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TRENDS IN DEVELOPMENT OF MILITARY VEHICLES CAPABILITIES BASED ON ADVANCED TECHNOLOGIES

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Abstract: *This paper presents the challenges and perspectives regarding the technologization of military vehicles designed to be used in combat operations or in combat support. The technological progress registered in the production of batteries for the commercial automotive field has generated more and more interest in the hybridization or electrification of military vehicles, but also in the utilization of UGVs on the battlefield. In terms of survivability, either discussing about tanks, infantry fighting vehicles, armoured personnel carriers, or light tactical vehicles, in addition to the armor protection offered to the crew, the emphasis is increasingly on the implementation of active protection systems designed to remove or diminish the effects of enemy strikes. Moreover, as UAVs are more and more present in combat operations, the concept of 360 degrees of protection of vehicles has changed now to a hemispherical need of protection, considering the highly effective threats from above. Another actual trend to be considered is the multi-platform concept with distributed capabilities rather than all-in-one platforms, introducing the collaborative combat approach. Nevertheless, considering the complexity of these advanced systems, their high costs when acquiring or maintaining them, and their impact on logistic support, the implementation of such technologies in military vehicles is not that accelerated.*

Keywords: Military vehicles, Collaborative combat, Multi-platform concept, UGVs

1. Introduction

The results of the evaluations of both the conflicts that are ongoing and those concluded have highlighted the new guidelines on military actions, in which the control of the confrontation space, in all its dimensions, has acquired new valences under the impact of advanced technologies.
In this context, a reaction is needed both from the concept and action perspectives, but especially in the development of military capabilities appropriate to the requirements of the current and future operational environment, where on the ground, armoured vehicles remain the most effective weapons, which can achieve perpetual dynamism, mobility and a unique combination of assault and resistance force on fixed positions.
Nevertheless, the armoured vehicle remains a basic item of military doctrine, providing soldiers the opportunity to move fast and under protection, increasing not only the operational range but also the combat effectiveness of the land forces.
This paper aims to present the latest advanced technologies [1] used or intended to be used in the near future in the design and production of military armoured or light-armoured vehicles involved in combat operations or in combat support operations. At the same time, considerations over their

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implementation limitations, impact on future battlefield development, and impact on logistic support assurance are to be presented in the current article. The methods and scientific research tools used by the authors were observation, evaluation, interpretation, and comparative analysis. All these allowed us to generate an up-to-date, balanced, and fluent structure of the scientific content of this work, highlighting relevant information for militaries, defence industries, and academia.

2. Latest military technology trends

According to [10] and [11], the main topics of interest when considering the latest advanced technologies used in the military domain are as follows:

- Robotics & Autonomous Systems;
- Artificial Intelligence (AI);
- Advanced Defense Equipment;
- Internet of Military Things (IoMT);
- Cyber Warfare;
- Hypersonic missiles;
- Immersive Technologies;
- Virtual Reality (VR);
- Augmented Reality (AR);
- Big Data & Analytics;
- 5G;
- Blockchain;
- Additive Manufacturing.

These technological innovations are part of the Fourth Industrial Revolution (4IR), as mentioned and analysed in detail in [2] and a strong basis for 5IR [8].

A percentage-based approach to the impact of ten of these innovation trends on military technology in general is presented in Figure 1.

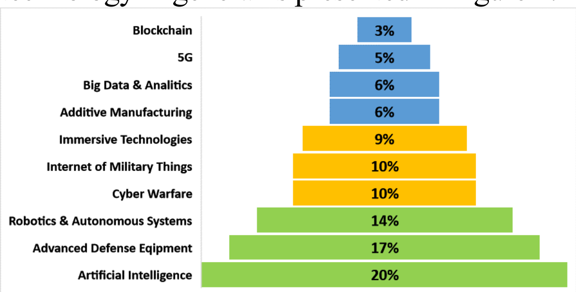

Figure 1: Impact of innovation trends on military technology (data adapted from [10])

When focusing specifically on technologies applicable to military vehicles, it can be stated that more than 50% of the above-mentioned innovation trends are of increasing interest.

Advanced defence equipment such as hybrid, electric, or even hydrogen-based propulsion systems, directed energy weapons, or active protection systems (APS) with hemispherical coverage have already been considered by the producers of military armoured vehicles worldwide.

At the same time, the adoption of AI in the military field enhances computational military reasoning for ISR missions (intelligence, surveillance, and reconnaissance). Computer-based devices that are continuously integrated into military vehicles, facilitate equipment safety management, empowering remote-controlled or autonomous weapon systems, reducing in this manner the soldier casualties. By leveraging digital twins and machine learning, the defence industry is testing new-generation military products and enable predictive maintenance for military equipment and technologies.

With the same intention of reducing soldier casualties on the battlefield, the use of robotics, remote-controlled or even autonomous military vehicles represents already a reality, not only a trend or a desideratum.

Moreover, for all these advanced technologies to work properly and efficiently, the use of the other two is needed – IoMT and 5G respectively, which facilitate the connectivity of ships, combat military vehicles, planes, UAVs, soldiers, command points, and operating bases that all work together in a cohesive and resilient network aiming to increase situational awareness, risks assessment, and to critically reduce response time.

3. Impact of advanced technologies on the main performances of military vehicles

As presented in [3], the requirements

established for the U.S. Army light armoured tactical vehicle were based on the "Iron Triangle" consisting of three main attributes desired for such a vehicle: payload, protection, and mobility.
The final pre-acquisition phase of tactical vehicles for the US Army and Marine Corps consisted of comparative testing of three vehicles: the HMMWV, MRAP, and JLTV.
As shown in Figure 2, they performed differently with respect to the "Iron Triangle".

Figure 2: Compared "Iron triangle" for HMMWV (left), MRAP (middle), and JLTV (right) [3]

The HMMWV provided good payload and mobility, but low protection level, while the up-armoured version of HMMWV had a better protection level, but mobility and payload significantly decreased. The MRAP offered great protection and payload, but not the desired mobility performances. Eventually, the JLTV offers the required balance of protection, payload, and mobility and for this reason, and finally, at the end of an intensive testing process, the U.S. Army and Marine Corps selected the JLTV as the winner of the competition.
Moving forward to other categories of armoured vehicles, such as infantry fighting vehicles or tanks, which are basically designed for combat operations, the "Iron Triangle" consisted until the 21st Century basically of mobility, protection, and firepower. Some manufacturers from the defence industries often increase the thickness of the armour, which translates into a higher weight of the combat vehicle, which has the effect of reducing the mobility of strategic terrestrial and air transport, reducing the speed of travel both to and on the battlefield.
In the last two decades though, far more elements need to be considered such as mobility, lethality, SDRI (surveillance, detection, recognition, and identification), autonomy, sustainability, adaptability, connectivity, and survivability. The balance between these new requirements is important to ensure that armoured vehicles are not restricted by their design constraints.

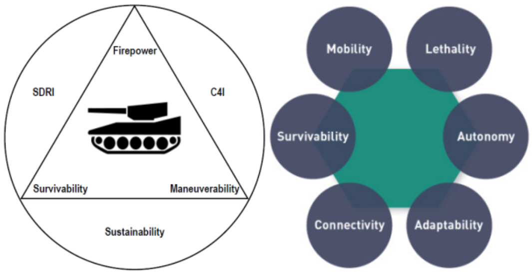

Figure 3: Updated "Iron triangle" according to actual requirements of the battlefield [4], [12]

As mentioned in [4], in the battlefields of the 21st Century it is all about the speed of collaborative combat in order to achieve operational superiority: therefore, the winner is the combatant who arrives first, detects first, identifies first, fires first and finally, hits and kills first.

4. Utilisation of UGVs on the battlefield

The evolution of robotics in parallel with the evolution of battery production technologies, corroborated with the development of hardware and software for connectivity and command & control devices, generated a great interest in unmanned and/or autonomous vehicles worldwide [9]. After initially being successfully applied in the industrial environment, unmanned platforms became more and more feasible also outdoors in domains such as agricultural, civil engineering, and space exploration but mostly in the military field.
An exhaustive analyse of automatization levels of UGVs is presented in [6], where four types of such platforms are considered. According to this research, "Automatic-

through Autonomous Unmanned Ground Vehicle (A-UGV) has been defined […] as an Automatic, Automated, or Autonomous vehicle that operates while in contact with the ground without a human operator". The four types of A-UGVs identified in [6] are:

- Level I: A-UGV without autonomy – being fully controlled by an operator.
- Level II: A-UGV with shared control –the control of the A-UGV is split between itself and the operator.
- Level III: a PC-controlled, unmanned A-UGV which can navigate guide paths with directed movement via a combination of software and sensor-based guidance systems (laser, embedded wire or magnets in floors, chemical tape, or other types of floor markings).
- Level IV: a level III A-UGV that can also re-plan and navigate without needing a guide path and using natural features from that environment.

Figure 4: Autonomy classifiers of an A-UGV (adapted from [6])

The twelve basic autonomy classifiers for A-UGVs are presented in Figure 4.

Moving forward to UGVs designed for military applications, the OODA loop (Observe, Orient, Decide, Act) needs to be considered if discussing about combat platforms with armament equipped (Figure 5).

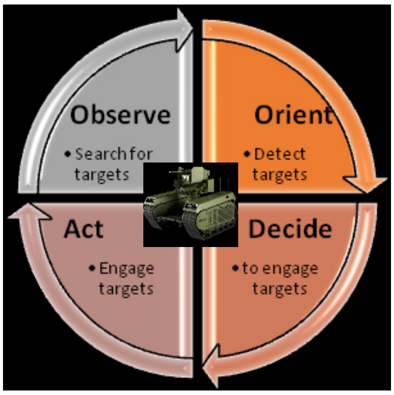

Figure 5: OODA loop for military combat UGVs

Based on the approach presented in [7], for the military UGVs, three levels of automatization can be considered:

- Soldier-in-the-loop UGV: when the platform needs the operator's involvement in each phase of the engagement process.
- Soldier-on-the-loop UGV: when the platform itself observes and orients but requires the operator's decision prior to executing an action.
- Soldier-out-of-the-loop UGV: when the platform observes, orients, decides, and acts completely autonomously, based on various interaction rules previously established by an operator.

To present a brief overview of the current progress regarding military UGVs design and production, the following examples shall be mentioned:

- THeMIS UGV (tracked, 1.6 tons, 20 km/h, hybrid Diesel-Electric), produced by MILREM ROBOTICS–configurable for logistic, combat, ISR, and EOD use [15].
- Type-X RCV (tracked, 12 tons, 80 km/h, hybrid Diesel-Electric), produced by MILREM ROBOTICS – configurable for combat applications with different types of armament systems such as 25-50 mm auto cannons or Loitering Munition Systems [16].
- Phobos UGV (wheeled, < 2 tons, 4x4), project phase in a partnership between French companies NEXTER and SERA Inginérie, aiming to develop robotic equipment and technologies for the French Land Forces [14].
- Patria AMV XP 8x8 HUGV (wheeled, 8x8), produced by Finnish company Patria,

the product being in the advanced testing and homologation phase [17].

To summarize the UGV on the battlefield topic, it can be stated that the future will be focusing in a significant proportion on this type of equipment, suitable for many applications such as logistic support (last-mile resupply, equipment/food/ammunition carrier) autonomous support to infantry sub-units, fire support or reconnaissance missions. The difficulties consist though in finding the best balance in their utilisation on the battlefield to get the maximum benefits, gaining the trust of the soldiers in such systems being also a challenge. Manned Unmanned Teaming (MUM-T), becomes in this context, a key to winning superiority combat, and by coupling human intelligence with AI in planning and decision-making processes, accuracy, operational flexibility, and continuity of machine learning can be obtained. By introducing unmanned autonomous systems into mission planning, properly combined with the utilisation of the manned system, the mission parameters and tactical sphere can be expanded while the risk to human and technological assets in uncertain or hostile environments would significantly decrease.

5. Trends in implementing collaborative combat

Until three to five years ago, the military combat vehicle design was focused on enhancing as much as possible technology on every single platform, in order to be able to fight one-to-one on the battlefield in almost every situation. However, nowadays approach tends to switch from very high-tech individual platforms to a multi-platform concept where collaborative combat is enabled.

Figure 6: THALES Combat Digital Platform, a collaborative combat approach [5]

A relevant example comes from THALES, a well-known producer on the military equipment market, who recently launched the CDP - Combat Digital Platform (Figure 6), as part of the French Army – “SCORPION” R&D-based endowment program.

CDP represents a cyber secure platform that was designed to share, analyse, and benefit from the consistent quantities of available data to grant information superiority for the military forces deployed in military operations. Being net superior to a normal C2 system, the CDP uses AI to bring collaborative engagements by LF to a new level. According to [5], “deployed at every level in the force, from the command center to vehicles on the front line, the system shares information between sensors and weapon systems continuously and flexibly under the supervision of human operators. Real-time cooperation between the sensors deployed by land vehicles, drones, and dismounted infantry significantly improves situational awareness in the battlefield thanks to automated data fusion, processing, and analytics.”

Another relevant approach for collaborative combat was presented at the beginning of 2023 at The International Armoured Vehicles Conference, held in London, UK, by [4]. In this context, the Bundeswehr anticipates that the secret to gaining superiority on the future battlefield is to switch from platform-to-platform (e.g., tank vs. tank, IFV vs. IFV) combat to a multi-platform scenario (collaborative SDRI + hit & kill). By doing so, the chances of

dominating the battlefield are higher but with a lower human factor involvement, contributing in this manner to a significant decrease in the number of soldier casualties.
A schematic representation of a ground multi-platform concept, designed by the authors, is presented in Figure 7.
To briefly describe the collaborative combat approach at the land forces level, we can consider the need for a group of several platforms, differently equipped in terms of armament systems, which together can fulfil a complete set of capability requirements.
However, to reach this desideratum multiple aspects need to be taken into account, such as the updated set of requirements for combat vehicles (see Figure 3), the different constraints imposed either by material or human resources, and last but not least the need to constantly adapt the doctrinal approach.

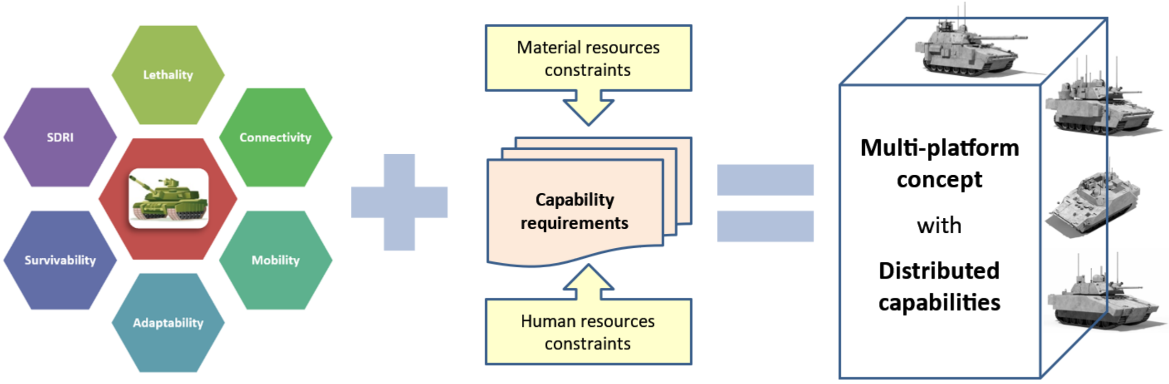

Figure 7: Schematic representation of a multi-platform approach as part of collaborative combat

The collaborative combat can be linked to the "Mosaic Warfare" concept, which supposes, according to [13], to send a multitude of weapons and sensors platforms in front of the enemy determining its forces to become overwhelmed. A particular example of how Mosaic Warfare could function in a ground conflict would be to send a UAV above or a UGV ahead of the main fighting unit of the LF. When spotting an enemy tank for example, the UAV/UGV sends back the coordinates, being afterward relayed to an NLOS (non-line-of-sight) armament system positioned on the rear side, which finally launches its best available munitions and eliminates the target.
To summarize the collaborative combat topic, it seems obvious that all-in-one platforms suitable for every capability will no longer prevail on the modern battlefield. Multi-platform combat concepts with distributed capabilities, combined with adequate MUM-T given the vast palette of unmanned systems that can be inserted in combat, could finally lead to achieving superiority, momentum, and assertiveness on future battlefields.

6. Conclusions

This paper presents some considerations regarding the latest technologies and trends in designing, producing, and operating military combat vehicles, acknowledging the transition from 4IR to 5IR.
Taking into account the dynamism of the multi-domain technological progress corroborated with the permanent evolution of the battlefield requirements, it is necessary that modern armies consider the implementation of some of the military innovation trends described in this research, in order to expect to gain superiority in potential future combat operations.
To briefly summarize the actual and future technological trends applicable in the military field overviewed in this research the following, without limiting to these, shall be highlighted:

- collaborative combat approach (switching from all-in-one platforms to a multi-platform concept with distributed capabilities);
- utilisation of wheeled or tracked

UGVs in combat or combat support operations;

- MUM-T (Manned Unmanned-Teaming) with increasing interest to exploit the maximum benefits of UGVs on the battlefield;
- hybridisation and soon electrification of military vehicles;
- hemispheric coverage of the APS equipment to be installed on the military combat vehicles, considering the threats from above (UAVs).

The technology offers the possibility to visualize the battlefield better and more accurately than ever and at the same time to take the appropriate measures to counter the effects of the opponent's attack. The collaborative combat approach allows the elimination of many vulnerabilities of the armoured vehicles generated by technological limitations and the coverage of the battle space in all its dimensions. It should not be forgotten, however, that no technology can prove its true value on the battlefield without being supported by an adequate training program, carried out in an actional conceptual framework adapted both to the characteristics of the operational environment but also to the technical and tactical characteristics of highly technological armoured vehicles.

Obviously, the modernisation and the technologization of an army represent a long, complex, and expensive process given the wide range of categories of weapons, equipment, and systems that it involves. Moreover, the impact on logistic support should also be considered when discussing the electrification of military vehicles, for example. Providing high amounts of electric energy, charging stations, and ensuring speed in recharging the batteries will be a serious challenge when being in the first line of combat.

Nevertheless, recent conflicts highlighted the benefits provided by the new-generation armament and weapon systems, combined with better communication between forces based on improved connectivity and SDRI.

Thanks to the latest advanced technologies used and designed to be used in the near future in the military field, the engagement of targets over a longer distance, based on faster processes with higher precision will soon be achievable and will lead to dominating the battlefield.

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