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# IMPLICATIONS REGARDING THE LOGISTICAL INTEGRATION OF EXOSKELETON-TYPE ROBOTIC SYSTEMS

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**ABSTRACT**

*The technological developments of the 2nd decade of the 21st century reveal the development of systems that facilitate economic operations within the economic and military supply chains to immediately meet the needs of consumption and use. Therefore, one of the technological systems with an important impact on the efficiency of carrying out specific operations in such systems is represented by the exoskeleton robotic system. This material approaches in a correlative manner the importance and role of exoskeleton-type robotic devices starting from the increased demands of the Future Soldier both on the operational line and in terms of adequate logistic support for its sustainment and self-sustainment. Therefore, even in the military logistics of the constitution combat forces of tactical and/or joint level, exoskeleton-type devices are used by military and civilian workers especially for carrying out activities appropriate to the loading and unloading of materials, in order to quickly respond to the requests for the timely granting of the complex logistical support both during the day, as well as at night. Moreover, this exoskeleton-type system can be easily used by logistics execution personnel who may also work in different areas of logistic support such as maintenance, movement and transportation, or medical support.*

**KEYWORDS:** combat structures, exoskeleton-type robotic system, Future Soldier, military logistics integration, operational logistics sustainment

## 1. Introduction

Continuous reconfigurations in the concepts and ways of action specific to the war of the future require continuous adaptations of the operational forces destined for the tactical and joint levels, in order to be able to counter multiple challenges and threats, based on the new requirements regarding the framing, training, and endowment with new equipment and modern weapon systems (The British Army, 2021).

The Future Soldier project represents a major target regarding the national and

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multinational operational development within NATO, with determinations and important implications for logistical support in the field. Within this framework, results the multitude of complex relationships and conditionings with modern equipment and armaments, in order to meet the operational objectives of the Alliance, of transforming and modernizing the components of the combative potential, so as to achieve a series of requirements for the Future Soldier regarding the specific ergonomics in the handling of weapons and the management of modern equipment and weapons systems in use, full effectiveness, and actional flexibility, under conditions of increased individual and organizational resilience (Madrid Summit Declaration, 2022). In this context, according to the received missions, the Future Soldier, his commanders, logistics leaders, and their operational structures of belonging (both inferior and superior) will focus their professional efforts on the predominantly *man-advanced technology (modern combat equipment and weapon systems)* relationship (Weissenböck, 2015). Figure no. 1 shows a representative image of the Future Soldier that involves the need to augment his physical potential and protection.




Figure no. 1: *An image representing the Future Soldier equipped for combat, requiring increased physical and protective potential*
(Source: Weissenböck, 2015)

In accordance with essential objectives and adequate development strategies among the Alliance states, the Future Soldier will be a member of each military combat organization, characterized by a high level of competitiveness, resilience, and capability to counteract any action of the opposing forces in extremely turbulent environments with increased lethality, involving complex agility and protection. At the same time, this soldier must have the ability to continuously adapt to the new ever-changing actional constraints (The British Army, 2021), which requires an adequate response of his body to the parameters of biological, physical, intellectual, and psychological resilience, as well as high resistance to specific factors such as pressure and stress (French Armed Forces Update, 2021).

In order to achieve the necessary success in tactical and joint operations, the Future Soldier has an essential role, which can only be fulfilled as a result of the specific processes regarding continuous training, the endowment and capacity of the individual and the systemic use of a complex range of advanced equipment and armament systems designed for effective, flexible and protected actions. This involves in a direct and complex manner both production logistics, "in-service" logistics, and operational logistics from the constitution of the combat structures in order to provide timely and sufficient, adequate, and resilient logistical support (by functional domains), according to the increased requirements necessary to fulfill the missions received.

Willing to obtain the relevant information necessary to achieve the scientific content of the article, we used several methods and scientific research tools such as observation, comparative analysis, evaluation, interpretation, induction, and deduction. All these allowed us to carry out actions appropriate to the modern, balanced, and understandable construction of the scientific content of this work, very important for military operational logistical support. The sequences of content included in this material are based on the established scientific research objectives, being integrated into a logical sequence throughout the article, starting from the characteristics of the Future Soldier – connected to equipment and dependent on logistics, to the specific elements of the exoskeleton-type robotic device, and then to the easy integration of this modern system in some areas of operational military logistics.

## 2. The Role of the Exoskeleton System for the Future Soldier

The need for continuous, effective, efficient, and protected activation of the Future Soldier, according to the missions received in tactical and joint operations, has generated research and innovation efforts for its design, starting from the individual equipment, backpack, portable weaponry, and ending with a robotic protective device, allowing it more effectiveness, flexibility, and resistance in the complex, dynamic and unpredictable battlefield space. Here, his acting behavior, despite a large load of tens of kilograms (which is intended to be lower), shall allow him to quickly relate to automated, cybernetical, digitized, and robotic weapon systems and equipment, in order to achieve both the goals set and success in combat.

The idea of creating the exoskeleton device started from the existence in nature of some species (e.g. crustaceans and insects) with skeletal structure outside of the body (a sort of external protective armor), such as crabs and lobsters (in crustaceans), grasshoppers and ants (in insects). In contrast to the exoskeleton is the endoskeleton found in human organisms and vertebrates, represented by bones inside each body, covered by tissues and cell membranes that individually allow growth and flexibility, but with vulnerabilities to external factors (Niruthan, 2021). Under these conditions, the importance of the exoskeleton for the Future Soldier is to cancel the mentioned disadvantage and increase his physical potential for defense and protection against enemy attacks with extremely destructive weapons (Mittal, 2020).

In accordance with those presented both at the current stage and especially in the future, the research of the specialists from the developed states of the Alliance has led to the realization of important innovations, which allow the improvement of strength, resistance, and ergonomics in conditions of maintaining individual protection and reducing the risks of physical injury during the development of specific activities such as movement, running, transport, etc. All this represents the subject of a modern device with the status of a portable robot called ***exoskeleton,*** which has the role of facilitating the loading of a combating soldier

(infantryman) by counteracting the stress (pressure) generated by the weight of the materials on the lower back and legs (Keller, 2022). Figure no. 2 shows a model of an exoskeleton-type portable system.



Figure no. 2: *A portable 2nd generation exoskeleton system*
(Source: Bellis, 2019; Mihăeanu, 2012)

During the 1960s, General Electric was the first company to produce an exoskeleton device, as part of the *"Exoskeletons for Human Performance Augmentation Program",* under the direction of John Main. The continuous concern over modernizing the exoskeleton needed by the Future Soldier, starting from the 1st generation (about 15 years ago) to the 3rd generation (today), is revealed by a number of companies of great importance operating in the top defense sector in the United States, such as Raytheon and Lockheed Martin (Niruthan, 2021).

## 3. The Importance of Integrating Exoskeleton-Type Systems in the Operational Logistics

The logistics specific to the exoskeleton-type system has several implications aimed at both the individual support and self-support side of the Future Soldier, as well as the facilitation of the carrying out of actions (operations) specific to the operational logistics in two forms of applicability: "upstream" and "downstream".

*The logistics of the individual support and self-support of* the Future Soldier involves all the necessary materials for loading, as well as the exoskeleton device designed to increase the physical and protective capacity as presented in correlation to chapters 1 and 2. These combined with the skills and physical readiness of the military will allow him to act continuously, flexibly, and effectively, in order to achieve operational success in any combat situation (Valpolini, 2018). An advanced exoskeleton needed by the Future Soldier will have similar performances, such as the "Guardian XO Max" model created by the specialists from "Sarcos Robotics", which is functional by supplying miniaturized batteries. This device allows an operator to lift a load of 45 kg by using a force equivalent to the one required for the lifting of 2.2 kg (Jurczak, 2019). For the operation of the mentioned exoskeleton-type robotic device the following are necessary: powering the system with miniaturized batteries and the existence of interchangeable cells, which allow the empty ones to be replaced appropriately by those

loaded in accordance with the requirements laid down (Jurczak, 2019). Figure no. 3 reveals an image of warehouse workers equipped with robotic exoskeletons-type "German bionic", who are in the process of loading-unloading of some packaged materials in order to fulfill orders.

According to the above-highlighted aspects, it becomes predictable that the increasingly complex operational requirements will generate the need that the Future Soldier immediately lifts depending on the situation, with flexibility, agility, and actional effectiveness up to 100 kg, which would be equivalent to lifting a weight of about 5 to 7 kg. These details are valid for the use of the exoskeleton, with the necessary adjustments, and for the types of operational logistics highlighted below.

*The "upstream" operational logistics* is the one suitable for the effective and efficient functioning of the Future Soldier and aims at the use of the exoskeleton-type system by the logistics workers (both military and civilian) in all maintenance, movement, storage, transport, and replenishment operations of the material consumption to the beneficiaries (militaries, equipment and weapons systems within the III to I lines of logistic support, in I to V classes of materials), as well as their timely movement to places within each large unit, unit, and fighting subunit (Keller, 2022).



Figure no. 3: *Workers equipped with exoskeletons, loading-unloading materials inside a warehouse*
(Source: Jurczak, 2019)

In the whole of this continuous process, at the tactical level within the framework of *the "downstream" operational logistics*, the exoskeleton-type system allows the strengthening of the physical strength and resistance of the soldiers within the logistics subunits and teams (located in the 1st line of logistic support) involved in the maintenance and evacuation/towing actions of the technique with repair needs, as well as for the reception, temporary storage, handling, loading-unloading, road and/or rail transport of materials to combat supply points and then from here by carriers to fighters, equipment, and modern weapons systems (Jurczak, 2019). For example, the exoskeletons used by the warehouse workers are based on a support structure mounted on the body of the military (or civilian), which supports his movements (loading-unloading) with the help of electromechanics (coddling the legs, the muscles of the back and spine on the lumbar section). At the same time, artificial intelligence technologies can be integrated

into exoskeletons, which continuously monitor not only the condition of the devices but also the bodies of the users (achieving the permanent adaptation of the devices to real operating conditions). In the event that an exoskeleton-type system detects irregularities, then it will immediately stop, concomitantly informing its user (Jurczak, 2019).

The experts of the German Army have carried out a series of field studies at different operational logistics and maintenance structures in order to develop design requirements for the new exoskeleton-type device with applications in the military logistics of the combat structures. This allowed the proper understanding of the logistical operations based on the main or secondary activities as well as on actions to protect the environment, which led to the development of research projects and the realization of the first prototypes of the said exoskeleton-type device (Hichert et al., 2022).

## 4. Conclusions

According to Jurczak (2019), the future exoskeleton-type system intended for the Future Soldier will integrate a lot of modern technologies (communication systems, on-board computers, cyber protection devices, temperature regulators, sensors for monitoring the health of the user, as well as devices that accelerate wound healing, including own oxygen supplies). However, the device will also have simpler versions suitable for military and civilians who will work in warehouses, transport, maintenance, or medical support.

Military researchers continuously analyze and evaluate exoskeleton technology in order to provide safety to military users, comfort, ease of use, integration with clothing and equipment, and ensure energy efficiency (Keller, 2022). Therefore, the individual combat equipment of Future Soldiers must be in complete synergy with exoskeleton-type devices and the types of weapons and combat systems existing in users, which will continuously shape the contents of doctrines and operational textbooks (Hambling, 2016).

All aspects related to the design, realization, assurance, and use of exoskeletons in the military operational domain, have logistical implications, according to the above-mentioned. Moreover, the individual suits, synergistically combined with the exoskeleton-type devices and with the portable combat systems, may complicate the logistical support to be given to the Future Soldier in any situation, in order to fulfil the missions received in any time conditions, season, and weather condition.

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