LIFE CAPSULES – THE EVACUATION OF THE FUTURE. AN UNMANNED AERIAL SYSTEMS TECHNOLOGY IN THE TRANSPORT OF WOUNDED SOLDIERS FROM THE BATTLEFIELD

Kapsuły życia – ewakuacja przyszłości. Technologia bezzałogowych systemów powietrznych w procesie transportu rannych żołnierzy z pola walki

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Abstract

Introduction and objective: The authors present the use of new technologies to implement specially designed "life capsules" as part of a system for evacuating wounded soldiers from the battlefield. The article shows the possibilities of transporting "life capsules" by means of manned and unmanned aerial systems and introduces essential mathematical calculations regarding the reliability of operation of unmanned and manned transport of wounded soldiers. **Material and methods:** In addition, the principles of forecasting reliability processes over the expected operating periods have been taken into account. The analytical process also envisages the use of differentiated transportation in the areas of land, air and sea technology. The integration of new technologies – unmanned aerial systems – and humanism in the process of transporting wounded soldiers from the battlefield, represents the highest value in improving the process of saving human lives. **Results:** The article presented here covers the basic solutions for transporting wounded soldiers from the battlefield. Taking out wounded soldiers, in addition to moral considerations, is also important for restoring the combat capability of a fighting arm. **Conclusions:** The paper presents the fundamental conditions aimed at improving the transport processes of wounded soldiers on the battlefield. These conditions are the basis for undertaking work aimed at developing and implementing transport life capsules. The developed design solutions of transport life capsules, due to their special usefulness, should be adapted to diverse combat situations. In the process of transporting wounded soldiers from the battlefield, the transport infrastructure is of vital importance, which applies to varying degrees to all means of transport, especially airborne means. The paper provides an overview of the method and means of transporting wounded soldiers from the battlefield. Diverse methods and means of transport should be subjected to detailed studies. The whole process of transportation should be the basis for undertaking research and development and implementation work.

Streszczenie

Wprowadzenie i cel: Autorzy przedstawiają wykorzystanie nowych technologii do wdrożenia specjalnie zaprojektowanych „kapsuł życia" jako części systemu ewakuacji rannych żołnierzy z pola walki. W artykule omówiono możliwości transportu „kapsuł życia" za pomocą załogowych i bezzałogowych systemów powietrznych oraz wprowadzono zasadnicze obliczenia matematyczne dotyczące niezawodności funkcjonowania bezzałogowego i załogowego transportu rannych żołnierzy. **Materiał i metody:** W pracy uwzględniono dodatkowo zasady prognozowania procesów niezawodnościowych w przewidywanych okresach eksploatacji. W procesie analitycznym przewiduje się także wykorzystanie zróżnicowanego transportu w obszarze techniki lądowej, powietrznej i morskiej. Integracja nowych technologii – bezzałogowych systemów powietrznych – i humanizmu w procesie transportu rannych żołnierzy z pola walki stanowi najwyższą wartość w doskonaleniu procesu ratowaniu ludzkiego życia. **Wyniki:** W artykule zostały przedstawione podstawowe rozwiązania umożliwiające transport rannych żołnierzy z pola walki. Wyprowadzenie rannych żołnierzy, poza względami moralnymi, ma również znaczenie dla przywracania zdolności bojowej walczącego wojska. **Wnioski:** W pracy omówiono zasadnicze uwarunkowania zmierzające do usprawnienia procesów transportowych rannych żołnierzy na polu walki. Uwarunkowania te stanowią podstawę do podejmowania prac zmierzających do opracowania i wdrożenia transportowych kapsuł życia. Opracowane rozwiązania konstrukcyjne transportowych kapsuł życia, z uwagi na ich szczególną przydatność, powinny być dostosowane do zróżnicowanych sytuacji bojowych. W procesie transportowania rannych żołnierzy z pola walki istotne znaczenie ma infrastruktura transportowa, która dotyczy w różnym stopniu wszystkich środków transportu, a w szczególności środków lotniczych. W pracy opisano ogólny zarys metody i sposoby transportu rannych żołnierzy z pola walki. Zróżnicowane metody i sposób transportowania powinny być poddane szczegółowym opracowaniom. Cały proces transportu powinien stanowić podstawę do podjęcia prac badawczo-rozwojowych i wdrożeniowych.

Keywords: drones, life capsules, evacuation, battlefield, unmanned aerial system, wounded soldier

Słowa kluczowe: drony, kapsuły życia, ewakuacja, pole walki, bezzałogowy system powietrzny, ranny żołnierz

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Introduction

Currently, there are approximately 50 armed conflicts globally, in which over 60 countries and 370 partisan groups are involved. Only in 2012, at least 100 thousand people were killed in armed conflicts. This number should be increased by civilian victims of humanitarian disasters that result from international conflicts, as well as civil wars and various "internal conflicts" that have been continuing for decades. Modern armed conflicts require providing a higher number of medical facilities that will allow to reduce the number of fatal victims thanks to the training of personnel and new technologies. Battlefield medicine is facing multiple challenges related to providing support in military operations, whose profile has been changing dynamically and will continue to change [1].

The participation of Poland in military peace missions that results from our membership in such organisations as the United Nations, NATO, or the EU, and the migration crisis related to the migrants from Ukraine lead to increasing threats to human life and health. As a result of these threats, the issues of injuries that result from the impact of battlefields are becoming the main area of scientific interest for the Military Institute of Medicine – National Research Institute, as a research institution. In the current situation of destabilisation and political and military threats in the international arena, one of the main subjects of interest is efficient, non-invasive, and quick evacuation of wounded soldiers from the battlefield. The analysis of the causes of death during armed conflicts revealed that a large part of deaths could be avoided, if alternative methods and measures were available. 90% of the deaths occur before the wounded reach the medical facilities [2]. According to the guidelines of Tactical Combat Casualty Care (TCCC), the care of people with injuries in the tactical environment has three main aims [2]:

- to provide aid to the injured person,
- to prevent additional casualties,
- to complete the mission.

Experts in military medicine and the academic circles agree that the out-of-hospital phase of care is the field in which the next "giant developmental leap" will be observed, mainly due to the continuous innovations in technology, training, and communications. The process of evacuating wounded soldiers from the battlefield may involve various means, which include [3]:

- manned and unmanned transport systems: unmanned aerial vehicles (UAV), "life capsules" carried by remotely controlled drones, or "rescue drones",
- manned transport systems – "life capsules" which will be an integral part of other methods of evacuating the wounded.

Traditional transport, with sue of a specially prepared stretcher and paramedics who are able to transport the wounded to a safe place or to a dressing station, is not very efficient. It is exposed to enemy fire and, apart from that, the prolonged time of transport to a specific point may have a negative influence on the health of the wounded soldiers. Moreover, lack of cover during evacuation may result in the transport being captured by the enemy, which, again, may threaten the safety of the wounded.

Using unmanned aerial vehicles as a method for evacuating the wounded

Drones carrying specially designed life capsules are a type of unmanned aerial vehicles that are able to fly without a pilot, carrying wounded soldiers on board or in life capsules. These aerial vehicles are remotely controlled by radio waves, or autonomously (on a predefined route). Unmanned aerial vehicles do not have a specified size or type of drive. They are very often equipped with devices for surveillance and monitoring, in form of optical electronic heads. One of the main properties of drones is the fact that they do not need any additional infrastructure to record and monitor the defined area or object in a quick way. Their main advantage is the extremely short time of response, i.e. launching and preparing the unit for take-off. Unmanned aerial vehicle systems are excellent devices which, thanks to their small dimensions and high agility, may fly between obstacles, buildings, and even enter premises through open gates, windows, or doors [4]. Models that are equipped with thermal and night-vision cameras (that use active infrared light or starlight reinforcement) may be used as searching devices in rescue activities, for everyday surveillance of the given area, and they may work all day long above forested areas. The image is transmitted in real time, which allows the competent services to react immediately in situations of threat [5–7].

Figure 1. The CityAirbus Generation
Source: www.airbus.com/en/newsroom/press-releases/2022-05-airbus-lays-the-foundations-for-future-urban-air-mobility-in

Systems for evacuating wounded soldier from the battlefield with armoured means of transport

Armoured means of transport include, among others, armoured personnel carriers, infantry fighting vehicles, and tanks. The aforementioned means of evacuation should be structurally prepared for the task, which is described by the reliability function in the following form:

$FP(t) = Pst(t) \times Pk(t)$ (1),

where Pst(t) is the reliability of the means of transport designated for transporting the wounded,

Pk(t) – reliability of the combat capsule for the transport of wounded soldiers.

These armoured means for transporting wounded soldiers should be structurally modified, adequately to the transport capsule used. Due to the structural limitations of means of transport, their design should allow for the installation or allocation of the capsule in specific means of transport. Life capsules should be appropriately equipped and adapted for such situations as injuries or accidents that do not require the application of special medical measures. Their main role is to smoothly evacuate the wounded soldier from the battlefield. Folded capsules should become a fixed element of the equipment or armoured means of transport. Individual capsules should have their own drives, which are started depending on the transport situation. Due to their high usability in battlefields, capsules should be characterised by a high level of functional reliability. This reliability is estimated with the use of the readiness index Wg(t) of the capsule to perform the tasks, in the following form:

$Wg(t) = exp(-\Lambda(t)) \times t$ (2),

where exp × (t) is the exponential function of the transport capsule,

t – time of use of the transport capsule.

The functional reliability of the transport capsule is essential for its users. This reliability is evaluated based on formula (2) and the value of damage intensity × (t). The intensity of damage to capsule elements is calculated from the formula:

$\Lambda(t) = n(t) / t$ (3),

where n(t) is the number of functional elements of the transport capsule,

t – value of the time of operation of the transport capsule until damage.

Transporting wounded soldiers with a helicopter

Wounded soldiers may also be evacuated from the battlefield with the use of helicopters. They may be transported in two ways:

- directly on board of the vehicle, or
- with the use of a transport capsule.

The second method is more efficient due to the transport capacity. In this case, the limitation is the lifting capacity of the helicopter. Therefore, the transport with a helicopter may be described by the following lifting capacity function:

U(l) = f (U(k) × Ck × Lr)   (4),

where U(k) is the structural lifting capacity of the helicopter,

Ck – weight of the transport capsule with a helicopter,

Lr – number of wounded soldiers.

Formula (4) demonstrates that elements of the transport capsule are characterised by different values of the readiness indices. Elements with the lowest values of the index (i.e. the number of damages) should be modernised or replaced when the value of the index is low. These operations will ensure the proper functioning of the transport capsule.

The listed elements of the transport system constitute an interconnected system according to a serial reliability structure. This means that the full functionality of the specific elements of the transport capsule is achieved, in particular, during the flight.

Transporting wounded soldiers with an airplane

The evacuation of wounded soldiers from the battlefield with the use of an airplane is similar to helicopter transport. The difference consists in the increased lifting capacity of the transport capsule. The parameters of the transportation process are described by the flight index Wl(t) in the following form:

Wl(t) = f (Us(f) × Ck(f) × Tl(t))   (5),

where Us(t) is the value of the lifting capacity of the airplane,

Ck(t) – weight of the transport capsule with a airplane,

Tl(t) – distance of the flight.

These factors have a major influence on the processes of transporting wounded soldiers with an airplane. The mentioned transport capsule should take into consideration the lifting capacity of the airplane and the duration of the flight to the sanitary facility. Each of the listed factors in formula (5), apart from the distance of the flight, has a fixed value. The evacuation of wounded soldiers with a transport airplane cannot be optimised. Adjust-

Figure 2. Airbus Skyways that enables shore-to-ship deliveries
Source: www.airbus.com/en/newsroom/press-releases/2019-03-airbus-skyways-drone-trials-worlds-first-shore-to-ship-deliveries

Figure 3. Next generation of CityAirbus
Source: www.airbus.com/en/newsroom/press-releases/2021-09-airbus-reveals-the-next-generation-of-cityairbus

ments can be made by changing the weight properties of the capsule, in two variants:

- by reducing the number of transported wounded soldiers,
- by using an airplane with a higher lifting capacity.

The disadvantage of this type of transport is the relatively high cost of operating the airplane and its protection during transport.

In the process of preparing the transport of wounded soldiers, it is possible to evacuate the casualties with the use of a foldable capsule located inside the airplane. Similarly as in the case of transport with the use of a helicopter, it is necessary to use a capsule with a foldable structure.

Transporting wounded soldiers on water bodies

Water bodies, both inland and maritime ones, provide useful ways for transporting soldiers who were wounded in the battlefield. Maritime transport is used only in special conditions, due to large distances. Similarly as it is in case of other forms of transport, this method also requires capsules in folded and unfolded forms. Evacuation of wounded soldiers by waters often used as the costs are low and it is relatively easy to secure the transport. Soldiers may be evacuated with the use of transport capsules or directly on board of the “transport barge”. The medical coast services should be notified about the transport process, so that they can provide appropriate medical care if necessary.

Discussion

Research conducted in 2022 in Ukraine revealed that high quality of training of the tactical and medical staff and the appropriate measures and methods of action significantly increase the survival chances of the wounded [8].The development of new materials, powerful engines (electrical or mechanical ones), strong batteries of high capacity or alternate sources of energy for mechanical or electrical engines (powered by electricity, gas, or solar power), as well as antennas with advanced GPS systems are the main areas of focus in the development of future methods of evacuation [9].

In 2018, a research project on the transport of blood for transfusions and diagnostic tests between hospitals in London conducted by the National Health Service demonstrated that the use of drones would allow the British economy to save 21 billion dollars annually [10]. In 2021, the 4D-TBO project by Airbus was launched. It focused on the analysis of real-time transmission of four-dimensional data concerning the flight trajectory (latitude, longitude, altitude, and time). Further tests on the use of drones in medicine for transporting chemotherapy drugs confirmed the development of this technology in the medical sector and proved that the technology has changed the meaning of the notion of transport forever [11].

The first known use of unmanned aerial vehicles (by Austrians) took place in August 1849. These were balloons, filled with explosive materials, which were used as bombs. One of the first creators of drones was Charles Kettering, who, in cooperation with Elmer Sperry, Orville Wright, and Robert Milikan, designed an airplane named “Kettering Bug” in 1959. In spite of its rather primitive design, this was an automated airplane that could determine its altitude, the covered distance, and position with the use of sensors.

Systems of unmanned aerial vehicles are excellent devices, for example, for monitoring large areas, i.e. protecting property or the state borders. Additionally, these units may also take aerial photographs that are used in geodesy.

First research on unmanned aerial vehicles was conducted in the USA, UK, Russia, Germany, and Israel. The forerunner of these aircraft was the “Predator” that was created in 1994. Three years later, it became a permanent part of the American Air Force that was used in military operations. other tasks of unmanned aerial vehicles include the protection and monitoring of mass events as well as accidents or crisis situations that require intervention. UAVs may be use by the following public administration bodies: the fire brigades, the police, border guards, armed forces, as well as geodesic companies [12].

China and Japan are the pioneers in using drones during natural disasters, i.e. earthquakes and tsunamis. During the earthquake in Sichuan in 2008, in which 69 thousand people were killed and 18 thousand were missing, the drones proved that they were a valuable tool for assessing the actual damage. The use of drones by the Chinese government enabled to assess the state of motorways, buildings, schools, hospitals, power plants, bridges, and other facilities. In 2011 in Japan, unmanned aerial vehicles were used to assess the damages at the nuclear power plant Fukushima Daiichi. Another example that perfectly illustrates the influence of unmanned aerial vehicles on the assessment of the existing threats was the massive earthquake in Nepal in 2015 [9].

As far as natural disasters are concerned, three type of missions may be distinguished:

- Aerial monitoring, whose aim is to assess the size or area of damage. Stage 1 consists in using unmanned aerial vehicles equipped with high-resolution cameras. The main aim of this stage is to provide a preliminary assessment of the damages to infrastructure immediately after the natural disaster.
- Light load logistics, including supplying water, food, drugs, and equipment to remote areas that are affected by the consequences of a natural disaster.
- Assessment of the consequences of the natural disaster.

Each natural disaster requires building different shapes and structures of unmanned aerial vehicles, together with various strong engines and batteries.

The key element in the development of this segment is finding the perfect balance between the software (software and network) and the equipment (battery power, engine). Sample types of smart platforms, drones, and unmanned aerial vehicles are presented above [9].

The electronic system of control and communication with the unmanned aerial vehicle is responsible, among others, for: the drone's flight up and down, its rotation, responsiveness, and stability. Most control systems are equipped with the same set of sensors that differ only in terms of the rate of calculations and the algorithms used [13]. these include:

- flight controllers, which is responsible for steering the aircraft,
- Electronic Speed Control – unit responsible for the engine,
- power supply board that distributes the power supply to regulators,
- SIM module that enables transmission of telemetric data,
- proximity camera – an element of the anti-collision system,
- numerical keyboard for entering PIN codes.

The following documents should be drawn up for every means of transport:

- a concept design of the method of transporting wounded soldiers,
- technical transport capacity,
- technological design of transport,
- prototypes of the equipment and adaptation of the means of transport,
- documentation of the prototyping research with a description of test results,
- documentation of the state research with a description of test results,
- serial production of prototype solutions.

Conclusion

The paper presents the basic solutions that enable to evacuate wounded soldiers from the battlefield. Taking out wounded soldiers, in addition to moral considerations, is also important for restoring the combat capability of a fighting arm. The methods of transporting the wounded with the use of manned and unmanned vehicles are of a conceptual nature, so they still require preparing detailed designs, developing prototype solutions, and conducting the required laboratory and operational tests. The structural solutions used in the transport capsule, which is the fundamental element of the transport processes also require further, thorough design and research works. In the opinion of the authors, due to the fact that the capsule may be used in various means of transport, it should be adapted for evacuating wounded soldiers from the battlefield and thus have a foldable structure.

The essential factors in evacuating the wounded from the battlefield are the process of identifying wounded soldiers and the duration of their transport. Drones that are adequately prepared for such work may provide important support in this process. They should be equipped with the appropriate recording cameras and equipment that will transmit signal to dressing or sanitary stations. Drones used in battlefields should be capable of identifying the wounded and should be equipped with basic dressing materials.

Conclusions

The presented analysis of the transportation of wounded soldiers leads to the following conclusions:

- The conditions aimed at facilitating the processes of transporting wounded soldiers from the battlefield are the basis for taking actions with the aim to develop and implement transport life capsules.
- The developed structural solutions of life capsules, due to their high usefulness, should be adapted to various combat situations.
- Transport infrastructure is an important element of the process of evacuating wounded soldiers from the battlefield. This applies, to various extents, to all means of transport, in particular to aerial ones.
- The diversified methods and ways of transporting wounded soldiers should constitute the basis for taking further research, development, and implementation works.

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