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Modernization and development of transport applications of an autonomous airship

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Abstract: Autonomous airships have historically found their application in transport, before the technology was mostly abandoned. Since then, the demand for sustainable alternative transport solutions in the 21st century has reintroduced research on such aerial systems. More so, reviews point to blimps as a successful or even preferred platform in various missions, where heavier-than-air platforms have been commonly used. Due to its lightweight and low-risk character, airship technology proves useful in low-wind environments [1].
This paper presents the design, modernization attempts, and functional expansion of a small autonomous airship—ACCA (Autonomous Cargo Containment Airhsip), with the aim to apply it in short-range cargo transportation. The project focused on improving the airship prototype's propulsion and electronic systems, stabilizing the frame, as well as building the autonomous movement system which would ensure reliable navigation. The payload capacity was expected to be 5 kg. The results portray small autonomous airships as cost-effective and energy-efficient, contributing to the broader discourse on autonomous aerial transport. ACCA holds a prospect for scalable deployment in last-mile delivery and emergency logistics.

Keywords: Autonomous airship, autonomy, cargo, airship, blimp, aircraft, transport, innovation, modernization

1. INTRODUCTION

In recent years, an interest in sustainable and autonomous transport solutions has grown, particularly in the context of short-range logistics and last-mile delivery. Along with other types of innovative, modern transport solutions that have emerged, occurred a comeback to lighter-than-air airship technology. Its unique advantages, such as low energy consumption, extended hovering-time capabilities, and minimal infrastructure requirements, seem attractive for utilizations in areas such as surveillance and telecommunications [2, 3].

While autonomous drones have seen much more widespread adoption, the challenges they face are predominantly caused by their limited payload, short operational time, and constraints by regulations. Airships may then work as a replacement in those specific missions where their stability and endurance outperform those of multirotor UAVs (unmanned aerial vehicles).

The ACCA project constituted the development and modernization of a small-scale autonomous airship based on a previous prototype. The main objective was to design a platform capable of transporting lightweight cargo (up to 5 kg), led by an autonomous steering program, with enhanced propulsion, high structural stability, and gas efficiency.

The following sections describe the construction of the airship, discussing key design challenges, as well as the electronic systems and autonomous navigation, finishing with a plan for future developments in the ACCA project.

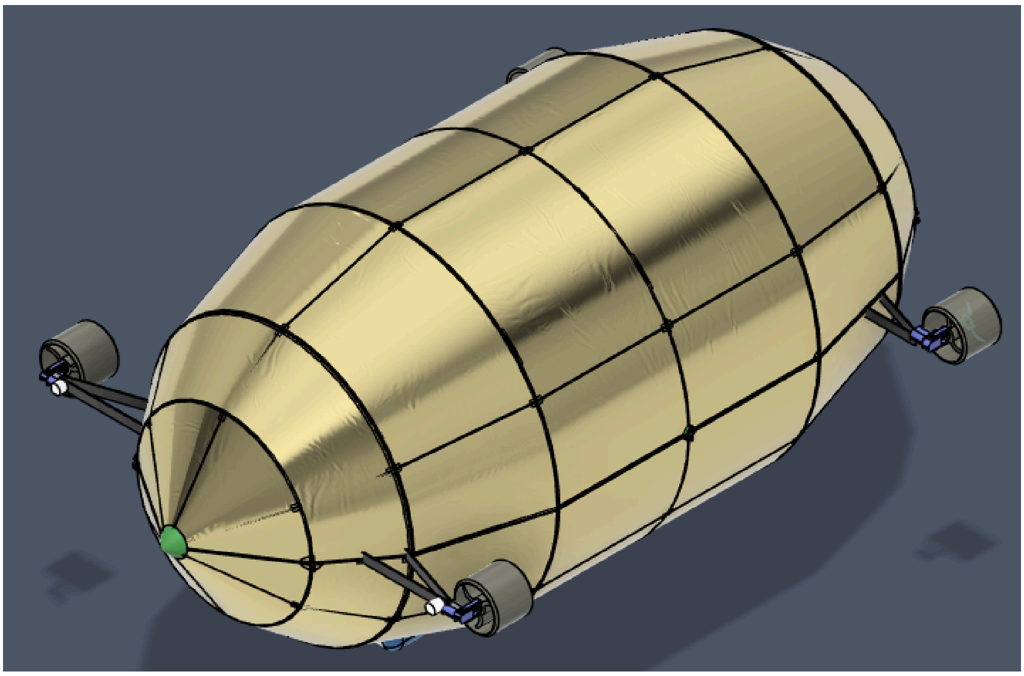

Fig. 1. ACCA airship render.

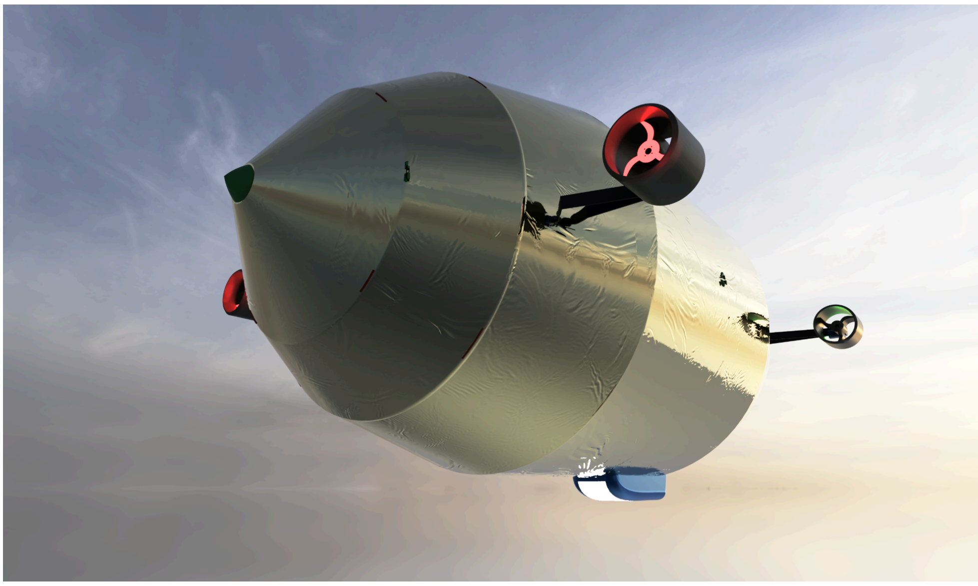

Fig. 2. ACCA airship realistic render.

2. CONSTRUCTION DESIGN

The structural design of the airship was created with the aim of maximizing lift efficiency while providing durability, modularity, and low total weight. The frame supporting the propulsion system, electronic components, and cargo attachment mechanism was built from durable carbon rods, wooden elements and 3D-printed parts, like fixings. This allows for precise adjustments during the testing phase and makes prototyping affordable. A modular gondola basket beneath the plating contains the main computing unit (Raspberry Pi 5), batteries, and main sensors. It was designed to allow quick access to the components. Stratospheric balloons filled with carrier gas mounted by the frame, under the plating, will lift the airship. The plating is meant to mitigate the risk arising from static electricity buildup on the external surfaces of the airship. The carrier gas during tests will be hydrogen [4], however public presentations will require the use of stable helium.

To complete the construction, it was necessary to determine the weight distribution and center-of-mass stabilization, since both are crucial for achieving flight stability and ensuring responsive autonomous navigation. To accommodate the airship's gas expansion and contraction during flight, the design also incorporates a flexible mounting system between the plating and the rigid body. The chosen approach to construction provides reliability in its functionality as well as facilitates the development of future airship iterations.

3. THE PROPULSION SYSTEM

The propulsion system for the airship was designed to be efficient and stable. It is integrated with the onboard autonomy framework. Each engine assembly consists of two servo motors connected with light-weight 3D printed brackets, at the end of which an electric motor is placed.

Brackets are interconnected with each other in a way that allows the engine to be rotated in two axes independently, providing the operator with a high degree of maneuverability and precision. This arrangement also allows for operations in enclosed environments or ones requiring constant corrections, such as facing angled winds.

Considering the vehicle's purpose as a lightweight cargo mover, capable of carrying payloads up to 5 kg, propulsion components were selected to balance thrust and the consumption of energy. The system comprises multiple electric motors, organized to ensure multidirectional steerability and stable hovering capabilities in low-wind environments. Custom-designed mounting arms, 3D-printed from lightweight composite filament, provide support for the motors and enable easy maintenance and adjustment. The drive system needs to integrate closely with the airship's control architecture, allowing the transition between manual override and fully autonomous flight modes. The propulsion units are powered by lithium-ion battery packs, selected because of their high energy density and weight-to-capacity ratio, which optimizes energy efficiency.

The airship's stability needs to be actively maintained during flight, particularly in response to changes in position, wind conditions, and payload distribution. To achieve this, the propulsion system adjusts thrust levels dynamically based on input from onboard sensors—positioning modules and inertial data. This is coordinated by the operating system.

Additionally, the configuration can be used for precise control of lift and forward motion—an essential for navigation during cargo pickup and delivery. The testing phase of the propulsion system includes thrust calibration and performance assessment under different payloads and weather conditions, with a mission to improve flight process [5].

4. SYSTEM OPERATION AND CONTROL

The ACCA airship operates on an integrated control architecture that interconnects collecting data from the sensors, autonomous decision-making and real-time actuator management. At the core of the system is a Raspberry Pi 5 microcontroller which coordinates flight logic, sensor communication and propulsion commands. Onboard software includes custom modules for path planning, obstacle avoidance, altitude control and landing procedures. Navigation is based on a combination of a LIDAR module, a GPS positioning system and proximity sensors, enabling the airship to read its position accurately and respond dynamically to its environment. Control algorithms are implemented with the ability to switch between manual, semi-autonomous and fully autonomous modes, depending on mission requirements or operator intervention [6].

All critical telemetry is wirelessly transmitted to a base station for real-time monitoring and post-mission analysis. To enhance operational safety, redundant communication protocols and a basic fail-safe behavior module are included, so that the airship will perform an emergency landing in case of system failure or power loss. The operation protocols and control lay the groundwork for reliable and repeatable performance.

4.1. AUTONOMOUS NAVIGATION

The autonomy system is being developed with the goal of enabling fully self-directed flight, eliminating the need for continued human supervision. A core innovation the project presents is the use of a machine learning model trained to control the airship's navigation and basic task execution [7]. The training process focuses on achieving high performance using a minimal dataset, which reflects real-world constraints in collecting extensive flight data.

Instead of relying exclusively on rule-based logic, the system is designed to learn and adapt through exposure to curated flight scenarios, allowing it to handle tasks such as route following [8, 9], avoiding obstacles, and transport of lightweight cargo. The training is carried out on a dedicated computing unit configured for AI workloads, and the final model is later run on an onboard device designed to handle the operations directly on the airship.

Initial field tests are planned under favorable weather conditions to validate the model's behavior in hospitable environments. While traditional techniques such as sensor fusion and predefined flight routines remain available as fallback options, the target vision of the project is to implement an adaptable, learning-based autonomy system. This approach opens the path for further options, e.g. reinforcement learning in dynamic environments [10].

5. FUTURE DEVELOPMENTS

With further developments of the ACCA platform, several improvements are planned. The goal is to enhance the airship's reliability, autonomy system, and adaptability to real-world conditions. One major area of development is to expand the environmental research capabilities of the airship through integration of new sensors. These would include temperature, humidity, wind speed, and atmospheric pressure sensors, allowing the system to assess local weather conditions and adapt its behavior accordingly. Real-time data about the weather conditions could be used to dynamically adjust flight parameters, delay missions in unsafe circumstances, or readjust the procedures for landing.

Additionally, future iterations of the autonomy framework are expected to be further developed by machine learning techniques for even more purposeful decision-making, including path optimization [10].

Other planned upgrades also include improving the energy management system, heavier payload support, and working on compatibility with intended ground docking stations. For the propulsion system, a PID-based control loop is being considered as an implementation for precise thrust vectoring and pitch stabilization.

6. CONCLUSION

This work presents the design, modernization, and functional expansion of the ACCA autonomous airship as a lightweight, energy-efficient platform for short-range cargo transport. Through the integration of the propulsion system, a stable structural framework, and an autonomy system, the airship proposes a feasible alternative to conventional UAVs, especially in some logistics scenarios. The current system focuses on the core functionality, but future developments aim to enhance the adaptability to dynamic environmental conditions, and to further improve system intelligence. The ACCA project makes its contribution to the growing body of research on lighter-than-air autonomous vehicles, clearing the pathway toward more innovative and sustainable aerial logistics solutions in the coming decade.

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