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Design and Development of Drone Recovery System Using Parachute

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Abstract: Unmanned Aerial Vehicles (UAVs), or drones, have become increasingly important in various fields, including aerial photography, delivery services, and surveillance. However, as drone usage has expanded, so have the risks related to system failures and accidents. Such failures can result in expensive damages and even threaten public safety. A promising way to address these risks is by implementing a drone recovery system that uses a parachute mechanism. This paper discusses the design, development, and implementation of a parachute-based recovery system for drones. It looks into the essential components of the recovery system, such as parachute selection, deployment methods, material choices, and performance testing. The goal is to improve the safety of drone operations by ensuring controlled descents during emergencies, thus minimizing the risk of crash-related damage.

Keywords: *Drone Recovery, Parachute System, UAV Safety, Descent Rate, Deployment Mechanism, Material Selection.*

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I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) or drones exist widely in agriculture alongside defense needs and logistics operations and entertainment activities. The special capabilities drones provide cannot match their constant risk of flight breakdowns which threatens both aircraft equipment and surrounding environments. A failure occurring with drones will trigger uncontrollable descent alongside rapid motion that leads to destructive outcomes.

An assortment of drone recovery systems exists today but parachute-based systems prove both dependable and inexpensive for such applications. The drone flies safely to the ground after failure through parachute deployment which reduces its descent speed. The recovery system decreases drone impact forces which protects the drone from major structural damage.

This paper delves into the conceptualization, design considerations, deployment mechanisms, and performance testing of a parachute recovery system. The paper analyzes both benefits and difficulties that occur with this technology to prove parachutes play a key safeguarding role when drones encounter unexpected situations.

II. LITERATURE REVIEW

Aerospace engineering has produced extensive research about parachute aerodynamics that focuses on improving safety and efficiency of parachute recovery systems. Parachute aerodynamic performance depends mostly on three key parameters which include drag coefficient together with terminal velocity and duration needed for terminal velocity. Researchers have examined multiple parachute forms with various designs in order to assess aerodynamic performance.

The research by Tripathy (2024) studies how changing parachute shapes and sizes affects the drag coefficient together with terminal velocity and descent stability factors. The evaluation of parachute drag force demonstrates its dependence on the projected area together with fluid density and velocity parameters. Experimental drop tests demonstrate that aerodynamic efficiency depends on the three shapes: circular, square and equilateral triangular parachutes. The square parachute design generates the most drag force leading to the highest drag coefficient whereas the triangular parachute manifests the least drag coefficient thus making it the least stable for descent.

Apart from existing literature parachute shape stands as a fundamental factor that impacts drag force resistance. Round parachutes according to Knacke's (1992) classification present superior stability yet they can develop canopy collapses like the ones used in Tripathy's study. The work by

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Slegers et al. (2012) studied different parachute shapes and proved that circular designs minimize drag force variations and distribute weight uniformly the same way as shown by Tripathy's research.

The projected area of parachutes impacts drag coefficient according to Benson (2020) as well as NASA's aerodynamic research which leads to diminished terminal velocity. The experimental findings from Tripathy's work confirm that enlarged parachutes achieve a decrease in terminal velocity no matter what form is used.

Research indicates how the square parachute delivers superior aerodynamic efficiency because of its maximum drag coefficient even though the triangular canopy remains unstable like previous tests on unbalanced canopy designs (Tsokos, 2016).

Regression analysis performed in Tripathy's study demonstrates a direct relationship between parachute area and drag coefficient where square parachutes produce linear drag increases which surpass the findings observed from circular and triangular configurations. Statistical analysis from this study authenticates findings from Al-Madani et al. (2018) about the direct impact of canopy dimensions on aerodynamic performance.

Aerodynamic efficiency depends heavily on parachute shape and size along with material specifications according to the literature. Evidence from Tripathy's study validates prior studies showing that square parachutes generate better drag effects together with circular parachutes achieving a stable midpoint between drag effects and flight performance. Future investigations need to optimize parachute materials and deployment systems since they will improve the safety and efficiency of UAV flight operations and aerospace systems.

III. METHODOLOGY

The drone recovery system is designed to minimize damage during emergency situations by deploying a parachute when critical faults such as loss of signal or free fall are detected. This section outlines the methodology employed in the development, integration, and validation of the system.

➢ *System Componenet*

- Parachute: Constructed from nylon fiber or parachute fabric for durability and effective drag generation.
- Parachute Deployment Mechanism: A spring-loaded release system enclosed in a carbon fiber container.
- Fault Detection System: Detects loss of signal or free fall and initiates the deployment sequence.
- Electrically Activated Servo: Triggers the release mechanism upon receiving a fault signal

➢ *Operational Framework*

- Fault Detection: The system continuously monitors flight parameters to detect loss of signal or free fall conditions.
- Signal Transmission: Upon fault detection, a signal is transmitted to the electrically activated servo.
- Release Mechanism Activation: The servo unlocks the compressed spring, initiating deployment.
- Parachute Deployment: The spring force ejects the parachute from the container, ensuring rapid deployment.
- Safe Descent: The deployed parachute generates sufficient drag to decelerate the drone and reduce impact forces.
- Drone Recovery: The drone lands safely, minimizing structural damage and enabling potential reuse

➢ *Parachute Packing and Deployment Mechanism*

- The parachute is folded in a specific pattern and compressed by the spring to facilitate smooth deployment.
- A spring-loaded mechanism ensures reliable parachute ejection regardless of environmental factors such as wind, altitude, or drone orientation.

➢ *Decent Rate Control*

The descent rate is determined by parachute size selection, ensuring a controlled descent velocity that prevents excessive impact forces upon landing.

IV. DESIGN AND IMPLEMENTATION

The design together with implementation of drone recovery technology represents key elements which make the system reliable as well as safe and efficient in operation. The parachute deployment mechanism exists to join perfectly with drone components while using low-density materials and attaining top operational standards. This system targets three main functions: fast parachute deployment under control situations, and reliable parachute housing structure maintenance and productive actuation systems and deployment reuseability.

The recovery system implements a carbon fiber containment structure which protects the parachute system components during flight operations. The main ejection force of the recovery system comes from a compression spring which produces fast and forceful parachute release during critical moments. The parachute deployment mechanism relies on servo-operated latch controls to prevent premature release until suitable emergency actions trigger its deployment. Once the servo activates it releases the latch and lets out compressed spring energy for parachute deployment so it deploys immediately effectively.

The packaging process for the parachute follows a specific folding configuration which enables it to open up properly when the parachute deploys. The system design includes modular elements to make its components detachable when needed for easy inspection alongside maintenance and replacement operations.

A. *Deployment Mechanism*

The deployment mechanism stands as the main operational element within the drone recovery system which

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activates the parachute during failures to ensure prompt and effective deployment. The deployment mechanism includes a storage spring inside the housing that stores mechanical energy during packing and a servo latch system as an attachment system to secure the parachute until release time.

The compression spring rests at the housing base near the bottom where the parachute exists. While in storage position the spring experiences maximum compression to keep potential energy stored that the parachute uses to advance forward upon need. The deployment method stands out with its reliable functionality because it replaces complex electrical and pneumatic systems thus diminishing system failure risk.

An emergency event that triggers the expulsion of a parachute initiates the servo latch to unlock from its hold. The compressed spring energy transforms immediately into movement energy which drives the parachute upward through the housing. A quick deployment outcome is guaranteed by this system design which optimizes the chances of smooth controlled descent.

The system becomes more successful because the parachute has an exact fit and flight path when combined. The structure of the device enables the parachute to exit without any barriers on its launch path. The homing controller uses spring force which has precisely measured strength to launch the parachute so it can pass over the drone shape then rapidly expand at its maximum potential.

B. Structural Interigrity

The deployment system housing utilizes carbon fiber as its main material because this fiber possesses superior strength at minimal weight levels. Carbon fiber protects the parachute system by delivering a sturdy and resistant enclosure that shields it from wind exposure and rain elements and normal flight-induced stresses.

Inside aerospace applications carbon fiber demonstrates its best properties by providing drone structures with high strength and low weight capability. The flawless function and maneuverability of flight depends strongly on this measure. The housing design takes aerodynamic principles into account which prevents it from undermining drone stability and increases drag.

The servicing process becomes easier through a detachable design feature of the housing. An inspection along with easy maintenance happens possible because this modular system allows for quick servicing needs. Drone maintenance efficiency increases substantially because the modular housing system permits quick detachment without requiring any other component disassembly which cuts down operational downtime effectively.

The housing has a critical position near the drone’s top section to create proper parachute ejection paths. Positioning the housing at the top of the drone allows unimpeded parachute deployment which enables complete expansion and stable drone descent during minimal time.

C. Actuation and Release Mechanism

A deployment system contains the most significant component known as the actuation and release mechanism which activates the parachute through controlled measures. The mechanism functions through a servo-operated latch which anchors the parachute safely inside its housing unit.

Within the housing the servo device establishes connection to an operational arm which protects the parachute during storage. As part of standard system functioning the servo keeps itself locked to stop unwanted parachute releases. An electronic control system operates the servo component which receives emergency deployment signals from sensors or manual override functions.

The servo executes its arm rotation when activating the signal which releases the latch that confines the parachute. The released spring energy through the action flies the parachute out of its housing. The servo mechanism executes its precise and reliable functions during deployment to minimize any accidental deployment events.

Integration with drone flight control systems combined with precise timing control is enabled by servos through actuation functions. Servos represent an excellent tool for aerial systems because of their power-efficient design along with their small size.

D. Parachute Folding and Deployment

A parachute functions as the key component of the recovery system because it creates the maximum drag force which stabilizes descent. The folding process for the parachute follows a particular pattern during manual preparation to achieve both deployment speed and deployment efficiency.

The folding process enables the parachute to expand carefully while it enters the air shortly after ejection. The housing design prevents deployment failures by addressing risks associated with incorrect packing along with material blockage inside the container. The material choice meets multiple criteria because it offers exceptional strength with low weight and demonstrates excellent resistance to environmental destruction.

➢ *This System uses an Established Order throughout its Deployment Mechanism:*

- The servo releases the latch.
- The expanding compression spring activates by pushing the parachute into the outside.
- The parachute moves out of the housing while it passes through its unfolding process.
- Parachute expansion occurs when air resistance operates on it to achieve stable descent.

Throughout every step of its deployment sequence the system maintains reliable and consistent parachute deployment across all drone altitudes and orientations.

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E. Reusability and Resetting Procedure

The designed system introduces a manual reassembly feature for parachutes that enables quick deployment without requiring maintenance work. The drone speeds up mission readiness due to the absence of substantial maintenance work that needs component replacements.

The recovery process ends with correct parachute folding that enables storage in an organized housing compartment. Deployment system security depends on manually locking the compression spring then installing the servo latch.

The housing contains detachable components that simplify maintenance because users can assess parts while also conducting replacement work. The operational costs with maintaining system durability remain affordable through this approach.

V. RESULT

➢ *Stress Analysis Over Time*

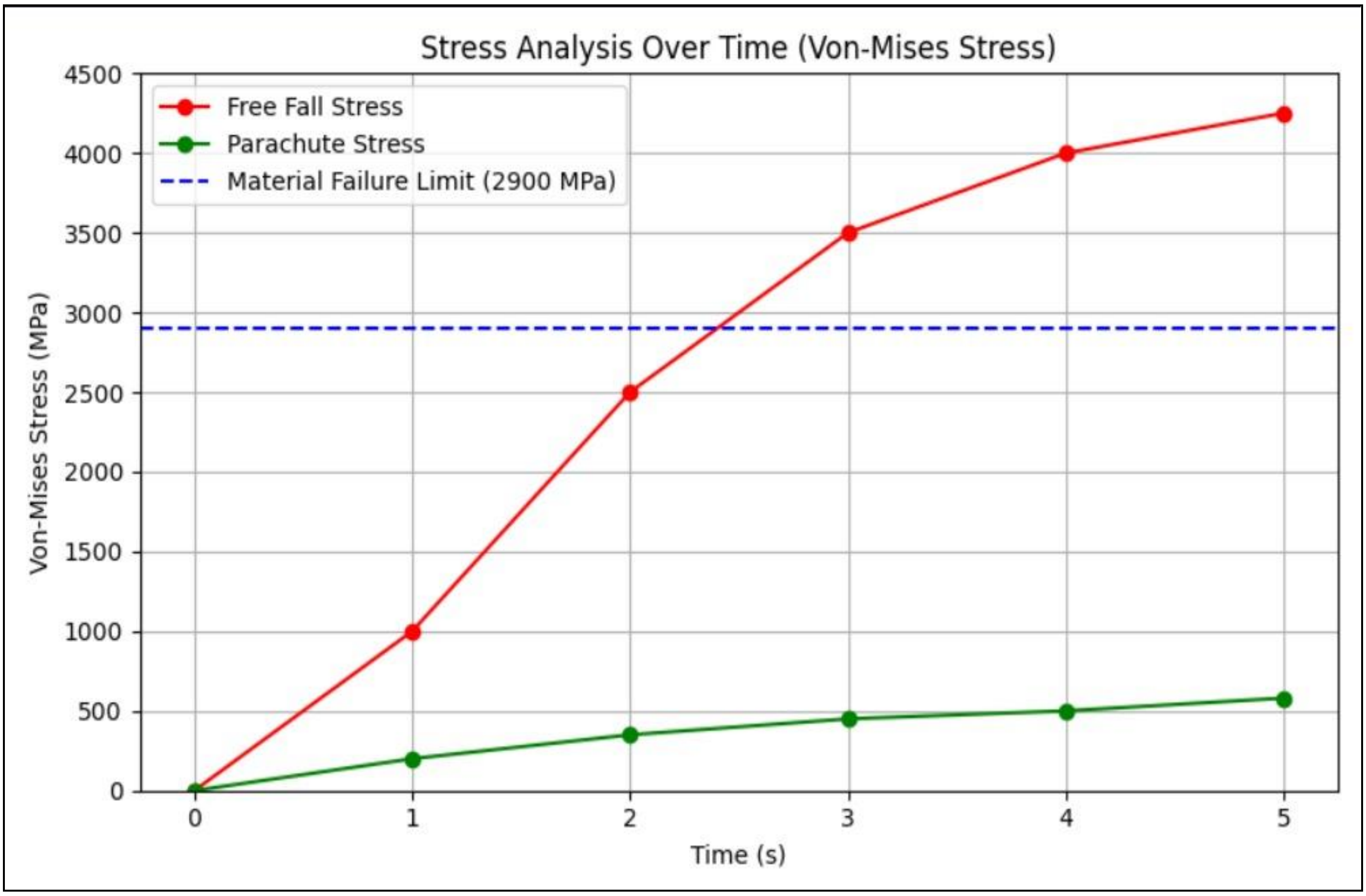

Fig 1 Stress Analysis Over Time

We conducts a time-based stress investigation that uses Von-Mises Stress to evaluate how system strain changes between unstopped fall and parachute-aided descent phases. The vertical axis displays stress in megapascals (MPa) at each time increment shown on the horizontal axis.

The stress levels for free fall are depicted by the red line in the graph. When time spans five seconds the stress exceeds 4300 MPa which represents a value above the material failure threshold defined by the blue dashed line at 2900 MPa. Under free fall conditions the material would experience structural failure because the stress reached beyond its operational limit.

The stress conditions during parachute-assisted descents appear on the green line of the graph. Stress growth during this measurement displayed a slower increase because it stopped at 550 MPa less than 5 seconds which is well below the failure threshold. A parachute or any controlled descent system proves effective in protecting the structure by reducing mechanical forces on it.

The graph shows effective data which proves that uncontrolled free fall generates excessive stress higher than material limits yet a parachute-controlled descent maintains stress values under safe operating limits.

➢ *Decent Speed Analysis Over Time*

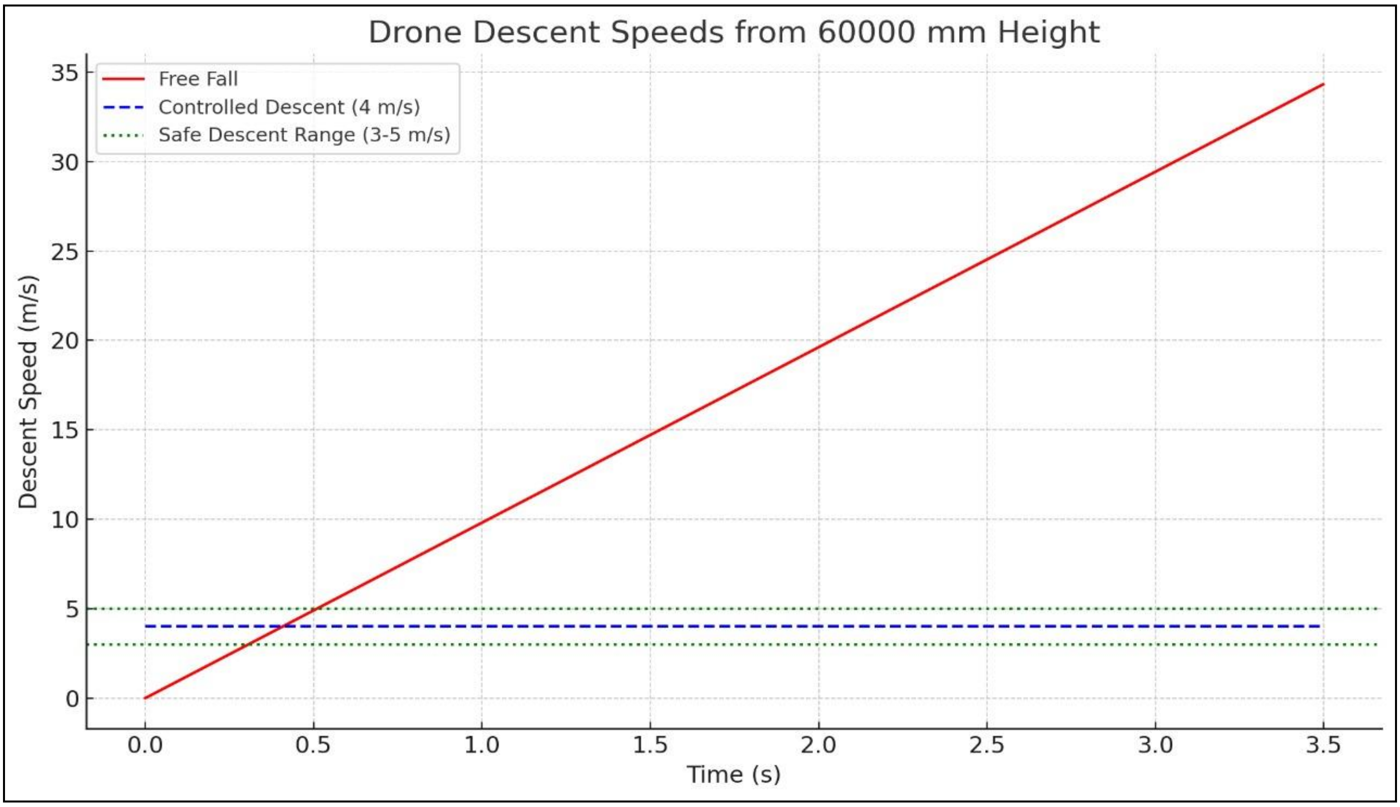

Fig 2 Decent Speed Analysis Over Time

We. examined drone descent patterns by using both uncontrolled free fall and controlled descent scenarios when starting at 60,000 mm. When she falls freely during a free fall scenario, she does not control the drone. The drone increases velocity based on gravity based on relation v = g.t, and g corresponds to about 9.81 m/s². The drone rose from a speed of 34.3 m/s in just 3.5 seconds, causing dangerous conditions that had serious effects during landing. The drone worked in a controlled descent in this scenario by imposing a limited speed of 4 m/s. The drone travels at a constant speed corresponding to the optimal area of land between 3 m/s and 5 m/s, allowing for reduced impact and a stable touchdown. Test results confirmed that simultaneously dangerous, uncontrolled free-fall waste demonstrates the safety benefits of demolition control. This assessment shows that descent speed control plays a fundamental role in protecting the drone, along with guaranteed reliable automatic touchdowns.

VI. CONCLUSION

The parachute recovery system gets designed for fast deployment and lightweight construction with simple restability properties at its core. Due to the use of carbon fiber housing the system maintains its durability while preserving the drone's weight performance without impact. Both compression springs in the deployment mechanism operate quickly to eject the parachute and the servo-actuated latch system grants precise timing control for release operations. The system incorporates manual folding technology to parachute components along with reset functions that enhances its ability for multiple uses thus reducing replacement requirements. Design elements allow for easy maintenance because they enable quick inspections and service of components anytime the system is needed. The recovery system provides excellent safety improvements for drones by delivering solid performance alongside operational functionality combined with extended serviceability.

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