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Unmanned ground robotic platforms: from information support to intelligent control

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ABSTRACT

One of the key directions in the development of advanced military technologies is the creation of unmanned combat systems. Ground forces, being the most “contact-intensive” and exposed to the highest casualty rates in any type of war, have the greatest need for such innovations. In practice, their technological development has lagged behind aviation, where Unmanned Aerial Vehicles (UAVs) have already become widespread and demonstrated high operational effectiveness in modern conflicts. In recent years, however, a new trend has emerged — the development of Unmanned Ground Vehicles (UGVs), which are still in the early stages of development and operational integration. This article presents a structured classification of UGVs according to their design features (modernized Soviet-era vehicle platforms or specially developed electric chassis), functional roles (logistics, evacuation, engineering, reconnaissance), mass and size categories (light, medium, heavy), and control methods (operator-controlled or autonomous). Particular attention is given to the formation of a unified information and control space, where UGVs operate as part of a larger network-centric system alongside UAVs, communication systems, surveillance assets, and fire control units. The article also outlines the future prospects of UGV technology, including enhanced autonomy, the use of artificial intelligence, the development of robotic swarms, and full integration into modern battlefield architecture. This approach will significantly reduce risks for personnel while increasing the effectiveness, speed, and coordination of combat operations.

Keywords: unmanned aerial vehicles; unmanned ground vehicles; unmanned ground platforms; autonomous control; classification; network-centric system; artificial intelligence

Relevance. Recent military engagements in Ukraine have demonstrated that the efficacy of combat operations is contingent on the degree of automation in logistics processes and the capacity to mitigate risks to personnel. Of particular importance are the so-called unmanned ground vehicle (UGV) platforms or ground robotic complexes, which are capable of performing transportation, evacuation, reconnaissance and engineering support tasks, including in high-risk areas.

A survey of international practice (USA, Israel, Great Britain) indicates a gradual transition from experimental systems to regular use by military units [1, 2]. For Ukraine, which is currently engaged in a full-scale war, the deployment of such platforms is of both tactical and strategic importance.

In its plans and programmes for the development of military robotics, the US Department of Defence identifies the following categories of technical means and UGVs based on them: 1) unmanned aerial vehicles (UAVs); 2) unmanned ground vehicles (UGV); 3) unmanned surface vehicles (USV); 4) unmanned underwater vehicles (UUV). The latter are divided into: The following points 4.1 and 4.2 refer to remotely operated underwater vehicles (ROVs) and autonomous underwater vehicles (AUVs), respectively. In December 2007, the overarching directives for the advancement of unmanned and unmanned systems – the Unmanned Systems Roadmap – for the period 2007-2032 were formally endorsed, delineating the objectives and trajectory for the conception of unmanned vehicles. The primary robotic vehicles were developed as part of the Future Combat System (FCS) programme, which was part of a comprehensive programme to modernise the equipment and armaments of the US Army [3, 4].

A thorough examination of scientific and technological trends within the military domain enables the identification of the primary domains of scientific and technological research in the realm of armaments and military equipment, namely: The following subjects are to be addressed: 1) artificial intelligence and blockchain; 2) the Internet of Things and its security; 3) unmanned vehicles and robotics, drones and drone swarms; 4) underwater transport, in particular submarines; 5) new materials, in particular those with invisibility effects, armored materials, and biomaterials; 6) electrification of military transport and alternative energy sources; 7) aircraft safety; 8) communication networks, including wireless, mobile adaptive networks, and their security.

The field of artificial intelligence is widely regarded as one of the most promising areas within Industry 4.0 and the subsequent Industry 5.0. Subsequent advancements in this domain, in conjunction with progressions in energy storage technologies and the fabrication of novel materials, are poised to effect substantial transformations in both the military and prevailing classes of armaments.

Literature Review. Network war is a form of conflict that focuses on coordination, connectivity, and information dominance rather than purely physical destruction of the enemy. The key element is the creation of distributed networks of military and non-military actors interacting in real time. Network-centric warfare (NCW) is an advanced form of network warfare that emerged in U.S. military doctrine in the late 1990s. Its core is the integration of sensors, shooters, command and control, and support elements into a single information environment to achieve decision superiority and operational dominance [5, 6].

Principles of Network-Centric Warfare are the following (Table 1): 1. Integration of all combat elements into a single information space. 2. Situational awareness for each participant. 3. Decentralized but synchronized decision-making. 4. Rapid reaction based on shared data and automated decision support. 5. Significant increase in operational effectiveness [7, 8].

Table 1. **Comparative characteristics of different wars**

Characteristic	Conventional War	Network War	Network-Centric War
Command structure	Centralized	Distributed	Unified network information space
Main objective	Destruction of forces	Disruption of coordination	Information dominance
Role of information	Auxiliary	Important tool	Core element of strategy
Means	Troops, aviation, navy	Cyber, social, informational	Integrated combat and information systems
Decision-making	Centralized	Partially autonomous	Networked and instantaneous

Examples of Network and Network-Centric Operations: 1. Operation Desert Storm (1991) — first massive use of integrated information systems in real-time coordination. 2. Iraq War (2003) — implementation of network-centric concepts with UAVs, satellites, and command systems. 3. Russian-Ukrainian war (2022–2025) — integration of drones, artillery, EW and command systems through Starlink and other networks.

Role of unmanned ground vehicles (UGV) platforms is important: 1. They act as critical nodes in network-centric operations. 2. They perform reconnaissance, logistics, fire support, and remote attack missions. 3. Integrated with Unmanned Aerial Vehicles (UAVs), artillery, electronic warfare (EW), and command centers, 4. UGVs increase battlefield awareness and enable distributed, coordinated action [9, 10].

The paper aims to create a structured classification of UGVs according to their design features (modernized soviet-era vehicle platforms or specially developed electric chassis), functional roles (logistics, evacuation, engineering, reconnaissance), mass and size categories (light, medium, heavy), and control methods (operator-controlled or autonomous).

Methodology is based on a classification of unmanned Ground Vehicles (UGV) and includes classifications of (1) unmanned Ground Vehicles and (2) control systems.

As for the first, according to design features there are the following directions (Table 2):

1. The process of modernizing Soviet-era equipment is underway. The most expeditious method of creating a UGV is to adapt existing vehicles (ZIL-131, UAZ-469, KAMAZ-4310). A significant number of these models remain in Ukrainian Armed Forces warehouses and can be retrofitted with remote or semi-autonomous control systems. The primary benefit is the low cost of the base platform and the availability of spare parts. The primary disadvantage associated with this approach is the significant fuel consumption and the resulting wear and tear of the units, both moral and physical.

2. The utilization of bespoke electrically operated platforms is a key component of the system. These are created using modern technologies, including electric wheels, a modular design, and the capacity for rapid module replacement (e.g. reconnaissance, cargo, medical). While such solutions hold greater promise in the long term, they necessitate a more complex production base.

Table 2. **Comparison of two approaches: modernization of soviet cars and creation of new electric platforms**

Criterion	Modernized soviet vehicles (ZIL, UAZ, KAMAZ)	Modern electric platforms
Accessibility	High (large quantity in stock)	Limited, new production needed
Cost	Low (≈20–35 thousand USD/unit)	Higher (≈70–120 thousand USD/unit)
Energy efficiency	Low (high fuel consumption)	High (power supply, hybrids)
Repairability	High (spare parts available)	Average (modern components required)

According to intended use: 1. Logistical (delivery of fuel, lubricants, water); 2. Evacuation (transportation of wounded personnel, towing of damaged equipment); 3. Reconnaissance (equipped with cameras, thermal imagers, UAVs for complex operations). 4. Engineering (demining, laying crossings, fortifying positions).

According to the mass and size characteristics (Table 3): 1. Light (up to 500 kg) – mobility, ease of production, low cost; 2. Medium (0.5–2 t) – versatile, capable of performing a wide range of tasks; 3. Heavy (2–10 t and above) – towing armoured vehicles, performing engineering tasks.

As for the second, according to the control methods there are the following directions (Table 4): **1.** Operator control (RC/FPV) is performed using joysticks, consoles, and FPV systems. Used for tactical tasks in real time. **2.** Autonomous control is based on GPS, INS, LiDAR, camera data, and SLAM algorithms; it allows routes to be flown without constant human supervision. 3. Mixed systems which involve switching modes depending on conditions – the most realistic option for the modern battlefield.

Table 3. **Classifying UGVs by weight and functional capabilities**

Type of operation	Load capacity	Range	Autonomy	Critical parameters
Delivery of spare parts	500-800 kg	50-70 km	8 hours	Accuracy of delivery time
Evacuation of equipment	1200-1500 kg	30-50 km	6 hours	Towing stability
Field repair	800-1000 kg	20-40 km	12 hours	Availability of tools
Fuelling	600-900 kg	60-80 km	10 hours	Fuel system tightness

Table 4. **Algorithm of interaction between sensors and control systems in UGV**

System component	Integration method	Advantages	Difficulties
The 'Trizub' management system	API interface for data exchange	Automatic status updating	Lack of standardized protocols
Wireless communication	Additional radio station modules	Compatibility with existing equipment	Limited bandwidth
Navigation systems	Hybrid GPS/GLONASS + inertial	Operation without satellite signal	The need for calibration
Accounting systems	QR coding of cargo	Simple tracking of material resources	Manual data entry

The above data provide an answer to the question about the relevance of using soviet equipment as a basis for the UGV. *Advantages:* 1) large quantities in stock; 2) availability of production facilities for repairs; 3) rapid commissioning. *Disadvantages:*1) high fuel consumption; 2) lack of armor plating and modern protection systems; 3) low reliability compared to modern models. Consequently, the utilization of soviet vehicles can be regarded as a provisional measure that facilitates the expeditious production of initial prototypes. Concurrently, the strategic direction should be predicated on the creation of novel electric platforms adapted to the requirements of modern warfare.

Technological aspects of UGV implementation include: 1. Localization and navigation. The combination of GNSS, INS, LiDAR and cameras ensures movement accuracy of up to 0.5 m even in difficult conditions. 2. Logistics automation. UAVs can reduce delivery times by 20–30% compared to traditional methods. 3. Economics. One Ukrainian prototype costs approximately 35,000 USD, which is several times cheaper than the loss of a trained crew or armored personnel carrier.

System UGV will make up a significant share of the military units' automotive support system (Table 5).

Conclusions. 1. The use of **unmanned ground robotic platforms** (UGV) is a relevant and necessary direction for the development of the **automotive support system** of the Armed Forces of Ukraine. **2.** In the short term, it is advisable to convert soviet vehicles into **temporary platforms**. **3.** In the long term, the focus should be on creating **specialized electric platforms with modular architecture**. **4.** Combining these approaches will simultaneously address the urgent needs of the war and lay the foundation for post-war modernization of the army. **5.** Prospects for the Armed Forces of Ukraine: reduction of combat and medical losses; increased pace and autonomy of operations; localization of production and creation of jobs; technological response to the challenges of hybrid and electronic warfare.

Table 5. **Integration of UGV into the automotive support system**

Level of integration	Integrated systems	Interaction technologies	Effectiveness	Prospects for development
Hardware	- Tractors and vehicles - Fuel systems - Charging stations	- NATO STANAG 4694, MIL-STD-1882 standards - CCS Combo 2 unified connectors - Automatic mounting systems	- Connection time ≤5 min - Compatible with 95% of equipment	- Quantum sensors for autonomous maintenance - Wireless power transfer
Software	- ASU ‘Trizub’ -Artroscalculation systems - Medical databases	- API v3.4+ - JSON/MIL-STD formats - HL7 for medical data	- Data delay < 2 seconds - AES-256 encryption	- AI route optimisation - Blockchain for logistics accounting
Tactical	- Reconnaissance UAVs - Artillery units - Medical evacuation teams.	- VMF for target exchange - ADatP-37 protocol - Automatic ‘security windows’	- Real-time coordination (5 Hz) - Accuracy of 0.1 m	- Quantum communication - Swarm interaction of platforms
Safety	- Electronic warfare systems - Cyber defence - Cryptographic systems	- Dynamic frequency change - Biometric authentication - Quantum-resistant algorithms	- Protection against 99.7 % of attacks - Automatic channel switching	- Quantum key distribution - Neural encryption

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Безпілотні наземні роботизовані платформи: від інформаційного забезпечення до інтелектуального керування

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АНОТАЦІЯ

Одним з найважливіших напрямів розвитку високотехнологічних військових розробок є створення безекіпажних бойових систем. Найбільше таких нововведень потребують сухопутні війська, як найбільш «контактний» рід військ, що несе значні втрати у війнах будь-якого типу. На практиці їх технологічне забезпечення істотно відстає від авіації, де безпілотні літальні апарати (БПЛА) уже набули масового поширення та продемонстрували ефективність у сучасних збройних конфліктах. Проте останні роки характеризуються активним формуванням нового напряму – розвитку безпілотних наземних транспортних засобів, або UGV (Unmanned Ground Vehicles), які перебувають на ранніх етапах становлення та вдосконалення. У статті розглядаються ключові підходи до класифікації UGV за конструктивними ознаками (модернізовані автомобільні платформи радянського зразка або спеціально розроблені електромобільні шасі), за функціональним призначенням (логістичні, евакуаційні, інженерні, розвідувальні), за масогабаритними параметрами (легкі, середні, важкі), а також за принципами керування (від оператора чи автономні). Особлива увага приділяється питанню створення єдиного інформаційно-управляючого простору, в якому UGV функціонують у взаємодії з іншими елементами мережевоцентричної системи – БПЛА, системами зв'язку, спостереження та управління вогнем. Показано перспективи розвитку наземних безпілотних платформ у напрямку збільшення їх автономності, впровадження штучного інтелекту, створення рою роботизованих систем та інтеграції в загальну архітектуру бойових дій. Такий підхід дозволить знизити ризики для особового складу та суттєво підвищити ефективність бойових операцій.

Ключові слова: безпілотні літальні апарати; безпілотні наземні апарати; безпілотні наземні платформи; автономне керування; класифікація; мережевоцентрична система; штучний інтелект