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The European Land Force Commanders Organisation

FINABEL - THE EUROPEAN LAND FORCE COMMANDERS ORGANISATION

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Introduction

In an era of increasingly complex operational environments, the integration of advanced machines and autonomous systems has the potential to reshape the future conduct of warfare. As military doctrines pivot toward Multi-Domain Operations in response to a multipolar world and the return of large-scale conflict, armies must innovate their sustainment strategies to meet the complex demands of modern warfare. This development is essential to bolster manoeuvrability, resilience, and the ability of armies to support dispersed, joint, and technologically integrated forces in contested and dynamic conflict zones. In this regard, two emerging paradigms, Human-Machine Teaming (HMT) and Human-Autonomy Teaming (HAT), are particularly promising, where the blend of human adaptability with the precision and efficiency of automation and robotics has transformative potential in various military logistics and medical activities. While the two concepts engage with different aspects of the sustainment network, they synergise to promise a faster delivery of more robust and accurate solutions to critical support functions.

Thus, this paper examines the potential of these paradigms to redefine forward sustainment operations within European land forces, highlighting their role in army (re)supply, battlefield repair/maintenance and medical support services. It reinforces that while these innovations come with challenges, including technological limitations and operational integration hurdles, European militaries must adapt and pave the way for a future where human expertise and autonomous capabilities are mutually enhanced to sustain missions and ensure operational effectiveness.

1. New Paradigms in Sustainment Operations

The Resurgence of Large-Scale Combat Operations and the Critical Role of Sustainment

"You will not find it difficult to prove that battles, campaigns, and even wars have been won or lost primarily because of logistics"
Dwight D. Eisenhower (Eisenhower, nd., as cited in Reece, 2023)

Over the past two and a half decades, there has been a clear trend towards increased adoption and reliance on unmanned assets in military operations (Freedman, 2016). This shift coincided with the emergence of risk-transfer warfare, a concept that Shaw (2005) identified as central to Western military thinking. This approach aimed to reduce the number of personnel directly engaged in battlefield activities and, by extension, minimise friendly casualties (Calhoun et al., 2021). The use of unmanned and semi-autonomous aerial systems within this strategy was enabled by US-led air superiority and the relative insulation of allied rear areas of operations (Buzzard & Dowgielewicz, 2018). However, the structure of the international system, increasingly defined by multipolarity and the resurgence of great power competition, as well as the spectre of near-peer conflict, no longer allows for the military approach that such forms of asymmetric, US-led hegemonic warfare practices were predicated upon (Lundy et al., 2020).

On the contrary, European allies must prepare for the increasing likelihood of conventional, protracted conflicts characterised by large-scale combat operations (LSCOs), as demonstrated by the ongoing situation in Ukraine. Indeed, as Russia's war of aggression in Ukraine exemplifies, operational environments are becoming increasingly "dynamic, complex, and uncertain" (Calhoun et al., 2020, p. 1). Crucially, the scale and intensity of these operations, which require armies to contest all domains, impose significant demands on sustainment activities. Accordingly, analysts of army doctrine have argued that the future success of allied forces in such scenarios is dependent on an "in-depth review of sustainment doctrine" (Lundy et al., 2020, p. 7). This aligns with the famous quote widely attributed to Eisenhower: "You will not find it difficult to prove that battles, campaigns, and even wars have been won or lost primarily because of logistics", with logistics often considered the cornerstone of sustainment activities (Eisenhower, n.d., as cited in Reece, 2023, para. 6).

While military doctrines vary in their definitions of sustainment, with the US distinguishing it clearly from logistics and NATO (2014) merging the two concepts, this paper will adopt the US definition, which describes sustainment as a range of activities 'necessary to maintain operations until successful mission completion' (Department of the Army, 2019). Sustainment, therefore, proves to be a vital determinant in the depth and duration of army operations, where its effectiveness ensures that a spectrum of options is always available to a commander.

Although sustainment embodies the provision of logistics, health service support, financial management, and personnel services at all levels of the army, this analysis focuses on the first two areas that are most relevant for forward front-line sustainment operations. The paper emphasises front-line sustainment as the operational edge of military environments, which presents the greatest challenges to sustainment activities (Department of the Army, 2019). In these zones, the strain on military operations is most concentrated, as the dispersion of forces at the end of extended supply lines, long communication channels, and complex, often congested terrain presents significant obstacles to their effectiveness. Additionally, higher casualty rates in these high-intensity settings drive a greater demand for medical resources, further compounding logistical pressures (Marsh & Hampton, 2022). In this context, the integration of artificial intelligence (AI), machines, and robotic systems has the potential to revolutionise core elements of sustainment activities, including supply-chain management, battlefield maintenance/repair/clearance, and medical army services and evacuations (Lacroix, 2023). Subsequently, HAT, also referred to as Human-Machine Collaboration (HMC) in UK doctrines, and HMT are thus emerging as alternative, novel frameworks which aim to minimise the degree of human control and improve decision-making on and off the battlefield (Mayer, 2023; Kaushal et al., 2024). As such, the rationale guiding current shifts in the incorporation of robotics and autonomous intelligent systems has less to do with reducing risk than optimising efficiency.

Human-Machine Teaming and Human-Autonomy Teaming

While at their core, the two interrelated paradigms are premised on the idea that humans and machines have comparative advantages and excel in different areas, it is important to distinguish between HMT and HAT. HMT is a collaborative process where humans and machines form a feedback-driven partnership, each adapting to and influencing the other's actions (UK Ministry of Defence, 2018). This synergy promises to leverage the complementary strengths of both and minimise their mutual limitations, enabling effective outcomes that exceed what either could achieve independently (Kaushal et al., 2024). Central to HMT is the interplay of four key elements: humans, who provide inputs, evaluate outputs, and guide machine operations; machines, such as drone swarms, which possess varying degrees of agency to support specific missions; interactions, which refer to the processes by which humans and machines synchronise their efforts to achieve a shared goal; and interfaces, the tools and mechanisms that facilitate communication and collaboration between the aforementioned components (Nurkin & Siegel, 2023).

For example, an operator managing a casualty evacuation (CASEVAC) mission with an Unmanned Aerial Vehicle (UAV) provides initial parameters, such as casualty locations, to guide deployment. The UAV autonomously analyses battlefield conditions, identifying safe and efficient evacuation routes while considering adversary positions and environmental hazards. Throughout the mission, it provides real-time updates, like changing weather conditions, enabling the operator to adjust the plan. This contrasts with traditional human-machine interactions, such as operating a mortar, where the system's role is fixed and entirely reliant on human input (Kaushal et al., 2024).

On the other hand, HAT addresses the cognitive limitations of individual decision-makers by augmenting human capabilities, particularly in pattern recognition and intuitive, flexible thinking through the integration of computational and reasoning power of intelligent systems (Calhoun et al., 2020). Central to this concept are AI and Machine Learning (ML) technologies, which enhance a military's capacity to rapidly assess situations, plan effectively, and make informed, robust and timely decisions (Mayer, 2023). The primary distinction between the two paradigms thus lies in the level of autonomy and the nature of the collaboration. In HAT, the human acts as a supervisor or decision overseer, with intelligent systems operating independently. In contrast, in HMT, the human takes on the role of an operator, where the machine's actions are primarily determined by human input.

Nevertheless, there is a degree of overlap between the two models. As highlighted in the RUSI report, Kaushal et al. (2024, p. 5) assert that "the most advanced [military] application will include elements of both". This is particularly relevant to sustainment operations, which inherently demand high levels of coordination, integration, and efficiency to ensure success.

2. Logistics and Supply-Chain Management

Logistics remains a critical component of sustainment operations. Defined broadly, it refers to the planning and execution of the movement and support of forces, encompassing several key elements, such as supply, resupply, transportation, battlefield repair, field maintenance, and general engineering support (Department of the Army, 2019a).

Supply, resupply and transportation

Outside military settings, AI applications in predictive analysis and commercial logistics have been widely criticised (Pournarder et al., 2021; Toorajipour et al., 2021). From managing stock inventories and identifying supply chain delays to creating optimal routes and predicting supply-chain disruptions, it is no surprise that observers are beginning to highlight their revolutionary potential in military supply chain management (Lacroix, 2023). The idea is that AI and ML systems have an inherent capacity to attain the speed of relevance necessary for practical logistics in the hyper-shifting, data-dense operational environments of modern conflicts. Such systems could ensure the synchronised distribution of all types of military supplies integral to the logistics system, such as medical supplies, foodstuffs, and materiel, delivering the right resources to the correct location at the right time. Therefore, HAT enhances responsiveness and efficiency by advancing adaptive logistics, which prioritises flexibility and real-time decision-making in managing supply chains.

In the context of HMT in (re)supply, initiatives such as the UK Ministry of Defence's Autonomous Last Mile Resupply (ALMRS) project and the US Army's Ground Expeditionary Autonomous Retrofit System (GEARS) project illustrate the growing intent to incorporate autonomous delivery systems in military supply chains (Demarest & Robertson, 2023). Within the ALMRS project, UAVs such as Animal Dynamics' autonomous paraglider, Stork, and Barnard Microsystems' InView showcase these advancements (Turner, 2018). The Stork, designed for stealth, can transport critical supplies up to 300 km at 70 km/h, while InView features a modular, vertical take-off and landing design (Turner, 2018, para. 6). Both UAVs are equipped with novel guidance systems and sensors, and efforts are underway to integrate intelligent logistics systems into a network of autonomous vehicles. This network involves a reconnaissance unit that scans the environment to plan delivery routes and a delivery unit that navigates based on this information. By reducing the burden on human logisticians and minimising risks in hazardous zones, this HMT approach offers significant advantages in both land and maritime domains. Although developments in Unmanned Ground Vehicles (UGV) are still ongoing, the use of cargo drones in Ukraine, capable of delivering loads of 180kg to the frontlines, signals that the shift toward autonomous (re)supply is well underway (Saballa, 2024).

Field maintenance and general engineering support

Another significant component of logistics is field maintenance and general engineering support, which are vital for sustaining operational effectiveness in complex and contested environments. Field maintenance focuses on diagnosing issues, performing minor repairs, and replacing components to restore equipment to operational status without removing it from the battlefield (Department of the Army, 2019a). For instance, AI-driven predictive maintenance for armoured combat vehicles offers significant benefits to military organisations by proactively identifying and addressing potential equipment failures. Using sensor data and machine learning, AI can detect patterns signalling impending issues, enabling timely maintenance that extends the vehicle's lifespan (Narayanan & Padhy, 2023).

Moreover, general engineering support encompasses tasks such as constructing and repairing military infrastructure (e.g., roads, bridges, and defensive structures) while ensuring mobility through obstacle clearance, route reconnaissance, and building crossings. An example includes the Israel Aerospace Industries' (IAI) autonomous combat bulldozers (Repurposed Caterpillar D-9 bulldozers) designed to clear battlefield obstacles and help with terrain shaping and the construction of fortifications (Wullman, 2024). Battlefield clearance and minesweeping robotics also play an increasingly pivotal role here. For example, in the naval domain, Unmanned Surface Vehicles, such as those developed through the EDA's Modular Lightweight Minesweeping Next Generation (MLM-NG) project, have proven invaluable for developing mine-clearing capabilities in potential naval conflict zones, ensuring safe military maritime navigation (European Defence Agency, 2024).

3. Health Service Support and Medical Evacuations

Army Health Service Support and the Automated Survival Chain

Army health service support is a critical aspect of military sustainment. Hence, it is necessary to adapt to meet the challenges of LSCOs by incorporating autonomous hardware (robotics, medical devices) and AI-based software. In this context, Gurney et al. (2024, p. 1) propose a "survival chain," modelled on the "kill chain," that should be increasingly automated to offload human tasks and "accelerate critical decisions about casualty care," thereby preserving combat power (Talley et al., 2024, p. 1). Indeed, a combatant who is injured or falls ill and who is not adequately diagnosed or treated represents a loss of manpower and thus compromises the longevity of an operation (Kim et al., 2023). This is particularly problematic in the context of large-scale conflicts, which place greater pressure on medical support units (Worsham et al., 2024). Therefore, technological integration of advanced machine systems could accelerate the procedures involved in the survival chain, lowering the burden on military medical staff while simultaneously maximising return to duty (Worsham et al., 2024).

In this context, the "survival" chain involves a series of stages to ensure casualty care, starting with immediate response at the point of injury, which typically involves systems such as combat medics and the application of tourniquets (Gurney et al., 2024). This is followed by tactical field care, where medics stabilise casualties, often under hostile conditions, by applying techniques such as haemorrhage control. Forward surgical treatment then provides life-saving interventions near the front lines, after which casualties are redirected to higher-level care facilities for more comprehensive treatment (Gurney et al., 2024).

Triage

Triage refers to the process of distinguishing between casualties as a means to rationally allocate finite resources available to medical units (Falzone et al., 2016). This is particularly complex, especially considering the objective of military triage is to identify those soldiers who could be treated rapidly to return to the battlefield, vital to the completion of a mission. AI systems are particularly beneficial in this context. Some militaries have already begun investing in this domain, such as the US Army with its AI-powered APPRAISE-HRI, which uses vital-sign data to assess trauma patients' risk of haemorrhage (Lagasse, 2024). Similarly, DARPA's ITM program supports the development of AI and ML algorithms capable of independent decision-making regarding both mass casualty triage and small unit triage (Keller, 2023).

Casualty Evacuation

The evolving nature of modern warfare has rendered many traditional CASEVAC strategies inadequate. Unlike medical evacuation (MEDEVAC), which involves en-route care by medical personnel, CASEVAC focuses on the rapid transport of casualties without such care (Department of the Army, 2019b). Lt. Col. Ihor Shcherbakov states that "the methods of medical evacuation of the wounded used in previous wars [...] are no longer effective in our realities" (Manuel, 2024, para. 14), following the introduction of FoxTac unmanned logistics and evacuation stretchers in the Ukrainian army.

While UAVs are increasingly employed to deliver critical medical supplies like blood (Easley, 2022), their application in casualty evacuation remains underutilised. Handford et al. (2018) emphasise their potential to minimise risks to human life and enable rapid extraction of casualties from high-risk or inaccessible areas where conventional aerial or ground assets cannot operate. As warfare shifts to a multi-domain, force-on-force model, air manoeuvrability for traditional evacuations will diminish. Military teams will need to rely more on self-evacuation and automated systems, like FoxTac stretchers and BAE Systems' T-650 heavy-lift UAVs, strategically positioned for rapid response (Manuel, 2024; Gosselin-Malo, 2024).

Furthermore, unmanned vehicles (UVs) are much cheaper than manned vehicles and will only become more affordable as technologies are optimised and systems proliferate, introducing economies of scale (Handford et al., 2018). HMT in evacuation also poses no risk to personnel life, meaning there is a higher tolerance for the insertion of evacuation systems in risky kinetic areas of operation. Nevertheless, as an individual casualty will be carried onboard, the decision to evacuate the wounded personnel will remain a key consideration.

In sum, these two paradigms have the potential to bolster the core enablers of effective military sustainment: integration, anticipation and responsiveness. Together, these improve survivability and strengthen the military's capability to avoid and withstand hostile actions while retaining their full capacity to fulfil their primary mission.

4. Challenges to European Military Sustainment

There are two principal challenges that Europe must overcome to effectively integrate and deploy HMT and HAT for future sustainment operations. The first is conceptual; Europe must not conflate logistics and sustainment planning with military mobility. Arguably, the European Union (EU) has allocated substantial resources and effort toward developing mobility initiatives such as the 'Action Plan on Military Mobility 2.0' (European Commission, 2022), and PESCO projects like 'Military Mobility' (European Defence Agency, 2022). However, rather than fundamentally reconceptualising its approach to military logistics, a domain that Fiott (2024) contends lacks the necessary political attention, this paramount aspect has remained largely overlooked. At most, the efforts behind establishing a comprehensive approach to supply line networks are "nascent" and "incoherent" (Fiott, 2024, p. 4). To address this, the EU must distinguish between core elements of sustainment, including (re)supply, transportation/mobility, health service support, maintenance, and general engineering. Recognising and developing each component is vital for effective sustainment operations.

Secondly, European allies must establish common frameworks for developing and integrating AI systems across sustainment activities. This requires pooling data from diverse member states from commercial and military sources to enhance AI capabilities. Greater investment in autonomous systems for sustainment tasks is also vital, with the UK's £300 million 'Human-Machine Teaming' project offering a strong model alongside improved European coordination (Patel, 2024). A state capable of overwhelming adversary robotics gains a decisive advantage in targeting military or civilian human elements. As disruptive powers like Russia and China heavily invest in such technologies, this growing asymmetry presents a pressing challenge for European forces (Franke, 2019).

Conclusion

In conclusion, this paper has demonstrated that the integration of HMT and HAT represents a pivotal advancement in military sustainment operations. By leveraging autonomous machines and intelligent systems, European land forces can enhance efficiency, reduce human error, and improve decision-making processes across the military sustainment network. However, the effective integration of these teams requires awareness and political willingness on the part of European actors to challenge their own technological, regulatory and ideational limitations regarding the development and operationalisation of relevant technologies. Embracing these technologies will be crucial for maintaining strategic autonomy and operational superiority in future combat scenarios.

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