Using Novative UAVs To Support Maritime Emergency Operations

Rozhok Anastasiia [(1)], Adorni Emanuele [(2)] and Revetria Roberto [(3)]

[(1,2,3)] Dept. of Mechanical, Energy, Management and Transportation Engineering
Università di Genova Genoa, Italy

E-Mail: rozhok_anastasiya@mail.ru, Emanuele.Adorni@gmail.com, Roberto.Revetria@unige.it

1. *ABSTRACT:* In the past years, the airship industry became an emerging business with the possibility of developing new transport methods for both tools and people by respecting the environmental constraints given by the United Nations Framework Convention on Climate Change. With this paper, we want to describe a possible scenario of applying this technology. The issue of lost or broken equipment on marine infrastructures is not a rare event. The scenario proposed regarding the delivery of equipment and spare parts to an oil station at sea broke pipe during a storm. We think that the suggested application of this technology may, in the future, help many people. By showing the calculations of the final chapter, we think that using the airships will be a convenient technology in the near future to solve these problems without involving human personnel.

Keywords: *airship, operation spare parts, patrolling.*

2. INTRODUCTION

Currently, the use of UAVs covers a wide range, from patrolling territories to cargo delivery. In addition, airships are used for various manipulation tasks, logistics operations, inspection or repair of power lines (Luque-Vega L. F. et al., 2014).

Transportation of heavy loads and delivery of various spare parts to port areas, including marine platforms, for example, for oil production, is complicated by the inaccessibility of these areas. Also, when it comes to such delivery to hard-to-reach places, the environmental impact must be taken into account, since using several modes of transport, planes or helicopters, harms nature, including the large amount of greenhouse gases emissions, mainly CO_2. The use of large transport ships is convenient in delivering large-sized cargoes but requires a long waiting time. In this article, we propose the concept of an airship carrying a payload in the form of spare parts, which communicates with a hub using a signal and allows cargo delivery to various hard-to-reach places, such as marine platforms, when equipment has sailed away or broken down.

Our article consists of the following parts. Chapter 2 describes the state of the art and shows the most significant articles in the literature review on the topic. Chapter 3 describes the scenario of using airships for emergency rescue purposes, such as people lost at sea. In Chapter 4, we describe a scenario for delivering spare parts to marine platforms using airships. Finally, in Chapter 5, we present universal formulas for calculating the necessary parameters of a fleet of several airships, including the size and payload capacity that will allow it to "float" and deliver the necessary spare parts on board.

II. LITERATURE REVIEW AND THE STATE OF ART

The employment of airships for reaching far infrastructures by having a minimal impact on the environment is starting to be a reality. Airships can be employed for many applications, from patrolling (Adorni E. et al., 2021) to delivery of equipment. The application that we are suggesting in our work start from reconnaissance operations. For patrolling operations, we consider airships the safest technology, capable of "floating" over any territory, having the possibility of carrying heavy payloads, communicating through antennas, and sharing the data collected. They can be equipped with state-of-the-art instrumentation with extremely high resolution and are ideal for accessing hard-to-reach areas or operating in hostile environments that would be deadly to human operators. UAVs can reduce the hazards faced by emergency responders, loss adjusters, and risk engineers, increase the effectiveness of rescuers, provide unique viewing angles unavailable to manned aircraft, and are cost-effective.

Unmanned Aerial Vehicles have had many applications during the fifty years. Autonomous UAVs can be used nowadays for collection of data (Hildmann H. and Kovacs E., 2019) and they can play a key role in future cities (Sterbenz J.P., 2016). For civilian purposes, they have been considered especially as mobile measurement/ utilization platforms (i.e., platforms for delivering an increasingly wide range of sensors and actuators). The necessity of minimizing the time spent between the travels of an airship is a mandatory aspect during patrol scenarios. The civilian purposes that we thought relevant to analysis for this first project were the scenarios of providing first aid and delivering equipment to marine infrastructures, focusing more on this second event.

Speaking of delivery, it is worth dividing it into several categories. First, since affordability is an attractive factor, many companies are currently trying to occupy the UAV delivery market. A prime example is Amazon (Ackerman E., 2013), which considered delivery by drone and the use of a giant blimp and a swarm of drones to deliver small orders. Another advantage of delivery in such a case is the large area of the airship, allowing it to be used as a platform for advertising, which would be visible from several angles.

UAV delivery can be commercial, such as food, books, clothing, and other goods, but it is also possible to use the fleet for government purposes, such as delivering goods in case of emergencies.

Many researches explained the advantages of the employment of airships as mean of delivery (Gupta et al., 2016, Hayat S. et al., 2016, Chen M. et al., 2015, Erdelj M. and Natalizio E., 2016). A good review of the literature on using different drones for delivery purposes is presented in Hayat S., et al., 2016. The authors presented the network characteristics and requirements for different UAVs for the intended civilian applications in terms of communications and networks. The authors divided the existing applications into four groups with different qualitative and quantitative communication needs. Range, bandwidth, latency tolerance in real-time, etc., were considered.

The main features of the blimp that make it enjoyable to work in this field are:

1. High autonomy and durability in flight: lifting power is not created by aerodynamics, but by buoyancy, which saves fuel;
2. Energy efficiency: in an airship, being an elevator provided with gas, the engines are used only for propulsion. This leads to deficient energy consumption per hour of flight. There is also the possibility of covering the surface of the airship with a large solar panel, which will minimize the use of non-renewable resources;
3. Low environmental impact: (emissions, noise, turbulence): the low energy consumption is immediately reflected in a lower environmental impact. Air and noise pollution is almost negligible relative to traditional aircraft;
4. Ability to operate in areas with no airports: an airship can land and take off vertically, so it does not need long runways. This does not mean it can operate without basic infrastructure, which is necessary.

This study was conducted by Surmin et al., 2018.

Two studies by Capitta et al., 2017 and Capitta et al., 2019 describe the transportation of natural gas using airships. The authors note the main aspects related to the conceptual design of an innovative means of transporting natural gas, such as:

- Advances in meteorology, both the understanding of atmospheric phenomena and the availability of real-time data on the entire planet's climate, allow for increased safety;
- Technological advances: the introduction of GPS overcomes one of the significant difficulties of navigating historic airships, which is determining the vehicle's position in the absence of reference points;
- Improvements in structural materials: new aluminum alloys, titanium, carbon fiber, Kevlar, and composites;
- Improvement of body materials: replacing fabrics and natural membranes with synthetic materials such as nylon, polyester, polyurethane.

This significantly reduces the weight of the component, which makes up a significant portion of the airship's weight, increases service life, reduces permeability to gases, and reduces maintenance requirements.

- Reliability, efficiency, and a high power-to-weight ratio of the hotplug internal combustion engine.
- Process automation;
- Remote control: the ability to reduce cost and weight to perform multiple tasks and missions with otherwise unacceptable levels of risk.

In their analysis, the authors present theoretical calculations and some features of an airship model, a prototype unmanned pilot-scale airship (7.5 m long) capable of transporting natural gas encased in impermeable bags between two predetermined departures and arrival stations following ENAC rules.

III. PEOPLE LOST AT SEA

In case of an emergency scenario, the airship (as part of a fleet) will have the duty to provide first aid. In the case of a machine, it is not possible to respond physically to the rescue, but it would be possible to deliver a "Basic Disaster Supply Kit. The idea comes from the necessity of designing a vehicle that autonomously would deliver the kit and then would go back to its reconnaissance duty. So different are the scenarios in which a person is lost at sea or in the mountains or, perhaps, in the desert, within the scenario in which the airship would be used as a means for reconnaissance and patrolling port areas. Depending on n the scenario, the content of each emergency kit would be different. For example, the case of a rescue in a mountain area, instead of a device to convert salt water into drinkable water and a life raft, as in a sea scenario, we would need larger supplies of drinkable water, or we would need to implement first aid kits against burns and sun-related diseases in case of first aid to people lost in desert areas.

IV. DELIVERING THE SPARE PARTS

Autonomous airships can be employed for first aid operations and support for marine platforms and ships. If properly designed, airships can deliver tools, spare parts, and other equipment. UAVs can be a profitable and environmentally friendly way to deliver goods thanks to the latest technology, especially in big cities, where it is becoming increasingly difficult to move quickly from point to point, conversely, in places with undeveloped infrastructure, which are very difficult to reach by ordinary transportation. Airships will be able to travel at speeds of up to 100 km/h and less than 5% of the cost of cargo helicopters. UAVs can carry anything, not only spare parts but also oil and gas itself. They can become an essential node in complex logistical chains.

A possible scenario is an oil production station with a busted pipe or a pipe lost at sea during a storm. By sending a signal to the central hub on the coast, it would be possible for an airship to deliver spare parts and other equipment without involving human operations. An airship could land in a hard-to-reach place, or no land at all, but use an elevator. It does not need roads and could carry goods of enormous weight at a relatively low cost. The delivery container can be placed in a compartment on the bottom of the airship or attached directly to the aircraft itself. The base receives the parcel by picking it up from the compartment of the descending UAV or by detaching it from the rope of the descent mechanism, thanks to which the airship may not land on the ground.

In the case of the scenario proposed where airships would be delivering spare parts for events involving marine infrastructures, such as oil platforms and wrecked

ships, we think that different designs and configurations of an airship may be needed depending on the weight and characteristics of the equipment needed. It is preferable to have several different airships because parts can be heavy, bulky, and small, and it is much more convenient to have a whole fleet than just an airship running forward and backward. Different configurations are needed because of the weight of the equipment and the means of holding such equipment to the airship. This would bring to use the formulas presented in the following chapter to determine the proper values of the parameters of the airship.
It is also necessary to highlight the advantages and disadvantages of airships to deliver cargo and spare parts.

First of all, the environmental issues. Planes and helicopters are not very environmentally friendly. In 2010 the International Air Transport Association called for an end to heavy cargo planes due to CO2 emitted. The Boeing 747 uses 7,840 kg of aviation fuel to take off and fly 250 km. And 10 kg for each subsequent kilometer under ideal conditions. A short journey of 700 km produces about 45 tons of CO2. The same atmospheric emissions would produce 350-400 vehicles on such a journey. Airships emit 80-90% less harmful gases into the atmosphere. Furthermore, they do not leave inversion trails that contribute to the greenhouse effect due to the low flight altitude.

The next challenge, or even a severe problem, is weather conditions. UAVs have only recently begun to use heated batteries, allowing the vehicle to operate at sub-zero temperatures and not for a long time. There is also strong wind and precipitation, which cannot be ignored and are a significant obstacle to the widespread use of airships for cargo transportation. It is desirable not to have an empty or light-loaded envelope, as in places where it is challenging to arrive is usually very windy, and unloaded envelopes will go off course more often. However, modern, longer-lasting materials, including carbon fiber, will make airships less fragile and safer, and computer weather forecasting systems will avoid storms and help optimize the use of air streams.

V. CALCULATING THE PAYLOAD OF THE UAV

This work is the continuation of previous studies (Adorni E. et al., 2021, Adorni E. et al., 2022), which should bring us to determine the perfect approach to define the fittest parameters for our airship. Of course, we have to keep in mind the civilian intent of such technology, carrying out operations like reconnaissance and patrolling. The process we decided to approach is that to define the volume of necessary lifting gas, we first need to calculate the payload that the airship will have to carry. We think that this type of analysis will help give an idea of the model to use to have the most efficient design in terms of costs.

Archimedes' principle is the ruling law behind the physics of an airship. Being Lighter-Than- Air, the airship's envelope is filled with a lifting gas providing the body with the necessary lifting force. We found how the most relevant gasses that can be used are helium and hydrogen from our research. The following calculations are needed to determine the optimal capacity of the airship. This is because it is proportional to the internal volume of the envelope, plus considering the mass of the structure.

We start from the physical assumption that an LTA vehicle behaves as if it was underwater.
In particular, it would be submerged in the air, the fluid that will provide the airship with lift.
From this assumption, we will assume that the volume available for the lifting gas will be the same as the displaced air volume.

For buoyancy:
$$B = \rho a \cdot V a \cdot g$$
Where a indicates our fluid, the air. A collateral assumption will be that $V a$ is the same volume as the airship $V LTA$.
The effects of buoyancy will be that it will push up in the airship, but at the same time, it will pull down as if something is hanging from the airship. This hanging thing is only the mass of the airship that we have to find. In addition, the mass of the lifting gas has to be considered ($ml\&$). Given these considerations, the equation for the

buoyancy can be written as:

$\rho a \cdot Va \cdot g - ml\& \cdot g - mp \cdot g - mLTA \cdot g = 0$

A factor that we are considering as a constant will be air density. As we well know, this value is not fixed. It depends on parameters such as altitude and pressure. Because we do not intend to have our airship flying over certain altitudes, we can consider this a fixed value of $0{,}9\ kg/m$). Another density that has to be known is the density of the chosen lifting gas. Due to safety reasons, we decided that the best solution is to employ helium ($\rho\& = \rho_{He} = 0{,}1785\ kg/m$), even if this would result in additional costs. For structural reasons, we assume that our airship will have the shape of a prolate spheroid. This solid is the most accurate representation of an airship, given a circular section in the middle and an ellipsoid section on the horizontal plane.

The variables of the following equation will be V_a and m_{LTA}. In particular, m_{LTA} can be written as in relationship to the volume of the airship (Pant R.S et al., 2008). Considering the available resources on the market and making the proper assumptions to have a realistic problem, we can consider the material of the envelope of Mylar, a polyester, which studied optimal thickness can be of 1,5 mm (h_{env}). The density of this material has been found to be 1390 kg/m3.

Given our assumptions, we can write that:

$m_{LTA} = V_{LTA} \cdot \rho_{env}$

And the final equation will be:

$\rho_a \cdot V_a - \rho_\& \cdot V_a - m_{pay} - V_{LTA} \cdot \rho_{env} = 0$

Which can be written again as

$$V_a = \frac{m_{pay} - \cdot A_{env} \cdot h_{env} \cdot \rho_{env}}{\rho_a - \rho_{l\&}}$$

The following equation describes the surface of a prolate spheroid:

$$A_{env} = 2\pi a^2 + 2\pi \frac{ac}{e} \arcsin(e)$$

Where a the minor semi-axis, c the major semi-axis and e the eccentricity (given by $e = C1 - \frac{a^2}{c^2}$ in the case a<c), the following function can describe the value of Va:

$$V(a,c) = \frac{mpay}{0{,}7215} - 3{,}355 \cdot E2\pi a2 + 2\pi \frac{ac}{e} \arcsin(e) F$$
a

From the unknown variables V_a and m_{LTA}, once the payload's mass is known, only a and c
will be left as variables.

The function describing V_a results to be strictly dependent on the value of the thickness of the envelope. If, instead of a material such as Mylar, we would use another material such as polyurethane, we would be able to diminish the thickness of the envelope and obtain more efficient results.

VI. CONCLUSION

Airships are an innovative technology. They give us the possibility of delivering equipment to marine infrastructures and rescue victims at sea with minimal human personnel employment and a low impact on the environment.

With this article, we wanted to present the applicability of this technology. The relevant studies we described showed that this problem is urgent and will soon become an integral part of smart cities.

The scenarios we described refer to Support Maritime Emergency Operations, and the presented calculations of the aircraft's dimensions showed how the critical variable is the mass of the payload, which must be calculated prior. Once this is known, it is possible to understand the needed characteristics of the airship.

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