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Autonomous Military Vehicles

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Abstract: Autonomous military vehicles (AMVs) are robotic systems, from drones to ground vehicles, using AI and sensors to perform tasks like reconnaissance, logistics, and combat, aiming to reduce troop risk, enhance efficiency, and operate in hazardous areas. These systems are progressing from science fiction movies to designers' drawing boards, to engineering laboratories, and to the battlefield. The machines have prompted a debate among military planners, roboticists, and ethicists about the development and deployment of weapons that can perform increasingly advanced functions, including targeting and application of force, with little or no human oversight. A challenging nut that the US Army is trying to crack is introducing autonomous vehicles into frontline combat formations to fight alongside manned vehicles. This paper examines the potential applications of autonomous military vehicles.

Keywords: *Autonomous Vehicles, Self-Driving Vehicles, Connected Vehicles, Military, Army, Defense, Department Of Defense (Dod)*

I. INTRODUCTION

For several decades, autonomous systems including aircraft, ground vehicles, and waterborne craft have proliferated. Autonomous systems exist across all domains, including air, land, and sea. Today, autonomous vehicle technology is now rolling out to consumers, whether it is "basic" self-driving functions such as lane keeping and autonomous emergency braking, or fully autonomous driving as seen on Tesla vehicles using their in-built Autopilot. Examples of autonomous vehicles are shown in Figure 1 [1].

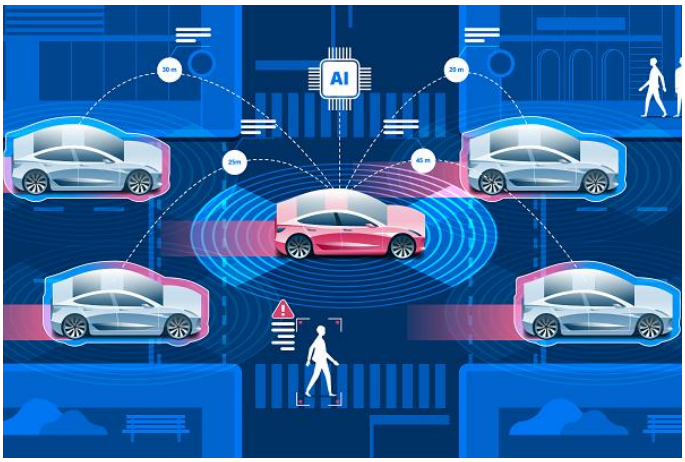

Figure 1: Examples of autonomous vehicles [1].

Automotive autonomy technology is changing economies and global industries – and is also a driving force behind military modernization. While there has not been a direct assault on a US military base yet, autonomous systems remain a threat and something the Defense Department is seeking solutions for. In the US, there are rules for how the military services can engage with those systems if they are deemed a threat – and defeating them will mean complying with those rules while at the same time working to protect both people and property. Fifteen years ago, the US Defense Advanced Research Projects Agency (DARPA) conducted its groundbreaking Grand Challenge, which aimed to accelerate the development of autonomous military vehicle technology. Figure 2 shows a typical autonomous vehicle on the battlefield [2].

Figure 2: A typical autonomous vehicle on the battlefield [2].

II. CONCEPT OF AUTOMOUS VEHICLES

Autonomous vehicles constitute one of the most spectacular recent developments of AI. As opposed to human-driven vehicles, autonomous vehicles essentially refer to self-driving vehicles. They are smart vehicles that are able to perceive their environment and to move on accordingly without human intervention. They operate with the capability to have automatic motions and navigate themselves depending on the environments and scheduled tasks. Figure 3 shows the architecture of autonomous car [3].

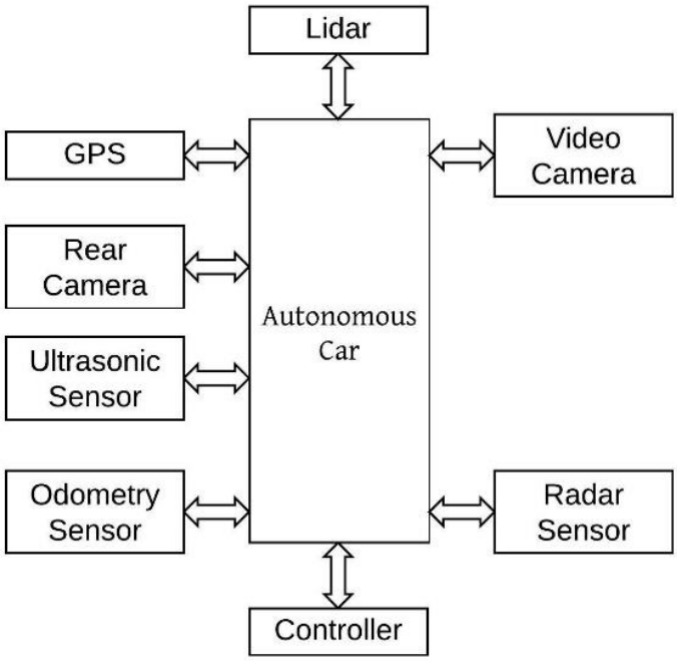

Figure 3: Architecture of autonomous Car [3].

Autonomous vehicle or driverless car is an ambitious project which requires the fusion of many technologies like electronics, communications, mechatronics, software engineering, artificial intelligence, GPS, and industrial IoT. It is a vehicle that uses a combination of sensors, cameras, radar, and artificial intelligence (AI) to travel between destinations without a human operator. It is designed to be able to detect objects on the road, maneuver through the traffic without human intervention, and get to the destination safely. It is fitted with AI-based functional systems such as voice and speech recognition, gesture controls, eye tracking, and other driving monitoring systems. Several companies have announced their plan to get involved in autonomous or driverless and electric vehicle technology

Connected and autonomous vehicles (Avs) are now becoming a cornerstone of the increasingly connected world. They are receiving a lot of attention from manufacturers, service providers, governments, universities, consumers, and other stakeholders. The main goal of autonomous vehicles is to build a self-driving system that can perceive the road better than the best human driver. They are incredible innovation that will likely transform transportation, especially in urban environments, in the near future. Although autonomous vehicles can improve performance and safety, there are a myriad of serious technology, regulatory, and security challenges to consider in preparation for full vehicle autonomy.

Autonomous vehicles combine artificial intelligence (AI) and robotics. They are regarded as a promising answer to traffic jams, accidents, and environmental pollution. They will constitute the backbone of future next-generation intelligent transportation systems (ITS) providing travel comfort and road safety along with a number of value-added services. They are used in search and rescue, urban reconnaissance, mine detonation, supply convoys, etc. [4]. They can help save lives on the battlefield.

Autonomous vehicle (AV) is also described as “driverless,” “robotic,” or “self-driving.” AV is regarded as a multidisciplinary technology. The enabling technologies in support of connected autonomous vehicles include camera, GPS & GNSS, and sensors, radar , LiDAR (Light Detection and Ranging), and Internet of things. The race to develop autonomous vehicles has heated up with many major automotive manufacturers such as Tesla, Audi, General Motors, Mercedes Benz, Uber, Google, and Amazon [5]. Figure 4 shows how autonomous vehicles work [6].

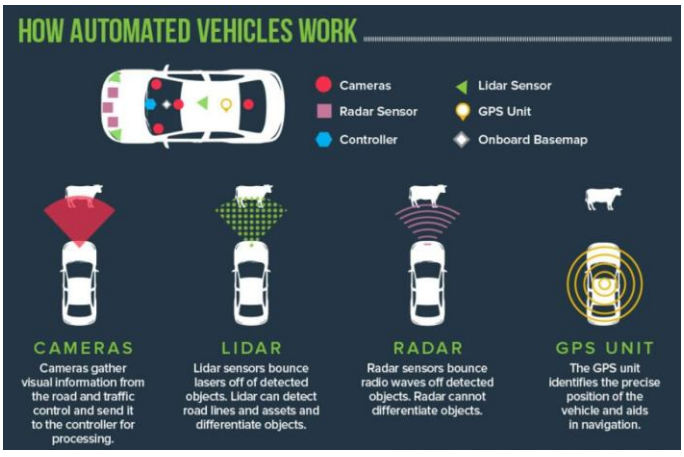

Figure 4: How autonomous vehicles work [6].

III. LEVELS OF AUTONOMY

SAE International (formerly the Society of Automotive Engineers) classifies autonomous vehicles on a scale of 0 to 5. The six levels are presented as follows [7,8]:

Level 0: No automation: All driving tasks and major systems are controlled by a human driver. The automated system has no vehicle control but can issue warnings.

Level 1: Function-specific automation: Provides limited driver assistance. The driver must be ready to take control at any time.

Level 2: Partial driving automation: At least two primary functions are combined to perform an action. The driver is obliged to detect objects and events and react if the automated system does not respond correctly.

Level 3: Conditional driving automation: Enables limited self-driving automation. Vehicles at this level can make informed decisions for themselves. In known environments (such as highways), the driver can safely divert his attention from driving tasks.

Level 4: High driving automation: An automated driving system performs all dynamic tasks of driving. The automated system can control the vehicle in almost any environment, such as extreme weather conditions. and fewer parking spaces.

Level 5: Self-driving automation: An automated driving system performs all dynamic functions of driving. No human intervention is required. A vehicle at this level requires no driver. It is on its own and must be able to react to all situations that might arise.

The six levels are shown in Figure 5 [9] and are summarized as follows: No Automation, Driver Assistance, Partial Automation, Conditional Automation, High Automation, and Complete Automation. The classification has been adopted by DOT. Vehicles sold today are in levels 1 and 2. Levels 4 and 5 will probably increase vehicle prices significantly. But how do we get to Level 5?

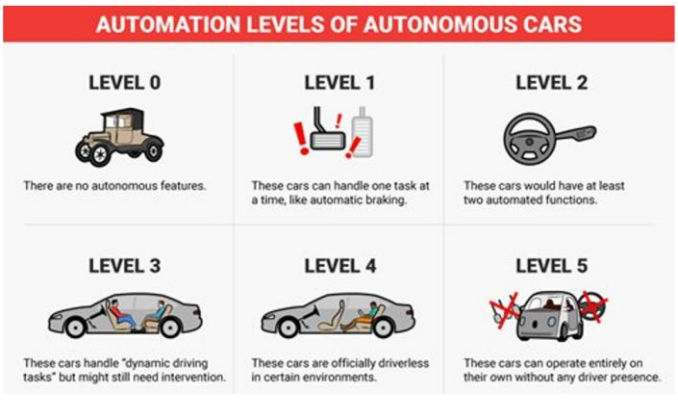

Figure 5: The six levels of autonomy [9].

IV. AUTONOMOUS MILITARY VEHICLES

Ground warfare is fast, complex, and lethal. The military trains to fight and win large-scale combat operations. As typically shown in Figure 6, this war environment is intense, lethal, and brutal [10]. It includes complexity, chaos, fear, violence, fatigue, and uncertainty. Although autonomous vehicles have slowly made their way into the commercial realm, the industry of vehicle autonomy for the military is new.

The Army is pushing to get modern technology in the hands of its soldiers faster. As the DoD’s land warfare component, the US Army needs to find a way to safely conduct reconnaissance

and related high-risk tasks in these environments. As the military evolves with advanced technology, one significant trend stands out: autonomous systems and unmanned vehicles. Significant technical breakthroughs in robotics and autonomous vehicles are enabling the use of autonomous systems to support high-risk missions and reduce risk for combat troops in military operations [11]. The US Army is turning to commercial startups to fast-track autonomous ground vehicles into combat formations. It is committed to bringing the best technologies to our warfighters and shaping the future of autonomous mobility for our Army at an unprecedented speed. The Army's autonomy push mirrors the Pentagon's larger effort to harness commercial startups, with ground vehicles serving as one of the most immediate test beds for adapting civilian self-driving advances to military operations.

Figure 6: A typical war environment [10].

The Oshkosh Family of Multi-Mission Autonomous Vehicles (FMAV) directly support modernization priorities for long-range precision fires, resilient formations, and scalable autonomy to deliver ready-now, production-based solutions that reduce risk and increase capabilities to soldiers in contested environments. The autonomous vehicles are engineered on proven tactical vehicles, with scalable autonomy and payload versatility to deliver what the Army needs today with the flexibility to adapt as the battlefield evolves [12].

V. APPLICATIONS OF AUTONOMOUS MILITARY VEHICLES

The use of autonomous systems in military operations is growing rapidly. The military can deploy autonomous vehicles for high-risk operations like route clearance, explosive ordnance disposal, casualty evacuation, resupply, and reconnaissance assistance. Common applications of autonomous military vehicles (AMVs) include the following [13,14]:

- *Military Logistics*: Military logistics is a vital area of transformation. From unmanned aerial vehicles (UAVs) to ground combat vehicles, autonomous systems are transforming military logistics. Military UAV logistics supports this by transporting critical supplies to remote areas, ensuring soldiers stay focused on their mission. They enhance efficiency and reduce risks to personnel. In the past, the military relied on human operators for logistics tasks. Moving supplies, equipment, or personnel across battlefields was a risky job. However, with the rise of autonomous military vehicles, there has been a significant shift. One of the primary goals of integrating autonomous systems into military logistics is to reduce human risk. Military logistics has always faced several challenges, including the need to maintain operational readiness and manage global deployments. Autonomous systems are helping solve some of the most pressing issues. Looking ahead, the future of military logistics could be fully autonomous.
- *Military Trucks:* Ground combat vehicles are another area where autonomous systems shine. The US Army has been pursuing autonomous trucks for resupply missions for around a decade. Autonomous military trucks and military utility vehicles are reducing human exposure to dangerous environments. The integration of driverless technology in military trucks boosts both safety and efficiency. Pickup trucks have long been associated with rugged versatility, dependability, and adaptability. These qualities make them not only popular among civilians but also indispensable in military operations worldwide. From transporting personnel and equipment to navigating challenging terrains, military pickup trucks play a crucial role in enhancing the efficiency and effectiveness of military forces. A typical military truck is shown in Figure 7 [13].
- *Military Robotics:* The Army has realized that robotics is going to be critical for our success in the future. Every US military service participates in the autonomous, unmanned and robotic arena. Programs include unmanned aircraft, ships, and ground vehicles, robotic mine detectors, and forays into other uses for robotics. The introduction of a robotic combat vehicle that can fight alongside tanks in combat could still be some way off. The US Army's Next Generation Combat Vehicle program will consist of both an optionally manned fighting vehicle and a family of autonomous robotic combat vehicles. While fully-armed robots are still in prototype and testing phases, they do exist. Human-out-of-the-loop weapons are robots capable of selecting targets and delivering force without any human input or interaction. Figure 8 shows a robotic combat vehicle [15]. There is a growing focus on battlefield survivability in the face of drone proliferation. Today, there are hundreds of drones and other mechanized tools in use on the battlefield, primarily used for search and rescue and cargo operation. A typical drone is shown in Figure 9 [13].
- *Team Autonomous Vehicles*: Most of the research and development today for autonomous ground vehicles focuses on single vehicles. However, the US military seeks to team autonomous ground vehicles with humans and other systems for routine battlefield tasks such as off-road reconnaissance and surveillance. The combined team enables more informed, faster, and safer travel by the ground vehicle to its desired destination. Extensions to this teaming system include night operations and routing under canopy, more efficient exploration using prior scene and terrain information, and optimization of routes to maintain cover. Figure 10 shows a typical team of combat vehicles [16].
- *Mission Support System:* Lockheed Martin's Squad Mission Support System (SMSS) is an unmanned transport and support system for special operations forces. The SMSS uses a "follow me" navigation which can maneuver autonomously. The military's long term vision for the unmanned system is for not only cargo, but for reconnaissance, surveillance, target acquisition, and armed variants which Lockheed calls "critical to today's

asymmetrical and urban battlefields." Figure 11 shows A mission support vehicle [17].

- *Multi-Mission Vehicle*: Seattle-based Overland AI has unveiled a fully autonomous tactical ground vehicle: the Ultra. Ultra can take on a variety of missions across multiple terrains and conditions, including GPS-denied and other extreme environments. It gives commanders an immediately deployable solution for reconnaissance, counter-UAS, and logistics operations. Ultra is shown in Figure 12 [18].

Figure 7: A typical military truck [13].

Figure 8: A robotic combat vehicle [15].

Figure 9: A typical drone [13].

Figure 10: A team of combat vehicles [16].

Figure 11: A mission support vehicle [17].

Figure 12: Multi-mission vehicle Ultra [18].

VI. BENEFITS

Human-driven military vehicles will need to be brought into the new paradigm of combat vehicles. Autonomous systems and unmanned vehicles are revolutionizing military logistics by enhancing efficiency, reducing risks, and ensuring timely deliveries. Other benefits of autonomous military vehicles include [10,19]:

- *Military Advantage*: Some military experts hold that autonomous weapons systems not only confer significant strategic and tactical advantages in the battleground but also that they are preferable on moral grounds to the use of human combatants. They generally point to several military advantages for using the weapons. Autonomous weapons systems act as a force multiplier. That is, fewer warfighters are needed for a given mission, and the efficacy of each warfighter is greater. Advocates credit autonomous weapons systems with expanding the

battlefield, allowing combat to reach into areas that were previously inaccessible. Moreover, personnel is kept out of harm's way.

- *Moral Justifications:* Several military experts and roboticists have argued that autonomous weapons systems should not only be regarded as morally acceptable but also that they would in fact be ethically preferable to human fighters. For example, roboticist Ronald C. Arkin believes autonomous robots in the future will be able to act more "humanely" on the battlefield for a number of reasons, including that they do not need to be programmed with a self-preservation instinct, potentially eliminating the need for a "shoot-first, ask questions later" attitude. Autonomous weapons could reduce the possibility of suffering and death by eliminating the need for combatants.
- *Training Cost Reduction:* Autonomous vehicles reduce the cost of operator training. It costs a lot to train a fighter pilot. The monetary benefits of autonomous vehicles come in the long-term savings on these operational costs, as many of those costs are removed when an autonomous vehicle can conduct some of the missions those operators would otherwise. Such costs include pilot instructor salaries, food, and lodging for the cadet and instructor.
- *Flexibility:* Autonomous vehicles could reduce workforce downtime. They can be designed to function 24/7 and they would not get distracted by sleep deprivation or hunger, for example. Additionally, human operators need to change shifts with their replacements; those shifts often require planning and costs, such as a patrol boat needing to dock to change operators. Long-term, focused missions are also made more possible with autonomous vehicles.
- *Loyalty:* Autonomous systems are loyal to their owners. Coercion and bribes are not effective on drones or robots. Drones cannot defect to an enemy force and cause damaging security breaches. Drones operated by artificial intelligence add additional security for a military looking to guard pivotal battlefield secrets.

VII. CHALLENGES

For an autonomous ground vehicle, reacting to other moving objects in a dynamic environment that is changing quickly can be difficult. Critics hold that autonomous weapons should be curbed, if not banned altogether, for a variety of moral and legal reasons. The international community has agreed to limits on mines and chemical and biological weapons, but an agreement on limiting autonomous weapons systems would meet numerous challenges. Some advocates of a ban on autonomous weapons systems seek to ban not merely production and deployment but also research, development, and testing of these machines. Other challenges of autonomous military vehicles (AMVs) include the following [10,20]:

- *Morality*: Among engineers and designers, there has been confusion of machine autonomy with moral autonomy. The language of morality that applies to human agents, not to robots. Robots cannot feel anger or a desire to "get even" by seeking retaliation for harm done to their compatriots. As autonomous weapons systems move from concept to reality, military planners, roboticists, and ethicists debate the advantages, disadvantages, and morality of their use in current and future operating environments. If robots malfunction and target civilian centers, there is no way to stop them.
- *Accountability:* Determining responsibility when an autonomous system causes harm or makes errors is legally and morally complex.
- *Pace:* AMVs must match the speed of manned units to remain effective, a significant hurdle for current ground vehicles.
- *Cybersecurity:* AMVs are vulnerable to hacking, ransomware, and supply chain compromises, requiring robust defense against sophisticated adversaries.
- *Novelty:* Autonomous systems are new and their development has been "under the radar" for all but a few naval professionals. This lack of familiarity, coupled with cultural issues, creates a high bar for autonomous systems in particular.
- *Manpower Reduction:* There is the challenge of manpower reductions in the fleet. In fact, this represents the single biggest challenge facing the development and integration of unmanned autonomous systems today. Lessons learned throughout the development process of most autonomous systems demonstrates that autonomous systems can actually increase manning requirements as legions of technicians and operators work with the system to ensure it works properly and is a welcome addition to whatever warfighting capability and community it is trying to satisfy.

CONCLUSION

Military, intelligence, and industry officials are universal in their praise for autonomous systems. Autonomous systems are radically changing the character of war. The goal of current military projects is to improve the technologies required for autonomous vehicle operation. The objective is to free up military personnel for the task, with the vehicle operating autonomously. The sector is more likely to see a transition to semi-autonomous vehicles first, before a move to fully autonomous versions. Combined with autonomous driving technology, this holds huge opportunities for the US military industry to develop the most reliable and capable autonomous military vehicles in the world [21].

While there has been considerable progress from DARPA's original Grand Challenge, there is still a significant amount of work to be done before self-driving armored vehicles become part of everyday military life. Autonomous vehicles are increasingly being developed, prototyped, and tested for future use in autonomous and teaming operations or scenarios with manned vehicles. If autonomous vehicles prove capable enough for the battlefield, the tech could someday start finding its way over to civilian uses, too. To stay on top of the developments in autonomous military vehicles one should consult the books in [22-24] and the following related journals:

- *Artificial Intelligence Review*
- *Applied Artificial Intelligence*
- *Artificial Intelligence and Law*
- *AI Magazine*
- *Vehicular Communications*
- *Automation in Construction*
- *Military Review*

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