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# Conceptual Design of Aerostat-Based Autonomous Docking and Battery Swapping System for Extended Airborne Operation

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**ABSTRACT:** In response to the ever-growing global demand for Unmanned Aerial Vehicles, efficient battery solutions have become vital. This paper proposes a design and concept of an Autonomous Mid Air Battery Swapping System for Vertical Take-Off and Landing Unmanned Aerial Vehicles. The proposed design integrates Aerial Mechatronics, Lighter than Air Systems, and Digital Modelling by leveraging the innovative concept of aerostats for battery swapping. This adaptive and effective technology paves the way for the next generation of autonomous Vertical Take-Off and Landing, ensuring a longer flight time and range. Modern-day technologies have empowered Unmanned Aerial Vehicles to operate autonomously and be remotely controlled, expanding their utility across diverse industries. The enhanced Vertical Take-Off and Landing capabilities include the ability to dock on an aerostat-mounted system, facilitating seamless battery swapping without human intervention and ensuring extended flight duration and operational flexibility. These advancements promise to broaden the applications of Unmanned Aerial Vehicles across various industries.

**Keywords:** Autonomous; Battery swapping; VTOL; Lighter than air systems; Aerial mechatronics



## 1. Introduction

UAVs are popular and versatile devices that can perform various tasks in different fields and scenarios, especially those that are risky for humans. VTOL is a feature that enables UAVs to take off, land, or hover without runways, improving their operational capabilities and performance. However, UAVs have limited battery endurance and outdated charging methods that restrict their mission length and travel distance. A potential solution is to use aerostats—floating vehicles capable of remaining airborne for extended periods—as aerial charging stations for UAVs.Aerostats can allow UAVs to dock and swap their batteries on a platform, extending their range and endurance, reducing their redeployment time, and maintaining their aerial presence.

To overcome preliminary UAV issues, an innovative docking and battery swapping system is integrated as the payload of the aerostat. This system comprises various components, including servo-driven motorized clamps, weight sensors, linear actuators, and electromagnets, all working together to achieve secure, precise, and efficient docking and battery-swapping maneuvers. The aerostat serves as a stable platform, enhancing the reliability of the process. This system is designed to significantly reduce downtime, increase operational efficiency, optimize power exchange capabilities, and extend the overall lifespan of UAVs. The incorporation of advanced technologies not only streamlines the docking process but also ensures alignment accuracy, resulting in a quicker and more effective battery swap. The approach to this system aims to enhance overall mission capabilities by decreasing redeployment time, thereby maximizing the UAV's operational effectiveness and minimizing disruptions in critical operations.

In short, this research aims towards infusing VTOL technology into a UAV, enriching its functions and capabilities whilst diminishing its limitations adjoining with an aerostat attached with a docking and battery swapping system platform engineered to dock and do a quick battery swap maneuver. This introduces a creative resolution to increase the endurance and operational capacities of the UAV. Our research not only investigates the creative utilization of UAV

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technology but also examines the potential of unconventional platforms, such as aerostats, offering valuable contributions to aerospace engineering and unmanned systems. See Figure 1.

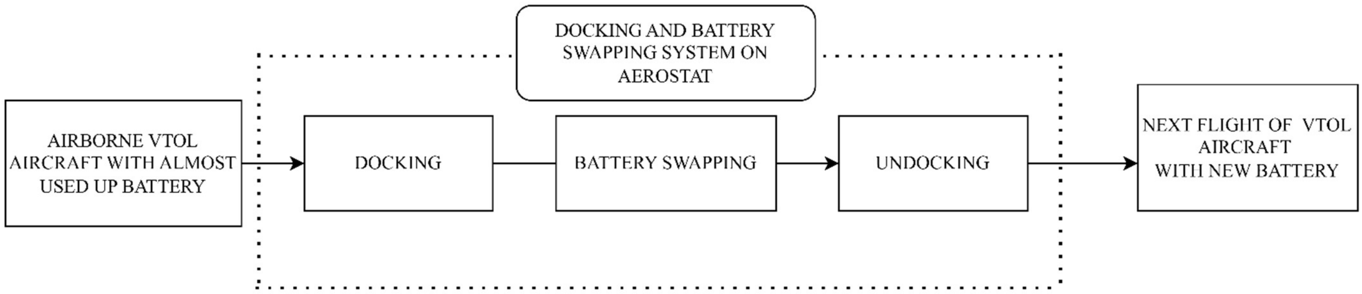


**Figure 1.** Concept Of Operations for Autonomous Mid-Air Battery Swapping.

*Related Work*

A review of relevant literature shows significant advancements in designing and developing autonomous docking and battery-swapping systems for Unmanned Aerial Vehicles (UAVs). Docking stations for UAVs have been classified into categories based on mobility, including fixed, mobile, and those integrated with other autonomous vehicles like Unmanned Ground Vehicles (UGVs), Unmanned Surface Vehicles (USVs), and UAVs. These docking stations serve essential functions such as enabling safe landing, battery recharging or swapping, and data and payload transfer in some cases. An increasing number of designs also incorporate storage capabilities for UAVs, highlighting the growing complexity and functionality of these systems [1].

Another approach leveraged radial basis function proportional-integral-derivative (RBF-PID) control algorithms to track the landing trajectory of a UAV on a mobile platform. This design, enhanced by a vision-based guidance system using the YOLOv3 framework, achieved a reliable real-time tracking capability even in the presence of external disturbances [2]. Charging mechanisms have also seen substantial innovation, with some systems utilizing wired contact platforms showing superior power output and efficiency over wireless platforms. For instance, one study compared the effectiveness of wired and wireless charging systems, concluding that wired platforms had higher landing success rates and more reliable performance [3]. Among the designs, an autonomous aerial docking system was developed using a bistable mechanical system combined with vision-based deep learning program for drogue detection and tracking. This system, designed to minimize energy consumption while ensuring precise docking, demonstrated fast transitions between docking states and high accuracy in real-time detection [4].

A particularly noteworthy solution involved an inverted docking station concept, allowing a quadrotor UAV to attach to the ceiling during battery swapping. This design not only allowed the UAV to remain airborne during the process but also enabled it to carry a payload throughout, thus improving overall operational efficiency [5]. Solar-powered docking platforms have also emerged, as demonstrated by a fully automated system designed for both UAV takeoff and landing, where solar energy was the primary power source for recharging drone batteries. The system employed a wireless charging base and integrated various automated functions, such as monitoring sensors and controlling environmental conditions to optimize the docking process [6]. Further exploration into the automation of UAV operations shows that many docking systems integrate innovative battery-swapping mechanisms, eliminating the need for stationary recharging stations. These systems enable UAVs to continue their operations without prolonged downtimes, as seen in a design that used infrared LED beacons for precise landing and fast battery swapping, which allowed multiple UAVs to be serviced simultaneously [7].

Another approach focused on minimizing downtime for UAVs involved the creation of an automated battery-swapping station for multirotor UAVs. This system achieved a swapping time of just 15 s, significantly improving upon previous designs that took up to 60 s. The station's capacity to hold multiple batteries allowed it to continuously swap and charge batteries without interrupting the UAV's operations, thus extending flight times and minimizing delays [8].The literature also points to the growing interest in designing UAV docking systems that interact with other autonomous vehicles. One such development involved a sphere-shaped docking interface that enabled a Vertical Take-Off and Landing UAV (VTOL-UAV) to dock with an unmanned ground vehicle (UGV). This design allowed the UAV to be carried, launched, recovered, and recharged by the UGV, providing a versatile and mobile docking solution that significantly expanded the operational capabilities of both vehicles [9].

In addition to hardware innovations, the development of energy-efficient trajectory tracking systems for UAV docking has gained attention. A hierarchical real-time controller was proposed to generate optimal mission time and trajectory references, achieving energy consumption close to the optimal solution while maintaining low computational costs. Although tailored to specific UAV architectures, this rule-based strategy highlighted the importance of real-time adaptability in managing UAV energy resources efficiently during docking [10].

Overall, the evolution of docking and battery-swapping systems for UAVs emphasizes the need for precision, efficiency, and autonomy. As UAV operations expand, the integration of robust docking stations and energy management systems will be critical to achieving extended airborne operations. The conceptual design of aerostat-based autonomous docking systems aims to build upon these advancements, integrating innovative battery swapping and guidance technologies to enable UAVs to remain in the air for longer durations while optimizing their operational capabilities.

## 2. Conceptual Design Framework

The conceptual design presented here is rooted in an innovative blend of technologies, offering a groundbreaking solution to the energy constraints faced by Vertical Take-off and Landing (VTOL) aircraft. A crucial element of this design is the strategic integration of Aerostats, acting as a tethered platform in the airspace to facilitate both autonomous in-air battery swapping and docking for a customized Hybrid VTOL UAV. This design is the seamless integration of docking and battery-swapping systems. The Hybrid VTOL, undergoing minimal reconfiguration involving battery placement, propeller adjustments, electromagnets for secure battery housing, and additional electronics, integrates smoothly with the Aerostat-based docking and swapping infrastructure. This integration ensures a cohesive and efficient operational framework, minimizing downtime and optimizing the Hybrid VTOL's functional airborne time.

The success of our design relies on precision navigational aids embedded within the customized Hybrid VTOL. Advanced navigation systems ensure accurate positioning and line-up during autonomous flight and the critical phases of docking and battery swapping. It's important to note that the design of precision navigation and embedded sensors, specifically tailored for VTOL and docking system guidance, is not within the scope of our work. This aspect should be designed by the consumer or any other entity specialized in this domain based on requirement or mission profile. Our design is exclusively focused on the docking and battery swapping mechanism, integrated on Aerostat for a customized VTOL UAV. An inseparable feature of this conceptual design is the consideration of scalability and adaptability. The proposed design envisions a modular system accommodating varying payload capacities and mission requirements. This adaptability ensures the design remains versatile and applicable across a wide spectrum of applications. Scalability extends to the Hybrid VTOL's reconfigurability, allowing swift and easy customization to meet evolving mission objectives.

To address potential instability issues, our theoretical framework incorporates tri-tethering or multi-tethering systems, providing enhanced stability to the Aerostat. These configurations mitigate disturbances caused by environmental factors, ensuring a stable platform for both the docking station and the battery swapping maneuver, contributing to the system's overall reliability.

This conceptual framework pioneers a new Aerospace and Aerial Mechatronics approach, challenging existing norms. The innovative method of in-air battery swapping, coupled with the strategic use of Aerostats and customized Hybrid VTOL configurations, positions our design at the forefront of advancements in autonomous aerial operations. This concept challenges existing methodologies and lays the groundwork for transformation across various diverse domains. A fundamental aspect of our theoretical framework is the utilization of simple, pre-existing yet precise equipment for the battery swapping process. This approach ensures reliability and ease of maintenance while maintaining high precision during critical battery-swapping movements. Commercially Available, i.e., the Shelf Equipment enhances the feasibility of making this conceptual design into a scaled version.

This design sets the stage for the realization of Aerostat Assisted Autonomous Docking and Battery Swapping for a Customized Hybrid VTOL. The integration of cutting-edge technologies, the emphasis on precision, and the dedication to adaptability collectively push this conceptual design into a new field of research, promising to reshape the landscape of autonomous aerial operations.

## 3. Design Methodology

### *3.1. Aerostat*

An Aerostat is a lighter-than-air aircraft that is made to bear payloads at a certain height above the ground which utilizes buoyant gases, primarily helium, to stay afloat. All the gas is filled inside the aerostat to generate lift. An ideal aerostat envelope has to be efficiently shaped such that it meets all the aerodynamic constraints and is stable in the wind. The gas used should be non-flammable and non-hazardous. To control their ascent, they are connected to the ground with the help of tethers. These tethers can also provide power to the aerostat while anchoring them to the ground. The structure of the aerostat should be strong enough to bear the loads due to the payload and the gas inside the envelope. The envelope material should be lightweight, durable, and possess high strength. Aerostats have been used in different applications such as surveillance, communication, tourism, meteorology, etc.

The aerostat envelope has to be designed by taking into account the following parameters:

- System Weight
- Drag Coefficient
- Static Lift
- Stability
- Envelope stress

Some common aerostat shapes are:

(a) Spherical

- Simple design
- Easy to manufacture
- Minimum internal pressure
- Lightweight
- Limited weather operation
- Coefficient of drag (Cd) varies from 0.15–0.4

(b) Streamlined

- Operable at high wind speeds
- Heavier
- Stationary fins are attached for increased stability
- All weather operation is possible
- Coefficient of drag (Cd) is around 0.03

(c) Hybrid

- Equipped with kite/sail
- High lift-to-weight ratio
- All weather operation is possible
- Coefficient of drag (Cd) varies from 0.15–0.4

(d) Shell shaped

- Turbines are generally installed in them
- Used for Power generation
- All weather operation is possible
- Coefficient of drag (Cd) is about 0.4

### *3.2. Design of Aerostat*

We will use a streamlined-shaped aerostat for our design due to its higher stability and advantages over other aerostats.

The design is unique, featuring three sails positioned at the aft section of the structure. These sails serve to enhance the aerostat's stability in various wind conditions. The aerostat's structural integrity is further strengthened by eight symmetrically placed reinforcements. These reinforcements span the entire length of the aerostat, running from the fore to the aft. They enhance the rigidity of the aerostat and serve a dual purpose by providing anchor points for the docking and battery-swapping platform. The docking and battery swapping system is a novel innovation that efficiently exchanges power sources during a UAV's operation. This system is suspended from the aforementioned reinforcements, ensuring a secure and stable platform for the maneuver. In terms of dimensions, the aerostat follows a streamlined shape with a major axis measuring 10 m and a minor axis of 4 m. This design choice as shown in Figure 2, optimizes the aerostat's aerodynamic properties, reducing drag and improving its overall performance in the air.

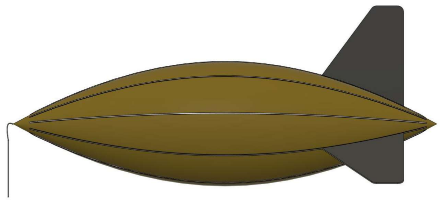

**Figure 2.** Aerostat with moor.

The aerostat is equipped with a mooring line for additional stability and to facilitate winching operations. This line provides a secondary stability means, anchoring the aerostat to the ground when necessary. It also plays a crucial role in winching, allowing for the aerostat's safe and controlled ascent and descent.

### *3.3. Hybrid VTOL Aircraft*

A paramount focus on UAV stability drives the selection of the provided configuration. This choice ensures that the center of gravity (CG) remains uncompromised even after incorporating new components. Equally crucial is the generation of an adequate thrust in both Forward Flight and Vertical Take-Off and Landing (VTOL) modes, guaranteeing a seamless transition between these states to prevent stalling. Importantly, this modification can be seamlessly integrated without substantial interference with the existing airframe, thereby retaining the UAV's structural integrity. Moreover, the chosen configuration (See Figure 3) is compatible with the aerostat system, with minimal risk of entanglement with support cables. Furthermore, it does not hinder the docking and battery-swapping processes, which are critical for uninterrupted UAV missions.

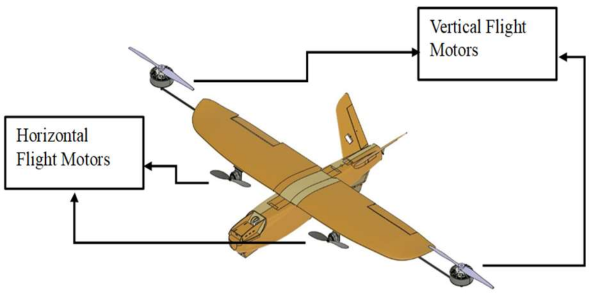


**Figure 3.** UAV Isometric View.

Importantly, these additions adhere to the UAV's weight restrictions, ensuring compliance with design parameters. In this context, a versatile fixed-wing UAV known for its reliability and adaptability, serves as a prime platform for implementing these enhancements, enhancing its performance and versatility in various operational scenarios. The hybrid VTOL aircraft theoretically weighs approximately 3 kg.

### *3.4. Battery*

#### 3.4.1. Battery Case Customization

The battery used for our hybrid VTOL is a 5200 mah lithium polymer battery. The Battery is enclosed in a 3D-printed casing designed and used for easy installation and removal (See Figure 4). The connector is rigidly fixed and exposed out of the casing, ensuring secure battery retention, and facilitating smooth swapping maneuvers. The casing also has diagonally opposite extruded cuts for precise alignment. The payload is placed right under the wings at the center of gravity (CG) position of the Hybrid VTOL aircraft, ensuring stability.

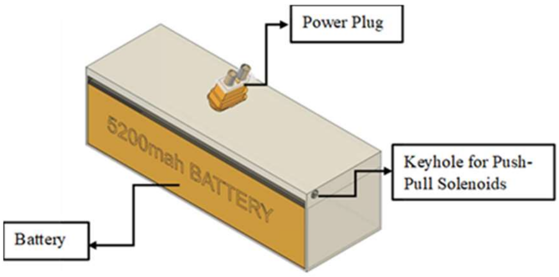


**Figure 4.** Battery.

#### 3.4.2. Electromagnets for Secure Battery Docking

Mid-air battery swapping is a pioneering technology that relies on robust battery holding. Here's where electromagnets come in. Integrated push-pull electromagnets in VTOL aircraft are integrated into the UAV and battery casing (See Figure 5), and these magnets provide a secure, quick-release hold during flight and docking. When the aircraft is connected to the power supply, the push mechanism is activated, releasing the drained battery. After executing the battery swapping maneuver, the electromagnets lock the new battery in place.

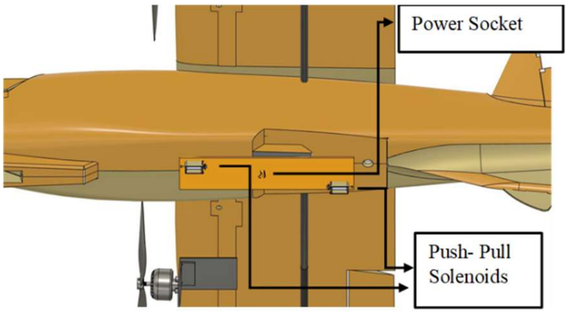


**Figure 5.** Battery Placement under UAV.

### *3.5. Docking and Battery Swapping System*

The docking and battery swapping system is an intricately crafted solution dedicated to the flawless integration of UAVs into their operational domain. Its core components feature Mg996 servo-driven motorized clamps (see Figure 6) designed for robust and precise function, with the primary role of securing the aircraft during pivotal operational phases. A sophisticated control mechanism employs a weight sensor positioned at the geometric center of the forward clamp base. Upon detecting the aircraft's weight, these sensors relay signals that activate and secure the clamps, orchestrating a meticulously controlled sequence of movements. At the system's focus lies a linear actuator, offering dynamic adaptability for precise battery placement. This component ensures a tailored alignment of batteries to meet the unique power requirements of the UAV, accommodating an array of battery sizes and configurations. Additionally, the system leverages magnets(see Figure 7) to further enhance its capabilities. These magnets play a crucial role in the aircraft's precision alignment and in the battery's detachment during the battery-swapping process, ensuring a seamless and precise connection.

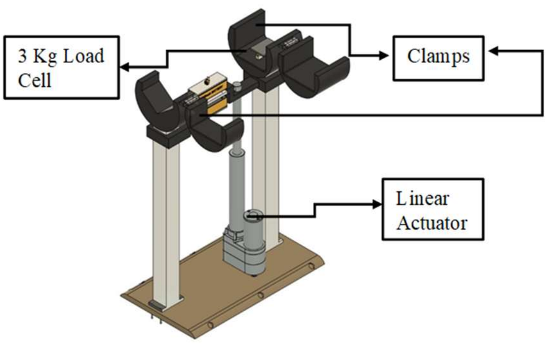


**Figure 6.** Docking and Battery Swapping System.

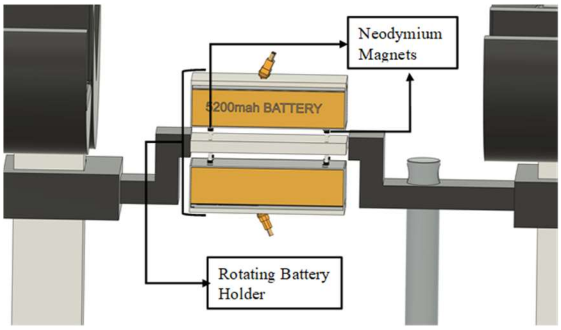


**Figure 7.** Rotating Battery Holding Mechanism.

Incorporating 3D printing to fabricate lightweight, reliable components and systems, along with the integration of a high-speed microcontroller, this advanced setup will further enhance the system's efficiency, responsiveness, and reliability. This will elevate UAV integration, charging, and mission preparation to new heights of professionalism and dependability. The suspended platform is a suitable design choice for the UAV docking and battery swapping system. It offers more stability than other positions, such as the top or the sides of the aerostat. It also minimizes the risk of accidents during the entry and exit of the UAV. It does not interfere with the sail of the aerostat, which is important for aerodynamic performance. It also facilitates the weight balancing of the entire system, which is crucial for the stability and control. Moreover, it enables convenient docking and undocking, reducing mission turnaround times and increasing efficiency.

Sizing of the Docking and Battery Swapping System

The dimensioning of the systems within this project is a meticulous process critical to ensuring precise and effective operation. Each component's size, shape, and placement are thoughtfully calculated and designed to optimize functionality and reliability.

Starting with the Docking and Battery Swapping System, the dimensions are tailored to accommodate the specific UAV it will service, aligning clamps, sensors, and actuators precisely to ensure secure docking and efficient battery swapping. The variable-length axial battery positioner is designed with adaptability in mind, allowing for the flexible arrangement of batteries of various sizes and configurations. Moving to the platform beneath the aerostat, its dimensions are strategically chosen to offer both optimal positioning for the system and stability within the aerostat's operational environment. The tethers connecting the platform to the aerostat are measured to exacting standards, with one providing electricity, ensuring efficient power transfer to the system, and the other two forming a diagonal support system to maintain stability. The dimensioning process also extends to the entire UAV, where weight distribution and size are meticulously calculated to ensure the aircraft's stability and performance.

Our design is inherently flexible and adaptable to a variety of constraints. The height of our design, in particular, can be adjusted per the requirements. The chosen height is primarily for better visual representation and does not limit the functionality or adaptability of our design. Furthermore, the necessary actuators can be modified or replaced based on specific needs, adding another layer of flexibility to our design. This adaptability is made possible thanks to advancements in 3D printing technology and the availability of commercially available actuators. Therefore, our design also offers room for modifications and improvements as required.

### *3.6. Electronics*

The electronic circuit for the docking and battery swapping system (See Figure 8) consists of a 3kg Load Cell to detect and convert the Mechanical Load into Digital Pulses. This is then connected to the HX711 Amplifier, which amplifies the incoming signal from the load cell and sends it to the Microprocessor for further action. Arduino Mega 2560 was chosen as the microprocessor due to its simplicity in programming, flexibility, and redundancy. A 3 RPM Direct Current Motor is connected to the LN298 Motor Driver, which controls the speed and direction and regulates the amount of voltage to the motor. This is used in the Rotating battery Holder using the Microprocessor. Two MG996R Servo Motors which are High Torque, 360-degree rotation are for the clamping mechanism of the Docking system, which the Arduino Mega controls. A 1000 mm Linear Actuator is connected to a relay in tandem for directional and speed control. All these components are controlled by the microprocessor, using appropriate programs. The sequenced control flow graph (see Figure 9) shows the detailed and timed process of the entire operation. This can also be called the Concept of Operations of the entire mission.

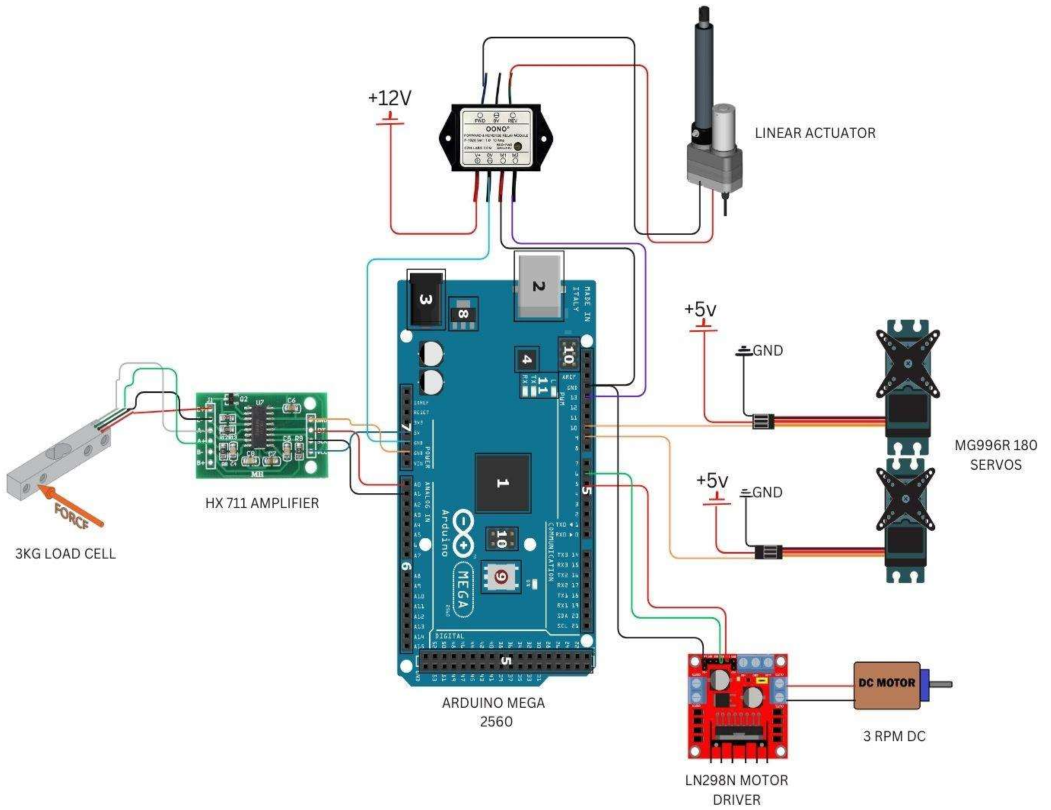


**Figure 8.** Integrated Circuits.

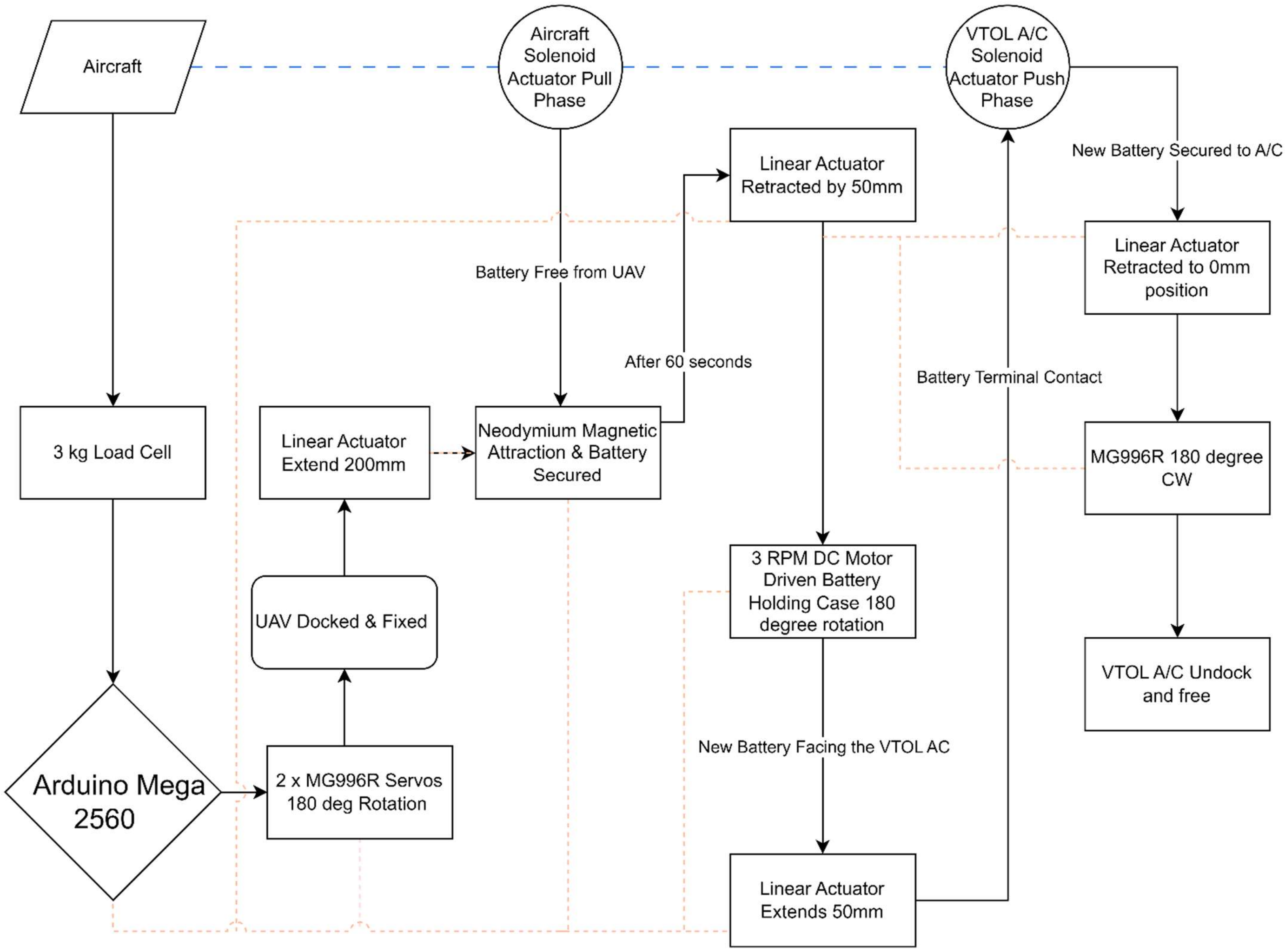


**Figure 9.** Signal Flow Graph.

### *3.7. Implementation of Features to Improve Stability*

Ensuring the stability of the Aerostat is paramount, as it directly influences the payload balance it carries. Our proposed system employs a tri-tethered configuration, utilizing high-tension tethers to enhance structural stability and minimize the risk of horizontal displacement. The tether setup incorporates a gimbal at the confluence point, allowing the Aerostat to align itself with the wind direction. Careful consideration is given to the selection of mooring and guide cables, considering their material and weight contribution to the overall system. In the Aerostat design presented in this report, a dual layer of fabric is strategically applied over fixture and connection points to distribute axial loads on the envelope effectively. Calculations for the confluence point are crucial, influencing the degrees of freedom of the Aerostat. The tri-tethered system is designed to limit lateral mobility, enhancing overall stability. Additionally, the positioning and shape of the sail significantly impact stability and alignment. Our Aerostat incorporates a purpose-designed sail to effectively catch and respond to the wind, ensuring controlled reactions to gusts. The system includes a suspended platform below the Aerostat to facilitate efficient docking and battery swapping. Three attachment points on either side of the platform connect to the front and aft converging points of the Aerostat through cables, effectively balancing axial tension. This design minimizes oscillations, enabling smooth maneuvers during docking and battery-swapping operations.

The decision to reconfigure a conventional aircraft into a Hybrid VTOL UAV can be justified on several grounds and offers substantial advantages over starting from scratch. This approach allows for tailored customization, leverages proven performance qualities, and proves more cost-effective. The hybrid concept itself combines long-range fixed-wing efficiency with versatile multirotor maneuverability, making it ideal for missions demanding mid-air docking and battery swapping. Furthermore, the process is scalable, paving the way for a diverse fleet of UAVs based on various base aircraft. Additionally, existing spare parts and maintenance infrastructure simplify logistics as well, and most of the parts are 3D printable. At the same time, the reconfiguration project itself fosters technological advancements applicable to broader aviation and robotics fields.

## 4. Results

### *4.1. Mission Profile*

The UAV's landing process on the docking station is a meticulously orchestrated sequence(see Figure 10). In step 1, the aircraft approaches the Docking and Battery Swapping System and lands on the platform. Initially, the system detects the downward weight of the aircraft using a 3 kg load cell. This information is then transmitted to an Arduino Mega microcontroller. Subsequently, the microcontroller issues a signal to two 180-degree servos, directing them to clamp and securely lock the VTOL aircraft in position, as shown in step Figure 10a. A vertical linear actuator extends to its full stroke of 200 mm to facilitate the docking process. The autonomous system onboard the aircraft initiates the pull phase of the solenoid actuators, bringing the battery into contact with magnets. Following a 30-s delay, the linear actuator retracts by 50 mm, disengaging the battery, which is shown in step Figure 10b. Simultaneously, in step Figure 10c, the rotary battery holder rotates 180 degrees, presenting a newly recharged battery to the surface. The microcontroller then commands the vertical linear actuator to extend by 50 mm, ensuring a successful connection with the battery terminal in step Figure 10d. Subsequently, the solenoid actuator switches to the push phase, securely locking the new battery in place as shown in step Figure 10e. After a 60-s delay, the linear actuator reverts to its initial position of 0mm, releasing the UAV from the docking system as depicted in step Figure 10f. The UAV is now primed for another flight, having completed a seamless and automated battery replacement process.

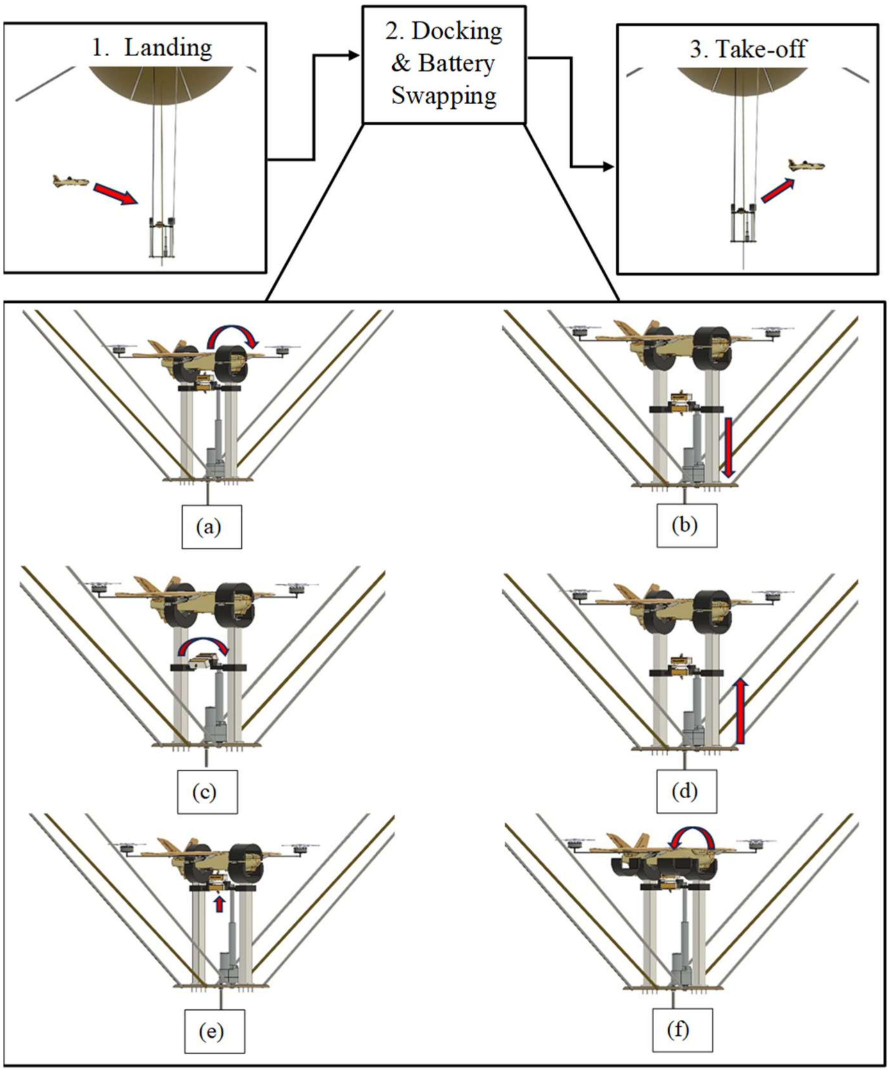


**Figure 10.** Mission Profile Sequence.

### *4.2. Comparative Validation*

Table 1 shows a comparative analysis of a conventional UAV landing and recharging method and the usage of docking and battery swapping systems mounted on an aerostat at an altitude for a hybrid UAV. Initial setup costs can be quite high for the latter, but on a larger scale, the operating costs can be cut down to a larger scale. Other parameters like time consumption, energy efficiency, and frequency of missions, which are paramount in the industry, all benefitd from such a technology.

**Table 1.** Comparison of Parameters.

| Parameters | Landing & Recharging of a Conventional UAV on Ground | Usage of Docking and Battery Swapping System Mounted on an Aerostat at an Altitude for a VTOL UAV |
|---|---|---|
| Time Consumption | High | Low |
| Frequency of Missions | Low | High |
| Energy Efficiency | Low | High |
| Setup Cost | Low | High |
| Operational Costs | High | Low |
| Operational Flexibility | Low | High |
| Versatility | Low | High |
| System Complexity | Low | High |

## 5. Future Scopes and Conclusions

With the increasing demands in the autonomous UAV industry for better productivity, and efficiency and to reduce costs, an integrated docking and battery swapping system mounted on a stable aerostat at a feasible height proves to be a practical approach. The flexibility in the design methodology compliments the ever-growing realm of additive manufacturing, providing the opportunity to mold the design according to the customer requirements whilst using the novel concept of operations as mentioned in the paper.

The proposed concept successfully lays the framework and design methodology for a compact, autonomous docking and battery-swapping solution for a reconfigured UAV. Integrated with various commercially available electronic sensors, and equipment and leveraging the 3D printing technology, the solution proposed is a novel concept in the field of Aerial Mechatronics. The mission profile derived leads to an increase in endurance, range, and efficiency of the flight profile, thus paving the way for extended aerial operations.


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## Author Contributions

Conceptualization: N.N., A.G., P.M.; Formal Analysis: A.G., P.M.; Investigation: N.N., A.G., P.M.; Methodology: N.N., A.G., P.M.; Software: N.N; Supervision: A.B.A., G.S.M.; Writing—original draft: P.M.; Writing—review & editing: N.N., A.B.A., G.S.M.

## Ethics Statement

Not Applicable.

## Informed Consent Statement

Not Applicable.


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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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