State of the Art of the Technologies Used for 6×6 Wheeled Terrestrial Robots

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***Abstract*—This article explores the current state of the art of technologies applied to 6×6 wheeled terrestrial robots, highlighting their increasing role in various domains, especially in security and defense. The paper introduces fundamental concepts of ground robots, defining perception, processing and actuation subsystems. International capabilities are presented through different examples of existing robots on the market. The paper discusses the technical advantages of the 6×6 configuration, emphasizing superior mobility over rough terrain, increased stability, redundancy and reliability, and an optimal cost-performance trade-off compared to 4×4 or tracked systems. It also examines the strategic importance of 6×6 robots in military missions, from reconnaissance and IED (Improvised Explosive Device) deactivation to logistic transportation and autonomous patrolling. A dedicated section argues the superiority of a hybrid (diesel-electric) propulsion solution for 6×6 robots, emphasizing energy efficiency, extended range and precise dynamic control.**

***Index Terms*—robot, 6×6 land vehicle, logistics, reliability, stability.**

I. Introduction

A ground robot is an autonomous or semi-autonomous mechatronic system capable of movement and physical interaction in terrestrial environments. It integrates subsystems for perception (sensors to collect data about the environment and internal state), processing (control units that interpret sensor data, generate action plans and make decisions), and actuation (propulsion, manipulation mechanisms and other devices that enable movement and physical interaction with the environment). Propulsion is usually achieved by wheels, tracks or articulated limbs (legs), adapted to navigate on a variety of surfaces, from flat and even terrain to rugged and uneven environments. The primary purpose of land robots is to perform specific tasks, which may include exploration, transportation, security, inspection, object manipulation or interaction with humans, often in hazardous environments or environments inaccessible to human operators [7].

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II. International Capacities

The Guardium (Fig. 1) is an unmanned ground vehicle (UGV), developed by G-NIUS and used by the Israel Defense Forces (IDF) along the Gaza border. It was jointly developed by Israel Aerospace Industries and Elbit Industries. The vehicle can operate in remote-controlled or autonomous mode, reducing the need for manpower while maintaining deterrence capability. The joint program ended in April 2016, but the vehicle remains in service with the IDF [1].

Figure 1. Guardium UGV [1]

Guardium is armored for protection against light fire attacks. It has infrared cameras, radars, high-sensitivity microphones, visible sensors and hostile fire indicators, mainly for surveillance. The vehicle can be remote controlled or pre-programmed for designated routes. Sensors and infrared camera allow operation in various terrain and weather conditions [1].

In autonomous mode, Guardium can operate for extended periods without human interaction, detecting and avoiding environmental elements and abnormal circumstances. In tele-operated mode, it transmits data to a command station, providing its location and a view of its surroundings. The vehicle's main camera rotates 360º and can capture thermal images and videos. It also records data and has self-sustaining capabilities, as well as back-up

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batteries [1].

TABLE I. GUARDIUM PERFORMANCE PARAMETERS

Parameter	Value
Armament	Remotely operated light weapons
Height	2.2 m
Width	1.8 m
Length	2.95 m
Weight	1400 kg
Maximum speed	50 km/h (in semi-automatic mode)

The NERVA LG (Light Robotic System) (Fig. 2) is a rugged, reliable and very easy to use mobile platform designed to support a wide range of missions in hazardous areas or areas inaccessible for human operators [2].

This compact robot is ideal for remote observation, detection, destruction (e.g. of Improvised Explosive Devices - IEDs), manipulation, jamming and triggering of other systems or devices. It is suitable for reconnaissance and exploration of hazardous areas, including those with IED or CBRN threats [2].

Figure 2. UGV NERVA LG [2]

The LG NERVA stands out for its ease of commissioning, as it is a portable system that can simply be dropped in the field and then used. It can reach high speeds, adapting to the pace of operations. It can be reconfigured in seconds in the field without special tools, allowing quick change of wheels/tracks (it can be configured with wheels or tracks) and batteries. This ensures that the robot always provides the most appropriate capabilities in the context of reconnaissance missions and exploration of hazardous areas. It can be operated remotely using a control station with advanced ergonomic capabilities, becoming a natural extension of operational equipment [2].

The MUTT (Multi-Utility Tactical Transport) (Fig. 3) is an unmanned ground vehicle (UGV) developed by General Dynamics Land Systems, designed to provide logistical and operational support to troops in a variety of environments. It is available in several wheeled configurations tailored to the specific needs of military missions [3].

The MUTT is designed to reduce the physical load on soldiers, with the ability to perform transportation of heavy equipment, water, ammunition and other supplies. It can also be equipped with various devices, including surveillance systems, reconnaissance or even weaponry. Its modular design allows it to adapt quickly to varying requirements, making it a benchmark in robotics. The wheeled versions are capable of operating both on land and in water [3].

Figure 3. MUTT (Multi-Utility Tactical Transport) UGV [3]

The MUTT is available in three configurations: 4×4 in Table II, 6×6 in Table III and 8×8 in Table IV, each with specific capabilities.

TABLE II. MUTT 4×4 PERFORMANCE PARAMETERS

Parameter	Value
Length	1.67 m
Width	1.37 m
Weight	657 kg
Payload	270 kg
Maximum range *	96 km

*Maximum range is achieved by using a motor-generator, coupled to a 19 l tank [4]

TABLE III. MUTT 6×6 PERFORMANCE PARAMETERS

Parameter	Value
Length	2.36 m
Width	1.52 m
Weight	1043 kg
Payload	408 kg
Maximum range *	96 km

*Maximum range is achieved by using a motor-generator, coupled to a 19 l tank [4]

TABLE IV. MUTT 8×8 PERFORMANCE PARAMETERS

Parameter	Value
Length	2.95 m
Width	1.52 m
Weight	1360 kg
Payload	1134 kg
Maximum range *	96 km

*Maximum range is achieved by using a motor-generator, coupled to a 19 l tank [4]

The Hyundai Rotem Multi-Purpose Unmanned Ground Vehicle (Fig. 4) is Korea's first unmanned military vehicle designed with the latest technologies. Benefiting from Hyundai Motor Group's leading autonomous driving technologies, this UGV is capable of performing search and reconnaissance missions as well as ammunition transportation. It has been tested in real-world operations after approval by the Republic of Korea Army (ROK Army) in 2021 [5].

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Figure 4. Hyundai Rotem UGV [5]

TABLE V. HYUNDAI ROTEM PERFORMANCE PARAMETERS

Parameter	Value
Battle-ready weight	2 t
Maximum speed	30 km/h
Range in electric mode	6 h at 5 km/h
Total operation time	12 h
Traction	6×6 with electric drive
Tires	Airless

The basic MPUGV platform can be modified according to customer requirements and operating environment. Various designs can be applied to the equipment depending on specific missions. Areas of use include:

- Transportation of wounded soldiers;
- Autonomous driving kit (optional);
- Remote controlled weapons;
- Transportation of equipment;
- Anti-tank operations;
- Surveillance and reconnaissance;
- Detection of chemicals and weapons fire;
- Mine detection [5].

III. CHOOSING A CONSTRUCTIVE SOLUTION

The 6×6 wheel drive configuration is crucial for terrestrial robots due to an optimal balance between mobility, stability and complexity. It is neither too simple nor too complicated, delivering excellent performance in a wide range of terrains.

Technical advantages of the 6×6 wheel drive configuration:

A. *Superior mobility on rough terrain*

With six wheels instead of four, the robot has more points of contact with the ground. This increases its grip and ability to distribute pressure, allowing it to traverse larger obstacles (rocks, logs, ditches) and tackle steeper slopes without losing traction.

The weight of the robot is spread over six wheels, which reduces the specific pressure on each wheel and therefore on the ground. This is essential to prevent clogging in soft ground (sand, mud) and to protect the running surface (e.g. in agriculture or exploration).

Even if one or two wheels lose contact with the ground due to an irregularity, the other wheels can maintain grip, providing continuous and stable traction. This is particularly important in dynamic and unpredictable environments [7].

B. *Articulated Stability and Lateral Movement Capability*

A 6×6 wheel drive configuration offers a larger footprint compared to a 4×4 wheel drive, contributing to increased stability both on side slopes and during fast maneuvers.

By controlling individual or groups of wheels, 6×6 robots can perform more complex maneuvers, such as turn-in-place or lateral movement, crucial in tight spaces or for precise positioning.

C. *Redundancy and Reliability*

If a wheel or its motor fails, the robot can continue its mission using the other wheels. This redundancy is vital in critical applications, such as space exploration, military or search and rescue missions, where a single point of failure must not lead to the failure of the entire mission.

Load distribution across multiple components reduces individual wear and tear, contributing to longer operational life and potentially lower long-term maintenance.

D. *Cost-Performance Optimized Trade-off*

The 6×6 wheel drive configuration significantly exceeds the off-road capabilities of a 4×4 wheel drive configuration on difficult terrain, offering a considerable performance boost.

The 6×6 wheel drive configuration is mechanically and energetically less complex than tracked systems (which have high rolling resistance and are heavy) or multi-legged robots (which are extremely complex to control and slow). This reduced complexity often translates into lower manufacturing and maintenance costs.

These advantages make the 6×6 wheel drive configuration a popular and efficient choice for a wide range of ground robots, from autonomous military and exploration vehicles to industrial inspection platforms and urban delivery robots.

IV. IMPORTANCE OF 6×6 TERRESTRIAL ROBOTS

6×6 land robots are playing an increasingly important role in national security and defense as well as in various military missions. Their rugged configuration and adaptability to varied terrain make them essential tools for protecting human personnel and performing dangerous or repetitive missions, contributing significantly to the efficiency and safety of operations.

Equipping the 6×6 robots with advanced sensors (thermal cameras, high-resolution optical, LiDAR, radar) allows them to perform day and night reconnaissance missions in complex and dangerous environments. These robots can be deployed in conflict zones or border areas to detect troop movements, vehicles or suspicious activities without exposing human lives. The 6×6 drive design solution provides increased mobility in difficult terrain, such as forested, urban or hilly areas often encountered in military operations.

One of the most critical applications is the detection, identification and deactivation of improvised explosive devices (IEDs) or unexploded ordnance. 6×6 robots are ideal for these missions because of their stability and ability to incorporate specialized robotic arms and jamming or controlled detonation equipment. The redundancy of the 6×6 propulsion system provides additional safety by allowing the robot to continue its mission even after a wheel is damaged. This reduces the risk for engineers and intervention personnel.

In areas of operations, transporting equipment, supplies, ammunition or even evacuating the wounded can be extremely dangerous. The 6×6 robots can be configured as autonomous transportation platforms, capable of following troops or navigating independently along predefined routes, reducing the exposure of human convoys to ambushes or IEDs. Their ability to carry considerable payloads and maintain traction over diverse surfaces is a major advantage.

6×6 robots can be used for autonomous perimeter patrols of military bases, ammunition depots or critical installations. Equipped with detection sensors and secure communication systems, they can identify threats, alert personnel and, in some cases, even intercept or intimidate intruders, acting as a first line of defense.

By integrating remotely controlled weapon systems or NBC (Nuclear, Biological, Chemical) decontamination equipment, 6×6 robots can take on extremely dangerous tasks, reducing the military's exposure to direct danger. Whether neutralizing enemy strong points or operating in contaminated environments, the presence of these robots enhances the survivability of troops.

V. Comparison between 6×6 and 4×4

The 6×6 drive configuration offers an optimal compromise between complexity and off-road capability, placing it at an advantage over 4×4 or tracked configurations in most operating scenarios.

Military missions often involve driving over ruins, rubble, ditches, boulders, or through dense vegetation. A 4×4 can easily get stuck if one wheel loses contact with the ground or if weight is not optimally distributed on a slope. The 6×6 configuration, with two extra wheels, significantly increases the number of active contact points, providing constant traction even when one or two wheels are suspended or slipping. This ability to overcome obstacles is vital for maintaining operational rhythm.

In uneven terrain, on steep slopes or when diagonally crossing obstacles, a 6×6 robot is inherently more stable. The longer base of support and better weight distribution reduce the risk of tipping, which is crucial for platforms carrying sensitive equipment (optical sensors, communication systems) or even weapons. Superior stability allows faster and safer maneuvering in heavy operating conditions.

In challenging environments, where the robot may be exposed to enemy fire, IEDs or accidental failure, the ability to continue the mission after the loss of one (or even two) wheels is a major operational advantage. A 4×4 robot becomes almost inoperable with a single major wheel failure, while a 6×6 can perform its task or safely withdraw.

The extra wheels allow more transport capacity without overloading each individual wheel. This means 6×6 robots can carry more equipment, making them more versatile for a variety of missions.

The addition of two wheels and associated propulsion system increases the complexity compared to 4×4, but this increase is manageable in terms of cost, maintenance and control systems. In other words, the 6×6 drive system is more complex than a 4×4 drive system, but its complexity is significantly reduced compared to that of a system with articulated legs, for example.

VI. Comparison between 6×6 Wheel Drive Systems and Tracked Systems

Tracked systems offer superior traction and very low ground pressure and are unrivaled in extremely soft or very rough terrain (e.g. bogs, deep sand). However, they come with significant limitations in the military environment.

In missions where reaction speed is essential (e.g. fast patrol, pursuit, threat response), 6×6 robots are much faster in most terrains. The tracks are slow and generate considerable internal friction, consuming much more energy and limiting maximum speed, a critical disadvantage in dynamic operations.

The high energy consumption of tracked systems translates into reduced operational range or the need for larger and heavier batteries. This is a major constraint in theaters of operations where access to recharging is limited. 6×6 robots are significantly more efficient, allowing longer missions.

Tracked systems are generally noisier than wheeled systems. In reconnaissance or surveillance missions, where stealth is crucial, the low noise of a 6×6 robot is a significant tactical advantage, reducing detectability.

Tracks are extremely complex and prone to wear, especially in dusty, sandy or gravelly conditions. A broken or jammed track can completely immobilize the robot and require complex repairs in the field. Wheeled robots are easier to maintain and the wheels are more resistant to punctual damage. Spare parts logistics are also simpler for wheeled systems.

VII. Stability of a 6×6 Robot

Stability in the context of a mobile robot refers to its ability to maintain its balance and prevent tipping, sliding or loss of control when operating on slopes, uneven terrain, or under dynamic motion (sudden braking, rapid turning). For military missions, stability is not just a matter of performance, but one of survivability and operational efficiency.

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With six wheels arranged over a longer length, the 6×6 robot benefits from an extended footprint. On a slope or uneven terrain, this larger footprint provides superior roll resistance, both laterally and longitudinally [7].

The total weight of the robot, including the payloads carried, is distributed over six contact points. This distribution reduces pressure on each wheel and prevents overloading, contributing to a center of gravity as close as possible to the geometric center of the robot.

Although 6×6 robots do not necessarily use rocker-bogie suspensions (typical of space rovers), their design often allows for some independence or articulation of the axles. This means that even if one or two wheels are suspended in the air, the other four or five wheels can maintain firm contact with the ground on uneven terrain [7].

On rough terrain, the six wheels and associated suspension systems (whether simple or more complex) absorb shocks and bumps more effectively. This results in a less wobbly and more stable platform, essential for the optimal operation of precision sensors (high-resolution cameras, LiDAR) that require stable orientation to collect clear and accurate data.

VIII. Hybrid Propulsion System in a 6×6 Land Robot

The integration of a hybrid propulsion system, combining a diesel (or thermal) generator with a battery electric system, offers multiple operational and technical benefits for a 6×6 ground robot. This configuration maximizes efficiency, range and overall performance. One of the most significant advantages is the optimization of energy efficiency. Diesel engines have a specific efficiency curve, being most efficient at a certain operating point (defined by speed and load). In a hybrid system, the diesel generator can operate predominantly at this optimal efficiency point, continuously charging the battery pack. Electric motors, on the other hand, offer maximum available torque from zero rpm and have high efficiency over a wide speed range [6].

The 6×6 robot will encounter large variations in load (rough terrain, ramp approaches, carrying weights). In a conventional diesel system, the engine would have to run constantly outside its point of optimum efficiency, resulting in high fuel consumption and accelerated wear. The hybrid system allows the combustion engine to be decoupled from the direct propulsion requirements, with the generator supplying energy to the batteries, which in turn power the electric motors. This results in significantly reduced specific fuel consumption.

The combination of the two energy sources allows an extended range compared to a conventional electric or conventional diesel system. The batteries provide power for short periods of heavy load or silent operation, while the diesel generator takes on the role of extending range over long distances or long missions [6].

For reconnaissance missions, surveillance or in noise-sensitive environments, the robot can operate solely on battery power for considerable periods, reducing its acoustic and thermal footprint. The generator can be switched on only when recharging is required, or when the power demand exceeds the battery capacity.

Electric motors offer considerable advantages in terms of dynamic performance and motion control.

Maximum torque is available as soon as the electric motors are energized, ensuring rapid acceleration and excellent climbing or overcoming ability.

Through inverters (VFD - Variable Frequency Drive), the speed and torque of each electric motor can be controlled with exceptional precision [6].

When braking or going downhill, electric motors can act as generators, recharging batteries and improving overall efficiency.

Mechanical complexity is significantly reduced as electric motors do not require a multiple-ratio gearbox, simplifying the transmission and reducing losses.

The hybrid system introduces a level of redundancy that increases the overall reliability of the robot.

In the event of a generator failure, the robot can continue to run on battery power for a while. Similarly, a failure of the electric propulsion system is less likely to completely stop the robot if the generator can support some of the functions (albeit in a limited way).

Batteries act as an energy buffer, absorbing the peak power demand of electric motors. This reduces heavy wear and tear on the diesel generator, prolonging its lifetime and reducing the need to oversize it.

IX. Conclusions

The content of the article highlights the particular importance of the current state of the art of technology applied to 6×6 wheeled land robots, underlining their essential role in modernizing security and defense operations.

International manufacturers in this field exemplify the way in which advanced sensing, processing and actuation subsystems are integrated in order to perform complex and hazardous tasks while minimizing human exposure.

Thus, a series hybrid propulsion system (diesel generator that charges the batteries, which in turn power the electric motors) is a technically superior solution for a 6×6 land robot. It combines the ruggedness and extended range of a conventional combustion engine propulsion system with the efficiency, precise control and superior dynamic performance of the electric drive, resulting in a more versatile, efficient and reliable vehicle in diverse operational environments.

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