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LARGE-SCALE OPERATIONS CARGO PARACHUTE SYSTEM

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Abstract: *The article describes the design process for a low-cost aerial delivery system (LCADS) that is a one-time use, disposable, airdrop system consisting of cargo parachute and container. The parachute systems is developed for military resupply missions and for humanitarian relief efforts in areas where ground supply and/or recovery of airdrop equipment is difficult or not feasible. LCADS consists primarily of three types of cargo parachutes capable of supporting and delivering in a wide range of weights, from 70kg up to 1000kg. During the product development will be targeted three types of delivery topologies each with its own type of low-cost parachute: 'Low Velocity' delivery where the cargo is slowed down considerably by the parachute down to 5-7m/s for fragile and sensitive equipment using a cross type parachute made of fabric bands; 'High Velocity' delivery where the cargo is only stabilized during descent and only marginally slowed down by the parachute for non-fragile equipment also using a cross type parachute made of fabric bands; 'High Altitude Precision Delivery', where the cargo is driven to a specific target using a self-steering a ram-air parachute. The parachutes are made from woven polypropylene fabric obtained from recycled source materials. These parachutes are 55% to 80% less expensive than the traditional nylon cargo parachutes due to a much lower cost of material. An added benefit for the LCADS, which are made from woven polypropylene fabric, is that these parachutes have shown to have a lower rate of descent than standard nylon cargo parachutes.*

Key words: *LCADS, Cargo Parachute, Airdrop, Polypropylene Fabric, Recycling*

1. INTRODUCTION

The need for efficient, reliable, and cost-effective aerial delivery systems has grown significantly in recent years. This demand is driven by both military operations, which require the resupply of troops in remote or hostile areas, and humanitarian missions, where aid must be delivered to regions inaccessible by traditional ground transport due to natural disasters, conflict, or other barriers. The development of a Low-Cost Airdrop Delivery System (LCADS) addresses these challenges with an innovative solution that emphasizes affordability, disposability, and effectiveness.

Aerial delivery systems have historically been a crucial component of logistical operations, particularly in scenarios where ground access is limited or non-existent. Traditional airdrop systems, while effective, often come with high costs and complexities associated with the recovery and reuse of the airdrop equipment. These challenges are exacerbated in environments where retrieval of the dropped equipment is impractical due to hostile conditions, dense vegetation, or remote locations. The introduction of a low-cost, disposable system like LCADS offers a pragmatic alternative by eliminating the need for equipment recovery, thereby streamlining the resupply process and reducing operational expenses [1]. LCADS is designed as a one-time-use airdrop system comprising a cargo parachute and container. It aims to deliver supplies reliably while minimizing the logistical complexities and costs associated with recovering airdrop equipment. The system's versatility is highlighted by its capacity to support a wide range of payloads, from 70 kg to 1000 kg. By utilizing recycled polypropylene materials for parachute construction, LCADS not only reduces costs significantly but also aligns with environmental sustainability goals [2].

In summary, the Low-Cost Airdrop Delivery System addresses critical logistical challenges faced by both military and humanitarian operations. By offering a cost-effective, disposable, and environmentally sustainable solution, LCADS enhances the efficiency and effectiveness of aerial delivery missions. Its development marks a significant advancement in the field of aerial logistics, providing a robust and versatile tool that meets the demands of modern operational environments. This article outlines the design, development, and testing process of the LCADS, focusing on the benefits and performance of using recycled polypropylene, and highlights the potential impact of this innovative system on future logistical operations.

2. SYSTEM DESIGN

The development of LCADS is particularly timely given the increasing frequency and severity of natural disasters globally. Climate change has led to more intense and frequent hurricanes, floods, and other catastrophic events, heightening the need for rapid and efficient delivery of relief supplies. Humanitarian organizations often face immense challenges in reaching affected populations quickly, especially in the initial hours and days following a disaster [3]. An effective and affordable airdrop system can make a significant difference in these situations, ensuring that essential supplies such as food, water, medical supplies, and shelter materials reach those in need without delay. In military contexts, the importance of reliable resupply mechanisms cannot be overstated. Troops operating in remote or hostile areas rely heavily on consistent and timely delivery of supplies to maintain operational effectiveness. Traditional supply lines are often vulnerable to enemy actions, terrain difficulties, and logistical bottlenecks. LCADS offers a robust solution by providing a rapid, reliable, and low-cost method of delivering essential supplies, thus enhancing the operational flexibility and sustainability of military forces [4]. Beyond the immediate practical benefits, LCADS also represents a significant step forward in sustainable engineering. The system's reliance on recycled polypropylene not only reduces material costs but also addresses the growing concern over plastic waste. The use of recycled materials in critical applications demonstrates a commitment to sustainability and environmental stewardship, aligning with broader global efforts to reduce waste and promote recycling. This approach not only benefits the environment but also sets a precedent for other industries to follow, encouraging innovation and sustainability in product design [5].

The versatility of LCADS is another key strength. It is designed to accommodate a variety of payloads and mission profiles, making it suitable for a wide range of applications. Whether it's delivering humanitarian aid in the aftermath of a natural disaster, resupplying troops in a conflict zone, or providing logistical support in remote areas, LCADS can be tailored to meet specific operational needs. This adaptability ensures that the system remains relevant and useful across different scenarios and over time [6].

As such the LCADS comprises three types of cargo parachutes designed to cater to different delivery needs: Low Velocity, High Velocity, and High Altitude Precision Delivery. Each type is tailored to specific requirements based on the nature and sensitivity of the cargo [7].

Low Velocity Delivery: Designed for fragile and sensitive equipment, this parachute system ensures the cargo descends at a controlled speed of 5-7 meters per second. The parachute features a cross-type design made from fabric bands, which significantly reduces the descent rate and minimizes impact forces upon landing.

High Velocity Delivery: This system is intended for non-fragile items where the primary goal is stabilization rather than significant deceleration. The high velocity parachute also utilizes a cross-type design with fabric bands, allowing the cargo to descend rapidly while maintaining a controlled trajectory.

High Altitude Precision Delivery: For scenarios requiring precise delivery to a specific target, this parachute system employs a self-steering ram-air parachute. This advanced design enables accurate navigation and placement of the cargo from high altitudes [8].

Detailed Design Choices

Cross-Type Parachute Design:

The cross-type design employs fabric bands arranged in a cross pattern, which provides a balance between simplicity and effectiveness. This design choice is optimal for both low velocity and high velocity systems, as it offers stability during descent and is easy to manufacture at a low cost. This type of parachute is engineered to achieve an optimal drag coefficient, ensuring the desired descent speed is attained for various payload weights. This involves fine-tuning the surface area and the material properties to maximize aerodynamic efficiency. The fabric bands used in the cross-type parachutes are reinforced to withstand the stresses encountered during deployment and descent. The material selection and weave pattern are crucial in preventing tears and ensuring the structural integrity of the parachute [9].

Fig 1. *Cross-Type Parachute*

Ram-Air Parachute Design:

The ram-air parachute design incorporates a self-steering mechanism that uses GPS and automated control systems to navigate to the target location. This involves complex algorithms that adjust the parachute's flaps to control direction and descent speed. The ram-air parachute features an aerodynamic shape similar to a rectangular wing, providing lift and allowing for precise control during descent. This design requires detailed aerodynamic analysis to ensure stability and accuracy. The materials used in the ram-air parachute must be lightweight yet durable, capable of withstanding high-altitude conditions and the stresses of guided descent. Advanced composites and reinforced polypropylene fabrics are typically used to achieve the required performance.

Additional Design Considerations:

Each type of parachute requires a reliable deployment mechanism to ensure successful deployment at the appropriate altitude. This includes the use of static lines, drogue chutes, or spring-loaded deployment systems, depending on the specific requirements of the mission. The parachutes are attached to the cargo container using reinforced harnesses and load distribution systems. These attachments are designed to evenly distribute the forces experienced during descent, minimizing the risk of damage to the cargo. The design of LCADS emphasizes modularity and scalability, allowing for easy adaptation to different payload sizes and mission requirements. This includes interchangeable parachute modules and adjustable harness systems to accommodate varying weights and dimensions

Material Selection

The selection of woven polypropylene fabric, sourced from recycled materials, is a pivotal aspect of the LCADS design. Polypropylene is known for its high tensile strength and resistance to abrasion, making it an ideal material for parachute construction. The fabric can withstand the forces encountered during deployment and descent, ensuring the parachute remains intact and functional. Polypropylene is lighter than many other materials, such as nylon, which contributes to the overall efficiency of the parachute system. The reduced weight allows for better control and stability during descent. Polypropylene exhibits excellent resistance to moisture, UV radiation, and temperature fluctuations. This ensures the parachutes maintain their integrity and performance in various environmental conditions, from arid deserts to humid tropical regions.

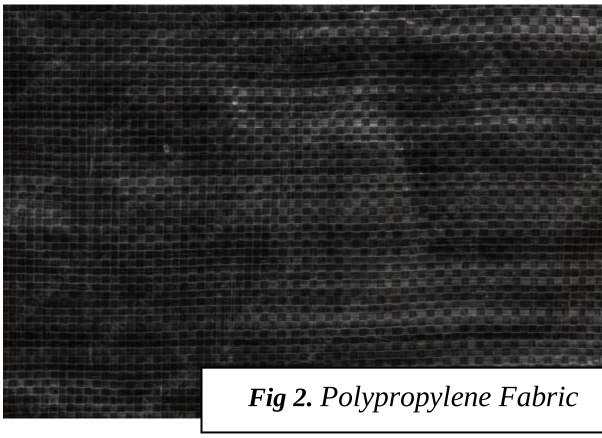

Fig 2. *Polypropylene Fabric*

Polypropylene offers several advantages over traditional nylon used in cargo parachutes:

Cost Efficiency: Polypropylene fabric is substantially cheaper than nylon, reducing the overall cost of the parachute by 55% to 80%

Recyclability: The use of recycled polypropylene aligns with sustainable practices, minimizing environmental impact and promoting the reuse of materials.

Performance: Tests have shown that polypropylene parachutes provide a lower rate of descent compared to nylon, increasing the likelihood of cargo survival upon landing.

Recycling polypropylene consumes significantly less energy compared to producing virgin polypropylene or other materials like nylon. This energy efficiency reduces greenhouse gas emissions and contributes to a lower carbon footprint for LCADS production. By using recycled polypropylene, LCADS helps divert plastic waste from landfills and incineration, supporting global efforts to reduce plastic pollution and promote a circular economy. This approach contributes to environmental sustainability by conserving natural resources and reducing environmental impact. The adoption of recycled materials in LCADS aligns with broader sustainability goals, promoting responsible resource use and supporting environmental conservation efforts. By prioritizing recycled polypropylene, the project exemplifies sustainable engineering practices that benefit both the environment and society at large.

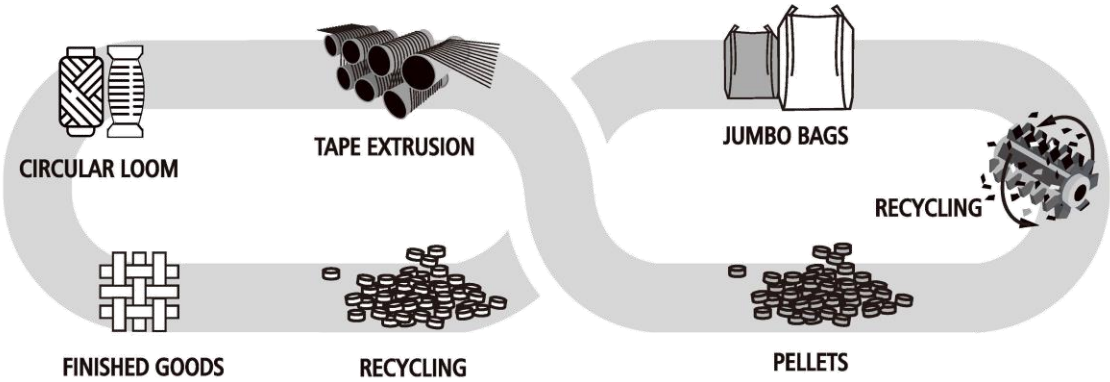

Fig. 3 *Recycling Process*

3. CONCLUSIONS

The Low-Cost Airdrop Delivery System (LCADS) represents a significant advancement in the field of aerial logistics. By focusing on affordability, disposability, and environmental sustainability, LCADS addresses the critical challenges associated with traditional airdrop systems. The use of recycled polypropylene fabric not only reduces production costs but also promotes the reuse of materials, contributing to environmental conservation efforts.

The development and testing of LCADS have demonstrated its capability to meet diverse operational needs, from low velocity delivery of fragile items to high velocity drops of non-fragile supplies, and precision delivery from high altitudes. The system's robust performance, combined with significant cost savings and environmental benefits, makes it a compelling option for both military and humanitarian applications.

As global challenges continue to evolve, the need for innovative and adaptable solutions like LCADS becomes increasingly critical. The success of this project highlights the importance of integrating sustainable practices into product design and development. Moving forward, further research and refinement of the LCADS will focus on enhancing its capabilities and exploring new applications, ensuring it remains a valuable asset in the arsenal of aerial delivery technologies.

The Low-Cost Airdrop Delivery System exemplifies how thoughtful design, material innovation, and a commitment to sustainability can come together to address pressing logistical challenges in a cost-effective and environmentally responsible manner. This system not only meets the immediate needs of military and humanitarian missions but also sets a precedent for future developments in the field of aerial delivery. By continuing to explore and improve upon these concepts, we can create even more efficient, reliable, and sustainable solutions for the complex logistical challenges of the future.

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