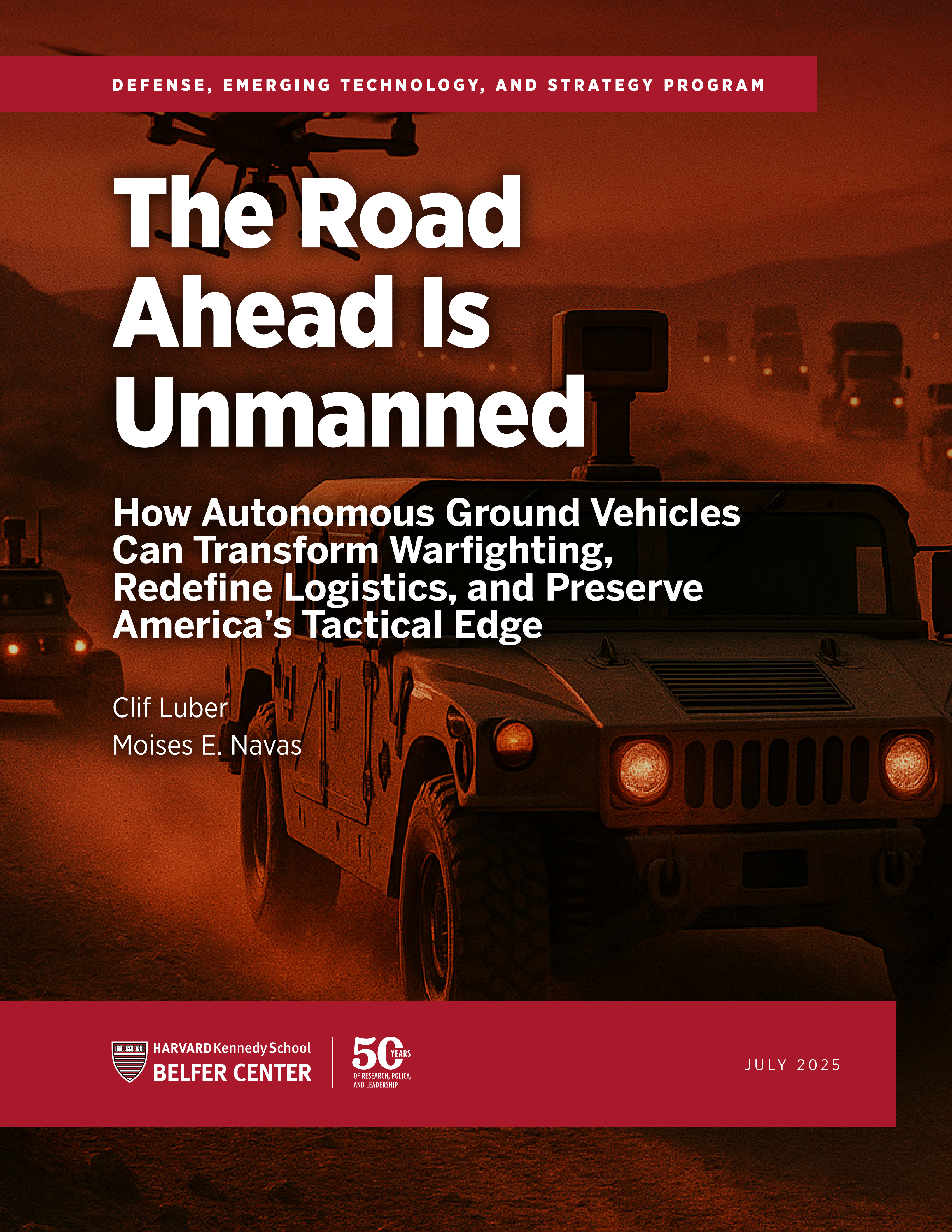

DEFENSE, EMERGING TECHNOLOGY, AND STRATEGY PROGRAM

The Road Ahead Is Unmanned

How Autonomous Ground Vehicles Can Transform Warfighting, Redefine Logistics, and Preserve America's Tactical Edge

Clif Luber
Moises E. Navas

HARVARD Kennedy School
BELFER CENTER

50 YEARS OF RESEARCH, POLICY, AND LEADERSHIP

JULY 2025

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About the Defense, Emerging Technology, and Strategy Program

The Defense, Emerging Technology, and Strategy (DETS) program has a dual mission to advance policy-relevant knowledge and strategy on the most important challenges at the intersection of security and emerging technology; and prepare future leaders for public service in relevant arenas. The DETS program focuses on defense policy issues, public sector strategy execution, and new technologies that have emerged as pivotal to the future of international security. Through its programming, the DETS program seeks to train a new generation of technology-savvy policy and strategy leaders within the Kennedy School.

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Executive Summary

The Department of Defense (DoD) should fundamentally reshape military operations and combat effectiveness through the rapid adoption and integration of autonomous ground vehicles (AGVs) in advance of publishing its next National Defense Strategy (NDS). Over the last decade, warfare has evolved to feature more complex and contested environments. Autonomous vehicle technology has also innovated tremendously due to private sector innovations. These dynamic changes mean the DoD should better leverage AGV capabilities to reduce risk to servicemembers and provide greater battlefield sustainment.

There is a pressing need for the U.S. military to actively embrace AGVs to maintain tactical and operational superiority to achieve strategic deterrence against our near-peer adversaries. To capitalize effectively on this emerging technology, the DoD must prioritize commercial autonomy solutions, enforce open-architecture standards to avoid vendor lock-in, and accelerate operational experimentation within frontline units through flexible and rapid acquisition frameworks like Other Transaction Authorities (OTAs). Adding AGV training and familiarization within standard military training and doctrine would improve operational readiness and battlefield integration for a future fight, while maintaining safety for service members. Institutional resistance and traditional acquisition practices present substantial hurdles and overcoming them requires immediate, decisive policy action and sustained leadership focus.

This report recommends the DoD immediately adopt an **"Autonomy First"** framework featuring commercially available autonomy software and modular hardware platforms, standardized interoperability across service branches, and continuous frontline experimentation with intensive ground autonomy unit training. Additionally, we strongly recommend allocating additional resources, mostly funding, to ensure sustained momentum and full operational integration of AGVs. The DoD and the Army should leverage existing, innovation-forward organizations (like the Defense Innovation Unit and the Chief Digital Artificial Intelligence Office) to advance AGV procurement and production. This will ensure that the U.S. military maintains its strategic edge, enhances lethality, and maximizes warfighter capabilities in the rapidly evolving battlefield landscape.

Key Recommendations:

Recommendation #1: Immediately Cease Acquiring Manned Ground Systems

To catalyze a shift toward autonomy, the DoD should place a moratorium on new programs or purchases of ground vehicles that lack autonomous capabilities. Existing manned vehicle programs may continue only if they include autonomy or are compatible with retrofitting kits.

Recommendation #2: Adopt Commercial Autonomy Software as Default

DoD acquisition should begin with commercial ground autonomy software, leveraging proven private-sector solutions to speed capability delivery. A "Blue Convoy" vendor list—modeled after Blue UAS—should streamline and secure autonomy procurement across Services.

Recommendation #3: Acquire and Deploy AGVs at Scale Right Away

One of the DoD joint innovation organizations should lead a unified, accelerated acquisition effort across all Services to procure and field hundreds of AGVs by FY 2028, with strict performance and delivery metrics. Simultaneously, U.S. allies should be encouraged to integrate AGVs into their forces to support interoperability and global deterrence.

Recommendation #4: Use Rapid Field Experimentation as the Default Acquisition Model

AGV development and deployment should be driven by rapid experimentation within pilot units under real-world conditions, with centralized oversight by the one of the DoD joint innovation organizations. This includes deployments to controlled environments like the U.S. Southern Border and leveraging innovation efforts such as Golden Dome.

Recommendation #5: Fund Doctrine and Training in Parallel with Procurement

Doctrine, training, and simulation for AGVs must be developed and fielded alongside hardware to ensure units can effectively integrate autonomy into operations. Service schools and COCOMs should immediately begin updating curricula, doctrine, and simulation tools to institutionalize man-machine teaming.

Introduction

Ground Autonomy is gaining tremendous momentum from both commercial and government customers. As defense tech becomes an industry of its own, all domain areas are being affected by the rapid advancement of technological innovation. However, the government lags in adoption in most domains; therefore, this paper seeks to propose efforts to ensure the ground domain turns momentum into meaningful action. Progress in commercial autonomy software from startups and continued interest from more traditional defense primes demonstrate that there is ongoing commercial-military convergence with software-defined warfare approaches and dual-use hardware.[1] Simply put, to gain or maintain a technological edge in the ground domain, an "Autonomy First" mindset must be adopted across the Services.

Through our research, it has become clear that many sources often conflate Unmanned Ground Vehicles (UGVs) and Autonomous Ground Vehicles. We make the concerted effort to clearly label our examples and recommendations with a clear distinction. Though we use UGVs as brief examples, our recommendations and focus remain on AGVs as the need for "Autonomy First" lends to. <u>All AGVs are UGVs: however, not all UGVs are AGVs</u>. While UGVs are still necessary on the battlefield; the effort towards autonomy in ground vehicles can only succeed with a focus on AGV production, technology, and policy.

Unmanned Ground Vehicle- UGVs are land vehicles that operate without a human operator on-board.

Autonomous Ground Vehicle- AGVs are robotic vehicles that can perform some or all aspects of their operations without the need for direct input from a human.

1. Current Landscape of Ground Autonomy

The current landscape of AGVs could support multiple military functions:

1.1 Logistics AGVs

Autonomous vehicle (AV) technology in military logistics spans a variety of uses, from teleoperation and "leader-follower" configurations, where a human-driven lead vehicle is followed autonomously by others, to fully autonomous navigation along pre-planned routes. The U.S. Army has long demonstrated leader-follower capabilities through efforts at the Tank Automotive Research, Development and Engineering Center (TARDEC), which began equipping Palletized Load System (PLS) trucks with robotic kits in 2017. With the core R&D proving the feasibility of unmanned convoys, this initiative is now shifting from internal development to commercial procurement.

Autonomous vehicles' technology level range from teleoperated or "leader-follower" (a human drives one vehicle and others follow autonomously) to fully self-driving along planned routes.[2] The technology for leader-follower convoying has been demonstrated for years through the Army's Tank Automotive Research Center, which outfitted dozens of PLS trucks with robotic driving kits in a program that began in 2017.[3] That internal effort is now transitioning to a commercial solicitation since the R&D prototype proved that unmanned convoys are feasible.

On the commercial side, self-driving truck companies such as Neya Systems, Forterra, and Kodiak Robotics have adapted their software for military use and demonstrated autonomous driving by tactical vehicles. The same core software that powers these companies' highway trucks worked for the military pickup truck, underscoring the capability to use commercial AV technology for military logistics and passenger vehicles.[4, 5]

1.2 Tactical Reconnaissance and Combat Support UGVs

Reconnaissance robotic vehicles are intended to scout ahead of units, provide fire support, or perform security missions. Examples range from man-portable robots with sensors (like small throwable robots used for room-clearing) up to larger armed UGVs such as the planned U.S. Army Robotic Combat Vehicle (RCV) family. These systems typically need a mix of remote control and autonomy, such as navigating to a vantage point autonomously and then having a human operator control a sensor or weapon. Many armed UGVs are still in prototype or testing phase globally. The U.S. Army is testing RCV light and medium prototypes (some built on modified vehicles like the Textron's Ripsaw chassis).[6] These have shown promise in exercises but are not yet in production or supporting operational units.

1.3 Engineering/EOD robots

A longstanding field from advancements and implementation of these vehicles during the War on Terror, these include unmanned ground vehicles for mine clearance, explosive ordnance disposal (bomb squads' robots), and engineering tasks (like breaching obstacles). They tend to be remote-controlled with perhaps limited autonomous navigation. Notably, the U.S. Army's most widely used UGV of the past decade has been the Common Robotic System - Heavy.[7] A mine-clearing robot, this UGV was used in Syria and Iraq to clear mines and IEDs (always deployed in safe areas after combat units secured the vicinity).

Across these categories, the core enabling technologies are sensors (cameras, RADAR, LIDAR), GPS and inertial navigation, and AI/software (for perception and decision-making). As Moore's law has continued and computer power drastically increases as semiconductor power doubles every two years, these core AV technologies have only become increasingly more mature now in 2025. Commercial investment has pushed these technologies to a high degree of maturity for on-road use. For example, self-driving cars can navigate cities, and energy companies are currently using autonomous haul trucks continuously on private roads in the Permian Basin.[8] Off-road autonomy in unstructured environments, as required for military operations, remains more challenging but has seen significant progress. Advanced AGVs can detect and avoid obstacles, follow terrain, and even function without GPS by using vision-based navigation.[9]

1.4 Current Programs and Status Updates

There are multiple existing DoD programs that have been started over the last 8 years:

1.4.1 Army's S-MET robotic mule

In fall of 2017, the Army hosted a demonstration of four prototypes for their first Squad Multipurpose Equipment Transport (SMET) vehicle contract.[10] This vehicle was intended to carry the physical loads for an entire infantry squad (9 soldiers) by carrying 1000 lbs. total for 60 miles in under 72 hours.[11] In 2018, the U.S. Army selected General Dynamics Land Systems' Multi-Utility Tactical Transport (MUTT) for this unmanned program of record.[12] In 2022, GD delivered 16 of them to the Army, and in 2024 the Army selected Phase II winners of the program.[13, 14]

Figure 1- Army's S-MET robotic mule[15]

1.4.2 Ground Expeditionary Autonomy Retrofit System (GEARS) program

GEARS is an ongoing Defense Innovation Unit (DIU) initiative for autonomous truck retrofits of the navigation system of 41 Palletized Load System (PLS) vehicles, with the possibility for more in the future.[16] The program transitioned to become the Autonomous Transport Vehicle System (ATV-S) and there are now two selected vendors: Carnegie Robotics and Forterra, who are both currently building their prototypes.[17] The operational perk of a system like this is reducing the risk of convoy targeting on troops' lives while also ensuring the continuous flow of supplies.[18]

1.4.3 Robot Combat Vehicle (RCV) program

RCV is the Army's largest autonomous vehicle undertaking for companies to build scouts and escorts for manned fighting vehicles to guard their flanks to deter ambushes, with ideally multiple autonomous RCVs controlled by a single operator.[19] The initial award was $24 million total to four companies to build a prototype for a "fly off" in August 2024. Though they initially wanted three different sizes of vehicles, due to financial constraints, the Army decided they would only down-select one vehicle for the final RCV program.[20] They chose to first focus on the Light variant, the smallest of the planned three sizes.[21] In March of 2025, the Army announced Textron's RIPSAW 3 won the sole RCV down-selection.[22] However, in May 2025, immediately after the Army Transformation Initiative was announced, the Army paused the RCV program citing it as expensive and too hardware focused.[23]

Figure 2- Robot Combat Vehicle[24]

1.4.4 Ground Vehicles Autonomous Pathways (GVAP) project

The GVAP project took autonomous navigation, machine learning, and software system integrators to create the RCV's rapid integration of multiple payloads. Eight companies were selected between the multiple categories to include Anduril, Palantir, Scale AI, Applied Intuition, Forterra, Kodiak Robotics, Neya Systems, and Overland AI. This program was a precursor to RCV but has transitioned to Services now.[25]

1.4.5 XM30 Mechanized Infantry Combat Vehicle program

The XM30, previously called the Optionally Manned Fighting Vehicle, seeks to be a replacement for the Bradley Fighting Vehicle as a part of the Next Generation Combat Vehicle family of systems.[26] The current prototypes selected are soliciting soldier feedback to ensure the vehicle can meet current and future operational needs.

Figure 3- XM30 Mechanized Infantry Combat Vehicle[27]

1.4.6 Common Tactical Truck (CTT)

The CTT program is an Army effort to begin fielding several tactical and logistics vehicles with some autonomous sensors starting with a trickle of new vehicles in 2028. Although the vehicles will not be fully autonomous they will have "some level of features such as digital linkages, cameras and sensors that will enable acceptance of autonomy systems."[28] We will argue later that this is not autonomous enough and not on a fast enough timeline.

1.4.7 NMESIS/ROGUE Fires

The Marine Corps recently started the ROGUE Fires program, a $30 million program for an uncrewed vehicle that carries a Navy Marine Expeditionary Ship Interdiction System (NMESIS) on a JLTV chassis. This is currently one of the only autonomous vehicle contracts in production in the DoD.[29]

Figure 4- NMESIS/ROGUE Fires[30]

2. Strategic Context

These programs are an effort to modernize and accomplish the lines of effort outlined in recent National Defense Strategies, which have increasingly focused on preparing the U.S. military for near-peer conflicts. Fighting a near-peer adversary introduces complex challenges. Peer conflict scenarios, such as potential engagements in the Indo-Pacific or Eastern Europe, involve contested or denied terrain, long supply lines vulnerable to enemy interdiction, and precision-guided threats capable of targeting traditional logistics operations.

Many industry experts believe that current commercial technology can meet the moment of great-power competition: "Commercial technologies and economies of scale exist that will enable the Army to close technological gaps," said Kyle Bruner, Project Manager for Force Projection at PEO CS&CSS.[31] Autonomous Vehicle (AV) technology development has steadily progressed ever since the DARPA Grand Challenge initiated major breakthroughs in autonomy; however, commercialization has lagged behind earlier predictions. The relatively slow adoption of commercial AV technology can be partly attributed to limited demand signals in the civilian market, where research and development (R&D) efforts have predominantly emphasized safety improvements for driverless robotaxis and larger vehicles like semi-trucks.[32] This limited scope has restrained the broader and faster development of autonomous capabilities.

It is important to highlight the contrast between commercial and military-grade AGVs. Increasingly, this line is blurring, as many military AGVs are adaptations of commercial platforms or incorporate commercial components. For instance, the Army's selection of autonomy vendors for the GEARS program explicitly sought out "existing commercial experts to embed autonomy" into military trucks. The down-selected companies have roots in both defense and commercial sectors, and their autonomy software capitalizes on advancements developed primarily for self-driving civilian vehicles.

Despite strong foundational commercial capabilities, there remains an urgent need for the DoD to provide a clear and substantial demand signal to the market. This demand must go beyond safety improvements in civilian passenger and logistics vehicles and instead focus specifically on addressing military operational requirements. Lieutenant Colonel Will Ryan, DIU Autonomy Program Manager, recently said: "Incorporating these sophisticated systems into military contexts not only bolsters our tactical strengths but also paves the way for innovative strategies and operational efficiencies that save lives, reduce cognitive burdens, and free up Soldiers to execute more complex missions."[33]

Over the last decade, private industry has been shown mixed demand signals regarding accelerating the procurement, deployment, and scaling of AGVs.[34] Moving forward, the DoD should follow a less piecemeal approach so U.S. forces could enhance their future lethality, joint interoperability, and capabilities when alongside allied militaries.

3. Opportunities of Ground Autonomy

3.1 Force Protection

AGVs offer a transformative opportunity to protect U.S. and allied forces by reducing their exposure to lethal threats during high-risk missions. In traditional operations, logistics convoys and resupply missions are among the most vulnerable to ambushes, improvised explosive devices (IEDs), and indirect fire. AGVs provide a solution by physically removing troops from these predictable, high-threat scenarios.

Unmanned logistics vehicles can deliver critical supplies, such as ammunition, water, medical gear, into forward or contested areas without risking human drivers. This capability enables commanders to sustain forces in kill zones or denied terrain even when manned resupply would be tactically infeasible. Whether it's traversing mined roads, navigating under indirect fire, or resupplying dispersed units at night, autonomous vehicles provide a persistent, risk-tolerant means of logistics support.

Leader-follower systems have demonstrated the ability to significantly reduce the number of personnel required for convoy operations, cutting exposure by replacing multiple manned vehicles with autonomous followers.[35] Fully autonomous vehicles push this even further, offering the possibility of resupply under fire or through terrain too dangerous for manned movement.[36] As future operations emphasize dispersed formations and contested logistics, ground autonomy is not a luxury: it is a critical enabler of survivability.

3.2 Constant Operational Tempo

AGVs unlock a significant operational advantage: continuous, around-the-clock mobility without the limitations of human fatigue. AGVs offer a scalable solution to sustain pressure on the enemy while maintaining operational endurance.[37]

Unlike human drivers, AGVs do not require rest cycles, sleep, training proficiency updates, or sustenance. They can operate through the night, across shifts, and over extended missions without the performance degradation that affects human crews. This enables a sustained cadence of resupply, reconnaissance, or support that far exceeds current manned logistics timelines. Whether it's maintaining ammunition flow during prolonged engagements or delivering fuel across extended frontlines, autonomous vehicles reduce the natural friction points of warfighting logistics.

For units operating in dispersed or dynamic environments, such as multi-domain operations or littoral combat zones, this capacity for uninterrupted, automated support becomes critical. AGVs can be tasked with pre-planned, staggered, or reactive missions without delay, ensuring that no unit is left unsupported due to crew exhaustion, limited shifts, or weather-imposed restrictions.

The strategic payoff is tempo dominance: the ability to maneuver and resupply faster than the adversary, keep frontline units supplied during extended operations, and sustain momentum in ways that human-operated convoys cannot match. In a future fight where responsiveness, resilience, and speed are decisive, ground autonomy offers not just marginal gains, it offers an exponential leap in battlefield tempo.

3.3 Operational Logistics Improvements and Distributed Resupply

Over the last decade, the U.S. military has made strategic-level guidance shifts to focus more force-wide efforts on lethality. Part of their mantra was focusing on distributed lethality. The focus on distributing assets is an effort to solve geographic constraints when facing a near peer enemy. Along similar lines, strategic-level leadership (Combatant Commands and Service Chiefs) should be focusing on distributed resupply. The concept of distributed resupply means instead of using large convoys, a commander could dispatch many small autonomous vehicles through multiple routes to a frontline unit, making it harder for the enemy to interdict all supply lines.

Another emerging concept seen in Ukraine is using small AGVs as "wingmen" for infantry, carrying extra ammunition or even mounting weapons to provide support.[38] Troops on patrol could be followed by a robot carrying heavy gear (water, ammo, anti-tank weapons), vastly increasing the unit's endurance and firepower. If contact with the enemy occurs, a robot could also serve as a mobile cover or an expendable decoy drawing fire. The Army's RCV program is developing unmanned scout vehicles moving ahead of manned tanks. In a logistics sense, one can imagine unmanned fuel tankers accompanying armored formations, refueling them periodically without needing a manned fuel truck to catch up.

3.4 Tactical Flexibility

AGVs would allow unit commanders to operate with smaller, more agile teams that are no longer tethered to traditional logistics patterns or fixed resupply points.[39] In future conflicts, particularly those against peer adversaries, maneuver warfare will demand dispersion, unpredictability, and constant adaptation. AGVs support this by allowing sustainment and support to follow maneuvers, rather than dictating it.[40]

Decoupling resupply from large, centralized convoys with AGVs would allow units to maneuver independently along multiple axes of advance: units can remain forward-deployed longer, reposition more fluidly, and operate in terrain or conditions that would otherwise be unsustainable due to supply constraints. AGVs help remove logistics as a constraint on operational creativity. This technological augmentation is especially critical as the DoD shifts towards more distributed, decentralized concepts of employment across domains and theaters.

3.5 Increased Efficiency and Safety

AGVs can increase operational efficiency by freeing up manpower and reducing vehicle idle time, enabling military personnel to focus on higher-priority tasks that require human judgment and expertise.[41] AGVs can operate continuously without the need for rest or shift changes by automating repetitive logistics functions, which increases vehicle throughput, minimizes downtime, and maximizes vehicle utilization rates.

More importantly, this will increase safety for all servicemembers. In the same way commercial autonomy is focused on safety, the DoD should consider the same benefits for improving service members' safety while operating or riding in vehicles. Furthermore, autonomous vehicles can play a strong role in combat environments by reducing troop exposure during logistics convoys and resupply missions. AGVs present a compelling case for modern militaries seeking to enhance logistical efficiency while simultaneously achieving cost savings and manpower optimization.[42]

3.6 **Edge Case Missions**

AGVs excel in edge case missions that would otherwise expose human personnel to extreme danger, such as evacuating wounded soldiers under fire, traversing contaminated or hazardous zones, and navigating through rubble-strewn or structurally compromised environments. In these scenarios, AGVs can be remotely operated or function autonomously to safely extract casualties, deliver supplies, or conduct reconnaissance without risking additional lives. Their advanced sensor suites and AI-driven navigation systems enable them to maneuver through unpredictable terrain, avoid obstacles, and adapt to dynamic threats in real time. These abilities would make them invaluable for casualty evacuation (CASEVAC), operations in chemical, biological, radiological, or nuclear (CBRN) environments, and search-and-rescue tasks following structural collapse or bombardment. As militaries increasingly deploy AGVs for these high-risk missions, they not only enhance operational effectiveness, but they also significantly reduce the risk to troops.

4. Challenges to Ground Autonomy Adoption

4.1 Technical Challenges

4.1.1 Terrain Complexity and Environmental Uncertainty

AGVs perform well on structured or semi-structured terrain, such as roads, training areas, or prepared bases; they continue to struggle in off-road, urban, and dynamically changing environments. Rubble, soft soil, narrow alleyways, overhangs, and unpredictable obstacles reduce sensor visibility and disrupt path planning. Many current commercial AGV systems assume a static or semi-structured world, which does not reflect the operational reality of military maneuver units.[43] Autonomous navigation through dense forests, urban centers, or contested terrain with shifting debris and craters remains a major hurdle, especially without active human supervision.

4.1.2 Sensor Limitations and Electromagnetic Vulnerabilities

AGVs rely heavily on a combination of LIDAR, RADAR, and cameras for navigation, perception, and obstacle avoidance. Each of these systems, however, has critical shortcomings in military settings. Dust, smoke, rain, mud, and cluttered terrain significantly degrade camera and LIDAR performance, while RADAR can suffer from reflections and noise in dense environments. Critically, both LIDAR and RADAR are active sensors: they emit signals to "see", which creates electromagnetic signatures that can be detected, targeted, or jammed by adversaries. Emissions control (EMCON) is a tactical necessity in high-threat environments, meaning that AGVs operating under stealth or near-peer engagement scenarios must balance perception needs with the risk of counter-detection.[44]

4.1.3 Defined Safety Requirements

It is worth noting that there are tradeoffs with safety, affordability, and performance.[45] If the DoD chooses to purchase a cheaper autonomy stack, then that comes with a safety and performance tradeoff. There are scenarios where EMCON is necessary and will require no LiDAR or RADAR emitting. However, those sensors, in combination with cameras, are necessary for safe on-road transportation, which is more commonplace in every Combatant Command.[46] The stack must remain robust to allow for safe application in various operational scenarios.

Figure 5- Balancing Safety, Affordability, and Performance in Autonomous Vehicles[47]

4.1.4 AI Brittleness and Training Data Limitations

Even with robust sensors, AGVs remain only as capable as the AI models that interpret the data.[48] These models are often brittle in edge cases, rare but critical scenarios, like a partially buried IED, an injured troop lying in the path, or an ambiguous barrier in a dark alley. Operationally realistic training data, covering contested environments, adversarial camouflage, dynamic urban threats, and degraded GPS conditions, is scarce. Without continuous access to large-scale, annotated datasets representative of combat environments, AGVs will struggle to safely and effectively perform high-stakes missions.[49]

4.2 **Operational & Tactical Challenges**

4.2.1 Persistent Human Burden and the "One Robot, Two Soldiers" Problem

Despite the promise of reduced manpower, many AGVs still require close human oversight, whether for remote operation, navigation approval, or command authorization.[50] In practice, this often means that AGVs must be accompanied by drone overwatch, a remote pilot, or an escort element for security and situational awareness. The result is a paradox: instead of freeing troops, some AGVs can increase the cognitive and operational load on already stretched units. The "one robot, two soldiers" problem has emerged in multiple field experiments, where enabling the robot requires more human effort than it replaces.[51] Without true autonomy and seamless battlefield integration, AGVs risk becoming tactical liabilities rather than force multipliers.

4.2.2 Lack of Doctrinal Integration and Tactical Fit

Many AGV systems remain "bolt-ons" with no clear doctrinal role or concept of employment. When new technology lacks a defined mission use-case, it is often sidelined during real operations. Without integration into mission planning cycles, maneuver tactics, or sustainment workflows, AGVs may be left behind, not due to their technical shortcomings, but because commanders don't know how to use them effectively under pressure. Doctrinal inertia and limited experimentation exacerbate this problem, making it essential that AGVs be fielded in tandem with updated TTPs (tactics, techniques, and procedures) and iterative doctrinal development.

4.2.3 Targeting Risk and Signature Management

High-profile or uniquely shaped unmanned vehicles quickly become magnets for adversary fires. In conflict zones where movement is monitored by drones or scouts, distinctive AGVs can attract ambushes or indirect fire, which undermines their logistical or tactical utility. Without signature management and deception techniques, AGVs may add risk rather than reduce it.

4.3 **Acquisition and Bureaucratic Challenges**

4.3.1 Slow-Moving, Hardware-Centric Development Cycles

The Army continues to rely on bespoke, multi-year development timelines built around traditional hardware programs. These models are poorly suited for autonomy, where the bulk of capability lies not in the vehicle hull, but in the rapidly evolving software stack.[52] Rather than fielding incrementally improved autonomy packages on commercial platforms, DoD often defaults to large-scale, requirements-heavy development contracts that delay deployment for years, and missing the technology window altogether.[53]

4.3.2 Absence of a Software-First Acquisition Mindset

Modern autonomy software is driven by perception algorithms, decision-making logic, and navigation stacks. Yet most acquisition pathways treat software as a subordinate element to platform procurement. As a result, the military has underutilized commercial off-the-shelf (COTS) autonomy solutions, many of which are already field-proven in harsh environments and are modular enough to integrate with military vehicles. The commercial sector has delivered scalable autonomy in logistics, mining, agriculture, and trucking, but the DoD has struggled to capitalize on this progress due to outdated acquisition frameworks.[54]

In March 2025, the Atlantic Council's Commission on Software-Defined Warfare released a final report that highlighted crucial gaps in the DoD regarding its approach to software.[55] Among the many challenges presented, one area in particular highlighted the need to place key individuals in short-term problem solvers well-versed in software. These software natives would bring a software-first mindset that would alleviate present adoption challenges.

4.3.3 Risk Aversion and Inter-Service Stovepipes

Institutional risk aversion further inhibits experimentation and adoption. Programs that fail to meet early expectations are often canceled or relegated to perpetual prototyping, rather than iteratively improved through field feedback. Moreover, autonomy efforts across the Army, Marine Corps, SOCOM, and other services are frequently siloed, with limited interoperability, cross-service lessons learned, or shared autonomy baselines. This stove piping leads to duplicated efforts and a lack of joint capability development.[56]

4.3.4 The "Valley of Death" Between Prototype and Program of Record

Even successful AGV prototypes often struggle to transition into sustained acquisition programs. This well-documented "valley of death" between innovation and procurement is particularly acute in autonomy, where emerging tech outpaces traditional testing and evaluation processes. Without dedicated transition funding, championed users, or flexible authorities like OTAs, many promising systems languish after early demonstration, never reaching full operational deployment.

4.4 **Interoperability and System Integration Issues**

4.4.1 Incompatibility Across AGVs and Command-and-Control Networks

Currently, many AGVs are built on proprietary communication links and control systems that do not easily integrate with existing military C2 architectures.[57] This limits the ability of commanders to task, monitor, and re-task unmanned systems through familiar mission command tools. In joint or combined arms settings, this can create stove piped autonomy operations that are difficult to coordinate, deconflict, or exploit for combined effect. Without seamless C2 interoperability, AGVs risk becoming tactical silos: useful in isolation but disconnected from the broader fight.[58]

4.4.2 Absence of Unified Autonomy Control Standards

There is no universally adopted autonomy control architecture across services, or even within a single service. The Army, Marine Corps, and SOCOM often rely on different platforms, interfaces, and vendor-specific software stacks, making joint interoperability a persistent challenge. The lack of a shared autonomy application programming interface (API) or autonomy middleware layer prevents plug-and-play development and leads to duplication across programs. This mirrors earlier challenges in the unmanned aerial systems (UAS) space, where the absence of standardized control protocols hindered integration and innovation.

4.4.3 Vendor Lock-In and Software Redundancy

Without open-architecture requirements or government-owned autonomy interfaces, the military risks becoming locked into proprietary ecosystems, where one vendor's software only works with their own hardware.[59] This not only increases long-term costs, but it also creates barriers to innovation and modularity. Services may find themselves paying to develop similar capabilities across different platforms with no ability to port autonomy software between vehicle types. The current approach incentivizes closed systems and reinforces acquisition silos.[60]

4.4.4 Legacy System Integration Challenges

Much of the U.S. military's ground vehicle fleet consists of legacy platforms not originally designed for autonomy. Retrofitting AGV kits onto these vehicles means there are both hardware and software integration hurdles to overcome, from power and wiring constraints to incompatible vehicle dynamics and digital interfaces. Without standardized autonomy retrofit kits and validated integration frameworks, efforts to upgrade existing fleets with autonomy will remain slow, costly, and non-scalable.

4.5 **Cybersecurity and Electronic Warfare Risks**

4.5.1 Data, Bandwidth, and Security Burdens

Operational use of AGVs generates enormous volumes of sensor and telemetry data.[61] Storing, transmitting, and securing this data at the edge is no small task, especially in bandwidth-constrained or GPS-degraded environments. As AGV numbers scale, the need for hardened, low-latency communications and secure onboard processing becomes more urgent. Without this infrastructure, autonomy systems could become unreliable when they are needed the most. Moreover, any breach of AGV command links or data stores risks adversary exploitation or system hijacking. A secure infrastructure is a difficult, but necessary, mission.

4.5.2 Vulnerability to Jamming, Spoofing, and Cyberattack

AGVs often rely on satellite navigation, radio-frequency communication links, and cloud- or edge-based AI systems to function effectively. This reliance makes them highly susceptible to jamming, spoofing, and cyber intrusion. Adversaries can disrupt navigation systems, sever command-and-control links, or inject malicious code into poorly secured platforms. These actions can result in erratic behavior, compromised missions, or even hostile takeover of the system. In highly contested electromagnetic environments, such vulnerabilities represent not just technical gaps, but strategic liabilities. Future AGV platforms must be designed with zero-trust principles, hardened communications, and cybersecurity baked into every layer, from firmware and mission software to wireless protocols and ground control stations. This includes encrypted data links, intrusion detection systems, and autonomous self-protection behaviors.

4.6 **Cultural and Institutional Barriers**

4.6.1 Limited User Trust and the "Black Box" Problem

At the tactical level, many operators are hesitant to rely on autonomous systems due to the "black box" nature of AI decision-making. AGVs often make routing or obstacle avoidance decisions without transparent logic, which can lead to unpredictability in high-stakes situations. This lack of explainability makes it difficult for troops to fully trust the platform's autonomy, especially in environments where a misjudgment could result in fratricide, mission failure, or loss of life. When it comes to accountability, commanders must also be willing to accept the actions of the AGVs if a mission fails or troops are wounded or killed. Trust in autonomy must be earned through repeatable, transparent performance under realistic field conditions, something most service members have yet to experience firsthand.

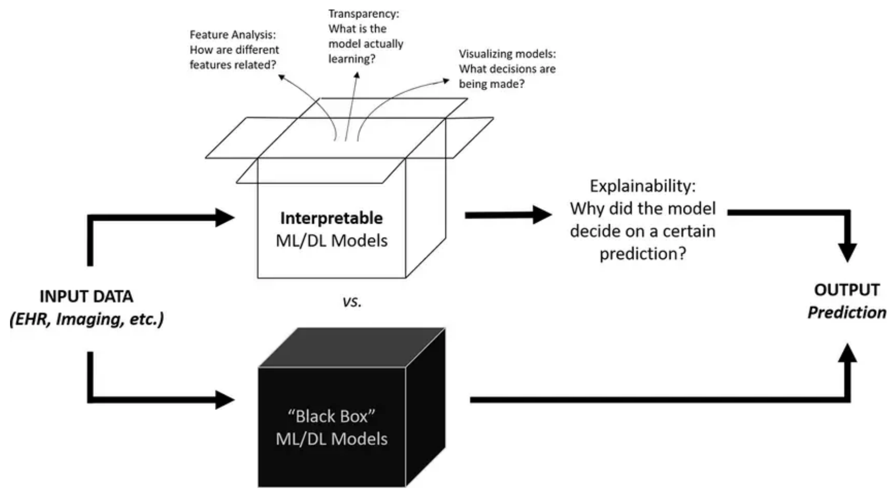

Figure 6- The Black Box of AI decision-making[62]

4.6.2 Operational Caution and Limited Training Exposure

Commanders remain cautious about deploying AGVs in live operations, in part because few have been trained on the system's capabilities, limitations, or doctrinal integration points. The current military training pipeline does not include standardized simulation environments or scenario-based exercises to acclimate units to working alongside autonomous ground systems. As a result, AGVs are often viewed as experimental or burdensome rather than as mission enablers. Without deliberate exposure at the tactical and operational levels, users cannot develop the practical intuition needed to effectively employ these systems under pressure. AGVs will continue to be seen as experimental until commanders believe they are force multipliers.

4.6.3 Organizational Resistance and Role Displacement Concerns

Institutional resistance also stems from personnel communities who perceive AGVs as a threat to traditional roles, particularly among transportation, logistics, and engineering specialties. As autonomy reduces the need for certain manpower-intensive tasks (e.g., convoy driving or route clearance), some within the force may resist integration out of concern for career displacement or force structure reductions. Simply put, if a commander is threatened with a smaller force to command, they may be resistant to the change.

5. Comparative Insights from Foreign Militaries

5.1 Ukraine: Grassroots Innovation and Tactical Adaptation

The Estonian-developed THeMIS UGVs have been employed by Ukrainian forces for tasks such as ammunition transport and casualty evacuation, providing critical support in high-risk environments and highlighting the value of UGVs in enhancing operational efficiency and force protection on the battlefield. However, despite these advancements, Ukraine's use of UGVs has also revealed significant challenges, particularly concerning electronic warfare vulnerabilities. Many UGVs, especially those developed rapidly by volunteers and startups, rely on direct human control and are susceptible to EW interference, leading to potential disconnections and mission failures. These experiences underscore the necessity for robust communication systems and autonomy in UGV design to ensure reliability under contested conditions.

Figure 7- Estonian-developed THeMIS[63]

Additionally, Ukrainian forces have developed and deployed the Zmiy ("Snake") UGV, which allows them to carry out engineering and resupply missions across various dangerous terrains with a lower risk to personnel.[64] With features like fiber optic cable control and autonomous navigation, the Zmiy can carry up to 500 kg of payload or lay anti-tank mines.[65] It also hosts strong ballistic and mine protection. As its reliance on secure communication channels and autonomy is put to the test on the Ukrainian battlefield, the Zmiy faces important challenges from electronic warfare, highlighting the continued need for robust control systems and sophisticated autonomous capabilities.

5.2 UK: Project THESEUS and Autonomous Logistics

The UK Ministry of Defence has launched Project THESEUS to modernize battlefield logistics through the deployment of autonomous ground vehicles.[66] This effort centers on enabling last-mile resupply using self-directed platforms capable of operating in challenging environments. Among the systems being trialed are the Viking 6×6 wheeled vehicle developed by HORIBA MIRA and the Titan tracked platform from QinetiQ.[67] These AGVs are engineered to transport heavy loads across varied terrain with limited dependence on GPS. Equipped with advanced sensors and AI-driven control systems, the vehicles are designed to reduce the need for direct operator input, improving both logistical efficiency and troop safety.

5.3 Russia: From Uran-9 Failures to Tactical Adaptation

Russia's initial foray into UGVs with the Uran-9 combat platform highlights significant challenges in deploying large, heavily armed autonomous systems. During its deployment in Syria, the Uran-9 experienced critical failures, including communication breakdowns, limited operational range, and weapon system malfunctions. These issues underscored the difficulties of integrating complex UGVs into dynamic combat environments and prompted a reevaluation of Russia's approach to ground autonomy.[68]

In response to these setbacks, Russia has shifted focus toward developing smaller, more expendable UGVs designed for specific tasks such as explosives delivery, resupply, and reconnaissance.[69] Many of these systems have been developed from the ground up by non-state actors and volunteer groups, reflecting a bottom-up innovation model. This approach has enabled rapid prototyping and deployment of UGVs tailored to the immediate needs of the battlefield, demonstrating a pragmatic adaptation to the limitations observed in earlier, more ambitious projects.[70]

5.4 **China: Setting the Stage for the Future Fight**

It is no secret that China has been laying the groundwork for a significant shift toward AGVs through its sweeping Military-Civil Fusion (MCF) strategy[71] This top-down policy coordinates civilian industry, private enterprise, state research, and military needs to accelerate dual-use technologies from commercial to battlefield applications that far exceed the United States' capabilities. To further emphasize the threat, China's commercial autonomy market is booming: nearly 20% of new passenger vehicles already feature high-level driving automation, with city-wide pilot zones for Level 4 robotaxis projected to reach half a million vehicles by 2035.[72, 73] These capabilities, including LiDAR, AI mapping, and control systems developed by Pony.ai and Baidu Apollo, offer a ready-made technical foundation for military AGVs.

Systems that autonomously track targets, coordinate drones, and even assign strikes have been demonstrated in recent PLA exercises, indicating that battlefield autonomy is developing. In addition to small autonomous robots, China is investing in larger-scale autonomous ground vehicles, such as armored multi-role systems and hybrid-electric logistics UGVs like the Sharp Claw series, which are all anticipated to gain from civilian autonomy technology.[74] China is in a position to convert current ground platforms into autonomous versions, which could hasten the PLA's transition to robot-assisted warfare, as civilian AV development surpasses American efforts and public acceptance of military AVs grows.

Figure 8- Chinese UGV, Sharp Claw Series[75]

Recommendations to the Under Secretary of Defense for Acquisition and Sustainment

Our policy recommendations are themed "Autonomy First" to align DoD stakeholders before publication of the next National Defense Strategy. They entail key shifts to ensure quicker adoption of AGVs while preparing warfighting units for the shift towards leveraging software-defined warfare in the great power competition force structure.

Recommendation #1: Immediately Cease Acquiring Manned Ground Systems

Shifting to an "Autonomy First" military will require acquisition discipline and meaningful program cuts to ensure AGV adoption. Transitioning to using AGVs in daily operations requires decisive acquisition decisions that are a forcing function for operational proficiency using AGVs. The DoD should announce an immediate moratorium on the creation of any new programs and R&D efforts that focus on vehicles with no autonomy. Furthermore, cease acquiring any additional unit of vehicle that does not have any autonomous function. To preserve current vehicle acquisition efforts and accelerate production of necessary new vehicles, all programs regarding manned vehicles will be grandfathered in and continue their development so long as they have an autonomous driving feature or can be upfitted.

Recommendation #2: Adopt Commercial Autonomy Software as Default

The DoD should mandate that ground autonomy programs begin by evaluating commercial software. This can be achieved through a SECDEF memorandum that orders the following:

- Rigid Contracting Officer compliance to the 1994 Federal Acquisition Streamlining Act to acquire commercial solutions over bespoke products custom-made by DoD requirements.
- Promote and encourage rapid acquisition through DIU solicitations, OTAs, or the new Software Acquisition Pathway.

- Mandate DIU to create a list of previously vetted ground autonomy vendors with robust security, dependable autonomy, and a reliable supply chain for their hardware. Similar to Blue UAS, "Blue Convoy," would act as a ground autonomy procurement shortlist for the Services, and be their mandated purchasing list for commercial software.
- Require DIU liaisons within each Service to function as a Manned-to-Autonomous Transition liaison to retrofit existing vehicles with autonomy kits as an interim step to AGVs.

Recommendation #3: Acquire and Deploy AGVs at Scale Right Away

Current efforts such as the XM30, RCV, CTT, etc., should continue and should be given extra funding and resources to encourage more rapid acquisition and adoption with larger quantity purchases and more robust software adoption (i.e. not buying a bare bones autonomy system). By the end of FY 2028, there needs to be no fewer than 250 vehicles of each class currently being produced or the program will face a review and be cut from the next FY budget proposal. The vehicles must also be truly software-defined (i.e. is it fully autonomous?) and not have an inadequate software stack that cannot meet a rigid safety case for service members. We must also balance the efforts on quality with the trap of exquisite systems that are unable to be mass produced in times of active war.

A joint innovation organization outside of the Services should lead the acquisition process for AGV acquisition to encourage speed and proper autonomy integration, but it should also align with all Services to ensure their desired quantity requirements are met. All Senate-confirmed and acting Service acquisition leads will become liaisons to either the CDAO, DIU, or another joint organization for this effort.

As the United States makes the transition to "Autonomy First", it is crucial that its allies be aligned in direction. During future Minister of Defense (MOD), Chairman of Defense Summits (CHOD) and allied Joint Staff Senior Leader conferences, members of the U.S. delegation should start encouraging AGV acquisition and adoption for allies and prioritize foreign military sales reviews for autonomous systems. This encouragement should begin setting the stage for standard command and control with NATO and Five Eyes partners.

Recommendation #4: Use Rapid Field Experimentation as the Default Acquisition Model

To accelerate integration and adaptation of AGVs, the DoD should institutionalize rapid field experimentation as the default pathway for AGV capability development and acquisition. Hundreds of AGV units spanning light, medium, and logistics variants, should be procured and distributed across designated pilot units within each service and selected by Army Futures Command, MARFORCOM, and SOCOM. These units will conduct early operational deployments and training rotations to evaluate real-world performance. Fielding progress will be reviewed bi-annually by a joint oversight group composed of the relevant Service acquisition and training authorities.

The Army and Marine Corps should also integrate AGVs into units deployed to the U.S Southern Border security operations as a proving ground for experimentation and interagency collaboration by offering a more controlled yet operationally relevant environment. Similarly, Golden Dome's level of funding and focus on innovation could create opportunities for the development and integration of AGVs, particularly in areas related to command and control, logistics, and reconnaissance. While the Golden Dome is primarily a missile defense initiative, its technological advancements and substantial investment could indirectly support the advancement and integration of autonomous ground vehicles in military operations.[76]

From these experimentation efforts, AGV developers will be required to publish quarterly field reports and "lessons learned" to a centralized autonomy knowledge portal managed by the CDAO. This approach will ensure that troop trust, concept refinement, and software improvement evolve together, creating a continuous feedback loop between the tactical edge and the acquisition enterprise. Taking lessons from Ukraine, the process must be quick and iterative now to avoid complications during active conflict scenarios.

Recommendation #5: Fund Doctrine and Training in Parallel with Procurement

The Army and Marine Corps units that operate with ground vehicles need to begin training to fight with and alongside AGVs. To speed along adoption, AGVs need to be added immediately to all training curriculums for all Army and Marine

Corps ground units. Waiting until another conflict begins featuring AGVs will be too late to change doctrine and warfighter familiarity. That time is now.

Therefore, the Army, through the Army Transformation and Training Command and Army Logistics University, should integrate general autonomy training into all courses. The Marine Corps, through its Training and Education Command (TECOM), should implement similar training. Both Services should additionally add in simulation-based autonomy training modules that can be inserted into existing digital training platforms. This training push is meant to improve familiarization for both lethality purposes and for service member safety.

Additionally, direct COCOMs to form a joint Army–Marine Corps cross function working group to write interim AGV CONOPS and SOPs into updated Doctrine. These updates should include man-machine teaming, updated safety cases, contested logistics, and robotic sustainment.

Other Services that are less reliant on ground vehicles for CONOPs such as the Navy, Air Force, and Space Force should integrate AGVs into their daily operations to both cut future manpower costs and to build familiarity to add value as an interoperability partner during Joint operations.

Conclusion

AGVs represent the next evolution of ground operations, operational concept flexibility, and next-generation logistics. The technology has reached a critical maturity allowing for realistic deployment across a range of combat and support scenarios. The DoD must act decisively by prioritizing commercial technology, fundamentally changing training doctrine to include AGVs, and aggressively pursuing operational experimentation in all ground unit training. By incorporating these recommendations, such as changing the current resource allocation and providing robust acquisition oversight of our recommended changes, the DoD can ensure that autonomous systems enhance warfighter capabilities. Failing to seize this moment risks leaving U.S. forces vulnerable and our logistics operations outmatched by adversaries willing to embrace ground autonomy faster and more effectively.

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