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Feasibility of Casualty Evacuation by Unmanned Systems

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Abstract

Development of unmanned systems has registered unprecedented progress. They provide a wide range of tasks in contemporary battlefields and the process of finding their new applications is still ongoing. Medical support is one of the areas where unmanned systems have found their application as well. The aim of the paper was therefore to carry out research on feasibility of casualty evacuation (CASEVAC) by unmanned systems. Research was executed as qualitative research using methods of analysis, observation, personal experience, comparison and generalization to comprehensively describe different aspects of CASEVAC executed by unmanned systems. Furthermore, as and quantitative research using method of comparison focused on multiple parameters of unmanned systems that are essential requirements for fulfillment of CASEVAC tasks. Research process started with study of available documents concerning unmanned systems their analysis based on personal experience and identification of factors that influence feasibility of CASEVAC by unmanned systems. Furthermore, we compared multiple parameters of different unmanned system solutions with required ones and identified suitable solutions. We found out that beside unmanned aerial systems that were traditionally deliberated for CASEVAC tasks great development of unmanned ground and aquatic systems has been achieved. The feasibility of unmanned systems for CASEVAC was confirmed and areas of further development have been identified. The paper comprehensively analyzes a variety of aspects that have to be taken into account when considering execution of CASEVAC by unmanned systems and sort them into categories.

KEY WORDS: *unmanned systems, unmanned ground systems, unmanned aerial systems, unmanned aquatic systems, casualty evacuation, medical evacuation*

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1. Introduction

Main task of military medical services is to preserve and restore health and recover fighting ability and combat power. Military medical services therefore provide a full range of medical care, containing preventive measures, treatment and medical evacuation (MEDEVAC).

MEDEVAC is the medically supervised process of moving any person who is wounded, injured or ill to or between medical treatment facilities as an integral part of the treatment continuum. MEDEVAC is executed by dedicated transportation assets, under supervision of medical personnel to most suitable medical treatment facility (MTF).

Complex operational environment and complicated tactical situation not every time offers possibility to transport wounded, injured or ill person by MEDEVAC assets and in escort of medical personnel. According to Brezina and Majchút [3] transport has an essential role in solving crisis events. Above-mentioned facts are the reasons why CASEVAC is sometimes organized to cover insufficiency of sources or to reach medical timelines. CASEVAC is opportunistic transport of casualties executed either by transportation assets not dedicated to MEDEVAC or executed without supervision of medical personnel and in majority of cases both conditions are met.

Unmanned military systems and robots are being used more and more [11] in contemporary military conflicts and executes unprecedented scale of tasks and operations to support military troops. The use of unmanned aerial vehicles in many roles is one of the fastest growing of all fields in military aviation [19]. Unmanned systems provide tasks from purely military tasks to tasks of logistic support. For purposes of medical support are unmanned systems used to resupply forwarded medical capabilities, including resupply of blood and blood products or medical equipment. The range of these tasks and operations will definitely grow in future military operations.

The idea of unmanned systems to be used for CASEVAC is not new. Medical subject matter experts have been dealing with it for more than two decades. The aim of the paper is to comprehensively investigate aspects of the CASEVAC executed by unmanned systems and possibility to use commercially produced unmanned aerial systems, unmanned ground systems and unmanned aquatic systems for military CASEVAC.

2. Different Aspects of CASEVAC Executed by Unmanned Systems

When considering execution of CASEVAC by unmanned systems on battlefield great variety of aspects have to be taken into account. The aim of this chapter is to comprehensively analyze these aspects. Due to the fact that a great number of different issues were identified it will be therefore beneficial to classify them into several categories with similar or akin aspects.

2.1 Technological Aspects

The most important area of the aspects as far as feasibility of CASEVAC by unmanned systems are technological aspects. We can divide them into three subgroups.

We will begin with aspects in connection with unmanned systems alone. The first precondition to use unmanned system for the purposes of CASEVAC is ability to carry enough weight. Unmanned systems have to be able to carry weight of the casualty/casualties itself increased by weight of the medical equipment and medical material. Contemporary development of the majority of unmanned systems allows evacuation maximally two casualties at once. But multiple advantages of transportation only one casualty will be probably decisive for single casualty CASEVAC to the future.

The second precondition is to have the range that is enough to carry out CASEVAC mission. This range is defined as needed distance to evacuate the casualty to the zone where medical continuum of care could proceed by further MEDEVAC or by medical treatment of the casualty in the closest suitable medical capability (Forward Surgical Team, MTF Role 1, MTF Role 2, MTF Role 3, etc.).

Presence of medical equipment on board of the unmanned system necessary to monitor health status of casualty or even medical equipment able to provide limited required medical care would be beneficial for survivability and the prospective treatment of casualties. Such medical equipment could be supervised by artificial intelligence or remotely by medical personnel. Furthermore, the provision of ballistic protection of casualties as not necessarily required feature. But the existence of ballistic protection could increase survivability in case of intentional or unintentional kinetic actions of the enemy.

Moreover, aspects in connection with safe ride standards that include restraints and safety issues concerning air quality, noise levels, temperature levels, vibration levels, lightning and acceleration limits of unmanned systems. The category of unmanned systems which is influenced the most by safe ride standards are unmanned aerial systems. Reaching acceptable levels of mentioned indicators in this category of unmanned systems is the biggest challenge. This fact favors unmanned ground systems and unmanned aquatic systems to be used in greater frequency in the theater of operations.

Chemical, biological, radiological and nuclear (CBRN) environment is the one that creates space for massive use of unmanned systems for CASEVAC purposes. Use of unmanned system will not put another personnel into risk of being contaminated by CBRN agents [9], will provide fast and accurate transportation of casualty to the safe zone in relatively short period of time and will offer time for decontamination of casualty and further treatment according to the needs.

It is important to mention aspects in connection with artificial intelligence which have become ubiquitous in the modern battlefield. This phenomenon must be taken into account where security of CASEVAC executed by unmanned systems is concerned. Recognition of CASEVAC means that are included under protection according to International Humanitarian Law especially the Geneva Conventions and their Additional Protocols is key challenge in development of unmanned systems designated for CASEVAC. On the other hand, strong advantage of unmanned systems using artificial intelligence for CASEVAC purposes could be reliability and removal of human errors. Analyses of aviation incidents cite human factors to be the predominant cause. As unmanned aerial vehicles become increasingly automated, human factors will be mitigated suggesting a future increasing safety profile [8].

2.2 Geographical and Meteorological Aspects

Second area of aspects that influence unmanned systems to be used for CASEVAC are geographical and meteorological aspects, in general aspects that do not dependent on unmanned system itself and at the same time are not dependent on destructive actions of the enemy. Aspects that are interconnected with the condition of not being able to use unmanned system due to the following reasons. Terrain complexity has potential to restrict or vice versa support use of unmanned systems for purposes of CASEVAC, e.g. lowlands, mountainous terrain, swampy terrain, wetlands, terrain with a rich tangle of rivers, seas and oceans etc. Actual weather conditions will definitely impel decisions on the use of unmanned systems in the air, on the ground, on or underwater level. What is more, extremely hot or cold weather conditions will cause limitations of unmanned systems use for CASEVAC purposes or will require special equipment, e.g. ground unmanned system specially adapted for the use in winter conditions on the snow and ice.

2.3 Tactical Aspects

The third area of aspects are tactical aspects, especially those in connection with destructive actions of enemy. Unintentional kinetic actions executed by automatic weapon systems creates necessity to provide unmanned systems by autonomous protective capability IFF [18]. Then deliberate kinetic or non-kinetic actions of enemy despite properly used symbols of Red Cross, Red Crescent or Red Crystal in accordance with Geneva Conventions should not be omitted.

2.4 Clinical Aspects

Clinical aspects are extremely important, and this fourth area covers all aspects related to the clinical status of casualties. Decisive is the fact that casualty prior to the CASEVAC executed by unmanned systems is stabilized due to the impossibility of emergency care provision during transportation. Fully automated or remotely controlled medical devices can partially cover provision of medical care and possibility to react on changing clinical status of the casualty. Nevertheless, treatment of the casualty and ability respond toward stabilization of casualty' medical conditions will be very limited.

More restraints are imposed by combination of casualty clinical status and unmanned system (ground, aerial or aquatic) to be used for CASEVAC. Especially for the CASEVAC executed by the unmanned aerial systems there are numerous limitations but basically can be stated that there are no absolute contra-indications. Each case must be judged on its merits, weighing the advantage of the transfer to the casualty against the possible harmful effects of the evacuation. The crucial moment of every casualty evacuation is time. Medical timelines have to be reached. Generally, the fact of reaching medical timelines is the factor that will be usually in favor of using unmanned systems. The more are medical timelines reduced to minimum the higher is probability of successful prospective treatment in the higher echelons of medical care. Survivability and treatment of casualty would be supported by provision of data on medical status of the casualty to the receiving medical capability gained by medical equipment on board of unmanned system.

2.5 Other Aspects

The fifth area of aspects are ethical ones, and those aspects cannot be excluded. Unmanned systems are to be used for CASEVAC so long as the relative risk to the casualty is not increased by using of unmanned system itself when compared to the clinical status of the casualty and the prospect of CASEVAC benefits. Consequently, there will still always need to be a risk versus benefit decision for the evacuation of wounded military personnel [8, 9].

Economic aspects are ones that will support the use of unmanned systems for every possible purpose on the battlefield and of course this will include the use for the purposes of CASEVAC.

3. Unmanned Systems

Unprecedented development of unmanned systems has been achieved in the last decade. It has been accelerated by ongoing armed conflicts in the world, especially Russo-Ukrainian war [22], Israel-Hamas war, but as well conflict between Israel and Iran, hostilities in Nagorno-Karabakh and other territories in the world. One of the possible purposes that unmanned systems can be used for is evacuation of the casualties. According to Parker [18] four levels of care could be provided on board unmanned aerial vehicles, but the most likely provided care in the near future is the transportation of casualty itself without any other personnel on board. That is why this process of moving the casualty by unmanned system is likely to be referred to as CASEVAC executed by unmanned system.

Large number of different companies worldwide are devoted to the development of unmanned system technologies. Besides traditional unmanned aerial systems also unmanned ground systems and unmanned aquatic systems are undergoing rapid development.

3.1 Unmanned Aerial Systems

Unmanned aerial systems were first to be deliberated as a means of CASEVAC in contested environment. Mainly due to the broad advantages that are connected with transportation of casualties in the air providing great velocity and thus reaching medical timelines. Several defense and commercial companies demonstrated outstanding development of unmanned systems technologies in connection with possible execution of CASEVAC by these systems. Technical solutions are mentioned as follows.

BAE Systems – T-650 is an electrically powered UAV that features an impressive payload capacity of up to 300 kilograms. The system has a range of 30 kilometers with its maximum payload or 80 kilometers without payload. Constructed from lightweight carbon fiber, the T-650 can achieve a maximum speed of 140 kilometers per hour and features extendable arms that can be detached for transportation purposes. The T-650 is an evolution of the T-600, which serves as BAE Systems' testbed platform and technology demonstrator (see Fig. 1).

In September 2023 BAE Systems and Malloy Aeronautics showcased the capabilities of the T-600 during NATO's Robotic Experimentation and Prototyping with Maritime Uncrewed Systems (REPMUS) exercise in Portugal, during which it successfully released an inert Sting Ray training-variant anti-submarine torpedo during a flight mission at sea for the first time.

Fig. 1 BAE Systems T-650 in CASEVAC version. Source: www.euro-sd.com

Currently the T-650 is working on batteries, which justifies the relatively reduced range when loaded. However, BAE Systems sources confirmed to EDR On-Line that development studies are ongoing for a hybrid system based on a thermal engine and batteries, which would considerably increase the range. BAE Systems is planning to have a prototype of the T-650 ready by late 2025, early 2026 [6].

Fig. 2 DPI UAV Systems – DP-14. Source: www.army.mil

DPI UAV Systems – DP-14 Multi Mission UAS is multi-mission unmanned aerial system designed for precision aerial resupply (see Fig. 2). The DP-14's advanced tandem design enables class-leading cargo carrying capacity, range, endurance while minimizing footprint. The system can carry 195 kilograms payload to beyond 130 kilometers and sprint up to 194 kilometers per hour. All terrain landing gear for uneven ground, slopes to 15 degrees and heaving pitching rolling ships [5].

Fig. 3 Tactical Robotics, Ltd. Cormorant UAV. Source: www.vertical.mag.com, www.auvsi.org

Tactical Robotics, Ltd. – Cormorant UAV – can carry two patients, it cruises between 185 and 222 kilometers per hour and has 5 hours loiter time (see Fig. 3). It has two laser altimeters, a Dopler altimeter for use in dust or brown-out situations, GPS, and inertial/electro optical navigation sensors [18].

Tactical Robotics has successfully performed a first "mission representative" demonstration with the Cormorant UAV for its lead customer, the Israel Defense Forces on May 24, 2018 [20].

Table 1.
Unmanned aerial systems - comparison of selected parameters

Parameters	BAE Systems T-650	DPI UAV System DP-14 Multi Mission UAS	Tactical Robotics, Ltd. Cormorant UAV
Range	30 km (maximum payload) 80 km (without payload)	130 km	50 km (maximum payload)
Maximum speed	140 km/h	194 km/h	222 km/h
Payload capacity	300 kg	195 kg	500 kg
Capacity of patients	1	1	2
Onboard generator		4,5 kW with 3 kW available for payloads	
Material of construction	lightweight carbon fiber		carbon (fiber)-composite
Number of rotors	4	2	2
Protection of casualty/casualties	yes	yes	yes

Source: own elaboration

Comparison of selected parameters of unmanned aerial systems confirmed fact that most probable is execution of CASEVAC with one casualty only. Decreased ranges, significant speed in connection with expected payload of one casualty or two casualties are sufficient for reaching adequate medical capability (Forward Surgical Team, MTF Role 1, MTF Role 2, MTF Role 3) in compliance with medical timelines. Provision of casualties' protection is provided but is limited, higher level of protection containing ballistic protection would increase weight of unmanned system itself and decrease the range. Information about source of electricity was mentioned only in case of DP-14 but other unmanned aerial systems can use medical devices with own source of energy therefore functionality of casualty medical status monitoring and provision of medical care is not disabled.

3.2 Unmanned Ground Systems

Unmanned ground systems were firstly not considered as far as CASEVAC is concerned and development of the idea is relatively new. But in contemporary armed conflicts they are demonstrably useful for the purpose. Even though they are not able to transport casualties in short period of time for long distances. When choosing of unmanned system to be used for CASEVAC deliberation of casualty medical status which is an indicator of urgency and transportation means safety are of highest importance. Specific categories of unmanned ground systems are systems that can convert land vehicles to become an autonomously operated platform. Unmanned ground systems of different producers that could be used for CASEVAC are depicted in the following text.

Fig. 2 Hanwha Defense 6x6 Intelligent UGV. Source: www.gbp.com.sg

Hanwha Defense - the Intelligent Unmanned Ground Vehicle (I-UGV) is an artificial intelligence based unmanned ground vehicle which has been designed in the Republic of Korea to meet domestic and export requirements. The I-UGV can carry out remote-controlled operations or GPS-enabled autonomous driving to perform various missions such as surveillance and reconnaissance, transport of cargo and wounded soldiers. The fully electric I-UGV features enhanced mission capabilities, compared to the existing 4×4 Multi-Purpose UGV, or M-UGV, and other UGVs built in South Korea and was on trials with a Republic of Korea Army infantry unit in 2021.

The I-UGV can travel 100 kilometers per charge and move at a top speed of 40 kilometers per hour on paved roads and 20 kilometers per hour on unpaved roads. It has a 500 kilograms payload capacity and a detection range of 4 kilometers both at day and night. The I-UGV is fitted with a high-end remote-controlled weapon station that can lock on to targets automatically using acoustic sensors to determine the source of gunfire during the confusion of combat [7].

Fig. 3 THeMIS Cargo CASEVAC
Source: www.milremrobotics.com

Milrem Robotics - THeMIS Cargo CASEVAC provides rapid evacuation for urgent casualties from the point of injury to higher-level medical facilities. It reduces the need for manpower usually used for CASEVAC. The vehicle facilitates most NATO stretchers used in the armed forces.

Diesel-electric hybrid drivetrain enables low fuel consumption, high reliability, and reduced life cycle cost and offers possibility of full electric mode for silent operations. Zero meter turning radius enables easy maneuverability in narrow surroundings and THeMIS Cargo CASEVAC offers low center of gravity without jeopardizing ground clearance. Compact size allows easy transportability with standard equipment and air transportability is designed according STANAG 3542 [17].

Fig. 4 Ukrainian Unmanned Ground Vehicle
Source: www.defence-blog.com

Ukrainian Unmanned Ground Vehicle (U UGV). The robot has the capability to transport a real person, with a capacity of up to 100 kilograms. It boasts a mission range of up to 10 kilometers, features a secure radio channel, high-definition video streaming, and is equipped with a relay system for unmanned aerial vehicles. Powered by four independent electric motors offers durability and precision.

One of its most distinctive features is its ability to be operated remotely through the UAS-based "Dovbush" system, making it a versatile tool for search and rescue missions in challenging environments. The development of this MedEvac robot represents a significant leap forward in battlefield medical operations, where time is often of the essence [15].

Tab. 2 Unmanned ground systems – comparison of selected parameters

Parameters	**Hanwha Defense Intelligent UGV**	**Milrem Robotics TheMIS Cargo CASEVAC**	**Ukraine UGV**
Range	100 km (per charge)	1,5 h (electric) 15 h (hybrid)	10 km
Maximum speed	40 km/h (paved roads) 20 km/h) (unpaved roads)	20 km/h	
Payload capacity	500 kg	750 kg	100 kg
Capacity of patients	not specified	2	1
Number of motors			4
Protection of casualty/casualties	none	none	none

Source: own elaboration

Comparison of selected parameter of unmanned ground systems can be found in tab. 2. Possibility carry significant payload in I-UGV and THeMIS Cargo CASEVAC allows to transport more than one casualty. All unmanned ground systems provide open air transportation of casualties that made it sensitive to the weather conditions. The range in combination with speed in the terrain predetermines these unmanned systems to be used for transportation of casualties to the closest medical capability that would most likely be Forward Surgical Team or Role 1 MTF.

3.3 Unmanned Aquatic Systems

Unmanned aquatic systems have recently undergone unprecedented technological developments. These systems can be divided into unmanned aquatic water surface systems that are capable of operating on the water surface without any onboard human operator and unmanned aquatic underwater surface systems that operate underwater surface. During investigation has been found that none of the manufacturers of unmanned aquatic systems, despite their level of development, designated its use for CASEVAC purposes. Therefore, none of the unmanned aquatic systems was part of research.

4. Investigation Results

Based on our research we identified essential parameters as well as aspects that have potential to influence unmanned systems feasibility to be used for CASEVAC. By comparison of required parameters with parameter of unmanned systems that are available on open sources. Several solutions suitable for CASEVAC were identified.

All commercial solutions that were part of our investigation for the use of unmanned systems, except for the systems that can convert land vehicles to become an autonomously operated platform, have the very same attribute that is the casualty during evacuation would not have any ballistic protection. That feature must be subject to further development, casualty must have protection comparable to the soft skin, better hard skin ground MEDEVAC assets, or other transportation assets that are used for CASEVAC. A common feature of the unmanned systems is the fact that platforms are being developed for other use and transportation of casualty is just secondary use of the unmanned systems.

Positive outcome of the research is the fact that due to their ability to carry enough weight for long enough distance unmanned systems are feasible solution for CASAVEC. According to the publicly presented development outcomes of unmanned systems for CASEVAC purposes their use in peace conditions could be possible in near future.

Source of a discussion for their use in combat conditions must be also ethical considerations and the fact that casualty should not be put into greater threat than is health risk based on his or her medical conditions. Important is note the fact that one piece of unmanned system would most likely transport one casualty. That creates implications for the value of the target for the enemy with one piece of unmanned system and one casualty, on the other hand limitations for medical planners. As well as the fact that costs and feasibility of such CASEVAC would probably make it executed only when specific conditions are met.

5. Conclusions

The contemporary degree in development of unmanned systems is high and it is expected that the range of tasks executed by unmanned systems to support military operations will grow. A specific way of unmanned systems use is CASEVAC. In the past especially unmanned aerial systems were taken into account as far as CASEVAC is concerned. Nowadays unmanned ground systems are rapidly developing for this purpose and is just a matter of time before unmanned aquatic systems either on or underwater level will be adapted for CASEVAC use as well.

Besides other important considerations, provision of medical care during evacuation supported by medical equipment on board, respectively monitoring of medical conditions and protection of casualty from possible intentional or unintentional enemy kinetic actions are the greatest concerns.

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