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CARGO DROP TECHNIQUES FROM TRANSPORT AIRCRAFT: A REVIEW OF METHODS AND THEIR APPLICATIONS

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Abstract

The efficient and precise delivery of cargo from transport aircraft plays a key role in logistics, humanitarian aid, military operations and other fields. This article presents an overview of the different techniques for dropping cargo from transport aircraft and their applications. The aim of the article is to analyse and evaluate the different airdrop methods, taking into account both technical and operational aspects. The article will discuss both traditional airdrop techniques and new innovative approaches, along with their advantages and limitations. Various areas of application of these techniques will be analysed, such as the delivery of military supplies, humanitarian operations, medical evacuations and many others. The conclusions of this review of cargo drop techniques from transport aircraft are intended to provide practical knowledge for engineers, planners and operators involved in such operations.

Keywords*: air drop operations, dropping cargo, aerial delivery, transport aircraft*

TECHNIKI ZRZUTU ŁADUNKÓW Z SAMOLOTU TRANSPORTOWEGO: PRZEGLĄD METOD I ICH ZASTOSOWAŃ

Streszczenie

Efektywne i precyzyjne dostarczanie ładunków z samolotów transportowych odgrywa kluczową rolę w logistyce, pomocy humanitarnej, operacjach wojskowych i innych dziedzinach. Artykuł przedstawia przegląd różnych technik zrzutu ładunków z samolotów transportowych oraz ich zastosowań. Celem artykułu jest analiza i ocena różnych metod zrzutu, uwzględniając aspekty techniczne oraz operacyjne. W publikacji omówiono zarówno tradycyjne techniki zrzutu, jak i nowe innowacyjne podejścia wraz z ich zaletami i ograniczeniami. Analizie poddano różne obszary zastosowań technik, takich jak dostarczanie zaopatrzenia wojskowego, akcje humanitarne, ewakuacje medyczne i wiele innych. Wnioski z tego przeglądu technik zrzutu ładunków z samolotu transportowego mają na celu dostarczenie praktycznej wiedzy dla inżynierów, planistów i operatorów zajmujących się tego rodzaju operacjami.

Słowa kluczowe*: operacje zrzutów, zrzuty ładunków, dostawy lotnicze, samoloty transportowe*

1. Introduction

Cargo airdrop from transport aircraft is an extremely important element in the field of logistics and military operations. Defined as an alternative to landing an aircraft to deliver personnel, equipment and supplies[1]. The history of the use of cargo airdrop from transport aircraft dates back to armed conflicts and humanitarian operations, where aircrews made deliveries of supplies, medical supplies and humanitarian aid to hard-to-reach areas. Often, these airdrops were the only way to reach troops on the battlefield or civilians in extreme conditions with vital support.

Over time, developments in the technology and capabilities of transport aircraft have led to the development of increasingly precise and efficient airdrop methods, greatly increasing the effectiveness and versatility of this technique.

Having the capability to drop cargo from a transport aircraft is extremely important for a well-trained air force. It allows the rapid and efficient delivery of support and supplies in a variety of military operations such as humanitarian operations, crisis response, battlefield troop support or special operations.

[1] European Tactical Airlift Centre, *The ETAP Tactics Techniques and Procedures (ETTP)*, version 8, 23 February 2022, 9.1.

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In situations where road or sea access is difficult or compromised, airdrop from transport aircraft becomes a key element in ensuring continuity of supply and support to troops and populations in need.

The following article will provide an overview of traditional and new innovative transport aircraft cargo airdrop techniques and their applications in different types of missions. A comparative analysis of airdrop techniques will provide a better understanding of their advantages, disadvantages and areas of application. In the final conclusions, prospects for the development of new airdrop techniques are presented, along with the identification of potential directions for the use of these innovative solutions in both armed forces and humanitarian missions. The issues discussed will provide a better understanding of the importance of this key transport capability in the context of contemporary challenges and operational needs.

2. Traditional cargo airdrop methods

Cargo airdrop from transport aircraft is a key element of military logistics and humanitarian operations. This chapter will focus on traditional airdrop methods, which have been indispensable tools in support of military operations and the delivery of humanitarian aid for many years. Five main airdrop techniques will be analysed: the Container Delivery System (CDS), Heavy Equipment (HE), Free Drop, Low Altitude Parachute Extraction System (LAPES) and Gravity Extraction Platform (GEP). Each of these methods has its own unique characteristics and applications, which will be discussed in detail.

Container Delivery System (CDS) airdrop is one of the most popular and versatile methods of resupplying troops on the battlefield and delivering humanitarian aid in hard-to-reach areas. Placing supplies in special containers allows for increased security and control during the airdrop, which is carried out using stabilising parachutes. This system allows for the precise and rapid resupply of military troops with various types of cargo, such as ammunition, fuel, water supplies, food, dismantled spare parts, as well as small pieces of ready-to-use equipment.

Depending on the type and number of parachutes used during a CDS drop, there are three main types of drop:

- Low-velocity airdrop – uses a free-fall parachute to minimise the effects of the load hitting the ground. In this type of airdrop, loads are usually packed on cushioning materials (honeycomb) that allow them to fall safely to the ground.
- High-velocity airdrop – uses a stabilising parachute, resulting in a higher rate of descent of the load. In this case, larger amounts of cushioning materials are used to protect the load from the effects of hitting the ground at high speed.
- Free drop – this is a drop without the use of parachutes[2].

The CDS drop process is initiated by the crew at the drop point, there is a truncation of the release gate (part of the cargo cabin equipment of the transport aircraft), which stops the cargo on board the aircraft. The pilot flying lifts the nose of the aircraft a few degrees, causing the containers to gravitationally eject from the aircraft deck, which land on parachutes[3].

It is worth noting that a CDS drop requires precise planning and proper assessment of atmospheric conditions to ensure the accuracy of the drop and minimise cargo spread. The use of advanced navigation technologies, such as GPS, significantly improves the precision and effectiveness of this drop technique.

[2] EADS CASA, *C-295 aircraft cargo loading manual*, original issue: July 2002, revision: 8 January 2020, 7B2.
[3] Airbus Defence and Space, *Aircraft operations manual volume II. Limitations & procedures*, original issue: September 2013, revision: 15 February 2022, 7D1-2.

Each CDS prepared for a drop consists of the following components (Fig. 1):

- parachutes;
- the A-22 Cargo Bag;
- honeycomb;
- a 0.5 inch or 0.75 inch plywood base.

Fig. 1. Prepared CDS for discharge
Source: archive of the 8th Air Transport Base.

Depending on the type and size of the cargo, specialised logistics staff prepare the appropriate platforms on which the cargo is placed. There are the following types of platform (Fig. 2):

- A-22 Cargo Bag – used on different types of aircraft, its size depends on the type of aircraft. The dimensions of the base of the bag are 122 × 122 cm.
- Stretched A-22 Cargo Bag – with larger base dimensions (122 × 183 cm) than the A-22, allowing larger loads to be dropped.
- Double A-22 Cargo Bag – with the largest base dimensions (122 × 244 cm) of those listed, also enhances the ability to drop larger and heavier loads.
- A-23 Cargo Bag – a hopper mainly designed for high altitude drops, but can be used for standard drops. It differs from the A-22 only in preparation and attachment to the load.

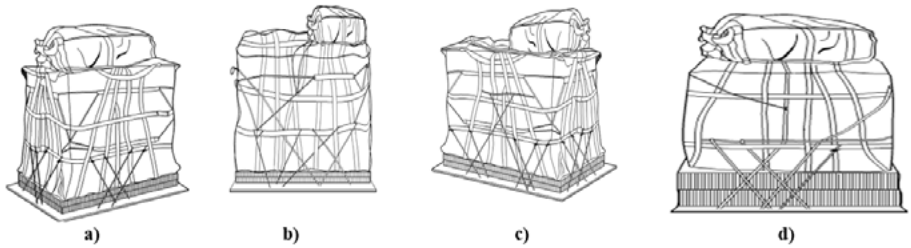

Fig. 2. Platform types: a) A-22 Cargo Bag, b) Stretched A-22 Cargo Bag, c) Double A-22 Cargo Bag, d) A-23 Cargo Bag
Source: Airbus Defence and Space, Aircraft operations manual volume II. Limitations & procedures, original issue: September 2013, revision: 15 February 2022, 7B21-7B22.

Depending on the parachute fitted, CDS-type containers can be dropped from various heights. Minimum heights range from 150 to 200 metres above the terrain. The instructions of the individual aircraft specify the number of containers that can be dropped from different heights.

The Heavy Equipment (HE) airdrop method from a transport aircraft is an extraction airdrop technique that allows large and heavy loads such as tanks, vehicles, guns or cannons to be delivered to a designated area. This method is particularly suitable for the airdrop of bulky cargo whose weight may exceed the capabilities of other airdrop techniques[4].

During an HE drop, the payload is placed on a metal Type V Airdrop Platform and secured with cushioning layers to protect it from damage as it falls to the ground. It is assisted by a main parachute that minimises the effects of the cargo hitting the ground surface. In order to secure the cargo on board the aircraft, a special system of securing locks is used to hold the cargo in place during flight. As the aircraft prepares to drop, some of the locks are released, leaving only one lock to stop the load from leaving the platform.

When the aircraft is over the drop zone and the drop is initiated, the system begins the process of ejecting the cargo extraction parachute. Once fully open, the extraction parachute breaks the locking mechanism (break link), releasing the last lock holding the load. Thus, the payload is released from the aircraft and, when lowered, the extraction parachute causes the main parachute to open, which controls the descent of the payload over a designated area.

As in CDS drops, we also have different platform lengths in HE drops. The size depends on the number of panels used. As a standard in transport aviation for HE airdrops, we distinguish between the following platform sizes[5]:

- 8-foot;
- 12-foot;
- 16-foot;
- 20-foot;
- 24-foot;
- 28-foot;
- 32-foot.

With HE drops, as with CDS drops, as the length of the platform increases, the weight of the load that can be loaded onto the pallet increases, however the height of the load decreases. Choosing the right platform size depends on the dimensions and weight of the load to be dropped.

Depending on the parachute fitted, HE-type platforms can be dropped from different heights. Minimum heights range from 250 metres above ground level.

[4] EADS CASA, *C-295 aircraft cargo…*, 7C-1.
[5] Army Publishing Directorate, *Airdrop of Supplies and Equipment: Rigging Airdrop Platforms; Airdrop Derigging and Recovery Procedures; Reference Data for Airdrop Platform Loads*, 13C7-1-5, March 2016, 3-2.

Fig. 3. PDS on board a CASA C-295 aircraft prepared for airdrop
Source: archive of the 8th Air Transport Base.

Free-fall, this method involves dropping a load from an aircraft in such a way that the load falls freely to the surface of the earth under the force of gravity, without the use of parachutes or other devices to retard its fall. It is often used to drop cargo that is less susceptible to free-fall damage, such as packages of food, medicine or emergency equipment that are designed to be dropped safely to the surface. A typical example of this type of drop is the delivery of leaflets used in psychological warfare.

In certain situations, a free drop can be carried out using an extrication parachute, which allows the load to be extracted from the aircraft in a controlled and safe manner. This technique is known as an extraction "parachute drop".

The use of an extraction parachute allows for controlled extraction of cargo from an aircraft, which is particularly useful when the cargo is heavy, unusually shaped or may be difficult to eject. The extraction parachute is usually attached to the cargo. Once the cargo is extracted from the aircraft, the extraction parachute is released and the cargo falls freely to the ground surface, subject to the force of gravity[6].

The Low Altitude Parachute Extraction System (LAPES) drop method is an effective way of delivering aerial platform loads at low altitude. It is used when tactical conditions do not recommend a low-altitude drop. The use of the LAPES drop allows the delivery of platform loads, with the aircraft flying only 5 to 10 feet (approximately 1.5 to 3 metres) above the ground. This method uses parachutes to slow the descent and extraction parachutes[7].

The LAPES drop procedure begins with the load being placed on metal modular platforms, which are properly secured and immobilised using special fastening systems. These platforms can be single or double in a tandem arrangement and can be dropped from the aircraft deck in a single incident.

Once the crew has decided on the drop, the parachute system pulls the platform out of the aircraft. As it descends, the load takes on a positive profile, meaning that it is in a nose-up position. This flap effect reduces the impact on the ground surface, helping to minimise any damage to the cargo during landing.

[6] Ibidem, 1-2.
[7] Construcciones Aeronáuticas, S.A. (CASA), *Aerial Delivery and Combat Offload Operations with Airplane Model C-295M*, Supplement no. 11 to model C-295M, INTA-Approved Airplane Flight Manual, Document D.T.-5-C-01-5003, 11-23.

Depending on the size of the cargo cabins of the transport aircraft, 12- and 16-foot V-type platforms are used for LAPES drops, and cargo weights range from 3045 to 6045 kg, depending on the type of aircraft.

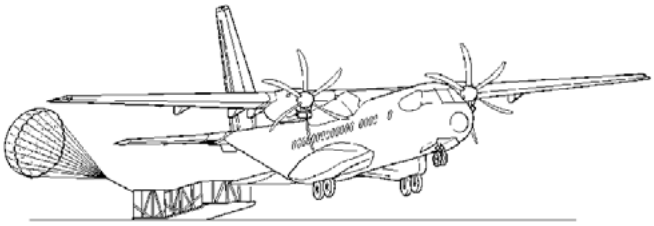

Fig. 4. LAPE drop from a C-295 aircraft
Source: Airbus Defence and Space, Aircraft operations…, 7D21.

The Gravity Extraction Platform (GEP) drop method is an alternative technique to CDS drop and is an effective way to deliver aerial supplies such as fuel, ammunition, ready-to-eat meals, dismantled spare parts, etc., and small pieces of equipment ready for use.

The GEP drop process involves placing the payload on V-type platforms made of extruded aluminium or on wearable wooden platforms (A-35 with a tray base size of 183 × 223.5 cm), which are equipped with energy-absorbing material, to dissipate forces during descent. The load is secured and immobilised by means of special drop devices on the platform. GEP airdrops use an ascending parachute and a main parachute to ensure controlled descent of the payload, minimising impact on the ground surface.

The primary advantage of this method is the ability to deliver large quantities of supplies simultaneously, significantly increasing the efficiency and effectiveness of logistics and humanitarian operations. In addition, the low descent velocity of the platform minimises the risk of cargo damage during the drop. The GEP method has found its way into many military missions and humanitarian operations where fast and precise delivery of supplies is crucial.

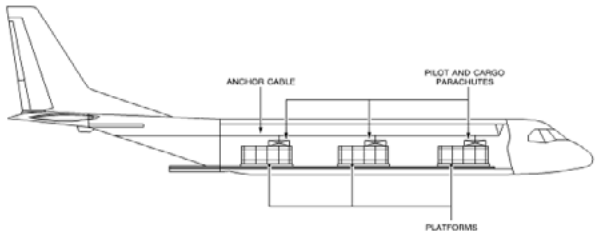

Fig. 5. General view of the GEP discharge system
Source: Airbus Defence and Space, Aircraft operations…, 7E-9.

3. New innovative airdrop techniques

In today's dynamic and changing operational environment, the drive to improve cargo drop techniques from transport aircraft is a key initiative for both armed forces and humanitarian operations. With advances in technology and evolving operational needs, research and engineering efforts are focusing

on a number of aspects aimed at improving the tactical use of cargo drop techniques but also reducing operational costs and expanding the tactical capabilities of transport platforms.

The main objective of this work will be to achieve greater precision, which is crucial for both the effectiveness of military and humanitarian operations. Advanced navigation systems, sensors and data analysis technologies allow the precise determination of the airdrop trajectory, taking into account varying weather conditions and terrain topography. An example of such a system is the implementation of the JPADS (Joint Precision Airdrop System), an advanced precision airdrop system that allows a variety of supplies to be delivered to a designated area with high accuracy. The main feature that distinguishes JPADS from other airdrop methods is that it is equipped with a wing-type gliding parachute, which gives it the ability to fly in any direction regardless of the wind and to change direction in flight at any time. The JPADS drop process is initiated by ejecting the load from the transport aircraft and then opening the parachute using the aircraft's static line. The AGU (Airborne Guidance Unit) takes control of the parachute and enables it to be directed precisely to the target. The AGU is equipped with a sophisticated computer, responsible for calculating the flight trajectory, communication equipment, a GPS receiver, temperature and pressure sensors, LIDAR radar and a steering cable control device. With these elements, the AGU maintains constant communication with the JPADS-MP (Mission Planner) on board the aircraft, which provides up-to-date data on wind strength and direction. JPADS has a number of distinguishing features from other airdrop methods, such as the ability to drop from high altitudes, stealth and security of delivery, making it an effective tool for logistical and humanitarian missions[8].

The introduction of new discharge techniques is also linked to the aim of reducing operating costs. Efficient use of resources and optimised procedures can reduce financial and logistical outlays, while not compromising the quality and accuracy of deliveries. This aspect is particularly important in today's environment, where operational efficiency and flexibility are key determinants of success. The Rapid Rigging De-Rigging Airdrop System (RRDAS), which is in the testing phase, is a state-of--the-art parachute system that enables the rapid and precise airdrop of cargo to designated targets. It uses reusable, self-filling airbags to provide a more reliable means of transporting and dropping supplies compared to traditional systems with cardboard and steel pallets. The system has been tested at the Yuma training ground, where soldiers were able to access equipment 40% faster than with previous systems, and pre-flight assembly time was reduced by 25%. The RRDAS is equipped with a stabilising mechanism that ensures the payload lands in the correct position, minimising the risk of damage during the drop. It can be used from a height of 230 m and allows load drops from 2300 to 10 000 kg. The RRDAS represents an innovative solution for the efficient and rapid delivery of supplies to hard-to-reach areas[9].

The safety of the aircraft crew and personnel operating the airdrop process is integral to modern innovations in the field, contributing to more efficient and safer logistics operations in both military and humanitarian operations. An example of a system that improves the operational reach of missions and the safety of personnel is the GD-2000 Silent Arrow transport glider project, an unmanned platform that has been designed to deliver supplies in conditions that make land delivery impossible. It has a payload capacity of 900 kg, allowing it to carry a wide variety of cargo. The glider has excellent manoeuvrability thanks to its spring-loaded deployable wings, allowing it to pinpoint its landing site even in difficult weather conditions. The GD-2000 Silent Arrow can stay in the air for 15

[8] R. Benney, J. McGrath, J. McHugh, G. Noetscher, S. Tavan, S. Patel, *DOD JPADS programs overview and NATO activities*, [in:] *19th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar*, Williamsburg 2007, 4-5.

[9] https://www.armyrecognition.com/weapons_defence_industry_military_technology_uk/us_army_tests_rrdas_rapid_rigging_de-rigging_airdrop_system_at_yuma_proving_ground.html [accessed: 2.03.2023].

minutes and can be left in enemy-controlled areas due to its simplicity and low cost. The glider has the potential to support special forces troops, as well as resupply small islands in the Indo-Pacific[10].

The use of simple airdrop systems, by transport aircraft, makes it possible to significantly change the characteristics of weapon use.

The Rapid Dragon palletised weapon system is a novel system that allows the launch of multiple long-range cruise missiles using a transport aircraft. Demonstrated by the US Special Operations Command in Norway, the system provides a new alternative to traditional weapon drop methods by allowing the use of standard drop procedures.

Rapid Dragon works by dropping a special pallet on parachutes from a transport aircraft such as a C-130 Hercules. The interior of this pallet contains AGM-158 JASSM-ER long-range cruise missiles, which, when launched, can head towards a target, providing significant firepower. Between four and nine AGM-158 missiles can be launched from a single pallet, and by dropping two pallets, the C-130 Hercules aircraft gains strategic bomber capabilities.

Rapid Dragon's designers put particular emphasis on the system's hard-to-detect features, which greatly enhances its effectiveness in military missions. The ability to configure transport aircraft to launch multiple cruise missiles enhances the combat capability of the air fleet, enabling effective operations with long range and precision[11].

Future directions for the development of new airdrop techniques, especially using drones (UAVs), focus on further improvements in the precision and reliability of supply delivery. The use of drones allows independence from weather conditions and increases safety as they do not require a crew on board. Advanced navigation systems, sensors and cameras in drones ensure precise target location and delivery of supplies with high accuracy. The deployment of augmented reality (AR) and artificial intelligence (AI) technologies enables automatic detection of optimal drop sites, analysis of weather conditions and flight paths, further enhancing precision and reliability of deliveries.

Optimisation of drone control and navigation systems is also a key area of development. Advanced computing algorithms, artificial intelligence and machine learning will be key to improving the drones' ability to plan a route, take into account changing weather conditions and make quick decisions in flight. This will make it possible to effectively adjust the flight path and accurately deliver payloads to designated targets, even in a dynamic battlefield environment.

Another direction for drone development will be to increase manoeuvrability and payload capacity. The introduction of advanced materials and construction technologies will allow drones to reduce their weight while maintaining their strength and ability to carry larger payloads. As a result, drones will be able to deliver more advanced equipment, medical supplies or food to battlefields or hard-to--reach regions, which could be crucial in humanitarian and health care missions[12].

4. Comparative analysis of drop techniques

Cargo airdrop from a transport aircraft involves a variety of methods, each with both advantages and limitations. It is useful to familiarise yourself with the characteristics of each technique in order to adapt them appropriately to your specific needs and operational conditions.

[10] https://www.altair.com.pl/news/view?news_id=39938&q=zrzut%20%C5%82adunku [accessed: 27.04.2023].
[11] MILMAG, *Rapid Dragon: Spaletyzowane pociski manewrujące w MC-130J*, https://milmag.pl/rapid-dragon-spaletyzowane-pociski-manewrujace-w-mc-130j/ [accessed: 18.12.2021].
[12] https://ts2.space/pl/najlepsze-drony-do-naglych-wypadkow-medycznych-2/ [accessed: 30.04.2023].

CDS (Container Delivery System) airdrop is a popular and versatile method of resupplying troops and delivering humanitarian aid in hard-to-reach areas. It uses special containers with parachutes that provide a controlled load drop. Advantages include the precision and speed of resupply, and it allows different types of supplies to be delivered to a designated area. However, it requires precise planning and assessment of atmospheric conditions to ensure the accuracy of the drop and minimise cargo spread. The HE (Heavy Equipment) drop method enables the delivery of large and heavy loads, such as tanks or guns, to a designated area. It is effective for resupplying troops in areas that are difficult to access, allowing supplies to be delivered to areas that cannot be reached by other methods. However, it requires specialised cargo attachment aboard aircraft and the preparation of appropriate platforms, which can increase the time and difficulty of operations.

Free drop is a simple and fast technique for delivering supplies to hard-to-reach areas. The absence of parachutes allows the dropping of large loads, which is particularly useful for resupplying troops in areas with limited infrastructure but needing areas of large size. The advantages of airdropping with parachute extraction include better control over the dropping process and reducing the impact of rapid aircraft rebalancing. This is particularly important if the load is large, bulky or may affect the stability of the aircraft during disembarkation. A winch parachute also allows for more precise extraction of cargo to a designated location, which can be crucial when delivering cargo to specific targets. However, the use of a winch parachute also comes with some disadvantages. The procedure requires more advanced planning and preparation compared to a traditional freefall. Appropriate selection of parachutes and ensuring adequate load stability during the drop are necessary. In addition, the use of a winch parachute may require specialised training of the crew and personnel responsible for the drop operation. The LAPES (Low Altitude Parachute Extraction System) drop method allows platform loads to be delivered from an aircraft flying at a low altitude above the ground. It is effective in a limited drop area and allows precise placement of the payload at a designated location. However, it requires specialised crew training and appropriate equipment, which can increase costs and limit the availability of this method in some operations. The Gravity Extraction Platform (GEP) drop method provides a precise and controlled drop to the target location. It is effective in delivering a variety of commodities, including fuel, ammunition and ready-to-eat meals. It requires specialised training of personnel involved in cargo preparation and mission planning to ensure the accuracy and safety of the operation. The advantages of airdrop using JPADS (Joint Precision Airdrop System) is a modern and advanced technology that offers many advantages over traditional methods. JPADS allows precise airdrops into a designated area, minimising the risk of damage or loss of supplies. Thanks to its navigation system, JPADS is able to pinpoint the exact location of the drop, which is extremely useful in military and humanitarian operations where accuracy is crucial. JPADS' advantages also include flexibility and the ability to change delivery points along the route, allowing operations to adapt to changing conditions. In addition, JPADS allows airdrops to be performed from high altitudes, increasing the safety of aircrews. Flying at higher altitudes and the flexibility of approach vectors reduces the risk of detection and crew exposure to enemy action. In addition, JPADS does not require extensive logistics facilities in the theatre of operations, allowing the delivery of supplies in hard-to-reach areas or in situations where other delivery options are untenable. However, precision airdrops using JPADS require specially trained personnel for cargo preparation and mission planning. Precision drop points (PIs) must be properly secured to prevent supplies from falling into enemy hands, an important factor in military operations. In summary, each method of airdropping has its own advantages and limitations, which must be taken into account in the planning and execution of logistics and humanitarian operations. CDS airdrop, HE airdrop method, free airdrop, LAPES airdrop method, low velocity gravity-ejecting platform airdrop and JPADS are a variety of techniques that can be adapted to specific operational

needs and conditions. The choice of the appropriate method depends on the purpose of the operation, the type of load, the availability of appropriate equipment and personnel training, as well as weather and terrain conditions. A well-planned and well-considered cargo drop operation can significantly increase the effectiveness and success of military and humanitarian missions.

5. Conclusions

A review of airlift drop techniques shows that the use of traditional methods is one of the most important transport options in situations where access to other modes of transport, is difficult or impossible. Particularly in humanitarian missions, where rapid and efficient delivery of aid is crucial to saving lives, traditional airdrop techniques are often the only relief option.

The methods described in this article for airdropping cargo from a transport aircraft will continue to be used and refined, building on common procedures used in the air forces of NATO countries. In addition, they will represent a significant advance in innovative weapon systems, enabling the flexible use of transport aircraft in offensive operations. Thanks to this advanced technology, it will be possible to increase combat capability and operational efficiency, which is crucial for military missions in different areas of operations.

In the future, drones can be expected to grow in importance, enabling even greater accuracy, reliability and safety for crews. The use of advanced algorithms, artificial intelligence and machine learning will allow automatic planning and execution of airdrops, taking into account changing weather conditions and a dynamic battlefield. Further development of manoeuvrability, payload capacity and the use of green technology will make drones a key tool in delivering supplies to the battlefield and hard-to-reach areas, both in the context of military and humanitarian operations.

BIBLIOGRAPHY

Papers and monographs

Airbus Defence and Space, *Aircraft operations manual volume II. Limitations & procedures*, original issue: September 2013, revision: 15 February 2022.

Army Publishing Directorate, *Airdrop of Supplies and Equipment: Rigging Airdrop Platforms; Airdrop Derigging and Recovery Procedures; Reference Data for Airdrop Platform Loads*, 13C7-1-5, March 2016.

Benney R., McGrath J., McHugh J., Noetscher G., Tavan S., Patel S., *DOD JPADS programs overview and NATO activities*, [in:] *19th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar*, Williamsburg 2007.

Construcciones Aeronáuticas, S.A. (CASA), *Aerial Delivery and Combat Offload Operations with Airplane Model C-295M*, Supplement no. 11 to model C-295M, INTA-Approved Airplane Flight Manual, Document D.T.-5-C-01-5003.

EADS CASA, *C-295 aircraft cargo loading manual*, original issue: July 2002, revision: 8 January 2020.

European Tactical Airlift Centre, *The etap tactics techniques and procedures (ETTP)*, version 8, 23 February 2022.

Internet sources

MILMAG, *Rapid Dragon: Spaletyzowane pociski manewrujące w MC-130J*, https://milmag.pl/rapid-dragon-spaletyzowane-pociski-manewrujace-w-mc-130j/

https://ts2.space/pl/najlepsze-drony-do-naglych-wypadkow-medycznych-2/

https://www.altair.com.pl/news/view?news_id=39938&q=zrzut%20%C5%82adunku

https://www.armyrecognition.com/weapons_defence_industry_military_technology_uk/us_army_tests_rrdas rapid_rigging_de-rigging_airdrop_system_at_yuma_proving_ground.html