 Army RDT&E Budget Justification, *supra* note 77, at 248, 249; FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 4201, at 726, 1141.

[676] *See TWV Hearing*, *supra* note 73, at 3 (statement of Rep. Don Bacon (R-NE), Member, S. Comm. on Tactical Air & Land Forces, H. Comm. on Armed Services); Sunjoo Hwang, *The Short Sightedness of Anti-Electric Vehicle (EV) NDAA Amendments*, AM. SEC. PROJECT (July 31, 2023), https://www.americansecurityproject.org/the-short-sightedness-of-anti-electric-vehicle-ev-ndaa-amendments/; *see also* Dorothy Robyn & Jeffrey Marqusee, *House Republican Opposition to DOD Clean Energy Technology Is Misguided*, INFO. TECH. & INNOVATION FOUND. (July 21, 2023), https://itif.org/publications/2023/07/21/house-republicans-opposition-to-dod-clean-energy-technology (arguing that skeptics in Congress should not become distracted by the "clean energy technology" aspect of hybrid-electrifying the operational vehicle fleet).

[677] *See* Hwang, *supra* note 676; 2023 DoD OES, *supra* note 93360, at 6.

[678] *See* WONG ET AL., *supra* note 40, at v.

[679] *See id.*

outcomes for MWS acquisition programs, such as cost overruns, schedule delays, and design flaws, which are all symptoms of broader acquisition process deficiencies.[680] However, before assessing how these MDAP shortfalls and more specific procedural inefficiencies continue to threaten HED acquisition programs, one must appreciate how the DIB's current limitations could challenge acquisition leaders' ability to leverage industry to effectively respond to DoD's requirements.[681]

1. The Weak U.S. DIB: "You Go to War with the Industrial Base You Have, Not the Industrial Base You Want"[682]

The capacity of the current U.S. DIB to support DoD's drive for timely HED innovation is anything but certain.[683] Those who doubt the DIB's ability to shift agilely and innovate rapidly will typically point to the fact that the DIB is still reeling from Congress's massive defense budget cuts after the Cold War, making new MDAPs even more challenging.[684] A basic understanding of the

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[680] *See id.*; Gregory Sanders et al., *2021 Defense Acquisition Trends: Topline DoD Trends after a Half Decade of Growth*, CTR. STRATEGIC & INT'L STUD. (Dec. 2, 2021), https://www.csis.org/analysis/2021-defense-acquisition-trends-topline-dod-trends-after-half-decade-growth.

[681] *Id.*

[682] *See* John Barrett, *You Go to War With the Industrial Base You Have, Not the Industrial Base You Want*, WAR ON THE ROCKS (Aug. 16, 2023), https://warontherocks.com/2023/08/you-go-to-war-with-the-industrial-base-you-have-not-the-industrial-base-you-want.

[683] *See* Robertson, *supra* note 43. The Congressional Research Service defines the defense industrial base as follows:

> The [DIB] encompasses all organizations and facilities that provide DOD with materials, products, and services. The composition of the DIB is diverse, and includes entities such as small and medium-sized businesses, university laboratories and research centers, and large multinational corporations. DIB functions are similarly varied, ranging from the production of complex platforms unique to the military (e.g., aircraft carriers) and the provision of highly specialized services (e.g., intelligence analysis), to the provision of general commercial products (e.g., laptop computers) and routine services (e.g., information technology support).

[684] IF10548, *supra* note 460, at 1; *see* Seth Jones, *The U.S. Defense Industrial Base Is Not Prepared for a Possible Conflict with China*, CTR. STRATEGIC & INT'L STUD. (Jan. 2023), https://features.csis.org/preparing-the-US-industrial-base-to-deter-conflict-with-China. For example, one study found that "the Pentagon's spending on [just] procurement, research, development and construction dropped 44%" in the years immediately before and after the fall of the Berlin Wall. *See* Robertson, *supra* note 43.

DIB illustrates how this decades-past drawdown still impacts DoD's ability to acquire innovative MWSs at a reasonable price, schedule, and quality.[685]

In general, the economics concept of the DIB differs significantly from commercial markets in that most of the products and systems DoD needs are unique.[686] This means that "[d]efense companies[, both large and small,] build what governments want, but rarely any more or anything different," and DoD's "orders have an unusual amount of sway over the shape of the companies fulfilling them. 'The defense industry is [therefore] hypersensitive to and responsive to its customers.'"[687]

This sensitivity of the DIB to DoD's needs played out dramatically after the Soviet Union dissolved in 1991, removing the U.S.' largest opponent at the time and obliging Congress to cut the defense budget nearly in half.[688] After the Cold War ended, the U.S. required a defense industry "built for peacetime," so Congress and DoD leaders reasonably opted for one that was smaller and more efficient over one that was adaptable but sprawling.[689] In 1993, DoD officials brought together over twenty defense industry leaders to brief them on DoD's dramatic plunge in anticipated spending on MWS contracts for the foreseeable future, forcing those companies to either consolidate (i.e., merge) or perish.[690] As a result, "[w]ithin a decade, the number of large prime contractors plummeted from 51 to five, creating the modern defense industry."[691]

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[685] *See* IF10548, *supra* note 460, at 1.

[686] *See* Robertson, *supra* note 43.

[687] *See id.* (quoting Steve Grundman, senior fellow at the Atlantic Council think tank).

[688] *See* IF10548, *supra* note 460, at 1.

[689] *See* Robertson, *supra* note 43.

[690] *Id*.

[691] *Id*. For example, "Lockheed had merged with Martin Marietta, Northrop with Grumman, Boeing with McDonnell Douglas, and Raytheon with Hughes, just to name a few." Marcus Weisgerber, *Five Ways 9/11*

Exacerbating the consolidation of prime defense contractors, in the early 2000s, DoD leaders favored an approach of building MWSs that were more advanced but less plentiful.[692] This acquisition strategy ultimately forced additional consolidations of defense contractors into fewer potential bidders.[693] It also led to unproductive MWS programs like those for the Navy's Littoral Combat Ship and the Army's Future Combat System.[694]

Experts believe the primary reason for such acquisition failures was the lack of competitive prime defense contractors who choose to bid for DoD's MWS contracts.[695] An omnipresent problem in MWS contracts is that, although the price that companies could charge for systems is considerable, the volume for any single supplier is often not high enough for several companies to find competition worth the investment.[696] For example, "[i]n 1998, five companies built surface ships and two made tracked combat vehicles. By 2020, those numbers had fallen to two and one respectively."[697] Additionally, the few defense contractors that survived increasingly began outsourcing and subcontracting more work than ever to other suppliers and built less in-house each year.[698] This situation created a precarious footing for DoD to be able to leverage industrial

Changed the Defense Industry, DEF. ONE (Sept. 12, 2021), https://www.defenseone.com/business/2021/09/five-ways-911-changed-defense-industry/185347.

[692] *See* Robertson, *supra* note 43.

[693] *See id.*

[694] See *id.* (discussing the Littoral Combat Ship and Future Combat System in detail).

[695] *See id.*

[696] *See id.*

[697] *Id*; *see* Off. of UNDER SEC'Y OF DEF. FOR ACQ. AND SUST., U.S. DEP'T OF DEF., REPORT, STATE OF COMPETITION WITHIN THE DEFENSE INDUSTRIAL BASE 5 (2022) [hereinafter OUSD, DIB].

[698] *See* Weisgerber, *supra* note 691.

might at the right time to "surge" its capabilities when major conflict looms nearer.[699] In addition, less competition meant that DoD acquisitions of new MWSs took longer, cost more, and were more susceptible to brittle supply chains.[700]

The post-Cold War DIB consolidation continues to have a lasting impact on the DoD's ability to surge acquisition and production of vital military materiel in future wars.[701] The scarcity of prime defense contractors is evident in the low number of bidders for DoD's largest ground vehicle contracts in recent decades.[702] For example, in 2022, only two companies responded to the Army's RFP for a "follow-on" production contract for the JLTV family of vehicles (FoV) program that was worth up to $8.6 billion.[703] Similarly, even for many of its recent vehicle prototype contracts, the Army typically only receives proposals from and awards contracts to four or fewer companies.[704]

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[699] *Id*. "Surge" capacity refers to the ability for defense companies to expand rapidly based on an emerging threat necessitating increased production requirements and increased workforce hours in existing facilities. *See* U.S. DEP'T OF DEF., NATIONAL DEFENSE INDUSTRIAL STRATEGY 15 (2023) [hereinafter 2023 NDIS].

[700] *Id*.; OUSD, DIB, *supra* note 697, at 6; Cynthia Cook, *Reviving the Arsenal of Democracy: Steps for Surging Defense Industrial Capacity*, CTR. STRATEGIC & INT'L STUD. (Mar. 14, 2023), https://www.csis.org/analysis/reviving-arsenal-democracy-steps-surging-defense-industrial-capacity.

[701] *See* 2023 NDIS, *supra* note 699, at 21. Three relevant data points illustrate this impact. First, as of 2024, military expenditures account for just 3.2% of the U.S. GDP, compared with 8.8% in 1963; this percentage has continued to trend downward in recent years. *See id.* Second, there are 7.1 million fewer people working in U.S. manufacturing jobs than there were in 1979 (a 36% reduction in the industry's workforce, despite the U.S. population growing by approximately 72% or over 100 million people during the same period). *See id.*; *U.S. Population 1950-2024*, MACROTRENDS, https://www.macrotrends.net/countries/USA/united-states/population (last visited Apr. 11, 2024). Third, there are 1.9 million fewer workers employed in DIB companies than there were in 1985 (a 63.5% reduction in DIB workers in those four decades). *See* 2023 NDIS, *supra* note 699, at 21.

[702] *See In re* Oshkosh Defense, LLC, 2023 CPD ¶ 2. The only two companies were Oshkosh Defense, LLC and AM General, LLC. *See id.*

[703] *See In re* Oshkosh Defense, LLC, 2023 CPD ¶ 2.

[704] *See, e.g.*, Josh Luckenbaugh, *Army Awards Prototyping Contracts for Heavy Truck Program*, NAT'L DEF. (Jan. 28, 2023), https://www.nationaldefensemagazine.org/articles/2023/1/28/army-awards-prototyping-contracts-for-heavy-truck-program (noting that the Army awarded prototype contracts for its CTT program to four companies but only six submitted proposals).

Despite this concerning footing, the swelling of DoD's budget in the wake of the 9/11 attacks demonstrated the ability for the DIB to move nimbly when properly resourced.[705] For example, between 2007 and 2012, in response to the mounting numbers of Service member deaths from IEDs, especially in Iraq, then-Secretary of Defense Robert Gates led DoD's efforts in successfully petitioning Congress for funds to field almost 14,000 purpose-built MRAP vehicles—costing nearly $40 billion—within only *three years* of DoD's initial RFPs.[706] Although the program was not without its critics, several studies credit these rapidly procured MRAPs "with saving thousands of lives, especially in Iraq, [where] they became the iconic vehicle of the post-9/11 wars."[707] Defense acquisition experts now look to the MRAP program as a roadmap for how DoD policymakers can effectively leverage the DIB to quickly adapt to new threats to U.S. ground forces.[708] Even so, this example also highlights the extent to which DoD heavily invested over the last two decades in MWS capabilities to defeat a counterinsurgency threat—for which the ability of the United States to produce enough materiel is generally taken for granted—rather than in capabilities necessary to defeat economic and militaristic peers, like Russia and the PRC.[709]

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[705] *See* Robertson, *supra* note 43.

[706] *See* McGinn, *supra* note 205; *see also infra* notes 705–708 and accompanying text (discussed the acquisition and contracting strategies that made the MRAP program successful). The MRAP is "an armored troop carrier designed to withstand roadside bomb blasts." *See* Weisgerber, *supra* note 691.

[707] *See* Weisgerber, *supra* note 691. *But see id*. ("But MRAPs were far less useful in the more rugged and roadless Afghanistan. Almost as suddenly as the MRAP production lines leapt into existence, they shut down again. The vehicle most associated with the counterinsurgency wars has little utility in the wars the Pentagon expects in the future.").

[708] *See* McGinn, *supra* note 205; Robertson, *supra* note 43.

[709] *See* Robertson, *supra* note 43. "In 1985, China's GDP was only 15% of US GDP. In 2016, China surpassed the U.S., and by 2021, China's GDP was 118% of U.S. GDP (adjusted for purchasing power)." *See Vital Signs*, *supra* note 593, at 10. *But see GDP (Current US$) – China*, THE WORLD BANK, https://data.worldbank.org/country/China (last visited Apr. 11, 2024) (listing China's GDP as $17.96 trillion as of 2022) and *United States*, THE WORLD BANK, https://data.worldbank.org/country/US (last visited Apr. 11, 2024) (listing United States' GDP as $25.44 trillion as of 2022).

Recent global threats highlighted the DIB's uncertain ability to rapidly and responsively meet the MWS large-scale production needs of DoD as it "quietly prepar[es] against the darkening security environment in the Indo-Pacific"[710] to meet the "pacing challenge posed by China."[711] For example, the U.S.' support of Ukraine and Israel in recent years—totaling nearly $50 billion worth of MWSs, equipment, and munitions provided to those militaries—has led to the U.S. DIB struggling to keep up production and DoD floundering for supplemental funding from Congress to replenish domestic reserves of key materiel like Javelin missiles and 155mm artillery rounds.[712] As the U.S. Secretary of the Air Force pronounced when discussing modernization challenges in early 2024, "[w]e are out of time [and] can no longer regard conflict as a distant possibility or a future problem that we might have to confront. The risk of conflict is here now, and that risk will increase with time."[713]

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[710] *See Vital Signs*, *supra* note 593, at 16; Jerry McGinn, *U.S. Weapons Pledge to Ukraine Exposes Cracks in Defense Supply Chain*, COSTELLO COLL. OF BUS., GEORGE MASON U. (Feb. 25, 2023), https://business.gmu.edu/news/2023-02/us-weapons-pledge-ukraine-exposes-cracks-defense-supply-chain. For example, the COVID-19 pandemic resulted in an immense, immediate demand for medical supplies as well as accompanying shortages of necessary materiel and manpower to sustain production of the DoD's needs. *See* Weisgerber, *supra* note 691.

[711] *See* Michael Marrow & Theresa Hitchens, *Air Force Launches Reorganization, As Kendall Warns 'We Are Out of Time' to Match China*, BREAKING DEF. (Feb. 12, 2024m 9:07 PM), https://breakingdefense.com/2024/02/air-force-reorganization-frank-kendall-china.

[712] *See* Jonathan Masters & Will Merrow, *How Much Aid Has the U.S. Sent Ukraine? Here Are Six Charts.*, COUNCIL ON FOREIGN RELS. (Feb. 23, 2024, 9:00 AM), https://www.cfr.org/article/how-much-aid-has-us-sent-ukraine-here-are-six-charts; Mike Stone, *US Army Says It Needs $3 Billion for 155mm Artillery Rounds and Production*, REUTERS (Nov. 7, 2023), https://www.reuters.com/business/aerospace-defense/us-army-says-it-needs-3-billion-155-mm-artillery-rounds-production-2023-11-07. This shortage, combined with the DoD's repeated need to rely only on Continuing Resolutions without any "new starts," ultimately forced President Biden to submit a Supplemental DoD Appropriation Request for $106 billion in late 2023; part of this supplemental funding would go to modernizing or building additional 155mm production facilities across the United States. *See* Stone, *supra*. *But see* 2023 NDIS, *supra* note 699, at 15 (noting that the Army's awarding of contracts worth $1.5 billion in September 2023 to resupply its 155mm artillery ammunition after much of its stock was diverted to Ukraine "represents a 200% increase of production capacity within a two-year span and demonstrates the DIB's ability to scale rapidly").

[713] *See* Marrow & Hitchens, *supra* note 711.

Accompanying the mounting concerns over the DIB's inability to respond to emerging global threats, the DIB must overcome several internal, systemic challenges before it can effectively support the United States' strategic focus on GPC. A 2023 report by the National Defense Industrial Association (NDIA) emphasized these increasing concerns, concluding that "U.S. national security policies and financial investments are not aligned to support the [DIB's] need to support great power competition."[714] Most significantly, the report found that the following "[k]ey industrial readiness indicators for great power competition are going in the wrong direction": fewer people in the DIB workforce,[715] fewer companies in the DIB,[716] a shrinking financial commitment by the U.S.,[717] less predictability in funding,[718] and limited surge capability.[719] In addition to these broad findings, the report's survey of NDIA member companies, including all sizes and types of defense contractors, identified their most pressing issues to be "that the federal acquisition process is growing more—not less—cumbersome; the lack of budget stability is breaking companies and causing significant workforce uncertainty; and the challenges of finding and retaining talent are impacting even our most strategic defense programs."[720] To mitigate these

[714] *See Vital Signs*, *supra* note 593, at 17; Mikayla Easley, *Report Finds Imbalance Between Defense Strategies, Industrial Base Capacity*, NAT'L DEF. (Feb. 8, 2023), https://www.nationaldefensemagazine.org/articles/2023/2/8/report-finds-imbalance-between-us-defense-strategies-industrial-base-capacity.

[715] *See Vital Signs*, *supra* note 593, at 5. "In 1985, the U.S. had 3 million workers in the defense industry. By 2021, the U.S. had 1.1 million workers in the sector." *Id.*

[716] *Id.* "In the last five years, the defense ecosystem has lost a net 17,045 companies and the Department of Defense estimates the number of small businesses participating in the defense industrial base has declined by over 40% in the last decade." *Id.*

[717] *Id.* "From 1985 to 2021, national defense spending dropped from 5.8% to 3.2% of U.S. GDP, and the Congressional Budget Office projects a further decline to 2.7% by 2032." *Id.*

[718] *Id.* "In 13 of the last 14 years, the federal government has operated under a continuing resolution (CR) for part of the year, preventing new starts essential for modernization and delaying increased production rates, multi-year procurement authorities, and advanced procurement funding essential for building capacity." *Id.*

[719] *Id.*

[720] *See Vital Signs*, *supra* note 593, at 5.

challenges, DIB companies unequivocally propose that the two most important steps DoD and the Congress can take to strengthen the DIB are to streamline acquisition processes and increase defense budget stability.[721] The NDIA report goes further, positing that a third necessary step is for government and private industry to cooperate in addressing these challenges, a strategy DoD is also prioritizing to help galvanize the DIB to prepare for future armed conflict.[722]

In late 2023, to support the 2022 NDS's focus on GPC, DoD published its first National Defense Industrial Strategy (NDIS).[723] The NDIS's "overarching goal is to make the [DIB] dynamic, responsive, state-of-the-art, resilient, and a deterrent to our adversaries."[724] To achieve this aim and to overcome the types of systemic challenges the NDIA report identified,[725] "[t]he NDIS lays out four long-term priorities to serve as guiding beacons for industrial action and resource prioritization": (1) resilient supply chains, (2) workforce readiness, (3) flexible acquisition, and (4) economic deterrence.[726] Among these, the need to seek flexible acquisition strategies that "result in reduced development times, reduced costs, and increased scalability" is the most critical

[721] *See id.* at 20. "The federal government must prioritize removing policies, regulations and authorities that are strangling the defense industrial base and make significant, sustained and predictable financial investments to rebuild the DIB's strategic endurance and resilience." *Id.* at 5.

[722] *Id.* at 20; *see* 2023 NDIS, *supra* note 699, at i.

[723] *See* 2023 NDIS, *supra* note 699, at i.

[724] *See id.* at 10. The stated purpose of the NDIS was to "offer[] a strategic vision to coordinate and prioritize actions to build a modern defense industrial ecosystem that is fully aligned with the [2033] NDS" and to call for "sustained collaboration and cooperation between the entire U.S. government, private industry, and our Allies and partners abroad." *Id.* at i.

[725] Although similar to the list of the DIB's challenges identified by the NDIA report, the NDIS includes the following, more thorough list of systemic challenges, each of which must be addressed to ensure the DIB can achieve the 2022 NDS's aims: underutilization of multi-use technologies; inadequate workforce; inadequate domestic production; non-competitive practices; long lead times and sub-par readiness; fragility of sub-tier suppliers; lack of market share, over-customization, and obsolescence; instability of procurement; funding uncertainty and constraints; and limited visibility into international ally and partner requirements. *See id.* at 10–11; 2022 NDS, *supra* note 38, at 20.

[726] *See* 2023 NDIS, *supra* note 699, at 10.

priority for achieving timely MWS innovation.[727] Unsurprisingly, these are also the areas in which MDAPs most often fail and where the DoD's HED acquisition programs must therefore avoid.

2. "Potholes" in the Road to Innovation: Persistent Shortfalls in MDAPs

Although recent improvements created more structure in the *processes* of defense acquisition systems,[728] they failed in several respects to improve their *performance* outcomes, especially for the largest MDAPs.[729] This Section first categorizes such persistent shortfalls into three main areas: program cost growth, schedule delays, and quality or design issues.[730] Second, it explores how these three problem areas will hinder future HE TWVs acquisitions and why they are actually symptoms of broader, systemic issues in many MDAPs like lengthy procedural requirements, shortsighted contracting methods, and insufficient competition.[731]

a. Three Common Performance Failures in MWS Acquisitions: Cost Overruns, Schedule Delays, and Design Shortfalls

There is no shortage of available research examining the shortfalls of defense acquisitions over recent decades.[732] Whether by government agency or independent entity, relevant studies consistently show common deficiencies plaguing DoD's acquisition of MWSs.[733] Most significantly, these problem areas relate to MDAPs' unexpectedly high costs (e.g., cost growth,

[727] *See id.* at 33.

[728] *See supra* Subsection II.D.3. (discussing recent improvements in DoD acquisitions processes).

[729] *See* WONG ET AL., *supra* note 40, at 20–27.

[730] *See infra* notes 732–**Error! Bookmark not defined.** and accompanying text.

[731] *See infra* notes 757–800 and accompanying text.

[732] *See* WONG ET AL., *supra* note 40, at 20–27.

[733] *See id*.

escalation, and overrun), schedule delays, and performance or quality shortfalls (e.g., discovering design defects late in development, failing to meet requirements, and obsoleting technology).[734]

Most commonly, MDAPs suffer from cost problems, especially cost escalation, growth, and overrun.[735] The most severe of the three, cost overruns occur when cost growth of a specific MDAP exceeds the amount Congress previously allocated through the respective DoD appropriation.[736] Cost overruns frequently increase annual defense spending by billions of dollars yet "result in the production of the same number of, or in some cases fewer, weapons than originally planned."[737] An illustrative example of excessive cost growth is the Air Force's F-35 Lightning II Joint Strike Fighter program, "which "remains [DoD's] most expensive weapon system program [ever,] . . . estimated to cost over $1.7 trillion to buy, operate, and sustain."[738] The

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[734] *See id*.

[735] "[C]ost escalation for weapon systems—that is, inter-generational cost changes between weapon platforms—significantly exceeds typical inflation measures for the general economy. . . Whereas *cost escalation* refers to the inter-generational increases in the cost of similar systems, *cost growth* refers to cost increases associated with a single program over its life." *Id*. at 22.

[736] *See id.* at 22–23. Acquisition costs of the DoD's MDAPs, which generally account for 10 to 20 percent of the DoD's total budget, include the combination of MDAPs' total RDT&E and Procurement costs. *See* David McNicol, *Acquisition Policy, Cost Growth, and Cancellations of Major Defense Acquisition Programs, DA Report R-8396*, INST. FOR DEF. ANALYSES iii (Sept. 2018), https://www.ida.org/-/media/feature/publications/a/ac/acquisition-policy-cost-growth-and-cancellations-of-major-defense-acquisition-programs/r-8396.ashx.

[737] *See* HEIDI PETERS, CONG. RSCH. SERV., R43566, DEFENSE ACQUISITION REFORM: BACKGROUND, ANALYSIS, AND ISSUES FOR CONGRESS 3 (2014). In a 2021 report, the GAO found that the DoD's 84 MDAPs "accumulated over $615.4 billion (or 52 percent) in total cost growth since program start, about 60 percent of which was unrelated to the increase in quantities purchased." GAO-21-511T, *supra* note 48, at 3.

[738] *See* JON LUDWIGSON, U.S. GOV'T ACCOUNTABILITY OFF., GAO-22-105943, F-35 JOINT STRIKE FIGHTER: COST GROWTH AND SCHEDULE DELAYS CONTINUE i (2022); *see* Grazier, *supra* note 628. The GAO provides the following summary of the astronomical cost growth of the F-35 program:

> The F-35 Joint Strike Fighter is the Department of Defense's (DOD) most expensive and ambitious acquisition program. In April 2017, we reported that acquisition costs alone are estimated at nearly $400 billion, and operating and sustainment costs are estimated to be over $1 trillion. 1 Meanwhile, due to evolving threats and changing warfighting environments, DOD has begun planning and funding the development of new capabilities for the F-35, known as F-35 follow-on modernization. The research, development, test and evaluation (RDT&E) funding needed for the first modernization phase, known as Block 4, is projected to be over $3.9 billion through 2022, which would exceed the statutory and regulatory thresholds for what constitutes

GAO estimates that unexpected upgrade and maintenance costs have already increased the program by more than $50 billion, which will only increase as the Air Force receives more deliveries of the problematic aircraft.[739]

When an MDAP's acquisition unit costs exceed certain thresholds, overruns amount to "Nunn-McCurdy breaches," which DoD leaders must report to Congress under 10 U.S.C. § 2433.[740] As several studies emphasize, "[t]he consequences of these cost overruns [and breaches] are substantial. When budgets are tight, excessive cost escalation or unplanned cost growth can lead to programs being considered for cancellation."[741] Among the Services, the Army has the

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> a major defense acquisitions program (MDAP), and would make it more expensive than many of the other MDAPs already in DOD's portfolio.

GAO-17-690R, *supra* note 629, at 1; *see* U.S. GOV'T ACCOUNTABILITY OFF., GAO-17-351, F-35 JOINT STRIKE FIGHTER: DOD NEEDS TO COMPLETE DEVELOPMENTAL TESTING BEFORE MAKING SIGNIFICANT NEW GAO-21-511T INVESTMENTS (2017) [hereinafter GAO-17-351].

[739] *See* Grazier, *supra* note 629; Paul Emanuelli, *Defects, Delays, and Indecision Plague the F-35 Program*, THE PROCUREMENT OFF., https://procurementoffice.com/defects-delays-and-indecision-plague-the-f-35-program (last visited Apr. 11, 2024), *from* PAUL EMANUELLI, THE ART OF TENDERING: A GLOBAL DUE DILIGENCE GUIDE (2023).

[740] *See* 10 U.S.C. § 2433; MOSHE SCHWARTZ, CONG. RSCH. SERV., R41293, THE NUNN-MCCURDY ACT: BACKGROUND, ANALYSIS, AND ISSUES FOR CONGRESS 29 (2016). "Program acquisition unit cost is the total cost of development, procurement, acquisition operations and maintenance, and military construction divided by the number of units procured," whereas "[p]rocurement unit cost is the total procurement cost divided by the number of units to be procured." U.S. GOV'T ACCOUNTABILITY OFF., GAO-11-499T, DOD COST OVERRUNS: TRENDS IN NUNN-MCCURDY BREACHES AND TOOLS TO MANAGE WEAPON SYSTEMS ACQUISITION COSTS 1 n. 3 (2011) [hereinafter GAO-11-499T].

[741] *See* WONG ET AL., *supra* note 40, at 24, 24, n. 115. *But see* David L. McNicol, *Influences on the Timing and Frequency of Cancellations and Truncations of Major Defense Acquisition Programs, P-8280*, INST. FOR DEF. ANALYSES vii (Mar. 2017). ("[W]hile cancelled programs on average had higher cost growth than programs not cancelled, most programs with [acquisition unit cost] growth of more than 50 percent were not cancelled. Clearly, there is more behind cancellations than cost growth."). *But see* U.S. GOV'T ACCOUNTABILITY OFF., GAO-14-77, CANCELED DOD PROGRAMS 5 (2014) [hereinafter GAO-14-77] (suggesting that MDAP cancellations should not always be considered failures and are sometimes "the best choice" because they can best reallocation limited resources). One reason that Services often cancel MDAPs with cost overruns is that 10 U.S.C. Sec. 2430 exacted a penalty MDAPs with cost overruns. Schwartz, *supra* note 740, at 29; *see* Pub. L. 114–92, div. A, title VIII, §828, Nov. 25, 2015, 129 Stat. 910, as amended by Pub. L. 115–91, div. A, title VIII, §825, Dec. 12, 2017, 131 Stat. 1466; Pub. L. 115–232, div. A, title X, §1081(d), Aug. 13, 2018, 132 Stat. 1986; Pub. L. 116–92, div. A, title VIII, §805(a), (b)(2), Dec. 20, 2019, 133 Stat. 1485.

highest rate of MDAP cancellations, accounting for around 25 percent of all cancelled MDAPs.[742] For example, two past Army "efforts to replace the M-2 Bradley—the Future Combat System (FCS) program and the Ground Combat Vehicle (GCV) program—were cancelled [in 2009 and 2014, respectively,] for programmatic and cost-associated reasons."[743] Therefore, the Army's HE TWV acquisition programs must strive to avoid similar cost issues.

The second most common MDAP shortfall is schedule delay, which plagued more than half of MWS acquisitions over the past decade.[744] Even for programs that are sufficiently funded and on schedule, "the average expected time between program start and operational capability for MDAPs in [the DoD's] portfolio is an estimated *11 years*."[745] Therefore, any additional delay in a MWS's delivery schedule likely guarantees warfighters will lack that capability in sudden conflict.[746] Like excessive costs, excessive schedule delays place MDAPs at greater risk of funding reduction or cancellation.[747] Therefore, HE TWV acquisition programs must proactively adopt strategies to avoid such delays.[748]

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[742] *See* McNicol, *supra* note 741, at 44. Although the military departments (MilDeps) and OSD are responsible for cancelling three-fourths of MDAPs, "[a] cancellation . . . may actually be initiated by an organization other than the one formally responsible for it. There are cases in which, for example, a MilDep cancels a program because it appears highly likely that if it does not do so, OSD or the Congress will—in which case, OSD or the Congress probably will decide how to reallocate the funding." *Id*. at 45.

[743] *See* ANDREW FEICKERT, CONG. RSCH. SERV., THE ARMY'S OPTIONALLY MANNED FIGHTING VEHICLE (OMFV) PROGRAM: BACKGROUND AND ISSUES FOR CONGRESS 4, 5 (2021) [hereinafter R45519].

[744] *See* GAO-23-106059, *supra* note 50, at 39.

[745] *Id.* (emphasis added); *see also* BELVA MARTIN, U.S. GOV'T ACCOUNTABILITY OFF., GAO-12-181T, FUTURE GROUND-BASED VEHICLES AND NETWORK INITIATIVES FACE DEVELOPMENT AND FUNDING CHALLENGES 6 (2012) (correctly estimating that the Army would need nine to ten years—two years more than the Army's ambitious estimate of seven years—to deliver its first JLTV production vehicles).

[746] *See* WONG ET AL., *supra* note 40, at 21.

[747] *See id.* at 31; GAO-14-77, *supra* note 741, at 5.

[748] *But see* R45519, *supra* note 743, at 12 (suggesting that too rapid of schedule demands can lead to insufficient industry interest, as shown in the Army's cancellation of its OMFV solicitation in 2020 due to lack of industry bids); Ashley Tressel, *Army Scraps OMFV Program to Start Competition Over*, INSIDE DEF. (Jan. 16, 2020) ("a

The third most common MDAP failure is poor performance or design of the ultimate, delivered MWS.[749] The F-35 program provides another illustrative example, remaining "mired in the development phase nearly 22 years after Lockheed Martin won the contract in 2001."[750] As the GAO first cautioned in 2005, the DoD began development of the F-35 "without adequate knowledge of its critical technologies or a solid design," resulting in massive additional costs to retrofit and redesign key components of the aircraft.[751] Every individual component that a program later adds to a MWS can increase the MDAP's costs by dragging out the R&D process.[752] This is particularly true for "speculative technology that has yet to be fully designed," as Navy leaders learned during the acquisition of their latest aircraft carrier, the USS *Gerald R. Ford* (CVN-78).[753] With its design including 23 new technologies, many of which were still being developed

combination of requirements and schedule overwhelmed industry's ability to respond within the Army's timeline").

[749] *See* WONG ET AL., *supra* note 40, at 24.

[750] *See* Grazier, *supra* note 628; U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-106047, F-35 JOINT STRIKE FIGHTER: MORE ACTIONS NEEDED TO EXPLAIN COST GROWTH AND SUPPORT ENGINE MODERNIZATION DECISION 19 (2023) [hereinafter GAO-23-106047]; Greg Schneider, *Lockheed Martin Beats Boeing for Fighter Contract*, WASH. POST (Oct. 27, 2001), https://www.washingtonpost.com/archive/politics/2001/10/27/lockheed-martin-beats-boeing-for-fighter-contract/c65b8843-131f-4827-9c69-c183066f1f57/.

[751] *See* GAO-23-106047, *supra* note 750, at 33; *see also* UNDER SEC'Y OF DEF. FOR ACQ. AND SUST. ELLEN M. LORD & AIR FORCE LIEUTENANT GENERAL ERIC T. FICK, F-35 PEO, U.S. DEP'T OF DEF., BRIEFING ON THE F-35 PROGRAM (Oct. 29, 2019) (discussing the F-35's various design flaws). Most significantly, the F-35's engine lacks the ability to manage the aircraft's heat generated by its other systems, increasing wear on the engine. *See* Grazier, *supra* note 628. Because the DoD pushed it into LRIP before completing sufficient testing, the Air Force will need to retrofit the 530 aircraft it has already received or ordered and the remaining 1,926 it intends to procure. *See* GAO-23-106047, *supra* note 750, at 33; U.S. Dep't of Navy, F-35 Program Selected Acquisition Report (SAR) 4 (Dec. 2021), https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2021_SARS/22-F-0762_F-35_SAR_2021.pdf; Grazier, *supra* note 628.

[752] *See* Grazier, *supra* note 628.

[753] *Id.*; *see* Megan Eckstein, *US Navy Completes Final Weapons Elevator on Aircraft Carrier Gerald R. Ford*, DEF. NEWS (Dec. 23, 2021), https://www.defensenews.com/naval/2021/12/23/us-navy-completes-final-weapons-elevator-on-aircraft-carrier-gerald-r-ford.

when construction began, efforts to finish developing and integrating those elements "increased the ship's costs by nearly 30% and delayed the ship's first deployment by four years."[754]

Even if DoD leaders adequately prioritize HED R&D programs and maneuver past congressional gridlock, these acquisition programs will likely continue to tread unsteady political ground.[755] They will thus face even greater risk of funding reductions or cancellation than other MDAPs, especially those that DoD policymakers already prioritize higher, if they appear to suffer from these three common deficiencies.[756] Therefore, before formulating possible acquisition and contracting strategies to best achieve HED innovation, one must examine the underlying causes for these failures to mitigate such risk in planning for future HED acquisition programs.

b. Systemic Issues Underlying MDAP Failures

After identifying the three main deficiencies in MDAPs, charting a path for HE TWV acquisition strategies requires examining the underlying shortfalls in the DoD's processes that typically lead to those poor outcomes.[757] These shortfalls generally fall within one of the three DoD acquisition processes of the JCIDs, PPBE, and DAS.[758] In particular, poor MDAP outcomes commonly result from three root causes: (1) inadequate initial evaluation of needs and poor

[754] *See* Grazier, *supra* note 628; Kevin Reilly, *The Cost of the Navy's USS Gerald R. Ford Aircraft Carrier*, BUS. INSIDER (Sept. 27, 2021), https://www.businessinsider.com/cost-of-navy-uss-ford-aircraft-carrier-2021-9; Diana Stancy, *USS Gerald R Ford Expected to Deploy for First Time in October*, NAVY TIMES (Sept. 29, 2022), https://www.navytimes.com/news/your-navy/2022/09/29/uss-gerald-r-ford-expected-to-deploy-for-first-time-in-october.

[755] *See* Grazier, *supra* note 628.

[756] *See* WONG ET AL., *supra* note 40, at 24, 31.

[757] *See id.*

[758] *See generally infra* notes 193–219 (discussing the three DoD acquisition systems).

planning to integrate new capabilities, (2) inconsistent funding by DoD leaders and Congress, and (3) inflexible acquisition strategies and contracting methods.[759]

Regarding the first and second issues, poor-performing MDAPs typically failed to deliberately assess the respective capability requirements prior to moving into prototyping and LRIP of the system.[760] They also suffered from inconsistent prioritization in DoD budgets.[761] For example, in 2004, the Army self-terminated the RAH-66 Comanche Scout/Attack helicopter acquisition program after 20 years and $6.9 billion spent developing and redesigning the aircraft, largely to shift the aviation budget to fight the Global War on Terror.[762] Although the Army's final termination decision demonstrated the value of ending an MDAP when leaders find that a capability need no longer exists, it also exposed the risks of investing heavily and inconsistently in an MDAP before leaders clearly understand the future capability requirements of warfighters.[763]

Constant changes to an MDAP's requirements throughout development phases creates uncertainty in industry, which already suffers from too few prime contractors to support the DoD's need for innovation.[764] For example, in 2014, the Army terminated its Ground Combat Vehicle program because it "relied on too many immature technologies, had too many performance requirements, and was required by Army leadership to have too many capabilities to

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[759] *See* WONG ET AL., *supra* note 40, at 24, 27, 31.

[760] *See id.* at 24.

[761] *See* Alex Hollings, *RAH-66 Comanche Stealth Helicopter: Why Did It Fail?*, NAT'L INTEREST (Nov. 8, 2021), https://nationalinterest.org/blog/reboot/rah-66-comanche-stealth-helicopter-why-did-it-fail-195863.

[762] *See* Julien Demotes-Mainard, *RAH-66 Comanche–The Self-Inflicted Termination: Exploring the Dynamics of Change in Weapons Procurement*, Defense ARJ, April 2012, Vol. 19, no. 2, 183–208, at 187 ("Comanche termination was, above all, a financial decision made by the Army to restore the balance in the Aviation budget, and enable the much-needed upgrades to aircraft that were deployed to Iraq and Afghanistan."); R45519, *supra* note 743, at 5.

[763] *See* Demotes-Mainard, *supra* note 762, at 186, 187.

[764] *See* IF11729, *supra* note 556, at 2 (discussing the risks for industry support of future JLTV production if the DoD restructures the force in a way that conflicts with current production).

make it affordable."[765] Much of the inconsistency in prioritization is inherent in the DoD's need to constantly assess ever-emerging and evolving national security threats, but some unpredictability may simply relate to the frequency of turnover among DoD senior leaders that is inherent in the military.[766]

Notwithstanding these needs- and funding-based pitfalls in MWS acquisitions, the most significant—and treatable—underlying cause for MDAP performance failures involves the use of short-term, inflexible acquisition strategies and contracting methods.[767] In particular, those systemic issues include MDAPs' ineffective use of OTs, expensive reliance on cost-plus contract types, inaccurate cost estimates, and failure to employ and enforce MOSA contracting.[768]

Although DoD policymakers largely encourage the use of OTs to achieve rapid acquisition and innovation to fill critical capability gaps, MDAPs' increasing reliance on these tools has led to a significant "decrease in the share of competed obligations, a key metric for efforts to maintain a competitive environment" in DoD acquisitions.[769] In total, the more OTs in recent years meant that "[n]early 50 percent of obligations went to contracts awarded without competition, the highest share in the past two decades."[770] While the key benefit of OTs is their speed in R&D, their lack of competitive procedures typically results in lower quality goods, higher costs, and smaller chance

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[765] *See* R45519, *supra* note 743, at 5; GAO-19-132, *supra* note 21, at 3.

[766] Inconsistent priorities may also be due to the nature of military personnel turnover, especially in senior DoD leaders who often differ in which modernization initiatives they choose to focus. *See* Telephone Interview, Lohnes, *supra* note 541; Telephone Interview, McGrew, *supra* note 282; Telephone Interview, Jadus, *supra* note 344.

[767] *See* WONG ET AL., *supra* note 40, at 15, 24, 31, 38.

[768] *See id.*

[769] *See* Sanders et al., *supra* note 680.

[770] *See id.*

of meaningful innovation by a DIB that is already "shrinking, not expanding and diversifying."[771] Such outcomes follow not simply from acquisition leaders' choice to utilize OTs but from their decision to use them in inappropriate situations.[772] The high costs of these types of short-term acquisition strategies add up and produce fewer useful outcomes, compounding larger cost issues from selecting poor contract types.[773]

Regarding contract types and fee structure in MDAPs, the most significant causes of cost growth and overruns are the use of "cost-plus" contracts and inaccurate cost estimates.[774] First, both cost-plus-award and cost-plus-incentive contracts most frequently lead to cost overruns in MDAPs.[775] Although fixed-price contracts result in the lowest cost overruns, this is partly because programs that use fixed-price contracts generally involve more mature technologies and predictable costs.[776] Second, "changes in cost estimates are responsible for around 40 percent of the accumulated cost overruns."[777] Therefore, the thoroughness of cost estimation, requirements evaluation, and market research at the start of programs are key factors of cost performance for MDAPs.[778] Also an issue at the start of programs, the failure of MDAPs to use long-term

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[771] *See Vital Signs*, *supra* note 593, at 13, 15.

[772] *See* Mark Cancian, *Military Forces and Acquisition Programs: How Did They Fare in the FY 2024 Budget?*, CTR. FOR STRATEGIC & INT'L STUD. (Mar. 17, 2023), https://www.csis.org/analysis/military-forces-and-acquisition-programs-how-did-they-fare-fy-2024-budget (explaining how low competition, vague requirements, and over-reliance on OTA funding led to significant issues with the cost and inefficiency of the delayed Armored Multi-Purpose Vehicle (AMPV) development)

[773] *See* WONG ET AL., *supra* note 40, at 15, 24, 31, 38.

[774] *See* Gregory Sanders et al., *Cost and Time Overruns for Major Defense Acquisition Programs*, CTR. FOR STRATEGIC & INT'L STUD. 2, 13, 14 (Apr. 2011), https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/110517_DIIG_MDAP_overruns.pdf.

[775] *See id.* at 13, 14.

[776] *See id.* at 13.

[777] *See id.* at 14.

[778] *See id.*at 13, 14; WONG ET AL., *supra* note 40, at 24, 38.

contracting strategies like MOSA is likely the most significant contributor of MWS acquisition shortfalls for novel warfighting capabilities.[779]

In many ways, the Air Force's F-35 program provided DoD acquisition leaders with valuable lessons, not only for "how not to buy a fighter jet" but also more broadly for how best to avoid unproductive contracting strategies.[780] In light of the F-35 program's immense budget that still failed to reduce known risks, its lessons are even more crucial for MDAPs with smaller budgets and more compressed delivery schedules.[781]

The primary reason for the F-35 program's astronomical costs, schedule delays, and design issues was the failure of the Air Force to acquire the IP for the system's data from Lockheed Martin in its original 2001 development contract, a shortfall that led to a string of problems since.[782] While not wanting to give up the IP and data rights is understandable from the contractor's perspective, especially considering their huge investment and proprietary interest from development, it was an obvious lapse in long-term contract negotiation by the Air Force.[783] As a result, the Air Force will continue to rely solely on the original contractor for expensive sustainment and maintenance of the aircraft as well as constant system upgrade needs.[784] In contrast, the JPO-JLTV acquired the data rights from Oshkosh in its original development contract for the JLTV, allowing the Army to award the FRP contract to AM General at optimized

[779] *See* Interview, Marold, *supra* note 285; Interview, Bryan, *supra* note 285.

[780] *See* WONG ET AL., *supra* note 40, at 24, 38; GAO-24-107177, *supra* note 629, at 1, 2.

[781] *See* Grazier, *supra* note 628.

[782] *See id.*

[783] *See id.*; GAO-24-107177, *supra* note 629, at 1, 2.

[784] *See* Grazier, *supra* note 628; GAO-24-107177, *supra* note 629, at 1, 2.

contract terms for a better product.[785] Although this caused consternation and a bid protest from Oshkosh, and it is not certain yet if the change in vendor will produce schedule delays, it illustrates the need for programs to acquire such data rights to reduce costs and quality issues.[786] Contracting for IP and data rights also better supports greater use of MOSA strategies, another problem area for poor-performing MDAPs.[787]

Studies repeatedly show that the failure to plan for immature technology, unexpected complexity, or emerging needs is another significant contributor to MDAP performance shortfalls and Nunn-McCurdy breaches.[788] For example, MDAPs like the F-35 program suffer immense cost overruns and schedule delays largely because they lack modular design and open systems to reduce such risks.[789] The timelines of technology obsolescence and capability upgrades for most electronic components are very short. "[I]n a resource-constrained environment, the desire for cost-effective, long-lived" MWSs and the years-long defense acquisition processes conflict with these short timelines.[790] Therefore, acquisition PMs must constantly balance between "maintaining design margins within system parameters" and "considering future periodic component upgrades to enable long service lives for systems by incorporating the latest technology."[791] Unfortunately, the bureaucratic and risk-averse nature of DoD acquisitions means that leaders often compromise the latter aim.[792] Because planning for periodic technology refresh and update insertions can be costly

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[785] *See* E-mail, Putrus, *supra* note 173.

[786] *See id.*; *In re* Oshkosh Defense, LLC, B-421506, 2023 CPD ¶ 2 (Comp. Gen. Dec. June 12, 2023).

[787] *See* GAO-13-651, *supra* note 290, at 6.

[788] *See* WONG ET AL., *supra* note 40, at 24.

[789] *See id.*

[790] *Id*. at 19, 20.

[791] *See id*. at 19.

[792] *See id*.

and time-consuming in initial stages of an MDAP, acquisition leaders frequently instead opt for rigid design specifications.[793] Such a contracting strategy is certainly more attractive to potential bidders, especially because it places them in a better negotiating position to retain ownership of the entire system's data rights and own the complete MWS design, thereby allowing for long-term sustainment and maintenance contracts throughout the system's life cycle.[794] However, as shown in the F-35 program, it also greatly increases the risk of future technology obsolescence, need for costly design upgrades, and expensive reliance on a single source for upgrades and maintenance.[795]

The final underlying reason for poor outcomes of MDAPs like the F-35 program is that such systems frequently enter production phases too soon, requiring repeated design changes after production begins.[796] The Secretary of the Air Force previously characterized this overlap between development and production phases, also called "concurrency," as a form of "acquisition malpractice."[797] In the case of the F-35, Air Force acquisition leaders ordered the system into production before even its first test flight.[798] Fortunately, the Air Force learned from its F-35 program shortfalls; for its new Next Generation Air Dominance (NGAD) fighter jet program, it intends to acquire the IP rights when it awards an initial development contract in 2024, incorporate modular design to a greater extent, and conduct significantly more R&D before entering production.[799] Although the Army seeks to do the same in its HE TWV and GCV acquisition

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[793] *See id.*

[794] *See* GAO-23-106059, *supra* note 50, at 57, 59, 66.

[795] *See* GAO-22-104752, *supra* note 286, at 11–13.

[796] *Id.*

[797] *See* Grazier, *supra* note 628; *US Weapons Man: F-35 Fighter Plan Was 'Acquisition Malpractice,'* ABC NEWS (Feb. 7, 2012, 11:38 AM), https://abcnews.go.com/Blotter/35-fighter-plan-acquisition-malpractice-pentagon-official/story?id=15530008.

[798] *See* Grazier, *supra* note 628.

[799] *See id.*

programs, two procedural inefficiencies continue to block the path of individual programs' R&D efforts.[800]

3. Procedural Inefficiencies Blocking the Army's HED Innovation: OTs and the MPT in Practice

In addition to the broader systemic procedural issues threatening HED programs' future success, various limitations at the ground level also hinder the Army's R&D efforts.[801] First, internal DoD and Army procedures have lengthened OTs' processing times significantly beyond Congress's intent for the rapid R&D, prototyping, and production instrument. Second, for entities like GVSC, the low $10,000 MPT for Simplified Acquisitions blocks many in-house R&D efforts to engineer key interface components of HED systems.[802]

Regarding the first procedural inefficiency, Congress granted OTA "to give DoD the flexibility necessary to adopt and incorporate business practices that reflect commercial industry standards and best practices into its award instruments."[803] As part of this statutory purpose, OTs are meant to "[e]ncourage flexible, *quicker*, and cheaper project design and execution."[804] Nevertheless, while many assume that OTs will always be faster to use than traditional contractual instruments, in reality, the OT award process is sometimes just as long or longer than traditional procurement processes.[805] While some delays result simply from the complexity of a given agreement, the

[800] *See* Telephone Interview, McGrew, *supra* note 282.

[801] *See id.*

[802] *See* Telephone Interview, McGrew, *supra* note 282; E-mail from Dean McGrew, Branch Chief, Powertrain Electrification, GVSC, DEVCOM, AFC) to author (Mar. 18, 2024, 12:25 EDT) [hereinafter E-mail 2, McGrew] (on file with author); *see also* note 255 (discussing MPT purchases); FAR 2.101 (2024); FAR 13.201 (2024).

[803] *See* OT GUIDE, *supra* note 268, at 4.

[804] *See id.*

[805] *See id.* at 44.

lengthier processing times for many OTs are largely due to agencies' internal contract award procedures.[806]

For example, some DoD agencies that award an OT will still "conduct the source selection process as if it were subject to FAR Part 15," making the OT award process just "as long as a procurement contract." Similarly, agencies that require their OT awards proceed through the same approval chain as a procurement contract cause their OTs to take nearly as long.[807] Relatedly, because OTs typically involve less money and lower statutorily required approval levels than procurement contracts, those at each step in the approval chain sometimes prioritize reviewing OT documents and awards lower than review of larger procurement contracts.[808] Finally, "because all of the terms and conditions in an OT are negotiable," the time spent drafting and negotiating these agreements between the contracting office and contractor also stretches out their processing times.[809]

By injecting additional internal procedures into the OT award process, DoD agencies further complicate what Congress intended to be a streamlined award process.[810] For the Army's HED R&D efforts at the GVSC, this means that the award process takes, on average, *seven to nine months* to simply go from a defined specification to a signed agreement for a prototype electric motor.[811] The DoD and Army's increasing addition of unnecessary bureaucracy into OT award processes is

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[806] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802.

[807] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802.

[808] *See* OT GUIDE, *supra* note 268, at 44; Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802.

[809] *See* OT GUIDE, *supra* note 268, at 44; Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802.

[810] *See* OT GUIDE, *supra* note 268, at 44; Telephone Interview, McGrew, *supra* note 282.

[811] *See* Telephone Interview, McGrew, *supra* note 282.

likely both due to the acquisition workforce's enduring inexperience and its general discomfort with OTs.[812] In contrast to DoD, industry can typically draft, negotiate, and process similar agreements in less than a month.[813] In this way, the OSD's expectations for OTs to mirror industry agreements "do not align with reality."[814] Worse still, the frequency and duration of Congress's CRs each FY, combined with the inconsistent funding of the Army's HED acquisition programs, mean that these self-imposed delays from the OT award processing can be fatal to those crucial agreements.[815]

In part because of these delays in OT award processing timelines, the Services are conducting more internal R&D into HED innovation than ever before.[816] Such in-house R&D requires agencies frequently must rely on the MPT and GCPC to quickly purchase supplies to engineer and develop modular components or key interfaces for vehicle hardware.[817] However, agencies often face challenges in achieving timely innovation—like that achieved through the GVSC's recent "Zeus" power inverter—because they are limited to only being able to use the GCPC for system purchases up to the $10,000 MPT.[818] Agency leads agree that simply raising the MPT for these type of internal engineering purchases to $20,000 could have immense results for hardware innovation, which could then support greater use of licensing to industry and MOSA

[812] *See* GAO-22-105357, *supra* note 266, at 31, 36, 43.

[813] *See* Telephone Interview, McGrew, *supra* note 282.

[814] *See id.*

[815] *See* OT GUIDE, *supra* note 268, at 44; Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802.

[816] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802; *see also supra* note 566 (discussing the Zeus inverter).

[817] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802; supra note 566 (discussing the Zeus inverter).

[818] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802; *see also supra* note 566 (discussing the Zeus inverter); note 255 (discussing MPT purchases).

contracting.[819] However, such a minor reform is just one of the broader potential solutions that DoD leaders must pursue to achieve timely HED modernization and best equip U.S. ground forces.[820]

V. The Roadmap to Innovation: Novel Solutions to Overcome Political and Procedural Challenges to HE TWV Acquisitions

Considering the significant political and procedural challenges blocking effective and timely HED modernization, equipping U.S. ground forces with such crucial capabilities will require a concerted, two-prong approach that involves both immediate policy-based action and novel acquisition process-based solutions. To provide a useful roadmap to HED innovation, this Part presents promising solutions that will allow DoD acquisition leaders to bypass political gridlock and avoid procedural potholes that frequently threaten MDAPs' success.[821] Subpart A provides three crucial steps to maneuver past political polarization that currently blocks HE TWV acquisition program funding, including DoD leaders' need to shift greater budgetary focus to HED acquisition programs, DoD policymakers' need to detach Army climate goals from those programs, and Army leaders' need to demonstrate the warfighting imperative for HED capabilities through effective, large-scale field exercises.[822] Subpart B provides several recommendations

[819] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 2, McGrew, *supra* note 802; *see also supra* note 566 (discussing the Zeus inverter); note 255 (discussing MPT purchases).

[820] *See* Finke & Hess, *supra* note 67.

[821] *See* Finke & Hess, *supra* note 67; *See infra* notes 824–997 and accompanying text.

[822] *See infra* notes 824–866 and accompanying text.

involving novel acquisitions approaches and contracting strategies that are rarely seen in the realm of DoD MWS acquisitions.[823]

A. Bypassing Political Gridlock to Sufficiently Prioritize HED Modernization

Prioritizing acquisition of HED capabilities for DoD's operational vehicles is crucial to U.S. ground forces' success in future LSCOs, not because of the ancillary environmental benefits such vehicles might provide but because of the crucial warfighting advantages such capabilities already demonstrate.[824] Therefore, ensuring that Congress sufficiently prioritizes HE TWV acquisitions through sufficient RDT&E and Procurement appropriations requires DoD leaders unequivocally communicate their ground forces' and national security's requirement for HED modernization.[825]

As DoD pursues various lines of effort for electrifying its ground vehicles, leaders can look to the lessons from the Army's transition from horses to motors in the interwar years to develop a systematic approach to seeking modernization.[826] That is, DoD and Army leaders should take a three-prong approach to bypassing political gridlock over HE TWV acquisitions.[827] The first prong involves the need for DoD leaders to focus greater RDT&E funding in budget requests to modernizing the operational ground fleet.[828] The second prong involves the need for leaders in DoD and Congress to change the vehicle acquisition conversation from one overly focused on

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[823] *See infra* notes 867–997 and accompanying text.

[824] *See* Cole et al., *supra* note 651, at 10; *see also* DOWNEY'S DREAM CARS, *supra* note 559 (discussing actor Robert Downey Jr.'s documentary covering, in part, the warfighting impetus for the Army's HED acquisition initiatives); Kinberly Hackbarth, *TV Show Filmed at Fort Irwin Airs*, U.S. ARMY (June 22, 2023), https://www.army.mil/article/267843/tv_show_filmed_at_fort_irwin_airs (discussing significance of filming).

[825] *See* Halimah Najieb-Locke et al., *supra* note 497.

[826] *See* Hom, *supra* note 12, at 2, 16, 23.

[827] *See id.*

[828] *See infra* notes 831–841 and accompanying text.

climate policy to one singularly focused on fighting and winning the nation's wars.[829] The third prong involves conducting large-scale field exercises to both capture warfighters' input and demonstrate loudly the enhanced lethality and survivability that HED provides ground forces in combat.[830]

1. Reexamining Priorities: Placing Greater Budgetary Focus on Ground Vehicle Modernization Efforts

The DoD's leaders and policymakers must better prioritize funding for HED R&D programs. The funding DoD currently requests is relatively miniscule compared to DoD's massive shipbuilding and aircraft RDT&E budgets. While this thesis does not advocate for pulling funding from those modernization efforts—or any particular MDAPs—to fund HED acquisitions programs, it is worth noting the relative importance of HED modernization for DoD's ground vehicles.[831]

First, DoD's hyper-focus on its other MWSs, at the expense of crucial modernization of its ground vehicles, ignores the enduring importance of TWVs and GCVs in warfare. Examining lessons learned from the Korean War, T. R. Fehrenbach noted the following:

> Americans in 1950 rediscovered something that since Hiroshima they had forgotten: you may fly over a land forever; you may bomb it, atomize it, pulverize it and wipe it clean of life—*but if you desire to defend it, protect it and keep it for civilization, you must do this on the ground*, the way the Roman legions did, by putting your young men [and women] in the mud.[832]

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[829] *See infra* notes 842–858 and accompanying text.

[830] *See infra* notes 859–866 and accompanying text.

[831] *See* Jahara Matisek & Jon McPhilamy, *Why Airpower Needs Land Power,* MOD. WAR INST. OF WEST POINT (Nov. 5, 2018), https://mwi.westpoint.edu/airpower-needs-landpower.

[832] *Id.*; T. R. Fehrenbach, THIS KIND OF WAR: A STUDY IN UNPREPAREDNESS 427 (Macmillan 1963) (emphasis added).

Similarly, despite the dramatic shifts that technological advances continue to bring to warfighting, such as UAS and AI technology, the "inexorable imperative" of warfare is not only to adapt to a changing world but also to remember the lessons from the past.[833]

The recent focus away from ground vehicle modernization also ignores the massive force-multiplying benefits that vehicle electrification provides in the form of supporting other modernization priorities, like M-SHORAD and C-sUAS.[834] The immediate speed and funding of HE TWV programs might not match the outcomes from DoD's hyper-prioritization of MRAP acquisitions in 2006.[835] However, better focusing R&D funding toward HED innovation in ground vehicles will no doubt produce technological advances in propulsion and R&D cost-savings that will benefit other MWS modernization priorities.[836]

Second, while reducing fuel demand is a significant operational and strategic imperative, the 2023 DoD OES's focus on reducing fuel demand of ships and aircraft before ground vehicles fuel demand ignores the importance of gaining the other immediate warfighting benefits of HE ground

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[833] *See* H.G. WELLS, THE MIND AT THE END OF ITS TETHER 19 (William Heinemann Ltd. 1945).

[834] *See* Telephone Interview, McGrew, *supra* note 282.

[835] *See* GAO-10-155T, *supra* note 50, at 3.

[836] *See id.* Specifically, GAO concluded the following factors contributed to the success of the MRAP program:

> DOD use of a tailored acquisition approach to rapidly acquire and field MRAP vehicles was successful. The program relied only on proven technologies and commercially available products; established minimal operational requirements; and undertook a concurrent approach to producing, testing, and fielding the vehicles. To expand limited production capacity, indefinite delivery, indefinite quantity contracts were awarded to nine commercial sources, with DOD agreeing to buy at least 4 vehicles from each. Subsequent orders were based on a concurrent testing approach with progressively more advanced vehicle test results and other assessments. To expedite fielding of the vehicles, the government retained the responsibility for final integration in them of mission equipment packages including radios and other equipment. DOD also made MRAP its highest priority acquisition, which helped contractors and others more rapidly respond to the need and meet production requirements, in part by early investing of their own capital to purchase steel and other critical components in advance of orders.

Id. at Highlights.

vehicles.[837] Additionally, acknowledging the difficulties of allocating limited financial resources among national security priorities, the policy ignores the "lower-hanging fruit" of ground vehicle HED innovation.[838] As already demonstrated through the game-changing benefits of TVEKs and other prototype HE ground systems, these benefits are not only achievable much sooner than HE propulsion for DoD's larger MWSs but their R&D may also support those longer-term modernization programs.[839]

Requesting greater funding for modernizing DoD's ground vehicles with HED capabilities is only half of the solution to overcome political challenges.[840] To ensure long-term congressional support for HED budget requests amidst shifting political power, DoD leaders must also better "market" this vital capability requirement.[841]

2. Changing the Conversation: Clarifying Misconceptions by Decoupling HED Acquisitions from Army Climate Policy

The perceived connection between the Army's HED acquisition programs and its climate policy goals is not only counterproductive to ground force modernization, it is also inaccurate.[842] In practice, the many expert Army acquisition personnel who are responsible for researching and developing HED capabilities look not to federal climate policy or GHG emission standards but

[837] *See* 2023 DoD OES, *supra* note 93, at 4.

[838] *See* Telephone Interview, Lohnes, *supra* note 541; Telephone Interview, Jadus, *supra* note 344; Telephone Interview, McGrew, *supra* note 282.

[839] *See* 2023 DoD OES, *supra* note 93, at 6.

[840] *See* Telephone Interview, McGrew, *supra* note 282.

[841] *See* Video Interview, Rogers, *supra* note 541.

[842] *See* Video Interview, Rogers, *supra* note 541; 2022 ACS, *supra* note 63, at 11; E-mail, Putrus, *supra* note 173; Telephone Interview, Jadus, *supra* note 344.

to warfighters' requirements to guide their vehicle design and acquisition strategies.[843] In fact, across the Army's various prototype contracts, draft PDs, and technical design specifications for HE operational vehicles, there is not a *single* requirement for specific GHG emission standards.[844] Cementing this point, the GVSC's engineers do not even evaluate GHG emissions of prototype HE TWVs in testing and demonstrations, except to the extent such data points are relevant to the vehicles' visibility to enemy surveillance.[845] In sum, despite political discord over the apparent climate nexus of Army HED acquisition efforts, which DoD's FY 2024 budget request only worsened, these HED programs have little to no connection to Executive or Army climate goals.[846] Therefore, Army acquisition leaders must immediately seek to clarify this misconception to secure consistent, sufficient RDT&E funding.[847]

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[843] *See* E-mail, Putrus, *supra* note 173.

[844] *See id.*; E-mail, Roberts, *supra* note 299. Although draft PDs for the Army's HE TWV and GCV R&D programs include a requirement to meet "Engine EPA Emissions Requirements," this does not impose additional GHG emissions requirements because federal statute provides a national security exemption to such emissions requirements for vehicles with "features ordinarily associated with military combat or tactical vehicles such as armor and/or weaponry." *See* 40 C.F.R. Sections 85.1703; 40 C.F.R. 89.908; 40 C.F.R. 1068.22; *see also* Chloeta Fire, LLC & Scout Environmental, Inc., Environmental Assessment for the Joint Light Tactical Vehicle at Training Areas Not Previously Analyzed, U.S. Army Garrison, Fort Bliss, TX, Final Environmental Assessment 3-2 (Nov. 2022), (concluding that the JLTV is exempt from EPA engine emission requirements).

[845] *See* E-mail, Putrus, *supra* note 173; E-mail 1, McGrew, *supra* note 170.

[846] *See, e.g.*, *supra* notes 665–669 and accompanying text (summarizing lawmakers' statements about DoD electrification efforts). It still uncertain whether such HE TWV acquisition programs would, in fact, result in a net reduction in GHG emissions, factoring in the potentially negative impacts from the increased demand of electricity—which may require coal or fossil fuels to generate—and domestic mining to source electric battery components. *See* Zeke Hausfather, *Factcheck: How Electric Vehicles Help to Tackle Climate Change*, CARBON BRIEF (May 13, 2019), https://www.carbonbrief.org/factcheck-how-electric-vehicles-help-to-tackle-climate-change.

[847] *See* Telephone Interview, Lohnes, *supra* note 541; Telephone Interview, Jadus, *supra* note 344. Illustrating the prevalence of the misconception that climate policy motivates the Army's vehicle electrification goals, in the course of writing this thesis, countless colleagues reasonably expressed a similar initial sentiment. *See* Blakemore & Nurkin, *supra* note 542 (eluding to this common misconception).

Army HE TWV acquisitions are not truly climate-focused initiatives, so they should constitute easier "sells" to secure funding from a polarized Congress.[848] Still, Army acquisition leaders and policymakers can look to lessons from those who successfully advocate for inherently climate-focused initiatives.[849] Professor Michael Vandenbergh is a leading scholar in methods of bypassing political gridlock over climate issues and served as the chief of staff of the Environmental Protection Agency during the federal government's most dramatic shift toward renewable energy investment.[850] He "eschews emotional pleas for protecting the planet, favoring a more pragmatic approach. . . [that] aims to bridge gaps between tree huggers and gas guzzlers by focusing on" common ground between seemingly opposed stakeholders.[851] Taking from his sociological approach, DoD leaders should seek to bridge understanding gaps within Congress and American society by shifting their focus *away* from the assumed environmental benefits of HE TWVs and *completely toward* the tactical, operational, and strategic imperatives.[852]

One obvious solution to clear up confusion over the Army's motivations behind its HED acquisition efforts is to remove all reference of climate change initiatives from future program budget justifications.[853] Likewise, in their communications accompanying such budget requests, DoD leaders should clearly emphasize that such programs are not climate-driven.[854] Instead, they

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[848] *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, Lohnes, *supra* note 541.

[849] *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, Lohnes, *supra* note 541.

[850] *See* Seth Robertson, *Driving the Response to Climate Change*, VAND. L. SCH. (Jan. 25, 2018, 9:14 AM), https://law.vanderbilt.edu/driving-the-response-to-climate-change/.

[851] *See id.*

[852] *See* Jennifer Catherine Cole et al., *Social Psychological Perspectives on Political Polarization: Insights and Implications for Climate Change*, ASS'N FOR PSYCH. SCI. 17 (Feb. 7, 2023), https://journals.sagepub.com/doi/10.1177/17456916231186409.

[853] *See* Telephone Interview, Jadus, *supra* note 344; Telephone Interview, Lohnes, *supra* note 541.

[854] *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, Lohnes, *supra* note 541; Telephone Interview, Jadus, *supra* note 344.

must focus solely on the persuasive data demonstrating the crucial lethality and survivability advantages of HE operational vehicles in combat.[855] As perhaps the most convincing and unexpected spokesman for this need to "rebrand" efforts to hybrid-electrify the TWV fleet, Will Rogers, the Army's senior climate advisor, echoes this exact recommendation. Agreeing that DoD leaders should detach discussion of climate goals from their HED acquisition efforts, he recommends that "future documents and communications to Congress be more disciplined from a messaging standpoint [to show that] these efforts are purely *in service of the mission* and *not to achieve climate aims*."[856]

By concentrating on the warfighting capabilities that HED capabilities provide U.S. ground forces and on the strategic deterrent effect of such modernization, Army acquisition leaders can more accurately and effectively advocate for these requirements to DoD leaders and Congress.[857] However, while prioritizing HED innovation and changing the conversation will allow DoD leaders to bypass political gridlock to secure RDT&E funding in the short-term, long-term support for energy modernization will require demonstrating the game-changing advantages of HED capabilities in the field.[858]

3. Showing the Force: Demonstrating the Battlefield Lethality and Survivability Advantages of HE TWVs Through Joint Exercises

[855] *See* Video Interview, Rogers, *supra* note 541; Telephone Interview, McGrew, *supra* note 282; Telephone Interview, Jadus, *supra* note 344; Telephone Interview, Lohnes, *supra* note 541.

[856] *See* Video Interview, Rogers, *supra* note 541.

[857] *See id.*

[858] *See* Hom, *supra* note 12, at 25; Telephone Interview, McGrew, *supra* note 282.

Developing HE TWVs will mean little without Army leaders quickly and clearly demonstrating their new capabilities to all relevant stakeholders.[859] Taking a lesson from General Marshall in the interwar years, after receiving sufficient quantities of HE TWVs, DoD leaders should similarly coordinate large-scale field exercises to demonstrate down to subordinate leaders and up to Congress the critical advantages of such new HED capabilities.[860] Similar exercises were crucial to building support for the Army's transition from horses to motor vehicles before WWII and again with the Army's implementation of the SFC in the 1980s.[861] As early testing of HE anti-idle retrofit kits has already shown,[862] such exercises will pay dividends in fostering ground forces' trust in the

[859] *See* Hom, *supra* note 12, at 23, 24, 25; Telephone Interview, McGrew, *supra* note 282.

[860] *See* Hom, *supra* note 12, at 23, 24, 25. After observing firsthand the warfighting benefits that HE TWVs provide their units—from the silent watch and low thermal signature to the operational independence and energy endurance—, it is likely many commanders who take part in these field exercises will echo a famous line attributed to General Marshall, albeit with some modification: "I want a [tactical vehicle] for a secret and dangerous mission. I want a [HE TWV]." *See Marshall Myth: West Point Football Plaque,* GEORGE C. MARSHALL FOUND. (Aug. 19, 2016), https://www.marshallfoundation.org/articles-and-features/marshall-myth-west-point-football-player ("Before taking the field, each player places his hands on a bronze plaque displaying a quote attributed to General George C. Marshall while he was serving as chief of staff of the army during World War II. The plaque reads, "I want an officer for a secret and dangerous mission. I want a West Point football player.").

[861] *See* Hom, *supra* note 12, at 2, 38. The way in which General Marshall led the transition from horses to motors provides several crucial leadership lessons for the Army's integration of HED into the ground fleet:

> Marshall planned and resourced the transition from horses to motorized vehicles within the US Army, but the emergency funding provided to him in 1939 [after Hitler invaded Europe] enabled him to execute the change within two years. Marshall clearly expressed his vision in his priorities and idea of how the force should fight, but his achievements are inexorably linked to funding. Marshall demonstrated his capability as a visionary leader by capitalizing on the moment. Immediately allotting funds to purchase new armored vehicles, then using them in a 400,000-man field exercise provided him the opportunity to influence organizational change and remove obstacles resistant to change. The critical concept to understand was that while progress towards motorization had occurred in the 1930s, it was not until the national emergency was declared that Marshall had the resources to act. Luckily, he was [] decisive in his actions and committed to executing his vision, facilitating a rapid transition within the US Army.

Id. at 38.

[862] *See* Telephone Interview, McGrew, *supra* note 282; E-mail 1, McGrew, *supra* note 170.

new technology, especially in terms of its tactical and logistical benefits.[863] They will also garner positive attention from DoD senior leaders responsible for expressing requirements to Congress, which will prove vital to funding later transitions from LRIP to FRP of HE TWV and GCV acquisition programs.[864]

Equally as important as developing confidence in the capabilities, large-scale field exercises will also be key to testing for design flaws and capturing input from warfighters to perfect the systems, thereby avoiding some of the F-35 program's pitfalls in design and technology obsolescence.[865] Nevertheless, being able to capitalize on continuous user feedback will also require early implementation of agile acquisition strategies and contracting methods, a path that has eluded many MDAPs.[866]

B. Overcoming Procedural Roadblocks with Novel Acquisition and Contracting Strategies

The DoD's MWS acquisitions have historically traveled a hazardous road, often mired with the pitfalls of inadequate competition, slow timelines, high prices, and shortsighted contracting strategies.[867] However, future HE TWV acquisition programs have the potential to chart a new path, foregoing many traditional vehicle acquisitions practices and focusing instead on more deliberate, responsive, and cost-effective strategies to achieve timely innovation.[868] To do so, however, DoD leaders must direct specific action in the following three areas: (1) releasing an

[863] *See* E-mail 1, McGrew, *supra* note 170.

[864] *See* Hom, *supra* note 12, at 2, 38; Telephone Interview, Lohnes, *supra* note 541.

[865] *See* E-mail 1, McGrew, *supra* note 170; WONG ET AL., *supra* note 40, at 24.

[866] *See* E-mail 1, McGrew, *supra* note 170; WONG ET AL., *supra* note 40, at 24.

[867] *See generally* WONG ET AL., *supra* note 40 (discussing decades of research on poor-performing MDAPs).

[868] *See* Telephone Interview, McGrew, *supra* note 282.

updated TWV strategy that provides a comprehensive but flexible vision for DoD's future ground vehicle fleet; (2) better leveraging commercial industry innovation by creating two novel AAF pathways, removing internal inefficiencies in OT processing, and requesting Congress raise the MPT for simplified acquisitions to support DoD R&D efforts; and (3) employing and enforcing win-win MOSA contracting strategies that "future-proof" HE TWV acquisition programs while incentivizing continued industry competition.

Although timely procurement of innovative technologies like HE TWVs requires these procedural improvements, acquisition leaders must employ caution before making too significant of changes too quickly, especially before they have the opportunity to evaluate the results from previous reform efforts.[869] Such reform attempts may be just as detrimental to MDAP performance as not pursuing improvements, especially when leaders do not allow sufficient time to evaluate the impacts of earlier changes.[870] Fortunately, while the solutions below are relatively novel in the realm of vehicle acquisitions, they should yield major benefits from comparatively minor changes.

1. Assessing and Expressing Requirements: Requiring an Updated TWV Strategy

One of the greatest challenges in attracting sufficient industry competition for operational vehicle R&D programs is the perception among industry, both traditional and nontraditional defense contractors, that DoD is an inconsistent customer.[871] The PPBE's typical two-year process

[869] *See* Dr. James Rich, *An Analysis of the Reasons Why Fostering Innovation in Contract Management is So Difficult, and Several Ways We Can Address These Challenges*, NAT'L CONTRACT MGMT. ASS'N (Oct. 2020), https://ncmahq.org/Web/Shared_Content/CM-Magazine/CM-Magazine-October-2020/Challenges-to-Innovation-in-Contracting--And-How-to-Overcome-Them.aspx.

[870] *See* WONG ET AL., *supra* note 40, at vi. "Indeed, since its inception, DoD's acquisition system has been subjected to a nearly constant stream of reform initiatives, many of which harken to earlier efforts whose effects may not have been fully assessed." *Id.* Therefore, acquisition leaders must be deliberate in evaluating "what worked, what did not, and where DoD should go to improve acquisition outcomes." *See id.*

[871] *See Vital Signs*, *supra* note 593, at 5.

from request to funding, coupled with DoD's shifting priorities in MWS modernization, further makes investing in DoD R&D efforts an unattractive prospect for industry.[872] To counteract this and build consistent trust with potential vendors in HE TWV programs, DoD and Army leaders must more deliberately and comprehensively evaluate their long-term, overarching vision for the ground vehicle fleet.[873] They also must seek to communicate this vision, both to industry and DoD's acquisition enterprise, by releasing an Army or Joint TWV Strategy.[874]

The Army last issued a TWV Strategy more than ten years ago, but it has since terminated many of the acquisition efforts therein.[875] Not surprisingly, that outdated strategy also did not discuss Army plans to seek HED capabilities, alternative energy sources, or any type of electrification initiatives for its TWV fleet.[876] Therefore, from the perspective of industry, Congress, or the JF, one would be reasonable in assuming that the Army remains hesitant to pursue HED modernization.[877] The 2022 ACS and the 2023 OES are still the only broader strategic documents that express a firm intent to electrify the ground vehicle fleet.[878] However, the strategic imperative of seeking HED capabilities in the DoD's operational vehicles is far from simply a climate policy or operational energy issue; it is a critical warfighting requirement that DoD leaders must more effectively communicate to relevant stakeholders.[879]

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[872] *See* R47178, *supra* note 203, at 18.

[873] *See* GAO-21-460, *supra* note 8, at 28

[874] *See id*.

[875] *See id.*

[876] *See id.*

[877] *See* 2010 TWV STRATEGY, *supra* note 636; 2014 TWV Plan, *supra* note 636; *see also* E-mail, Roberts, *supra* note 299 (concurring with recommendation to update Army's TWV Strategy).

[878] *See* 2023 DoD OES, *supra* note 93, at 6; 2022 ACS, *supra* note 63, at 11.

[879] *See* 2023 DoD OES, *supra* note 93, at 6; 2022 ACS, *supra* note 63, at 11.

Congress recently communicated the need for a more consistent and shared understanding of the Army's vision for its tactical fleet.[880] In the Conference Report for the FY 2024 NDAA, Congress required that the Army provide an updated Army TWV Strategy as part of its budget justification materials submitted in support of DoD's and the President's budgets for FYs 2025, 2030, and 2035.[881] The Army thus has an ideal opportunity to more accurately communicate to Congress, DoD leaders, and its acquisitions workforce the ground force's capability requirements for HED.[882]

Although the Army is typically the lead procurement authority for TWVs, all the Services use them in operations—especially the Marine Corps, with its primary expeditionary mission set—and support the Army's sustainment of TWVs across the globe.[883] Therefore, DoD leaders would be wise to not only ensure the Army provides such regular TWV Strategies but also to integrate them into a comprehensive but flexible DoD strategy that both supports the Army's efforts and provides broader guidance for the JF's TWV acquisition programs.[884] Nevertheless, expressing the need and intent for HED acquisition efforts is only the start; DoD leaders must also support novel acquisition strategies that enable HED R&D programs to more effectively leverage commercial industry's capacity for innovation.[885]

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[880] *See* FY 2024 NDAA CONFERENCE REPORT, *supra* note 598, § 112, at 47–48.

[881] *See id.*

[882] *See* Telephone Interview, Lohnes, *supra* note 541.

[883] *See* GAO-21-460, *supra* note 8, at 3

[884] *See generally* Telephone Interview, Lohnes, *supra* note 541 (discussing the CJCS initiative for Joint Futures Command to oversee these type of efforts).

[885] *See* Video Interview with Brian Baldrate, Vice President & Lead Counsel, GM Defense (Apr. 2, 2024) [hereinafter Video Interview, Baldrate]; Telephone Interview, McGrew, *supra* note 282.

2. Leveraging Industry Innovation: Adding Commercial Development and Hardware Acquisitions Pathways to the AAF; OTA and MPT Improvements

There are simple changes DoD can make to better empower its acquisitions workforce to leverage industry innovation not only for procuring HED capabilities for the ground tactical fleet but also for other MDAPs that involve commercially marketable components.[886] These acquisition approach reforms include augmenting the AAF with two new acquisition pathways, removing self-imposed complexity from OT internal processing, and increasing the MPT for hardware R&D purchases.

a. Augmenting the AAF with Two New Pathways

First, despite the streamlined processes from DAS reforms over the last two decades, there is still room for improvement.[887] The AAF was itself an innovative development in improving efficiency in government procurement procedures.[888] Nevertheless, there remain gaps in the AAF that hinder acquisition leaders' ability to acquire novel capabilities like HED.[889]

When DoD acquisition leaders first conceived the AAF pathways in 2015, they "said that these program structure models were meant to serve only as examples and starting points that can and should be revised, modified, and enhanced."[890] As demonstrated by the current challenges program offices face in engaging industry to develop HED capabilities, one particular area of

[886] *See id.*

[887] *See* WONG ET AL., *supra* note 40, at 25, 27.

[888] *See id.*

[889] *See id.*; Walter, *supra* note 50, at 15.

[890] *See* Walter, *supra* note 50, at 15.

needed reform is in "the military's ability to commercially develop and field cutting-edge products to complete its missions affordably and effectively."[891]

Experts agree that "[t]he military depends more than ever on the commercial market for new products and capabilities, especially for items . . . that have clear civilian market applications."[892] As the commercial HEV market continues to grow exponentially and access to fossil fuels becomes harder, technological advances in electric battery, hydrogen fuel-cell, and other alternative vehicle propulsion capabilities will yield ever-greater profits and reduce the market share for traditional ICEs.[893] Sooner or later, DoD will ultimately have no other choice but to transition to hybrid-power ground vehicles. For this reason, as DoD acquisitions programs explore options to hybrid-electrify its ground vehicle fleet, their leaders continue to pay close attention to commercial advances in HEV technology.[894]

Several PEOs already constantly seek opportunities to employ commercial business practices to develop HE TWVs by working with nonprofit organizations, research institutions, and industry to formulate optimal HED design specifications.[895] However, a constant challenge remains how best to drive innovation in a direction to support DoD's warfighting mission while attracting competition and reducing government risk through COTS solutions.[896] That is, while developing a commercially marketable product like HED, acquisitions leaders must consider how best to balance the competing needs to "reduc[e] the time required to bring a product to market,

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[891] *See id.*

[892] *See id.*

[893] *Id.*

[894] *See* E-mail, Putrus, *supra* note 173.

[895] *See id.*

[896] *See* Video Interview, Baldrate, *supra* note 885.

incentiviz[e] lower development costs, improv[e] affordability, and ensur[e] sustainment of a developed capability to maximize sales."[897]

An obvious reason for DoD's challenge in employing commercial practices to develop HED innovations is that the DAS "never was intended to be used for developing commercial products or capabilities."[898] Instead, the DAS inherently seeks "to develop low-volume, highly specialized, cutting-edge, noncommercial products and capabilities with militarily unique applications."[899] Even when DoD incidentally develops a product that has potential commercial marketability, it unsurprisingly "neither considers nor funds inclusion of features and attributes that would appeal to the commercial market."[900] As a result, industry contractors "have little if any incentive or resources to enhance the product for the larger commercial market" and instead focus on "addressing the DoD's performance requirements as stated in their contracts."[901] The developed product thus lacks any potential for future commercial sales, "which drives up the per unit costs because the developer is unable to take advantage of reduced costs available from increased economies of scale."[902] Worse yet, the contractor may subsequently be unable to sustain a line for a product that only DoD purchases.[903]

A leading expert in military medical acquisitions, Dr. Scott Walter advocates for DoD leaders to augment the AAF with a "Commercial Development Pathway" to overcome these challenges

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[897] *See* Walter, *supra* note 50, at 17.

[898] *See id.*

[899] *See id.*

[900] *See id.*

[901] *Id*.

[902] *Id*.

[903] *Id*.

and better leverage industry innovation through commercial business practices.[904] Although Dr. Walter proposes using this Commercial Development Pathway for acquiring products with more obvious commercial application, such as novel medical technologies, the pathway may also be relevant to developing HED systems for DoD's tactical vehicles.[905] Civilian companies that use medium- and heavy-duty trucks are transitioning their fleets to AEVs and HEVs.[906] The DoD's efforts to continually develop HED technologies, like EV batteries with improved energy density to power DoD's light- to heavy-duty TWVs, thus has obvious commercial application, which this new acquisition pathway could support.[907]

The DoD should use this pathway for programs that procure "novel commercial products and capabilities" that rely on a mixture of government and other funding, meet "minimally viable military requirements (such as robustness) while remaining commercially viable, and that produces items (capabilities) procurable by the military from the commercial market."[908] Key to this pathway is that DoD "provides only seed or incentive funding to influence development and never the full amount required to develop a product."[909] Additionally, there must be early and constant end-user involvement in developing requirements and contemporaneous industry engagement to constantly

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[904] *See* Walter, *supra* note 50, at 15, 17, 18, 20.

[905] *See id.* at 15, 17.

[906] *See* Mancillas, *supra* note 11, at 7; Seth Skydel, *FedEx Makes the Largest Commercial Electric Vehicle Purchase in the U.S., Continues the Zero-Emissions Trend*, FLEET EQUIP. MAG. (Jan. 14, 2019), https://www.fleetequipmentmag.com/fed-ex-largest-electric-truck-purchase-zero-emission/. The truck manufacturer Mack Trucks now produces multiple models of medium-duty BEV trucks. *See Mack Trucks Unveils the MD Electric Medium-Duty Truck*, BULLDOG MAG. (2023), https://www.macktrucks.com/magazine/articles/2023/march/mack-trucks-unveils-the-md-electric-medium-duty-truck.

[907] *See* Walter, *supra* note 50, at 15, 17.

[908] *See id.* at 17–18.

[909] *See id.* at 15, 17

assess whether the ultimate requirement supports marketability.[910] "If the projected return on the investment for commercial and military sales does not warrant investments, and the military must utilize a[nother] DAS pathway, [programs should] be prepared to fund part or all of the development[] and pay higher procurement costs to obtain the desired capability."[911] However, if there is a potential commercial market for which greater industry investment is warranted, the program can utilize one of various sub-pathways.[912]

One possible sub-pathway, as exemplified by the GVSC with its Zeus AC/DC electric inverter, is appropriate if DoD owns the IP or data rights, such as through a patent.[913] In that case, "a company could license the patent to develop a product for commercial sale to military and civilian users."[914] Such licensing partnerships shift R&D costs and risks to the company, and DoD can then incorporate the license into cost-saving terms in a subsequent contract or "procure the newly developed products from the commercial market, usually much faster and more affordably."[915]

Another sub-pathway involves using a Cooperative Research and Development Agreement (CRADA), for which DoD invests zero funds but allows companies access to its facilities, IP, or experts for collaboration.[916] A CRADA does not require DoD entities to use competitive

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[910] *See id.* at 18.

[911] *See id.*

[912] *See generally id.* at 18, 19 (discussing five possible sub-pathways under the novel Commercial Development Pathway, which also include venture capitalist partnerships and DoD-funded competitive prizes or awards).

[913] *See id.* at 19; *supra* note 566 (discussing the Zeus inverter); Telephone Interview, McGrew, *supra* note 282.

[914] *See* Telephone Interview, McGrew, *supra* note 282; Walter, *supra* note 50, at 17, 18.

[915] *See* Walter, *supra* note 50, at 18.

[916] *See* 15 U.S.C. § 3710a(a); Walter, *supra* note 50, at 19.

procedures, giving a company a significant advantage over competitors and resulting in "useful, marketable products benefiting both commercial and military customers."[917]

A third potential sub-pathway involves using a Commercial Solutions Opening (CSO), a contracting instrument under 10 U.S.C. §3458 that "enables the DoD to competitively acquire innovative commercial items, technologies, or services, and fulfill requirements for research and development solutions."[918] Similar to but less restricted than Broad Agency Announcements (BAAs) because they can support specific R&D programs, CSOs are a permanent statutory authority that allows DoD to utilize OTs to "fund industry scientific research, technology development, and development of prototypes using a merit-based solicitation procedure."[919] In addition to these three sub-pathways, acquisition programs could also utilize DoD-funded competitive prizes or awards for advanced technology achievements, as authorized under the America COMPETES Reauthorization Act of 2010, 10 U.S.C. §4025.[920] Finally, programs could establish partnerships with intermediary organizations, typically nonprofit entities that utilize venture capitalist investments to develop innovative technology.[921] All of these sub-pathways for commercial development would also help improve the *producibility* of these systems, a key factor

[917] *See* Walter, *supra* note 50, at 19.

[918] *See id.*

[919] *See id*. "CSOs were first authorized by Section 879 of the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2017 as a pilot program for DoD innovation hubs such as the Defense Innovation Unit Experimental (DIUx), to move at the speed of business. As a result of their success, Section 803 of the NDAA for FY 2022 provided DoD with permanent CSO authority." *Id.*; 10 U.S.C. §3458(a); National Defense Authorization Act for Fiscal Year 2022, § 803, Pub. L. 117-81, 135 Stat. 1541, 1814 (2021); *see also Commercial Solutions Opening,* DEF. ACQUISITION U., https://aaf.dau.edu/aaf/contracting-cone/defense-cso (last visited Apr. 11, 2024) ("Notwithstanding the limitation in DFARS 235.006-71, a CSO may also be used to fulfill requirements for R&D solutions ranging from advanced component development through operational systems development.").

[920] *See* Walter, *supra* note 50, at 18; 10 U.S.C. §4025.

[921] *See id.* at 19.

in industry's historic ability to rapidly deliver vehicles that were both responsive to DoD requirements and lower-priced like the MRAP and JLTV.[922]

In addition to adding a Commercial Development Pathway to the AAF, DoD policymakers should also establish a "Hardware Acquisition Pathway" to streamline acquisition programs' development of the type of innovative hardware components in HE TWVs.[923] Like software, or the intangible programs and operating information used in a computer, each physical hardware piece in a MWS may comprise a complete, operational system itself, albeit a necessary piece to make the entire system run.[924] Nevertheless, while the AAF includes a specific "Software Acquisition Pathway" (SAA), there is no equivalent pathway for hardware acquisitions.[925] Instead, DoD acquisitions instruction generally teaches that the structured, procedure-heavy MCA Pathway "is intended for large scale, traditional hardware acquisitions."[926]

Without a specific pathway like the simplified two-step process in the SAA Pathway, acquisitions programs for smaller-scale hardware acquisitions and development face uncertainty

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[922] *See* McGinn, *supra* note 205; *see also* E-mail, Putrus, *supra* note 173 (discussing the relatively low unit cost for each JLTV—around $250,000 per unit—which has led to Allied partner nations also purchasing the platform through Foreign Military Sales and exponentially increasing interoperability in future Allied activity around the world).

[923] *See* Telephone Interview, McGrew, *supra* note 282. In a traditional ICE, the vehicle's powertrain hardware includes its engine, transmission, and drivetrain, and its electric hardware includes its battery, alternator, and starter. However, in an HEV, these categories of hardware are blended and also include the vehicle's electric motor, inverter, and traction battery pack. *See Understanding the Different Types of Hardware Used in Automobiles*, MOSPART, https://mospart.com/understanding-the-different-types-of-hardware-used-in-automobiles (last visited Apr. 11, 2024).

[924] *See Difference Between Hardware and Software*, GEEKSFORGEEKS (Apr. 27, 2023), https://www.geeksforgeeks.org/difference-between-hardware-and-software.

[925] The purpose of the Software Acquisition Pathway is "to facilitate rapid and iterative delivery of software capability to the user." *See Software Acquisition*, DEF. ACQUISITION U., (last visited Apr. 11, 2024), https://aaf.dau.edu/aaf/software; DODI 5000.02, *supra* note 228, para. 4.2.d.; DODI 5000.87, *supra* note 309.

[926] *See* Off. of the Under Sec'y of Def. for Acq. & Sust., U.S. Dep't of Def. Adaptive Acquisition Framework (AAF) 101 Brief [hereinafter AAF 101 Brief], https://www.acq.osd.mil/asda/ae/ada/docs/031523%20-%20AAF%20Edu%20Session%20Briefing%20Deck.pdf (last visited Apr. 11, 2024).

in how much process is necessary when developing innovative hardware like that used in HEVs.[927] Therefore, DoD policymakers should augment the AAF with a Hardware Acquisition Pathway that also only requires a minimally viable product to proceed to the next step and that can similarly enable transition between other pathways as needed.[928] For example, a HE TWV program could utilize a Hardware Acquisition Pathway to leverage industry to develop the innovative hardware systems for the vehicle before transitioning back to a MTA or MCA approach. Ultimately, the exact format of this new pathway may be less important than the overarching clarity it provides to the acquisitions workforce when procuring such HED technology.[929]

b. Restoring Simplicity to Internal OT Procedures

Another way for DoD leaders to better leverage industry innovation for HED acquisitions is to simplify internal procedures for OTs.[930] The 2023 Other Transactions Guidebook (OT Guidebook) provides various procedures and best practices for PMs to consider in executing OTs.[931] Nevertheless, the document is unequivocal in its deference to DoD agencies' decisions in instituting whatever internal procedural requirements they wish in publicizing, soliciting, and evaluating potential solutions as well as in negotiating and awarding agreements.[932] For the selection and negotiation of terms, it provides that "[g]overnment teams have significant flexibility

[927] *See id.* at 15.

[928] *See id.*; DODI 5000.02, *supra*, para. 4.2.

[929] *See* Walter, *supra* note 50, at 18.

[930] *See* Telephone Interview, McGrew, *supra* note 282; Video Interview, Baldrate, *supra* note 885.

[931] *See* OT GUIDE, *supra* note 268, at 3. The OT Guidebook is published by the Office of the Undersecretary of Defense for Acquisition and Sustainment. *Id.*

[932] *See id.* at 3, 17. For example, the OT Guidebook states that "[a]gencies that intend to award only OTs from a solicitation are free to create their own process to solicit and assess potential solutions." *See id.* at 17.

in developing an appropriate award process for their projects" and that "[t]eams may streamline the award process."[933]

Notwithstanding these broad allowances for streamlined processes, contracting commands and program offices often inject unnecessary bureaucracy into these contracting instruments that Congress intended to be streamlined.[934] For example, programs frequently use a formal RFP timeline that allows for several months for industry to respond, then take several more months to evaluate potential solutions.[935] As a result of the ensuing seven- to nine-month average timeline of OTs, smaller MDAPs are unable to rapidly leverage industry innovation.[936] Worse yet, smaller companies are often unable to participate in such OTs when they are forced to wait—sometimes for years—before they receive return on their investment.[937] This, of course, diminishes the purpose of OTs by removing many NDCs as potential partners in innovation.[938]

To counteract the additional bureaucracy that the acquisitions workforce injects into OT award processes, albeit for likely valid reasons, leaders must require that these processes be better expedited and clarify what internal processes are actually necessary for OTs.[939] Another minor improvement likewise involves fewer formal agreements and more initial R&D within programs

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933 *See id.* at 17.

934 *See* Telephone Interview, McGrew, *supra* note 282; Video Interview, Baldrate, *supra* note 885.

935 *See* Video Interview, Baldrate, *supra* note 885; Telephone Interview, McGrew, *supra* note 282.

936 *See* Video Interview, Baldrate, *supra* note 885; Telephone Interview, McGrew, *supra* note 282.

937 *See* Video Interview, Baldrate, *supra* note 885; Telephone Interview, McGrew, *supra* note 282.

938 *See* Video Interview, Baldrate, *supra* note 885; Telephone Interview, McGrew, *supra* note 282.

939 *See* Telephone Interview, McGrew, *supra* note 282; Video Interview, Baldrate, *supra* note 885.

to better leverage industry innovation in the long-term; it also similarly offers significant potential to propel innovation more rapidly.[940]

c. Increasing the MPT for In-House Hardware Development

In general, engaging industry for MDAP R&D efforts produces greater results, fueled by commercial innovation and the rapid pace of business.[941] Nevertheless, the GVSC's recent internal development of the Zeus inverter system revealed the potential for DoD entities to better position MDAPs to subsequently attract more industry participation.[942] Developing key hardware components in-house allows programs to license such technologies to contractors, which in turn creates potential to rouse mutually beneficial innovation by industry.[943] This symbiosis produces cost savings in future procurement contracts and benefits companies that seek to utilize the technology in their own products—like EV batteries or motors—that they intend to market to both commercial and military customers.[944]

Engineering such hardware in-house, however, requires DoD entities like the GVSC to purchase component parts, preferably using the GCPC as a simplified acquisition under the MPT.[945] This means that the MPT is often the determining factor in the speed of internal R&D projects, with projects over $10,000 taking significantly longer due to the additional procedures of

[940] *See* Telephone Interview, McGrew, *supra* note 282

[941] *See id.*

[942] *See supra* note 566 (discussing the Zeus inverter); Telephone Interview, McGrew, *supra* note 282.

[943] *See* Telephone Interview, McGrew, *supra* note 282; Video Interview, Baldrate, *supra* note 885; E-mail, Putrus, *supra* note 173.

[944] *See* Telephone Interview, McGrew, *supra* note 282; Video Interview, Baldrate, *supra* note 885; E-mail, Putrus, *supra* note 173.

[945] *See* Telephone Interview, McGrew, *supra* note 282.

utilizing funds between the MPT and SAT.[946] Increasing the MPT amount for internal R&D engineering projects is thus a necessary change; it is also one for which there is precedence in recent years' updates to the MPT and SAT.[947]

If Congress again increases the MPT to just $20,000 for these types of projects, DoD entities like the GVSC would have significantly greater capacity to purchase key components to quickly develop valuable hardware in-house, reduce costs for future programs, and better leverage industry innovation for improved performance of future HE TWV acquisitions.[948] Further, "under [FAR]-based contracts, the government's acquisition of [IP] rights is tailored to the level of government involvement in development of the TWV."[949] Therefore, because DoD would have greater ownership and investment in the relevant IP and data rights, MWS acquisition programs could more effectively utilize MOSA contracting strategies to improve costs and performance of the systems throughout their life cycles.[950]

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[946] *See id*.

[947] *See, e.g.*, Federal Acquisition Regulation: Increased Micro-Purchase and Simplified Acquisition Thresholds, 85 Fed. Reg. 40064, 40065 (July 2, 2020) (to be codified at 48 C.F.R. pts. 2, 3, 9, 13, 16, 22, 25, 52) (raising the MPT to $10,000 and the SAT to $250,000); U.S. GEN. SERV. ADMIN., CLASS DEVIATION 2018-01, CLASS DEVIATION FROM THE FEDERAL ACQUISITION REGULATION – INCREASING THE MICRO-PURCHASE THRESHOLD AND SIMPLIFIED ACQUISITION THRESHOLD (2018) (prior to the 2020 increase, approving a class deviation from the FAR to increase the MPT to $10,000 and the SAT to $250,000 for GSA funded acquisitions); John Abel, *Federal Government Increases Micro-purchase and Simplified Acquisition Thresholds to Support COVID-19 Response Efforts,* WINVALE (Apr. 15, 2020), https://info.winvale.com/blog/gsa-increases-micro-purchase-and-simplified-acquisition-thresholds-to-support-covid-19-response-efforts (increasing MPT and SAT for certain medical supply purchases during COVID-19 pandemic).

[948] *See* Telephone Interview, McGrew, *supra* note 282.

[949] *See* GAO-21-460, *supra* note 8, at 28, 28 n.25. "Under the Defense Federal Acquisition Regulations, if the contractor developed an item or computer software exclusively with government funds, the contractor retains the intellectual property over the technical data pertaining to the item, but the government acquires "unlimited rights" to use the data without restriction. If the contractor developed an item or computer software with mixed funding, then the government normally acquires "government purpose rights." If the contractor developed the item or computer software completely at private expense, then DOD usually acquires only "limited rights" (for data) or "restricted rights" for software." *Id*. at 28 n. 25.

[950] *See id*.

3. "Future-Proofing" Contracting Strategies: Employing and Enforcing MOSA Contracting in DoD Vehicle Acquisitions

Modular contracting "is intended to reduce program risk and incentivize contractor performance while meeting the government's need for timely access to rapidly changing technology. It [also] enables [DoD] to deliver capabilities more rapidly and permits easy adoption of newer and emerging technologies."[951] Therefore, to achieve the game-changing benefits of MOSA contracting, DoD leaders must not only encourage but *require* acquisition leaders employ MOSA strategies to the maximum extent possible while still meeting the capability requirements of each MDAP and the broader aims of the FAR.[952]

A MOSA contracting strategy provides significant benefits in terms of a TWV or GCV acquisition program's performance, life cycle cost, and schedule.[953] First, "[a]cquisition programs using MOSA as a foundational practice have achieved a degree of modernization," particularly by allowing for rapid technology upgrades, or "technology refresh," the use of COTS hardware, and integration of innovative capabilities at the speed of commercial industry's advances.[954] In this way, MDAPs employing MOSA strategies can avoid technology obsolescence issues and increase U.S. MWSs' interoperability across the JF and with Allied partners' sustainment systems.[955]

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[951] *See* GAO-23-106059, *supra* note 50, at 47.

[952] *See* OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 14. The benefits of MOSA contracting include the following: enhanced competition and innovation, significant cost savings or avoidance, schedule reduction, opportunities for technical upgrades, increased interoperability, including system of systems interoperability and mission integration, and other benefits during the sustainment phase of a major weapon system." *See id*.

[953] *See* GAO-13-651, *supra* note 290, at 1.

[954] *See* OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 9; GAO-13-651, *supra* note 290, at 9.

[955] *See* GAO-13-651, *supra* note 290, at 14. According to NATO, "interoperability enables forces, units and/or systems to operate together, allowing them to communicate and to share common doctrine and procedures, along with each other's infrastructure and bases. Interoperability reduces duplication, enables pooling of resources and produces synergies among all Allies, and whenever possible with partner countries." *Interoperability: Connecting Forces*, N. ATLANTIC TREATY ORG. (Apr. 22, 2023), https://www.nato.int/cps/en/natohq/topics_84112.htm.

Second, open systems offer considerable cost savings and cost avoidance.[956] Although MDAPs employing a MOSA might sustain higher initial R&D, prototyping, and production costs, "[d]esigning weapons as open systems offers significant repair, upgrade, and competition benefits that could translate to millions of dollars in savings" over the life cycle of the system.[957] That is, incrementally adding, removing, or replacing modular components as needed can extend a MWS's life cycle by years, avoid higher costs of complete system upgrades, and reduce upgrade and maintenance costs later in a MWS's life cycle.[958] Additionally, an open "system architecture that allows severable major system components . . . afford[s] opportunities for enhanced competition and innovation" by industry by creating an ongoing market for technology upgrades to those components.[959] Greater competition, of course, incentivizes rapid innovation and lower procurement prices for DoD, especially for modular components with commercial marketability.[960]

Third, a MOSA strategy ensures schedule reduction and rapid deployment of new technology.[961] Although a MOSA requires additional planning and investment during the MWS's initial development phase, programs can transition more rapidly from prototyping to production

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[956] *See* GAO-13-651, *supra* note 290, at 14.

[957] *See id.* at Highlights.

[958] *See* OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 2; GAO-13-651, *supra* note 290, at 4.

[959] *See Modular Open Systems Approach (MOSA)*, DEF. ACQUISITION U., https://www.dau.edu/acquipedia-article/modular-open-systems-approach-mosa (last visited Apr. 11, 2024) [hereinafter *MOSA*, DAU].

[960] *See id*. Aside from the benefits for DoD, MDAPs with a MOSA can encourage benefits in the U.S. economy. *See* GAO-13-651, *supra* note 290, at 6 ("[a]n open systems approach has great potential to generate efficiencies for product manufacturers, lower total ownership costs for consumers, and transform industries because it spurs industry growth, competition, and innovation"); *see also* GAO-13-651, *supra* note 290, at 7 (using the personal computer industry as an example to show that "[a]n open systems approach can also spur industry growth and entrepreneurial creativity, transforming an industry and offering benefits to manufacturers, suppliers, and consumers").

[961] *See MOSA*, DAU, *supra* note 959.

and fielding of a crucial capability.[962] This is because, "[w]ith MOSA, rather than building a 'perfect' closed system"—which rarely occurs, as the F-35 program illustrated—"the [DoD] can field 'good enough' systems and build them up later with rapid and agile technology upgrades."[963] Additionally, "[t]raditional, closed systems have to be upgraded as a whole, forcing [DoD] to wait for major upgrades," which only the original contractor can provide.[964] In contrast, a MOSA enables programs to integrate new components for technology upgrades and to facilitate competition for other sustainment at the speed of industry's technological advances.[965] Ultimately, with parts that are easier to integrate, those upgrades and repairs also take less time and resources during the MWS's life cycle.[966] Notwithstanding the many benefits of MOSA contracting, employing and enforcing MOSA standards in future HE TWV programs requires discipline.

Enforcing MOSA standards in future HE TWV R&D and production contracts requires a deliberate approach by DoD leaders and acquisitions stakeholders.[967] There must be sufficient understanding and incentives between DoD program offices and contractors.[968] Program offices must have a formal requirement from superior offices to employ MOSA strategies but also effective guidance, training, trust, and resources to best equip offices to do so.[969] At the program level, PMs must develop and implement a MOSA "framework" that is specific to the respective

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[962] *See* OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, at 20.

[963] *See* Shaffer & Whitley, *supra* note 39.

[964] *See id.*

[965] *See* GAO-23-106059, *supra* note 50, at 24; Shaffer & Whitley, *supra* note 39.

[966] *See* GAO-13-651, *supra* note 290, at 7.

[967] For best practices in developing DoD MOSA strategies, see generally OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, para. 3.1.

[968] *See* GAO-13-651, *supra* note 290, at 9.

[969] *See id.*

program.[970] For example, to establish some form of a modular architecture, PMs must coordinate between both end-users and engineers to conduct "functional decomposition" of the MWS and establish clear requirements to express to industry.[971] Regarding contractor expectations and incentives, program offices "must articulate required data rights and [IP] information early."[972] Programs also "must clearly document in the contract which standards or architecture considerations contractors should follow, and the contract should include appropriate incentives and disincentives (fees, withholding item acceptance, etc.)."[973] There also must be a clear articulation in such documents of the MOSA evaluation and compliance criteria that programs will use.[974] Ultimately, the initial time and cost needed to employ MOSA strategies for HE TWVs will prove beneficial in the long-term.[975] However, the immediate concerns of DoD entities and industry must first be overcome.

Some acquisition stakeholders in government and many in industry express concern over the "risks of MOSA disrupting relationships that they rely on and, thus, they are unlikely to be forward

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[970] *See* Sanders & Holderness, *supra* note 310, at 4. "DoD has used the term "framework" to identify proposed MOSA solutions that satisfy similar technical requirements and common elements across related applications within a domain . . . A MOSA framework includes (1) architecture, (2) standards, (3) implementation, and (4) conformance, as well as the use of (5) data models and (6) additional tools." *Id*. The overarching term, in essence, "encompass[es] technical and business architecture, models, and guidance." *See id*. at 6, Table 2-1. For a discussion of what sections should be included in a MOSA framework, see OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, para. 3.1.

[971] *See* Sanders & Holderness, *supra* note 310, at 10. Functional decomposition involves a three-step process of (1) determining which functional modules serve as the building blocks in the system, (2) de-coupling interfaces to minimize dependencies between modules, and (3) "specifying well-defined interfaces that use consensus-based standards results in standardized interfaces. The functional decomposition process is paramount in implementing a modular approach to system development. De-coupling helps eliminate unnecessary interfaces, which then makes it easier to identify the interfaces that are good candidates for standardization." OUSD(R&E) MOSA FRAMEWORKS, *supra* note 286, para. 2.4.

[972] *See* Sanders & Holderness, *supra* note 310, at 9.

[973] *See id.*

[974] *See id.* at 13.

[975] *See id.* at 4.

leaning in ensuring that openness is achieved."[976] On the other end of the spectrum, there are those in DoD who perceive "the relationship with industry" as not merely fragile but "more adversarial, and breadth of IP and data rights—even within modules—is seen as a necessity."[977] These concerns are not merely theoretical, as both DoD leaders and NDCs recently expressed hesitance over whether MOSA would provide enough incentives for industry to engage in DoD contracts, especially given the immense costs and risks contractors typically assume when seeking a large MWS procurement contract.[978]

Nevertheless, there are simple ways to reduce these concerns over the need to acquire IP and data rights under MOSA principles.[979] For decades, private industries have employed commercial open system business models, which often emphasize licensing approaches.[980] Industry largely recognizes "the broad outlines of a MOSA business model are well established: focus investments and business strategies more on modules than interfaces."[981] Therefore, foremost effectuating the simple procedural changes above will better enable HE TWV acquisition programs to leverage industry innovation by conducting more internal R&D in early stages of development. Such early R&D for HED capabilities will place programs in better negotiating positions to demand MOSA in production contracts.[982]

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[976] *See id.* at 8.

[977] *See id.*

[978] *See* Brian Baldrate interview; E-mail, Putrus, *supra* note 173; E-mail, Roberts, *supra* note 299. "[W]hile all vendors have some potential gains from MOSA, reduced IP and data rights ownership may lead them to fear that their share of the benefits in a MOSA model may no longer justify investment, or even bidding." Sanders & Holderness, *supra* note 310, at 4.

[979] *See* Sanders & Holderness, *supra* note 310, at 4.

[980] *See id.* at 9.

[981] *Id.*

[982] *See* Telephone Interview, McGrew, *supra* note 282; E-mail, Roberts, *supra* note 299; E-mail, Putrus, *supra* note 173.

As a second way to reduce industry concern over IP and data rights ownership, programs should assess what IP and data rights in a system are truly necessary to achieve the benefits of MOSA.[983] For example, DoD may not need to acquire the IP and data rights for modular components in an HE TWV, like the traction battery pack, to optimize MOSA benefits.[984] In contrast, it may be more crucial for DoD to acquire early in initial development contracts the IP for key interfaces that allow for continuous upgrades and tech refresh, like the interfaces between batteries, inverters, and motors.[985] This will require a shift in how DoD acquires its ground vehicles.[986]

Third, acquisition leaders can generate creative win-win contracting strategies that respond to these valid industry concerns over their significant IP investment.[987] For example, there is a plethora of IP and data rights categories, ranging from low to high proprietary interest of each party to a contract, that RFPs and initial development contract negotiations should consider to accurately articulate what specific rights DoD truly requires.[988] Additionally, DoD can incentivize industry to provide necessary IP and data rights early in HE TWV initial development contracts by including attractive licensing terms and locked-in sustainment packages for a certain period.[989]

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[983] *See* GAO-23-106059, *supra* note 50, at 24.

[984] *See* 10 U.S.C. § 4401(b) (2024); GAO-23-106059, *supra* note 50, at 24; Brian Baldrate interview.

[985] *See* 10 U.S.C. § 4401(b) (2024); GAO-23-106059, *supra* note 50, at 24; Brian Baldrate interview; Telephone Interview, McGrew, *supra* note 282; E-mail, Roberts, *supra* note 299.

[986] *See* Brian Baldrate interview; E-mail, Roberts, *supra* note 299.

[987] *See* Data Rights Team, *supra* note 298, at 1, 2; *see also* 10 U.S.C. §2320 (Rights in technical data); DFARS Part 227.71 (Rights in Technical Data).

[988] *See* Data Rights Team, *supra* note 298, at 1, 2; *see also* 10 U.S.C. §2320 (Rights in technical data); DFARS Part 227.71 (Rights in Technical Data).

[989] *See* Walter, at 18, 19.

Fourth, combining MOSA contracting with greater purchasing of COTS solutions for HED will provide win-win benefits for DoD and industry, both prime contractors and NDCs. Aside from providing larger contractors more incentive to develop dual-market capabilities, "[m]aking more room for commercial approaches or a greater depth of modularization can lower the barriers to entry for [smaller technology] firms, making participation more attractive" for all.[990]

On a broader level, employment of MOSA contracting can be thought of as a spectrum rather than a "yes-no" analysis; that is, MOSA principles do not generally demand that all possible interfaces be open for the system to be considered open.[991] Instead, programs should seek to utilize MOSA goals as part of their best-value competition criteria and to reject vendor proposals that offer short-term gains but undermine the type of long-term benefits offered by greater use of MOSA.[992]

In some respects, deciding to engage in MOSA contracting requires that acquisition leaders ask industry to engage in a "stag hunt."[993] Economists and social scientists use the "stag hunt" model to illustrate how industry invests resources across competing markets, either cooperating to "hunt a stag" to achieve greater overall success or working independently to "hunt a hare," which involves less risk but also less reward.[994] The chances of success and the size of the reward determines whether industry will decide to "hunt the stag"—that is, whether companies will cooperate to some extent in order to have a better chance of capturing greater reward in the long-

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[990] *See* Sanders & Holderness, *supra* note 310, at 9.

[991] *But see* Sanders & Holderness, *supra* note 310, at 9 (proposing that "choosing not to adopt an existing standard or open interface implementation should require a justification").

[992] *See id.* at 5.

[993] *See* Sanders & Holderness, *supra* note 310, at 4, 5.

[994] *See* Ahlstrom, *supra* note 614.

term.[995] In this case, the greater reward is the enduring market for advancing HED components for continual technological refresh.[996] Greater numbers of potential defense contractors may thus have the chance to develop and deliver novel HED capabilities that not only better equip U.S. ground forces and protect national security but also have potential for dual-market financial benefits.[997]

VI. CONCLUSION

As the most recent NDS highlights, "[t]he need for [DoD] to deliver innovative capability to the warfighter quickly remains as pressing as ever."[998] To this end, to ensure strategic deterrence and military readiness, DoD leaders and Congress must prioritize timely, effective acquisition of HE TWVs to achieve the immense tactical, operational, and strategic advantages that HED capabilities offer on the battlefield. Doing so is vital to ensuring U.S. ground forces are best equipped to fight and win the nation's wars, especially future LSCOs on the horizon.[999]

Nevertheless, the roadblocks to HED innovation are formidable. From DoD budget requests that prioritize funding elsewhere to political misperceptions of the impetus behind the DoD's HED modernization efforts, the policy-based challenges are the first major hurdles blocking meaningful acquisition initiatives in the near-term.[1000] Nevertheless, these initial barriers present DoD leaders with an immediate opportunity to set conditions to advocate for U.S. ground forces'

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[995] *See id.*; Sanders & Holderness, *supra* note 310, at 4, 5.

[996] *See* Sanders & Holderness, *supra* note 310, at 4.

[997] *See id.*

[998] *See* 2022 NDS, *supra* note 38, at 20.

[999] *See* Mills & Wiechens, *supra* note 59.

[1000] *See* Telephone Interview, Lohnes, *supra* note 541.

HE TWV capability requirements. By appreciating the need for HED modernization, clarifying to Congress the reasons for doing so, and conducting large-scale field exercises to test and build trust in new systems, DoD leaders can do what they do best in the face of such challenge: lead the JF "to deter war and [] protect the security of the United States."[1001]

Another area in which DoD leadership will continue to prove crucial is in the subsequent DoD acquisition processes to procure HE TWVs. As with the political barriers blocking innovation, DoD leaders also face persistent procedural challenges in the form of a shrinking U.S. DIB to meet DoD's needs, a myriad of systemic shortfalls in similar past MDAPs, and self-imposed inefficiencies hindering rapid R&D innovation.[1002] Nevertheless, DoD leadership is likewise well-situated to respond to such challenges. Leaders and policymakers in DoD must more deliberately assess and communicate the overarching strategy for hybrid-electrifying the TWV fleet as well as pursue novel acquisition reforms to better leverage industry innovation while enforcing MOSA strategies to keep ground vehicles adaptable to a changing world. In doing so, DoD leaders can enable the acquisitions workforce to do what it does best: equip DoD with game-changing warfighting capabilities so U.S. ground forces are never forced to engage in a "fair fight."[1003]

As General Marshall learned while leading the Army's successful transition from the horse to the motor vehicle almost a century ago, transforming how a massive ground force moves on the battlefield is never an easy task.[1004] However, if DoD can again remain disciplined and innovative

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[1001] *See About*, U.S. DEP'T OF DEF., https://www.defense.gov/about (last visited Apr. 11, 2024).

[1002] *See* Telephone Interview, McGrew, *supra* note 282.

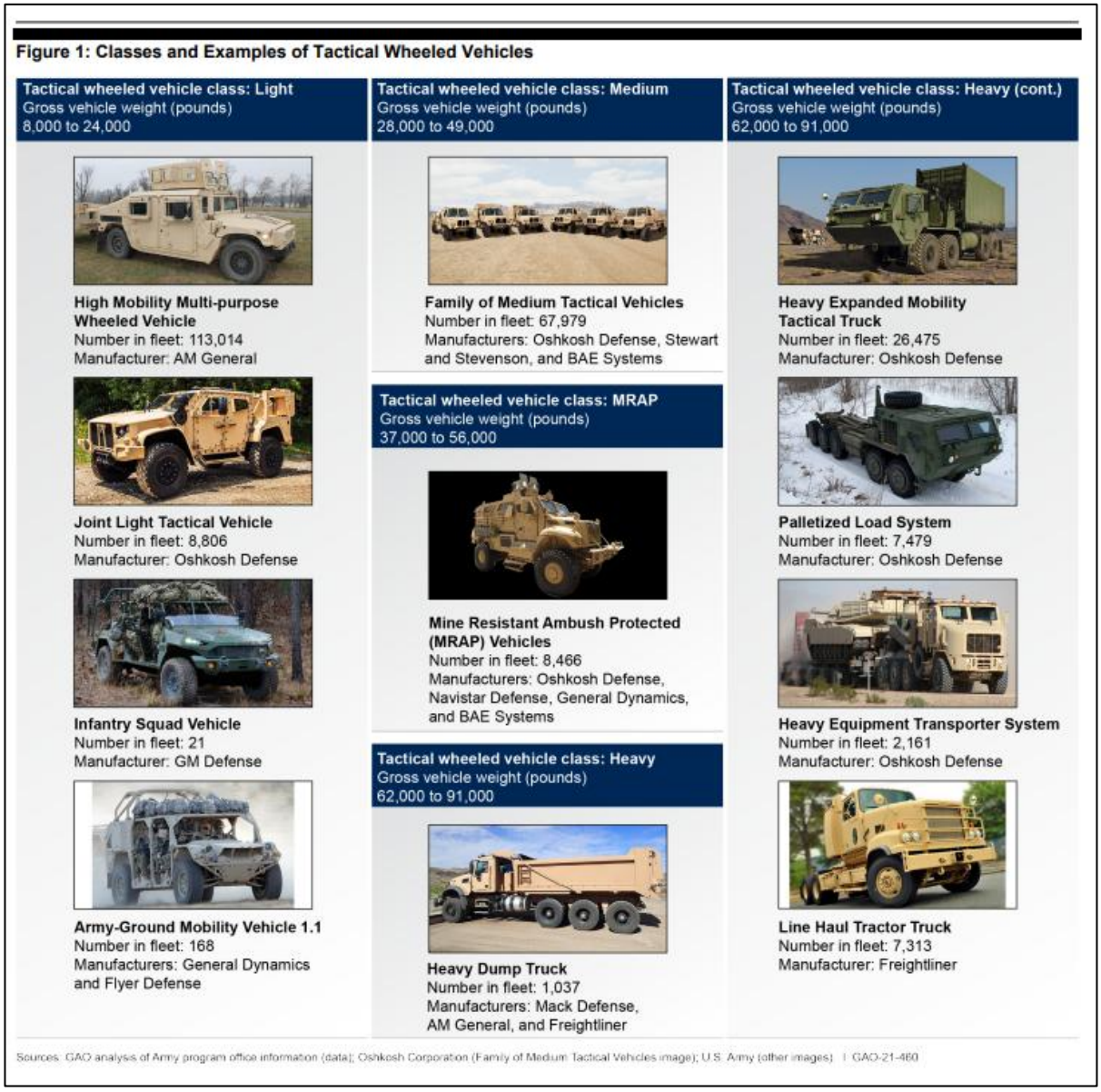
[1003] *See Vital Signs*, *supra* note 593, at 17.

[1004] *See* Hom article, at 2, 16.

in how it maneuvers past the obstacles that stand in the way of necessary HED innovation, it will move forward in the right direction.

Appendix A – The Army's Ground Vehicle Fleet (Photographs/Diagrams)

Appendix A-1 – Classes and Examples of TWVs[1005]



[1005] GAO-21-460, *supra* note 8, at 4 Fig. 1.

Appendix A-2 – Classes and Examples of GCVs[1006]

Figure 1: Ground Combat Vehicles

Abrams Main Battle Tank
Quantity: 2402
Manufacturer: GDLS

Equipped with 120 millimeter main gun. Abrams tanks are tracked with special armor, 1500 horsepower turbine engine. Provides soldiers with the mobility, firepower, and shock effect to close in and destroy enemy forces.

Bradley Family of Vehicles
Quantity: 4,042
Manufacturer: BAE

Equipped with a 25 millimeter gun and/or missile launch capability. The Bradley is an armored and tracked vehicle that provides mobile protected transport of infantry to critical points on the battlefield and performs cavalry scout and other essential missions.

Stryker Family of Vehicles
Quantity:4,466
Manufacturer: GDLS

Equipped with eight wheels. Provides combat support with ten variants and mission-dependent configurations that supports a variety of armaments, including a .50 caliber machine gun.

M109 Paladin Family of Vehicles
Quantity: 558 self-propelled howitzers and 521 tracked ammunition carriers.
Manufacturer: BAE

Equipped with a 155 millimeter cannon, the Paladin is a tracked, aluminum armored, self-propelled howitzer designed to destroy, neutralize, or suppress the enemy by indirect fire. Also includes a tracked ammunition carrier that provides operational support to the howitzer.

M88 Hercules
Quantity: 1,170
Manufacturer: BAE

Equipped with a boom, which enables a 35 ton lift capability, and a .50 caliber machine gun, the Hercules is an armored, tracked, recovery vehicle.

M113 Armored Personnel Carrier
Quantity: 5,218
Manufacturer: BAE

Equipped with a .50 caliber machine gun. Provides a mobile, survivable and reliable tracked-vehicle platform that, with upgrades, is able to keep pace with Abrams and Bradley equipped units.

Ground Combat Vehicle
Quantity: Not applicable
Manufacturer: Not applicable

Cancelled program that was previously expected to be the Army's replacement for the Bradley infantry fighting vehicle.

Armored Multi-Purpose Vehicle
Quantity: 2,897
Manufacturer: To be determined

Expected to replace the M113 in five mission roles: general purpose, medical evacuation, medical treatment, mortar carrier, and mission command. Currently in development.

U.S. Marine Corps combat vehicles[a]
Includes the terminated Expeditionary Fighting Vehicle and, its potential successor, the Amphibious Combat Vehicle which is still in development and intended to transport Marines, including ship to shore operations, to secure a beachhead.

Expeditionary Fighting Vehicle
Quantity: Not applicable
Manufacturer: Not applicable

Amphibious Combat Vehicle
Quantity: To be determined
Manufacturer: To be determined

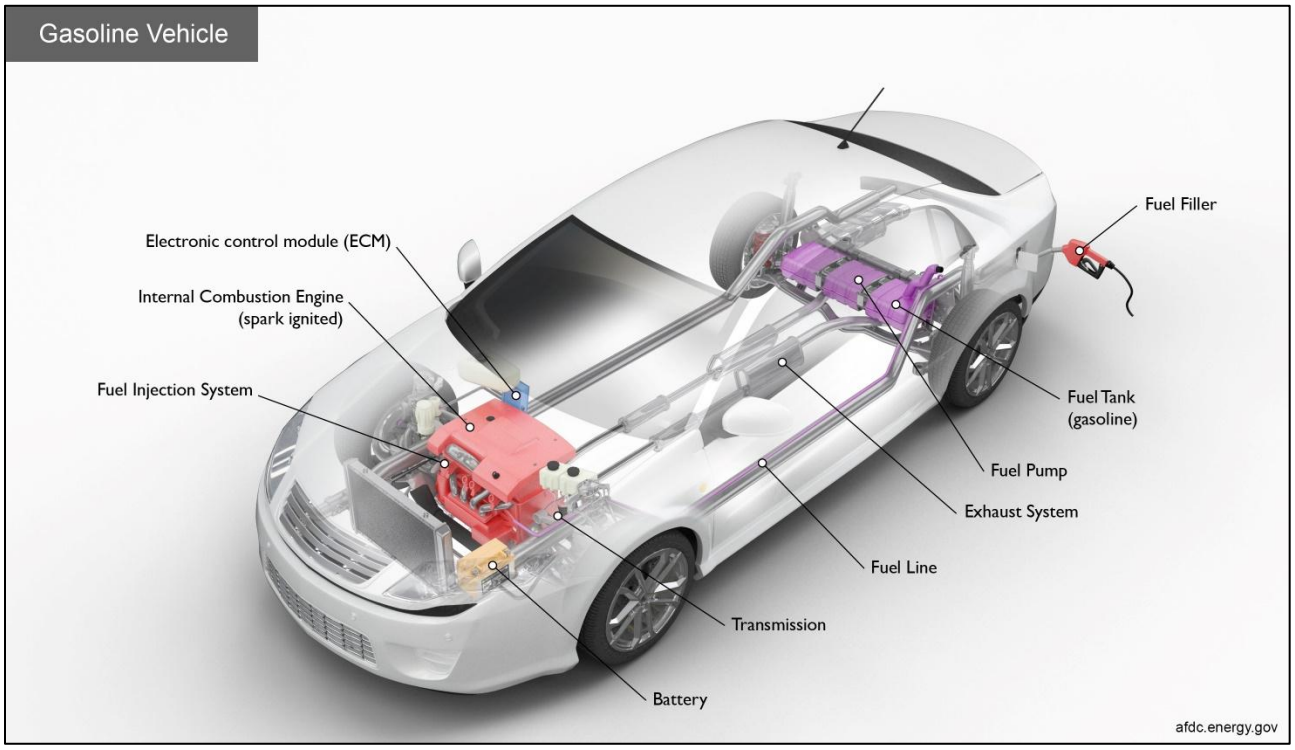
Source: GAO analysis of Army study documentation, Army program information, and information from past GAO reports; U.S. Army (photos). | GAO-15-548

[a]United States Marine Corps' vehicles, such as the Amphibious Combat Vehicle, were also included in the Army study however the primary focus was on Army combat vehicles.

[1006] GAO-15-548, *supra* note 6, at 4 fig.1.

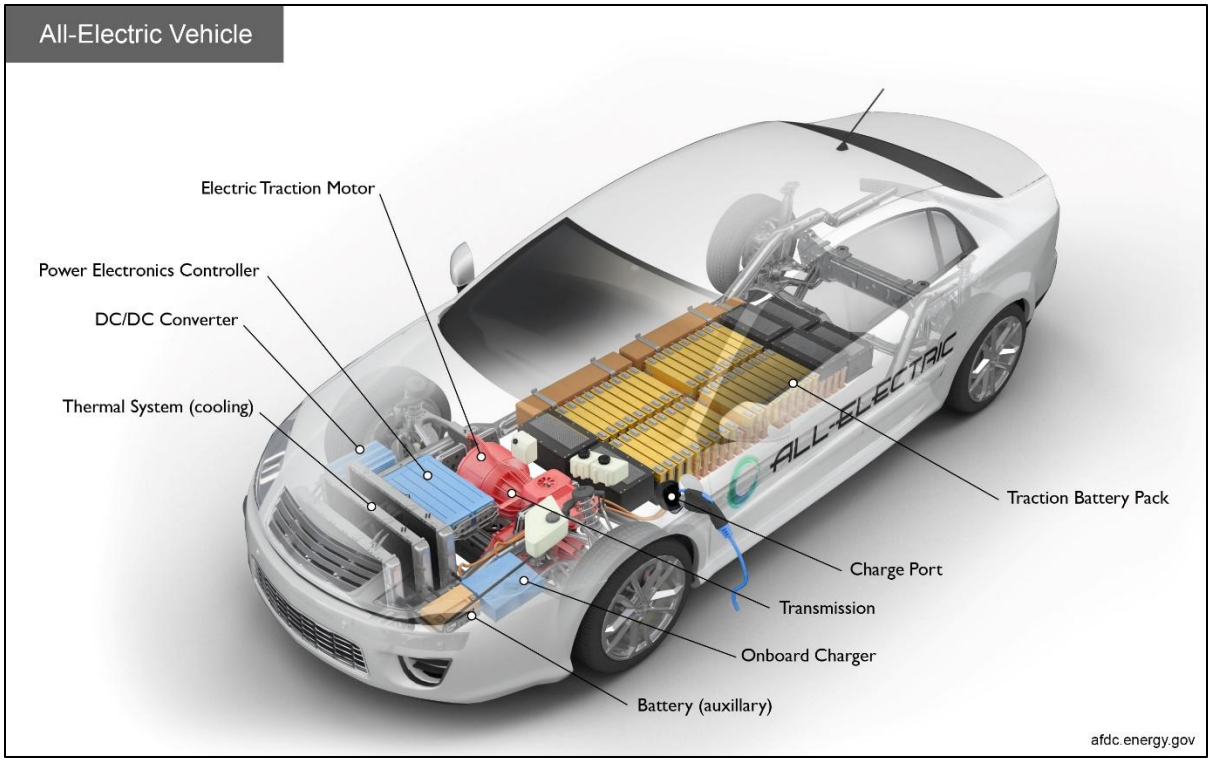
Appendix B – How Vehicles Work (Diagrams)

Appendix B-1 – Diagram of a Traditional Gasoline/ICE Vehicle[1007]



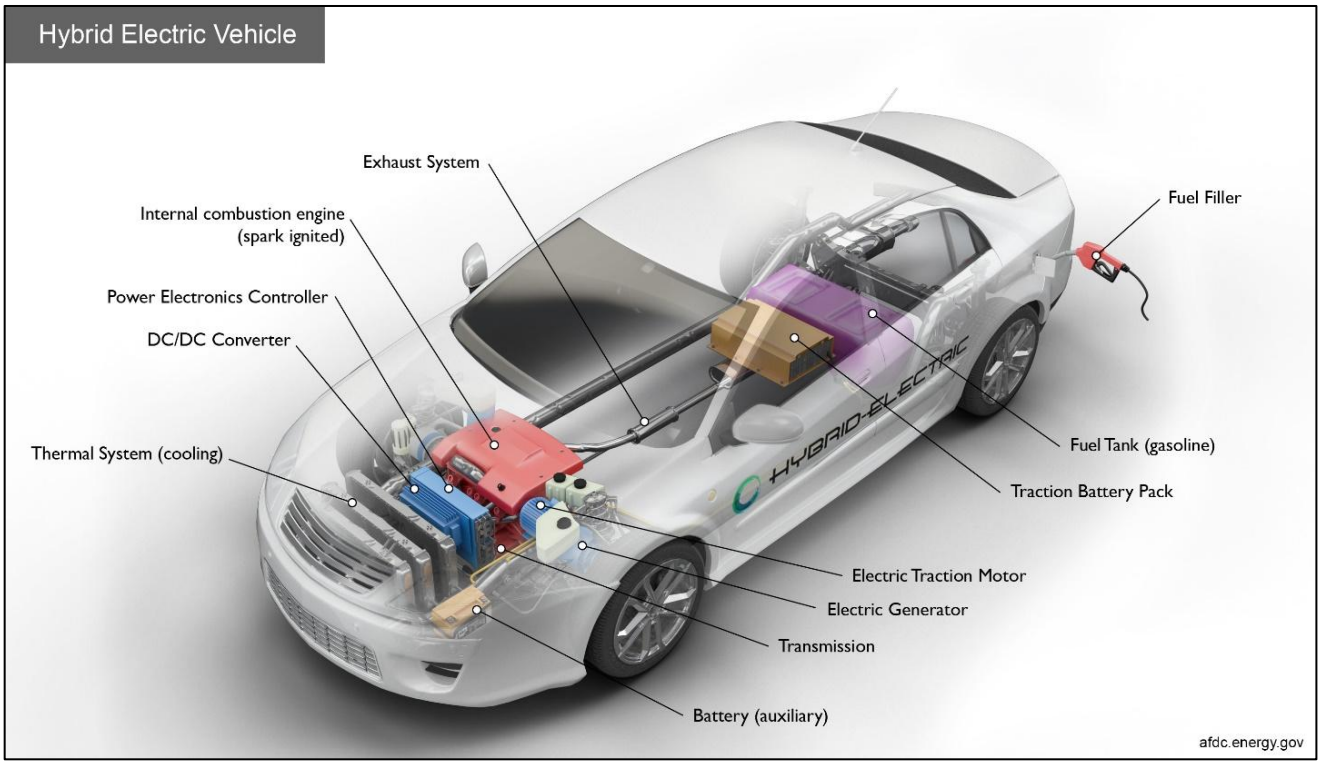
[1007] *How Do Gasoline Cars Work?* ALT. FUELS DATA CTR., U.S. DEPT. OF ENERGY, https://afdc.energy.gov/vehicles/how-do-gasoline-cars-work (last visited Apr. 11, 2024). Although the diagram is labeled as a gasoline car, this also illustrates the basic components of a diesel engine car. *Id.*

Appendix B-2 – Diagram of an All-Electric Vehicle[1008]



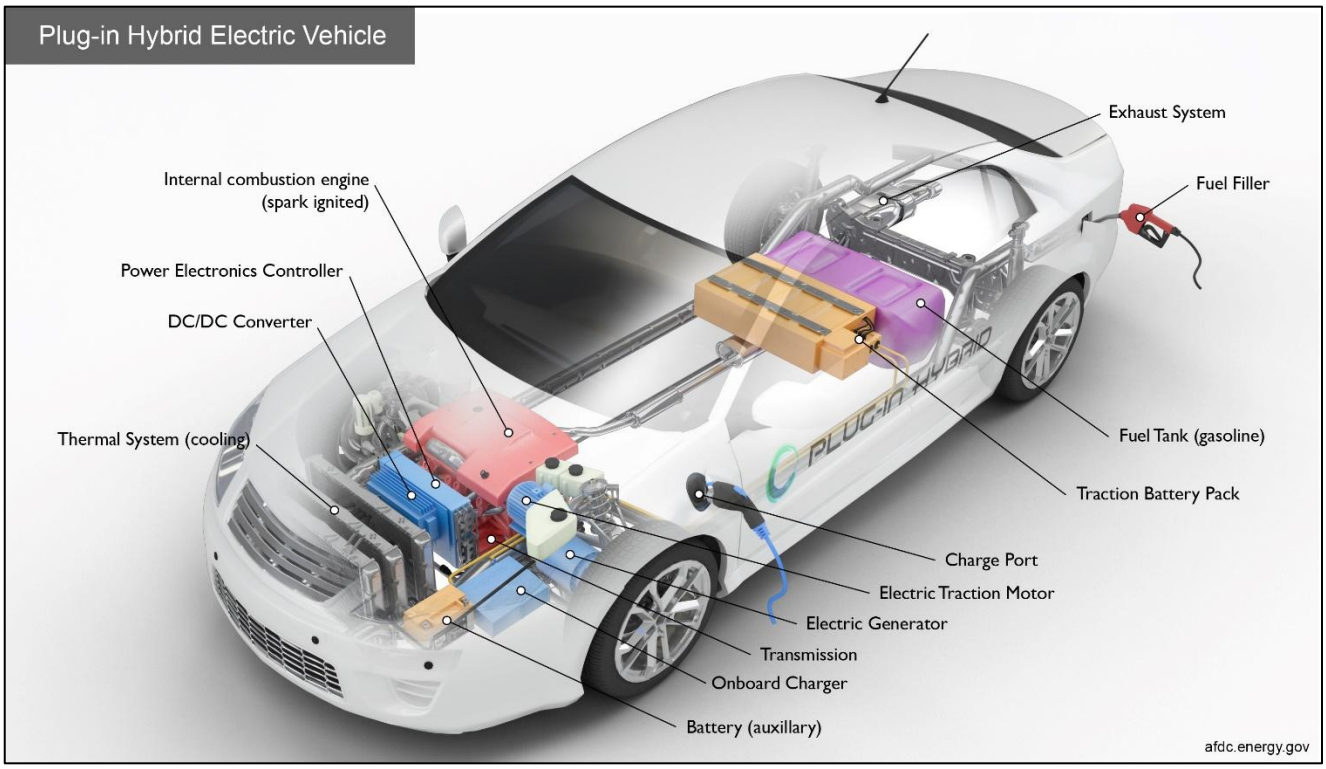
[1008] *How Do All-Electric Cars Work?* ALT. FUELS DATA CTR., U.S. DEPT. OF ENERGY, https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work (last visited Apr. 11, 2024).

Appendix B-3 – Diagram of a Hybrid-Electric Vehicle[1009]



[1009] *How Do Hybrid-Electric Cars Work?*, ALT. FUELS DATA CTR., U.S. DEPT. OF ENERGY, https://afdc.energy.gov/vehicles/how-do-hybrid-electric-cars-work (last visited Apr. 11, 2024).

Appendix B-4 – Diagram of a Plug-In Hybrid Electric Vehicle[1010]



[1010] *PHEVs*, DOE, *supra* note 142.

Appendix C – The Three Defense Acquisitions Processes (Diagrams)

Appendix C-1 – Joint Capabilities Integrations and Development System (JCIDS)[1011]

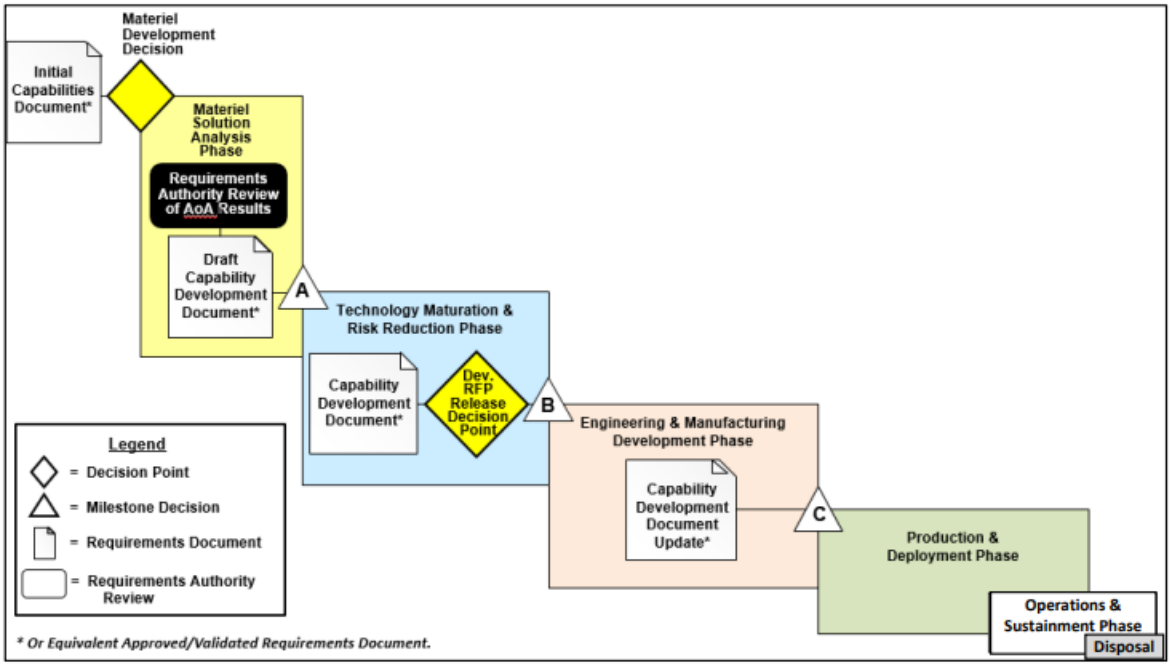


Figure D-2. JCIDS and MCA Interactions (Deliberate Process)

[1011] *See* CJCSI 5123.01I, *supra* note 197, at D-6, Fig. D-2.

Appendix C-2 – Planning, Programming, Budgeting, and Execution System (PPBE)[1012]

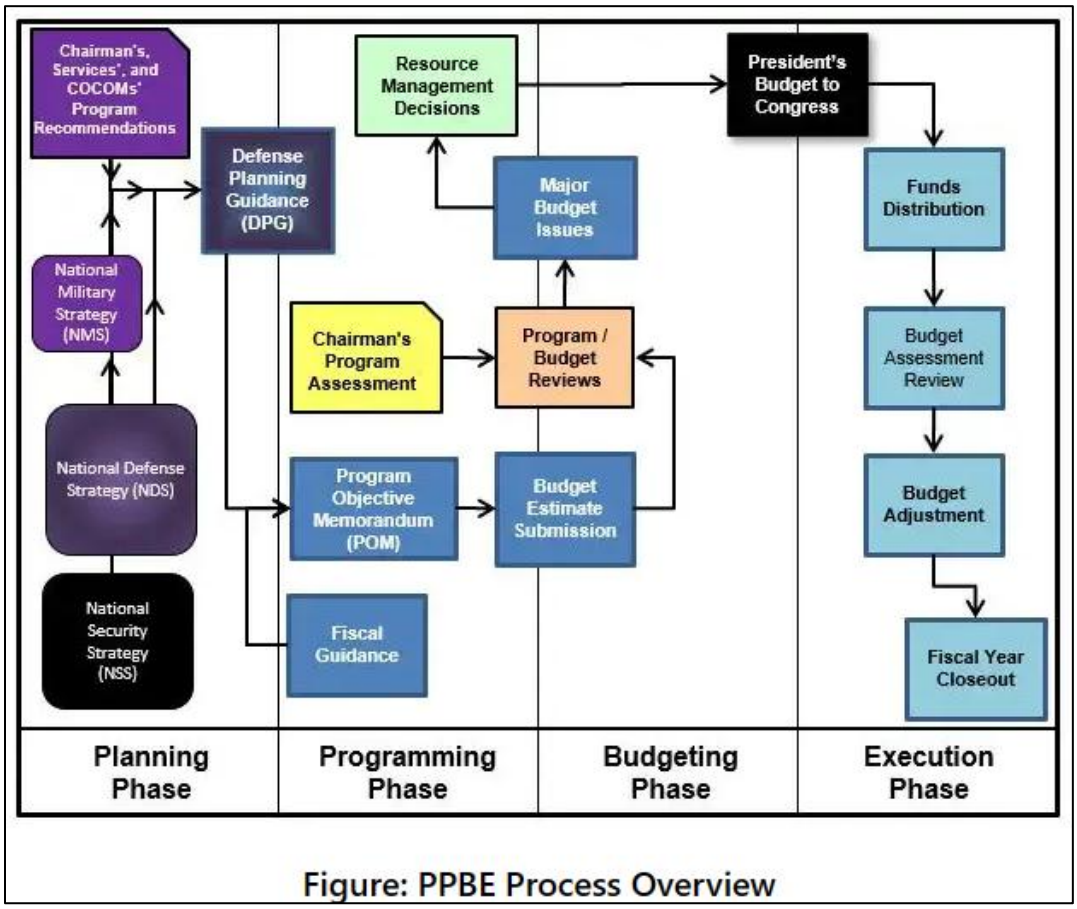
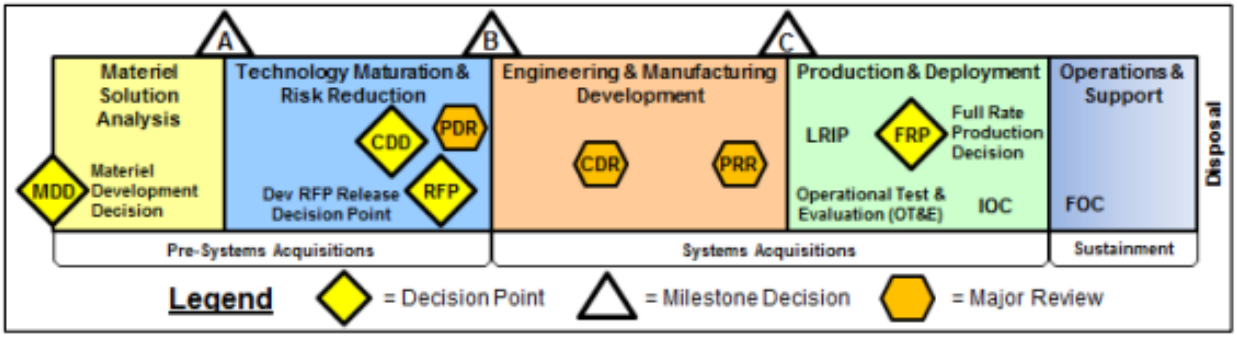


Figure: PPBE Process Overview

[1012] *Planning, Programming, Budget, and Execution (PPBE) Process Overview,* ACQNOTES (Feb. 9, 2024), https://acqnotes.com/acqnote/acquisitions/ppbe-overview.

Appendix C-3 – Defense Acquisition System (DAS)[1013]

Figure 1. DOD Systems Acquisition Framework



Source: http://acqnotes.com/acqnote/acquisitions/acquisition-process-overview, accessed February 13, 2019.

Notes: Each phase of the acquisition process has specific DOD regulations and federal statutes that must be met. At the end of each phase, there is a Milestone Review (A, B, C) to determine if the acquisition program has met these required regulations and statues to continue on into the next phase.

Critical Development Document (CDD): The CDD specifies the operational requirements for the system that will deliver the capability that meets operational performance criteria specified in the Initial Capabilities Document (ICD).

Preliminary Design Review (PDR): The PDR is a technical assessment that establishes the Allocated Baseline of a system to ensure a system is operationally effective.

Request for Proposal (RFP): A RFP is a document that solicits proposal, often made through a bidding process, by an agency or company interested in procurement of a commodity, service, or valuable asset, to potential suppliers to submit business proposals.

[1013] *See Acquisition Process Overview*, ACQNOTES (June 7, 2021), https://acqnotes.com/acqnote/acquisitions/acquisition-process-overview.

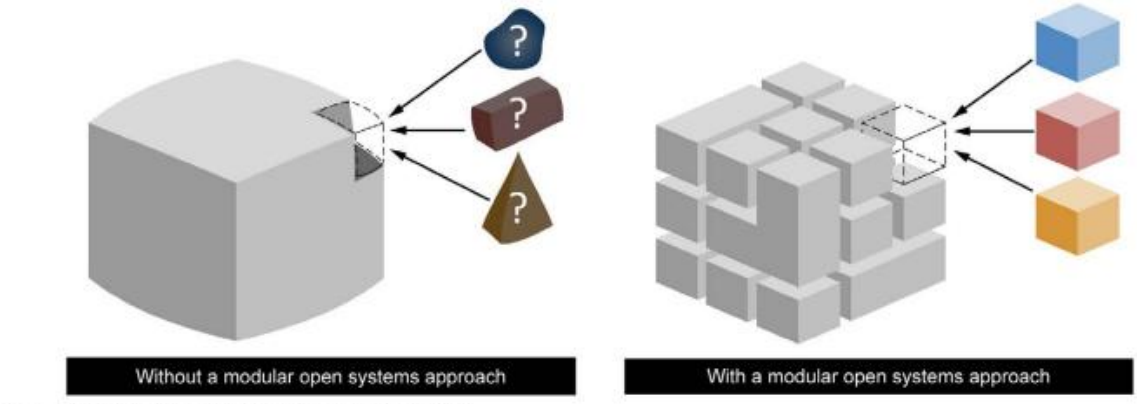
Appendix D – Contracting Strategies (Diagrams)

Contract Strategies and Types[1014]

		FFP	FPEPA	FPIF	FFP-LOE	Cost	CPIF	CPAF	CPFF	T&M
FAR Based	Federal Supply Schedules - FAR 8.4	•								•
	Commercial Items - FAR 12	•	•							•
	Simplified Acquisitions - FAR 13	•	•	•	•	•	•	•	•	•
	Contracting by Negotiation - FAR 15	•	•	•	•	•	•	•	•	•
	IDIQ Contracts - FAR 16.5	•	•	•	•	•	•	•	•	•
	Letter Contract - FAR 16.603	N/A								
	Agreements - FAR 16.7	Agreements, not contracts								
	Small Business - FAR 19	•	•	•	•	•	•	•	•	•
	BAA - FAR 35.106	•	•	•	•	•	•	•	•	•
	SBIR/STTR	•		•	•	•	•	•	•	•
	Defense CSO Pilot	•		•						
Non-FAR	Other Transaction Authority	Agreements, not contracts								
	Procurements for Experimental Purposes	Agreements or contracts (usually FFP)								
	CRADA (15 USC 3710a)	Agreements, not contracts								
	PIA (15 USC 3715)	Contract, agreement, or memorandum of understanding								
	TIA (32 CFR Part 37)	Agreements, not contracts								

Modular Open Systems Approach (MOSA)[1015]

Figure 5: Greater Availability of Suitable Replacements with a Modular Open Systems Approach

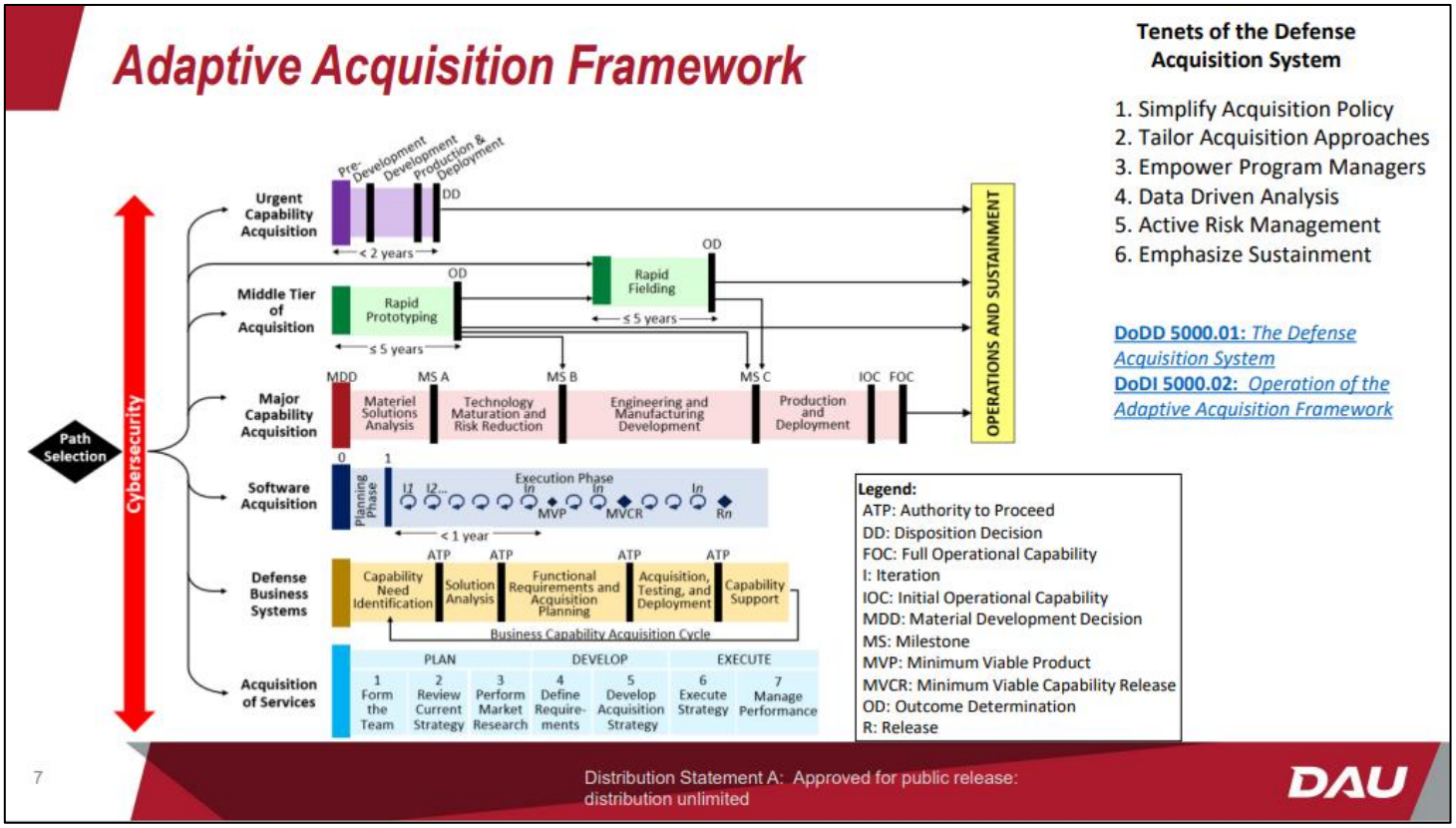


Source: GAO analysis of Department of Defense information. | GAO-23-106059

[1014] *Contract Type Matrix*, *supra* note 256.

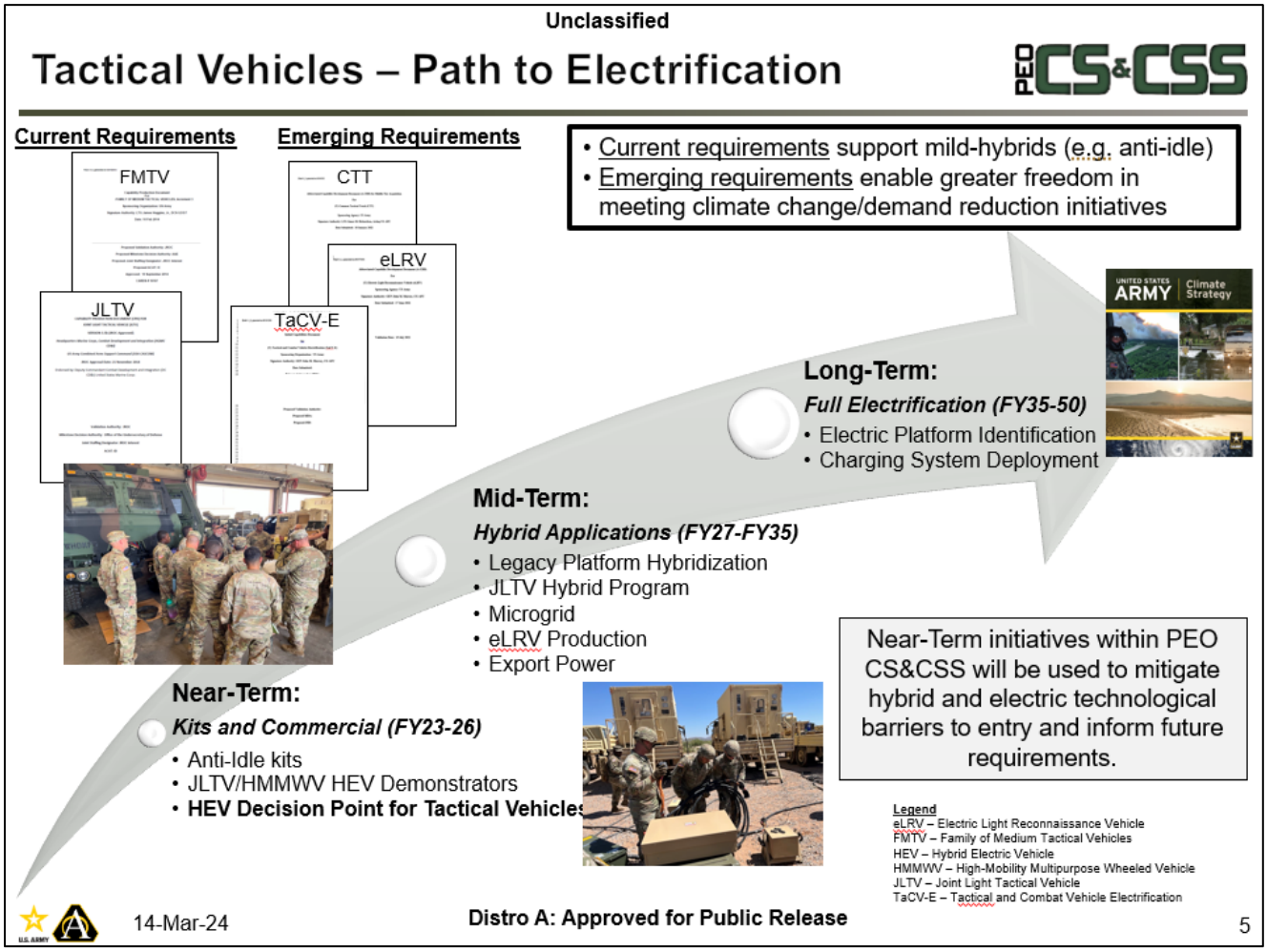
[1015] GAO-23-106059, *supra* note 50, at 25 Fig.5.

Appendix E – The Adaptive Acquisition Framework (Diagram)[1016]



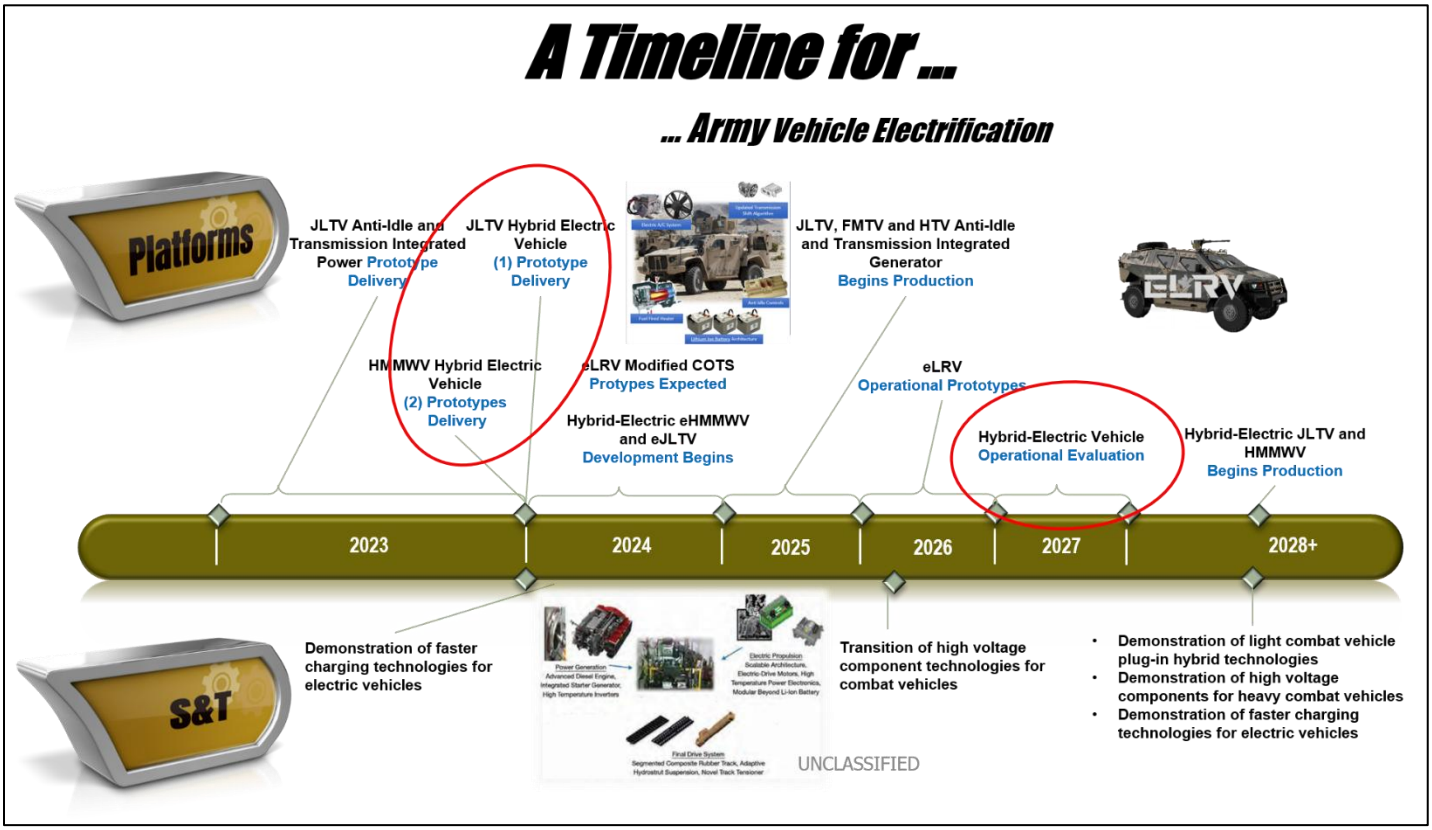
[1016] Clay Miller et al., *Acquisition Pathways*, DEF. ACQUISITION U. 7 (Nov. 2023), https://www.dau.edu/sites/default/files/2023-11/AcqDays_Topic%205_Adaptive%20AcquistionPathways%20v5.pdf

Appendix F – Army Hybrid-Electrification Strategy[1017]



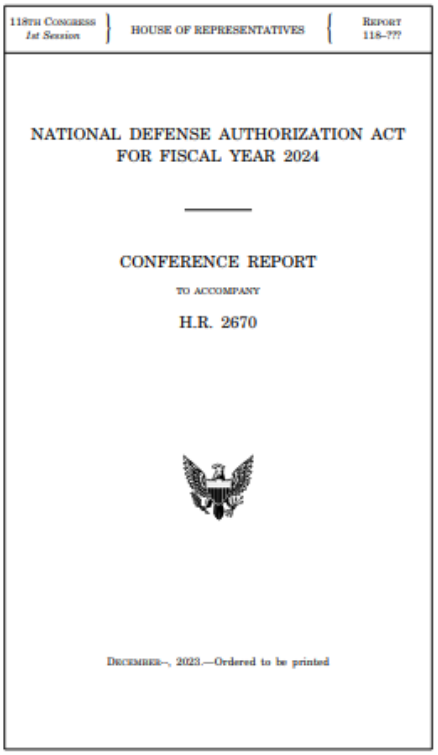
[1017] Steve Roberts, Tactical Vehicles: Path to Electrification (Mar. 14, 2024), *in* E-mail from Steven Roberts, Project Lead, Integration, U.S. Army Program Exec. Off., Combat Support & Combat Serv. Support (PEO–CS&CSS) (Mar. 14, 2024, 13:24 EDT) (on file with author).

Appendix G – Timeline for Army Vehicle Electrification[1018]



[1018] *Army HE Strategy*, Jadus Presentation, *supra* note 474, at 6.

Appendix H – Conference Report Accompanying FY 2024 NDAA (Relevant Pages), Showing Cuts to DoD Budget Requests for HE TWV Acquisition Programs[1019]



118TH CONGRESS, 1st Session | HOUSE OF REPRESENTATIVES | REPORT 118–???

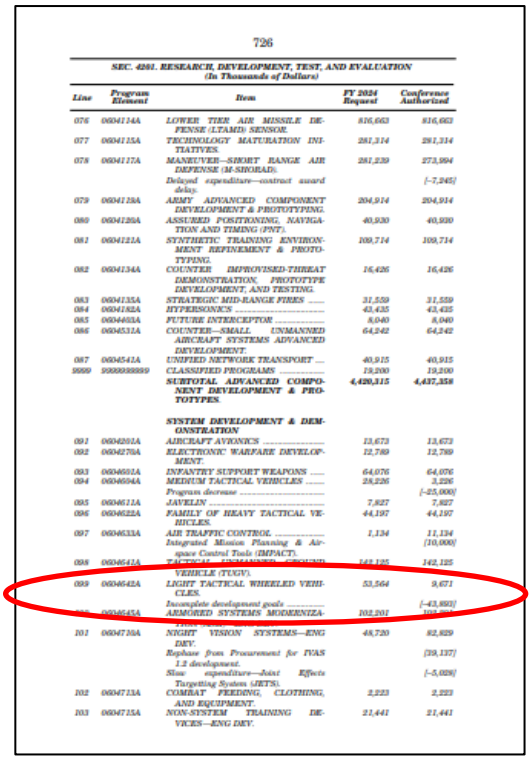
NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2024

CONFERENCE REPORT

TO ACCOMPANY

H.R. 2670

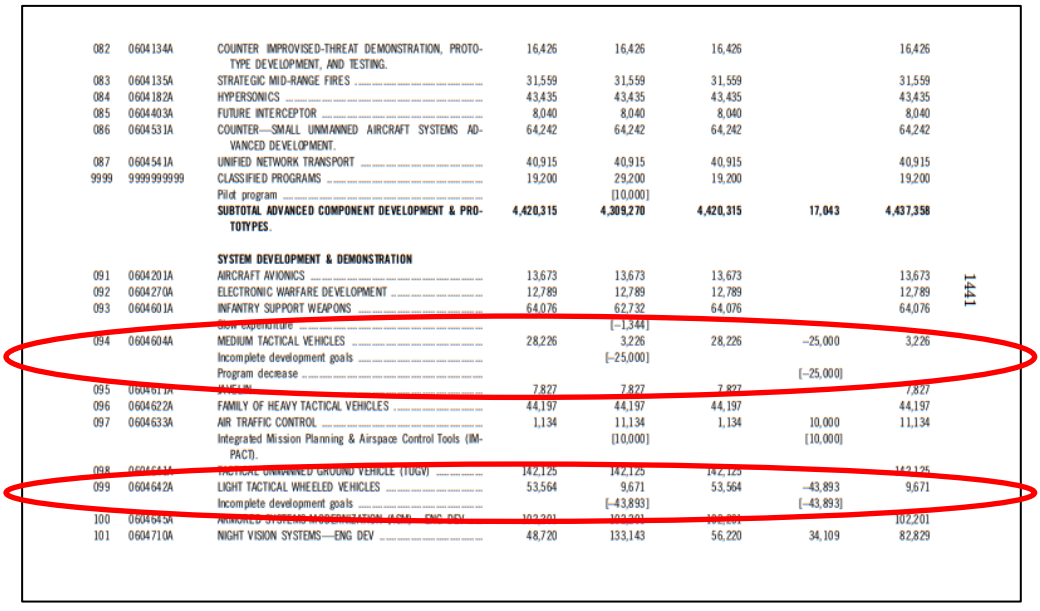
DECEMBER–, 2023.—Ordered to be printed



726

SEC. 4201. RESEARCH, DEVELOPMENT, TEST, AND EVALUATION
(In Thousands of Dollars)

Line	Program Element	Item	FY 2024 Request	Conference Authorized
076	0604134A	LOWER TIER AIR MISSILE DEFENSE (LTAMD) SENSOR.	816,663	816,663
077	0604115A	TECHNOLOGY MATURATION INITIATIVES.	281,314	281,314
078	0604117A	MANEUVER—SHORT RANGE AIR DEFENSE (M-SHORAD).	281,239	273,994
		Delayed expenditure—contract award delay.		[–7,245]
079	0604118A	ARMY ADVANCED COMPONENT DEVELOPMENT & PROTOTYPING.	204,914	204,914
080	0604120A	ASSURED POSITIONING, NAVIGATION AND TIMING (PNT).	40,930	40,930
081	0604121A	SYNTHETIC TRAINING ENVIRONMENT REFINEMENT & PROTOTYPING.	109,714	109,714
082	0604134A	COUNTER IMPROVISED-THREAT DEMONSTRATION, PROTOTYPE DEVELOPMENT, AND TESTING.	16,426	16,426
083	0604135A	STRATEGIC MID-RANGE FIRES	31,559	31,559
084	0604182A	HYPERSONICS	43,435	43,435
085	0604403A	FUTURE INTERCEPTOR	8,040	8,040
086	0604531A	COUNTER—SMALL UNMANNED AIRCRAFT SYSTEMS ADVANCED DEVELOPMENT.	64,242	64,242
087	0604541A	UNIFIED NETWORK TRANSPORT	40,915	40,915
9999	9999999999	CLASSIFIED PROGRAMS	19,200	19,200
		SUBTOTAL ADVANCED COMPONENT DEVELOPMENT & PROTOTYPES.	**4,420,315**	**4,437,358**
		SYSTEM DEVELOPMENT & DEMONSTRATION		
091	0604201A	AIRCRAFT AVIONICS	13,673	13,673
092	0604270A	ELECTRONIC WARFARE DEVELOPMENT.	12,789	12,789
093	0604601A	INFANTRY SUPPORT WEAPONS	64,076	64,076
094	0604604A	MEDIUM TACTICAL VEHICLES	28,226	3,226
		Program decrease		[–25,000]
095	0604611A	JAVELIN	7,827	7,827
096	0604622A	FAMILY OF HEAVY TACTICAL VEHICLES.	44,197	44,197
097	0604633A	AIR TRAFFIC CONTROL	1,134	11,134
		Integrated Mission Planning & Airspace Control Tools (IMPACT).		[10,000]
098	0604641A	TACTICAL UNMANNED GROUND VEHICLE (TUGV).	142,125	142,125
099	0604642A	LIGHT TACTICAL WHEELED VEHICLES.	53,564	9,671
		Incomplete development goals		[–43,893]
100	0604645A	ARMORED SYSTEMS MODERNIZATION (ASM)—ENG. DEV.	102,201	102,201
101	0604710A	NIGHT VISION SYSTEMS—ENG DEV.	48,720	82,829
		Replace from Procurement for IVAS 1.3 development.		[39,137]
		Slow expenditure—Joint Effects Targeting System (JETS).		[–5,028]
102	0604713A	COMBAT FEEDING, CLOTHING, AND EQUIPMENT.	2,223	2,223
103	0604715A	NON-SYSTEM TRAINING DEVICES—ENG DEV.	21,441	21,441

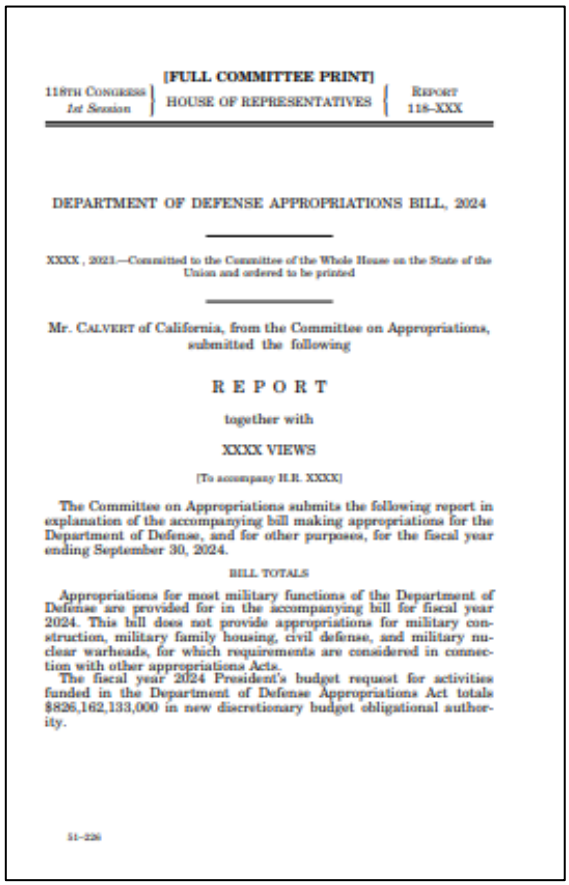


082	0604134A	COUNTER IMPROVISED-THREAT DEMONSTRATION, PROTOTYPE DEVELOPMENT, AND TESTING.	16,426	16,426	16,426		16,426
083	0604135A	STRATEGIC MID-RANGE FIRES	31,559	31,559	31,559		31,559
084	0604182A	HYPERSONICS	43,435	43,435	43,435		43,435
085	0604403A	FUTURE INTERCEPTOR	8,040	8,040	8,040		8,040
086	0604531A	COUNTER—SMALL UNMANNED AIRCRAFT SYSTEMS ADVANCED DEVELOPMENT.	64,242	64,242	64,242		64,242
087	0604541A	UNIFIED NETWORK TRANSPORT	40,915	40,915	40,915		40,915
9999	9999999999	CLASSIFIED PROGRAMS	19,200	29,200	19,200		19,200
		Pilot program		[10,000]			
		SUBTOTAL ADVANCED COMPONENT DEVELOPMENT & PROTOTYPES.	**4,420,315**	**4,309,270**	**4,420,315**	**17,043**	**4,437,358**
		SYSTEM DEVELOPMENT & DEMONSTRATION					
091	0604201A	AIRCRAFT AVIONICS	13,673	13,673	13,673		13,673
092	0604270A	ELECTRONIC WARFARE DEVELOPMENT	12,789	12,789	12,789		12,789
093	0604601A	INFANTRY SUPPORT WEAPONS	64,076	62,732	64,076		64,076
		Slow expenditure		[–1,344]			
094	0604604A	MEDIUM TACTICAL VEHICLES	28,226	3,226	28,226	–25,000	3,226
		Incomplete development goals		[–25,000]			
		Program decrease				[–25,000]	
095	0604611A	JAVELIN	7,827	7,827	7,827		7,827
096	0604622A	FAMILY OF HEAVY TACTICAL VEHICLES	44,197	44,197	44,197		44,197
097	0604633A	AIR TRAFFIC CONTROL	1,134	11,134	1,134	10,000	11,134
		Integrated Mission Planning & Airspace Control Tools (IMPACT).		[10,000]		[10,000]	
098	0604641A	TACTICAL UNMANNED GROUND VEHICLE (TUGV)	142,125	142,125	142,125		142,125
099	0604642A	LIGHT TACTICAL WHEELED VEHICLES	53,564	9,671	53,564	–43,893	9,671
		Incomplete development goals		[–43,893]		[–43,893]	
100	0604645A	ARMORED SYSTEMS MODERNIZATION (ASM)—ENG. DEV.	102,201	102,201	102,201		102,201
101	0604710A	NIGHT VISION SYSTEMS—ENG DEV	48,720	133,143	56,220	34,109	82,829

1441

[1019] FY 2024 NDAA CONFERENCE REPORT, *supra* note 645, § 4201, at 726, 1441.

Appendix I – House Armed Forces Committee Markups to FY 2024 DoD Appropriations Act (Relevant Pages), Showing Cuts to DoD Budget Requests for HE TWV Acquisition Programs[1020]



118TH CONGRESS, 1st Session | HOUSE OF REPRESENTATIVES | REPORT 118–XXX

[FULL COMMITTEE PRINT]

DEPARTMENT OF DEFENSE APPROPRIATIONS BILL, 2024

XXXX , 2023.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. CALVERT of California, from the Committee on Appropriations, submitted the following

REPORT

together with

XXXX VIEWS

[To accompany H.R. XXXX]

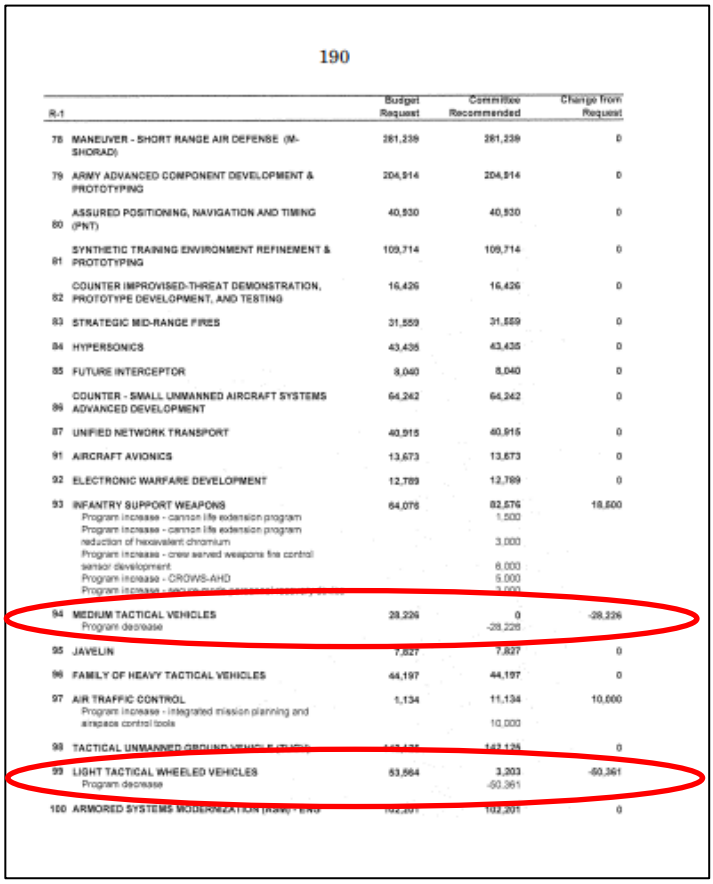
The Committee on Appropriations submits the following report in explanation of the accompanying bill making appropriations for the Department of Defense, and for other purposes, for the fiscal year ending September 30, 2024.

BILL TOTALS

Appropriations for most military functions of the Department of Defense are provided for in the accompanying bill for fiscal year 2024. This bill does not provide appropriations for military construction, military family housing, civil defense, and military nuclear warheads, for which requirements are considered in connection with other appropriations Acts.

The fiscal year 2024 President's budget request for activities funded in the Department of Defense Appropriations Act totals $826,162,133,000 in new discretionary budget obligational authority.

51–226



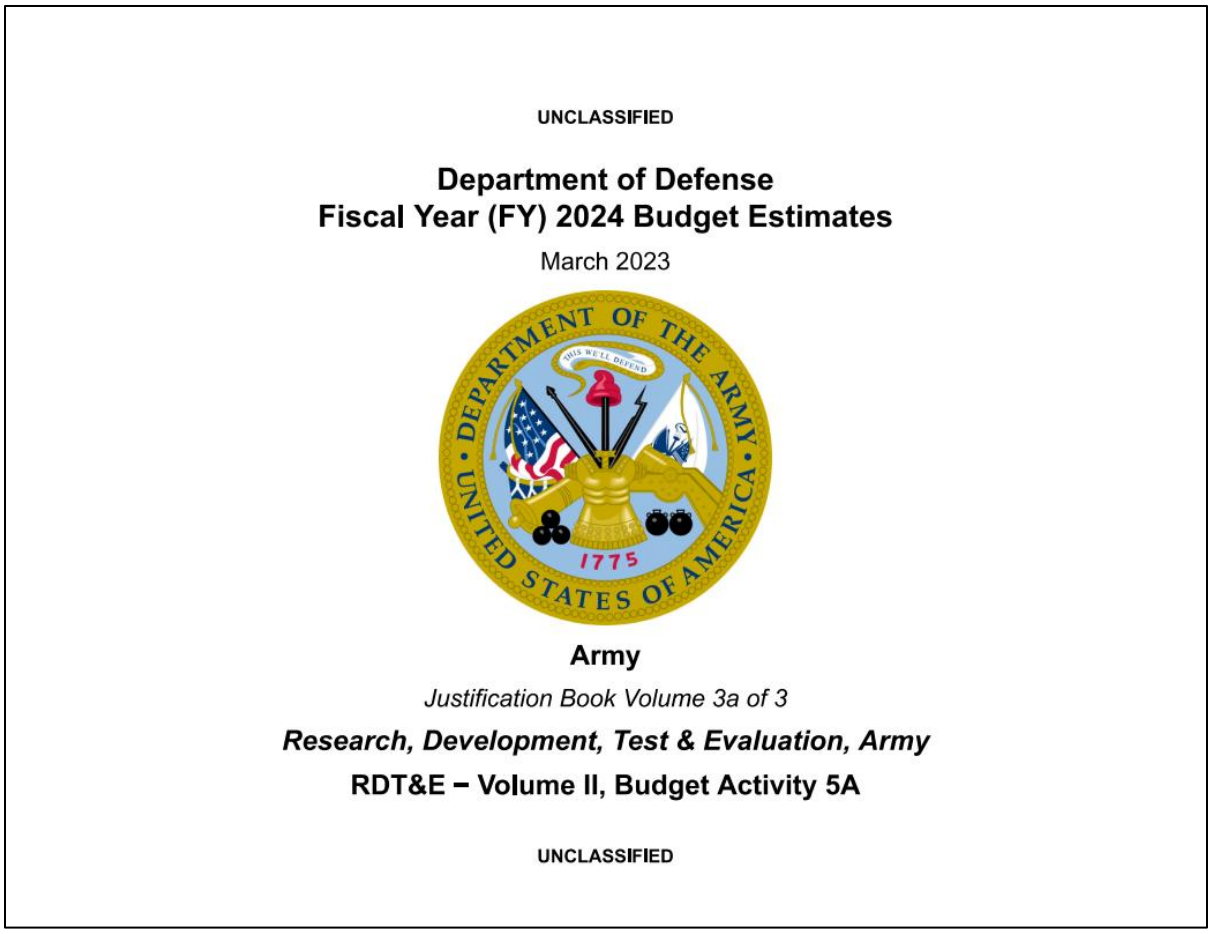
190

R-1		Budget Request	Committee Recommended	Change from Request
78	MANEUVER - SHORT RANGE AIR DEFENSE (M-SHORAD)	281,239	281,239	0
79	ARMY ADVANCED COMPONENT DEVELOPMENT & PROTOTYPING	204,914	204,914	0
80	ASSURED POSITIONING, NAVIGATION AND TIMING (PNT)	40,930	40,930	0
81	SYNTHETIC TRAINING ENVIRONMENT REFINEMENT & PROTOTYPING	109,714	109,714	0
82	COUNTER IMPROVISED-THREAT DEMONSTRATION, PROTOTYPE DEVELOPMENT, AND TESTING	16,426	16,426	0
83	STRATEGIC MID-RANGE FIRES	31,559	31,559	0
84	HYPERSONICS	43,435	43,435	0
85	FUTURE INTERCEPTOR	8,040	8,040	0
86	COUNTER - SMALL UNMANNED AIRCRAFT SYSTEMS ADVANCED DEVELOPMENT	64,242	64,242	0
87	UNIFIED NETWORK TRANSPORT	40,915	40,915	0
91	AIRCRAFT AVIONICS	13,673	13,673	0
92	ELECTRONIC WARFARE DEVELOPMENT	12,789	12,789	0
93	INFANTRY SUPPORT WEAPONS Program increase - cannon life extension program Program increase - cannon life extension program reduction of hexavalent chromium Program increase - crew served weapons fire control sensor development Program increase - CROWS-AHD	64,076	82,576 1,500 3,000 6,000 5,000	18,500
94	MEDIUM TACTICAL VEHICLES Program decrease	28,226	0 -28,226	-28,226
95	JAVELIN	7,827	7,827	0
96	FAMILY OF HEAVY TACTICAL VEHICLES	44,197	44,197	0
97	AIR TRAFFIC CONTROL Program increase - integrated mission planning and airspace control tools	1,134	11,134 10,000	10,000
98	TACTICAL UNMANNED GROUND VEHICLE (TUGV)	147,126	147,126	0
99	LIGHT TACTICAL WHEELED VEHICLES Program decrease	53,564	3,203 -50,361	-50,361
100	ARMORED SYSTEMS MODERNIZATION (ASM) - ENG	102,201	102,201	0

[1020] KAY GRANGER, H. COMM. ON APPROPRIATIONS, EXPLANATORY STATEMENT REGARDING H.R. 2882, FURTHER CONSOLIDATED APPROPRIATIONS ACT, 2024, DIVISION A – DEPARTMENT OF DEFENSE APPROPRIATIONS ACT, 2024, at 190, 193 (2024) https://docs.house.gov/billsthisweek/20240318/Division%20A%20Defense.PDF.

R-1		Budget Request	Committee Recommended	Change from Request
147	HYPERSONICS EMD	900,920	905,020	4,100
	AUR+C ahead of need		-13,364	
	Carryover		-12,536	
	Program increase - common hypersonic glide body		30,000	
148	ACCESSIONS INFORMATION ENVIRONMENT (AIE)	27,361	27,361	0
149	STRATEGIC MID-RANGE CAPABILITY	348,855	336,355	-12,500
	Carryover		-12,500	
150	INTEGRATED TACTICAL COMMUNICATIONS	22,901	22,901	0
151	JOINT AIR-TO-GROUND MISSILE (JAGM)	3,014	3,014	0
152	ARMY INTEGRATED AIR AND MISSILE DEFENSE (AIAMD)	284,095	296,095	12,000
	Program increase - intelligent multi-platform swarm defeat		12,000	
153	COUNTER - SMALL UNMANNED AIRCRAFT SYSTEMS SYS DEV & DEMONSTRATION	36,016	36,016	0
154	MANNED GROUND VEHICLE	996,653	996,653	0
155	NATIONAL CAPABILITIES INTEGRATION (MIP)	15,129	15,129	0
156	JOINT LIGHT TACTICAL VEHICLE (JLTV) ENGINEERING AND MANUFACTURING DEVELOPMENT	27,243	0	-27,243
	Program decrease		-27,243	
157	AVIATION GROUND SUPPORT EQUIPMENT	1,167	1,167	0
158	TROJAN - RH12	3,879	3,879	0
159	ELECTRONIC WARFARE DEVELOPMENT	137,186	137,186	0
160	THREAT SIMULATOR DEVELOPMENT	38,492	60,992	22,500
	Program increase - CSOC extended regional cyber spoke		12,500	
	Program increase - threat counter-artificial intelligence		10,000	
161	TARGET SYSTEMS DEVELOPMENT	11,873	26,873	15,000
	Program increase - replacement of foreign engines for aerial targets		5,000	
	Program increase - UAS 5G, AI, and cyber detection and mitigation		10,000	
162	MAJOR T&E INVESTMENT	76,167	92,967	16,800
	Program increase - advancing operational test infrastructure		16,800	
163	RAND ARROYO CENTER	37,078	37,078	0
164	ARMY KWAJALEIN ATOLL	314,872	314,872	0
165	CONCEPTS EXPERIMENTATION PROGRAM	95,551	95,551	0
167	ARMY TEST RANGES AND FACILITIES	439,118	447,118	8,000
	Program increase - WDTC		8,000	

Appendix J – FY 2024 DoD RDT&E Budget Estimates, Select Pages Showing Climate Nexus for HE TWV Acquisition Programs[1021]



UNCLASSIFIED

Department of Defense
Fiscal Year (FY) 2024 Budget Estimates

March 2023

Army

Justification Book Volume 3a of 3

Research, Development, Test & Evaluation, Army

RDT&E – Volume II, Budget Activity 5A

UNCLASSIFIED

[1021] FY24 Army RDT&E Budget Justification, *supra* note 77, at 1, 5, 166, 173–76, 248, 249.

UNCLASSIFIED
RESEARCH, DEVELOPMENT, TEST AND EVALUATION, ARMY
APPROPRIATION LANGUAGE

For expenses necessary for basic and applied scientific research, development, test and evaluation, including maintenance, rehabilitation, lease, and operation of facilities and equipment, $15,772,215,000.00 to remain available for obligation until September 30, 2025.

The FY 2024 Overseas Operations accounted for in the base budget are as follows:

In-theater and in-CONUS expenses that remain after combat operations cease and have been previously funded in Overseas Operations $3,166,000.00.

COST STATEMENT

The following Justification Books were prepared at a cost of $365,839.52: Aircraft (ACFT), Missiles (MSLS), Weapons & Tracked Combat Vehicles (WTCV), Ammunition (AMMO), Other Procurement Army (OPA) 1 – Tactical & Support Vehicles, Other Procurement Army (OPA) 2 – Communications & Electronics, Other Procurement Army (OPA) 3 & 4 - Other Support Equipment & Spares, Research, Development, Test and Evaluation (RDTE) for: Budget Activity 1, Budget Activity 2, Budget Activity 3, Budget Activity 4, Budget Activity 5A, Budget Activity 5B, Budget Activity 5C, Budget Activity 5D, Budget Activity 6, Budget Activity 7, and Budget Activity 8.

Exhibit R-2, RDT&E Budget Item Justification: PB 2024 Army			Date: March 2023
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* / BA 5: *System Development & Demonstration (SDD)*		R-1 Program Element (Number/Name) PE 0604604A / *Medium Tactical Vehicles*	

COST ($ in Millions)	Prior Years	FY 2022	FY 2023	FY 2024 Base	FY 2024 OCO	FY 2024 Total	FY 2025	FY 2026	FY 2027	FY 2028	Cost To Complete	Total Cost
Total Program Element	-	9.177	22.163	28.226	-	28.226	15.058	6.517	6.556	3.574	0.000	91.271
BX8: *Cold Weather All-Terrain Vehicle (CATV)*	-	1.759	-	-	-	-	-	-	-	-	0.000	1.759
H07: *Family Of Med Tac Veh*	-	7.418	22.163	28.226	-	28.226	15.058	6.517	6.556	3.574	0.000	89.512

A. Mission Description and Budget Item Justification

This Program Element (PE) supports continued modernization of the Army's Medium Tactical Wheeled Vehicle fleets by investigating technology insertions including, but not limited to: Predictive Logistics, vetronics, vehicle electrification and other climate change initiatives, Victory Architecture, autonomous operations and other emerging. technologies. Furthermore, the PE supports developing initial prototypes to enable refinement of Operational Requirements and early user feedback to support future sustainment and operational movement operating concepts to include developing technologies to improve safety, survivability and mobility in an arctic environment.

The Family of Medium Tactical Vehicles (FMTV) includes Cargo, Tractor, Load Handling System (LHS), Wrecker, Expandable Van, Shop Van, and Dump variants with payloads ranging from 3-tons to 10-tons and associated companion trailers. FMTV trucks perform over 55 percent of the Army's local haul, line haul, and unit resupply missions. It operates throughout theater as multi-purpose transportation vehicles in combat, combat support, and combat service support units. Funding from this Program Element will be used to support the continued evolution of the future FMTV fleet as well as tech insertion opportunities to keep the current FMTV fleet relevant on today's battlefield. This includes upgrades in survivability and crew protection, improved safety by leveraging advancements in commercial active safety technologies, modernizing the aging Low Velocity Air Drop (LVAD) fleet of vehicles, improved utilization through modularity, integration of advanced high efficiency powertrains and fuel saving technologies, and insertion of autonomous vehicle capabilities that will change the way transportation missions are conducted around the world.

FY 2024 Project H07 Base funds in the amount of $25.500 million will be used for Climate Initiatives, Predictive Logistics and Improved Vehicle Safety Technologies.

FY 2024 Project H07 Base funds in the amount of $2.726 million will be used to conduct Production Qualification Testing (PQT) of the FMTVA2 based LVAD. The three FMTV LVAD models (M1081, M1093, M1094) ended production in 2009 and represent the oldest vehicles in the FMTV fleet. These vehicles suffer from poor readiness due to maintenance and supply issues as many parts have gone obsolete. Updates to the LVAD fleet are needed to modernize the fleet.

Exhibit R-2A, RDT&E Project Justification: PB 2024 Army			Date: March 2023
Appropriation/Budget Activity 2040 / 5	R-1 Program Element (Number/Name) PE 0604604A / *Medium Tactical Vehicles*	Project (Number/Name) H07 / *Family Of Med Tac Veh*	

COST ($ in Millions)	Prior Years	FY 2022	FY 2023	FY 2024 Base	FY 2024 OCO	FY 2024 Total	FY 2025	FY 2026	FY 2027	FY 2028	Cost To Complete	Total Cost
H07: *Family Of Med Tac Veh*	-	7.418	22.163	28.226	-	28.226	15.058	6.517	6.556	3.574	0.000	89.512
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The FMTVA2 Production and Engineering Change Proposal (ECP) modernization effort restores vehicle performance that was lost due to the addition of armor protection kits as the threat to tactical vehicles and the FMTV has increased. The FMTVA2 also addresses Space, Weight, Power, and Cooling (SWaP-C) constraints from having to host an increasing amount of C4ISR and Counter-IED equipment. PD MTV is executing the FMTVA2 effort documented in a signed Acquisition Decision Memorandum by the AAE on 18 November 2015.

This Project also supports development of Climate Change initiatives such as Vehicle Electrification, Onboard Vehicle Power, Predictive Logistics (PL) and other climate change related technologies for the Tactical Wheeled Vehicle fleet.

The FMTVA1P2 ended production in 2021 and represents the highest density FMTV model with over 40,000 vehicles fielded to date. The FMTVA1P2 will remain in the tactical vehicle fleet until 2040 and beyond. To ensure supportability of the FMTVA1P2 through FY 2040 and beyond, the PD MTV, as lifecycle managers for the system, shall address potential obsolescence issues with the powertrain and Material Handling Equipment used on the FMTV.

Increasing survivability and crew protection of the FMTVA1P2 comes at the expense of decreased vehicle mobility and performance in soft soil and winter environments. The FMTVA1P2 is being asked to carry more weight than what it was originally designed for. Low risk, highly commercial improvements to the FMTVA1P2 driveline, suspension, and tires can be made to minimize the loss in mobility performance.

FY 2024 Project H07 Base funds in the amount of $.500 million will be used for development and integration of Improved Vehicle Safety Technologies, including active safety technologies such as front collision warning, collision mitigation, lane keeping assist, adaptive cruise control, and 360 degree situational awareness.

FY 2024 Project H07 Base funds in the amount of $2.726 million will be used for Low Velocity Air Drop (LVAD) Automotive Performance Qualification (PQT) testing.

FY 2024 Project H07 Base funds in the amount of $25.000 million will be used to continue the development, test, and integration of Climate Change initiatives such as Tactical Vehicle Anti-Idle Retrofit Kit, On Board Vehicle Power, Hybrid Propulsion, Predictive Logistics (PL) development and other technologies associated with the combatting climate change for the Tactical Wheeled Vehicle fleet.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2022	FY 2023	FY 2024
Title: FMTVA2 Production and ECP Modernization Effort	2.300	2.354	0.500
Description: Funding used to support the continued evolution of the future FMTV fleet as well as tech insertion opportunities to keep the current FMTV fleet relevant on today's battlefield.The FMTVA2 production and ECP modernization effort restores			

Exhibit R-2A, RDT&E Project Justification: PB 2024 Army		Date: March 2023
Appropriation/Budget Activity 2040 / 5	**R-1 Program Element (Number/Name)** PE 0604604A / *Medium Tactical Vehicles*	**Project (Number/Name)** H07 / *Family Of Med Tac Veh*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2022	FY 2023	FY 2024
vehicle performance that was lost due to the addition of armor protection kits as the threat to tactical vehicles and the FMTV has increased. Live Fire test assets are needed to support Live Fire Testing required per Chapter 139, Title 10 USC. Operational Testing required per Chapter 141, Title 10 USC. ***FY 2023 Plans:*** FY 2023 will continue to fund the Operational Test (OT) and implementation of Predictive Logistics ***FY 2024 Plans:*** FY 2024 will continue to fund the development of Improved Vehicle Safety Technologies ***FY 2023 to FY 2024 Increase/Decrease Statement:*** FY 2024 decrease due to the completion of Operational Test in FY2023 and transition to development of Improved Vehicle Safety Technologies with emphasis towards Climate Change initiatives and Low Velocity Air Drop (LVAD) requirements.			
Title: FMTV LVAD Next Generation Model ***Description:*** Updates to the FMTV Low Velocity Air Drop (LVAD) are needed to address obsolescence issues and to modernize the fleet. ***FY 2023 Plans:*** FY 2023 budget activities include the LVAD STS Work Directive Task 2, conversion of nine prototype test assets (M1081 and M1093), production of four Live Fire trucks along with LVAD Survivability Live Fire testing. ***FY 2024 Plans:*** FY 2024 will fund the LVAD Automotive Production Qualification Testing, Transportation testing, LVAD Airdrop safety certification testing. ***FY 2023 to FY 2024 Increase/Decrease Statement:*** FY 2024 decrease reflects completion of LVAD prototype build.	5.118	4.000	2.726
Title: Climate Change Initiatives ***FY 2023 Plans:*** FY2023 Project H07 Base funds in the amount of $15.000 million will be used for Anti-idle retrofit kit prototype testing for MTV and the development and engineering of kits for the HTV fleet. It will fund the integration, start of test, and procure both On board vehicle Power and HTV anti-idle prototypes kits. Funds will also support development and engineering of FuelSense 2.0 technologies, and an electric M915 Study, as well as fund the development of other technologies associated with the combatting	-	15.000	25.000

Exhibit R-2A, RDT&E Project Justification: PB 2024 Army		Date: March 2023
Appropriation/Budget Activity 2040 / 5	**R-1 Program Element (Number/Name)** PE 0604604A / *Medium Tactical Vehicles*	**Project (Number/Name)** H07 / *Family Of Med Tac Veh*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2022	FY 2023	FY 2024
climate change, power and battery modernization strategies and the support of artic strategies for the Tactical Wheeled Vehicle fleet. ***FY 2024 Plans:*** FY2024 Project H07 Base funds in the amount of $25.000 million will be used to develop engineer change proposals for the MTV Anti-Idle kits and continue to fund the HTV prototype development and test. It will procure On board vehicle Power prototypes kits, fund the integration and start of test. Funds will also support testing of FuelSense 2.0 technologies, as well as fund the development of other technologies associated with the combatting climate change, power and battery modernization strategies and the support of artic strategies for the Tactical Wheeled Vehicle fleet. ***FY 2023 to FY 2024 Increase/Decrease Statement:*** $10M increase specifically intended to continue to develop Anti-Idle capability for the Tactical Wheeled Vehicle Fleet.			
Title: SBIR/STTR Transfer ***FY 2023 Plans:*** SBIR/STTR Transfer ***FY 2023 to FY 2024 Increase/Decrease Statement:*** Decrease due to SBIR/STTR Transfer	-	0.809	-
Accomplishments/Planned Programs Subtotals	7.418	22.163	28.226

C. Other Program Funding Summary ($ in Millions)

Line Item	FY 2022	FY 2023	FY 2024 Base	FY 2024 OCO	FY 2024 Total	FY 2025	FY 2026	FY 2027	FY 2028	Cost To Complete	Total Cost
• D15500: *Family Of Medium Tactical Veh (FMTV)*	136.152	120.636	110.734	-	110.734	117.668	110.073	112.160	107.172	0.000	814.595
• D04016: *MEDIUM TACTICAL VEHICLE PROTECTION KITS*	3.800	20.000	0.000	-	0.000	-	-	-	-	0.000	23.800

Remarks

D. Acquisition Strategy

The strategy for the FMTVA2 Production and Engineering Change Proposal (ECP) Modernization Effort led to award of a Firm-Fixed Price Requirements contract that will have a base award of five years (two years for vehicle testing and three production years) with two, one-year option production periods and to conduct FMTVA2 Live Fire and Operational Testing. These efforts will utilize Government test facilities.

The strategy for the Next Generation FMTV LVAD Model Configuration is to address obsolescence issues and bring the configuration up to today's standards. This effort

will utilize a System Technical Support (STS) contract with the current FMTV Original Equipment Manufacturer (OEM).

The strategy to develop, integrate, and test Improved Vehicle Safety Technologies is to leverage active safety capabilities developed commercially and adapt for military use on the FMTV. The development and integration will be conducted either via STS Task Order with the vehicle OEM or an Other Transaction Authority (OTA) with industry.

The FMTV program will continually monitor emerging technologies and capabilities and leverage existing partnerships within the science and technology centers as well as through industry market research and partnerships in order to support the Army's Climate Change strategy . The anticipated outcomes of these efforts are fully validated Engineering Change Proposals that can be applied to the current and future FMTV fleet.

The FMTV program will procure prototypes via Other Transaction Authority (OTA) Agreements for test and evaluation, including soldier touch points to gain user feedback. The OTAs then offer a path to transition to production.

Exhibit R-2, RDT&E Budget Item Justification: PB 2024 Army			Date: March 2023
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* / BA 5: *System Development & Demonstration (SDD)*		R-1 Program Element (Number/Name) PE 0604642A / *Light Tactical Wheeled Vehicles*	

COST ($ in Millions)	Prior Years	FY 2022	FY 2023	FY 2024 Base	FY 2024 OCO	FY 2024 Total	FY 2025	FY 2026	FY 2027	FY 2028	Cost To Complete	Total Cost
Total Program Element	-	1.980	-	53.564	-	53.564	100.316	56.329	1.813	0.807	0.000	214.809
E40: *LTV Prototype*	-	1.980	-	53.564	-	53.564	100.316	56.329	1.813	0.807	0.000	214.809

A. Mission Description and Budget Item Justification

The Army Infantry Squad Vehicle (ISV), through enhanced tactical mobility, will motorize the Infantry Brigade Combat Teams (IBCT) and the 75th Ranger Regiment with their associated equipment to move quickly around the battlefield. This capability is required across the range of military operations conducting crisis response, initial entry, and selected decisive action missions. ISV deploys worldwide by sea, air, and land modes to support strategic deployment and operational maneuver in accordance with Army and Joint doctrine. This capability provides flexibility for entry operations (permissive and non-permissive) to counter threat anti-access strategies by using multiple austere entry points to bring in combined arms configured units.

The electric Light Reconnaissance Vehicle (eLRV) platform through electrification will provide commanders a substantial competitive advantage in the Multi-Domain Operational (MDO) Environment against threat capabilities through reduction in acoustic and thermal signature, silent mobility, increased dash speed, extended range, increased reliability and reduction in Class (CL) III requirements. These attributes will enhance lethality and survivability of the mounted reconnaissance squad, platoon and troop.

Funding supports modernization of the current Tactical Wheeled Vehicle fleets by investigating technology insertions including, but not limited to: predictive logistics, vetronics, Victory Architecture, autonomous operations and other emerging technologies. Funding also supports developing initial prototypes to enable refinement of Operational Requirements and early user feedback to support future sustainment and operational movement operating concepts.

FY 2024 Ground Mobility Vehicles (GMV) budget activities in the amount of $9.671 million includes the development and testing of the Infantry Squad Vehicle (ISV) Security Force Assistance Brigade (SFAB) vehicle configuration kits and the initiation of eLRV Middle Tier of Acquisition Rapid Prototyping (MTA-RP). Product Director Ground Mobility Vehicle (PD GMV) will award contract/agreements to up to four vendors to procure eLRV Prototypes, conduct developmental testing, and conduct a Soldier Touch Point.

The eLRV program is pursing a Middle Tier of Acquisition (MTA) Rapid Prototyping (RP) pathway to compete solution.

The Army's High Mobility Multipurpose Vehicle (HMMWV) is a lightweight, high performance four-wheel drive, air transportable and air droppable family of tactical vehicles. The vehicle comes armored and unarmored with several different configurations: Command and Control; Cargo/Shelter Carrier; Weapons Carrier and Ambulance and is capable of performing multiple mission roles for personnel and payloads across the full spectrum of military operations.

A HMMWV Hybrid Electric Vehicle (HEV) mitigates a gap in Large-Scale Combat Operations to employ semi-independent maneuver in a Multi-Domain Operational (MDO) environment. A HMMWV HEV will seek to improve and provide new capabilities such as silent mobility, extended silent watch, reduced fuel consumption,

increased automotive performance, increased on-board vehicle power (Direct Current), available export power (Alternating Current), integrated charging, potential Vehicle-To-Grid (V2G) and reduced greenhouse gas emissions.
HMMWV HEV funding supports the Army's Climate Strategy (Line of Effort 2.1) to modernize existing platforms by adding electrification technologies.

FY2024 HMMWV HEV budget activities in the amount of $43.893 million will initiate design, development and testing for prototype HMMWV HEV solutions.

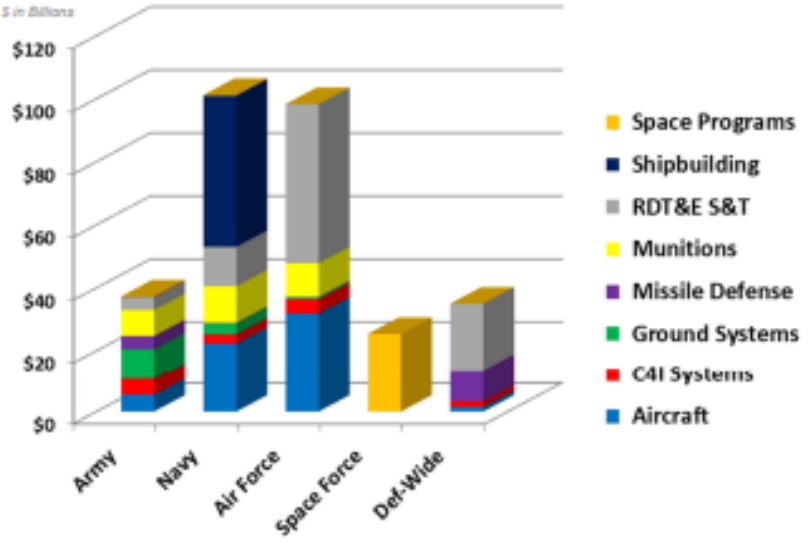
B. Program Change Summary ($ in Millions)	FY 2022	FY 2023	FY 2024 Base	FY 2024 OCO	FY 2024 Total
Previous President's Budget	2.055	0.000	0.000	-	0.000
Current President's Budget	1.980	0.000	53.564	-	53.564
Total Adjustments	-0.075	0.000	53.564	-	53.564
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-0.075	-			
• SBIR/STTR Transfer	-	-			
• Adjustments to Budget Years	-	-	53.564	-	53.564

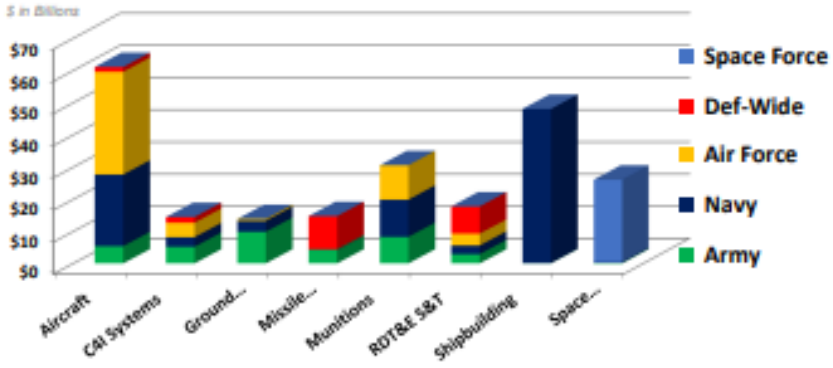
Change Summary Explanation
FY 2024 Increase of $9.671M is for Infantry Squad Vehicles (ISV) Security Force Assistance Brigade (SFAB) kit integration/testing and the first year of eLRV program.

FY 2024 increase of $43.893M is the first year of HMMWV Hybrid Electric Vehicle (HEV) funding and will initiate design, development and testing for prototype HMMWV HEV solutions.

Appendix K – The Distribution of Funding in FY 2024 DoD Budget Request for Procurement and RDT&E by Component and Category

The Distribution of Funding in FY 2024 for Procurement and RDT&E by Component and Category*





** Funding in Mission Support activities are not represented in the above displays.*

1022

[1022] OUSD, PROGRAM ACQUISITION COSTS, *supra* note 615, at ii.