DESIGN AND DEVELOPMENT OF A

MINE DETECTION DRONE

A Final Year Project Report

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Presented By:

Muhammad Ehtisham Hassan	333201
Ahmad Hassaan	345975
Ibtesam Baig	337968
Muhammad Afnan Qureshi	342605

Supervised By: **Dr. Emad ud Din**

EXAMINATION COMMITTEE

We hereby recommend that the final year project report prepared under our supervision by:

Titled: **Design and Development of a Mine Detection Drone** be accepted in partial fulfillment of the requirements for the award of **Mechanical Engineering** degree with grade B+

Supervisor: Dr. Emad ud Din	Dated:
Committee Member:	Dated:
Committee Member:	Dated:

(Head of Department) 20/8/2024 (Date)

COUNTERSIGNED

Dated: 21-8-24

(Dean / Principal)

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ABSTRACT

In recent years, there has been a notable surge in global drone utilization, driven by escalating demand for their versatile applications, particularly within the military sector, where they are predominantly employed for reconnaissance purposes. This project addresses a significant challenge faced by the defense sector: the reliance on conventional minesweeping methods, fraught with considerable risk and often resulting in unavoidable casualties.

The project endeavors to develop an autonomous aerial vehicle for mine detection, aiming to eliminate the necessity for manual detection entirely. This involves the design and implementation of a specialized mine detection drone capable of autonomously scanning designated areas for mines and promptly relaying pertinent information to the operator.

A comprehensive literature review will be conducted to help the design considerations for such drone systems, encompassing factors such as wingspan, maximum take-off weight, operational range, payload capacity, endurance, and other relevant parameters. Beyond the physical construction of the drone, the literature review will inform the selection of sensors, instrumentation, and data processing methodologies essential for effective mine detection.

The anticipated outcome of this project is the fabrication of a scaled drone tailored for mine detection, engineered from inception to possess the capability to identify landmines with a high degree of accuracy.

ACKNOWLEDGEMENTS

We would like to extend our sincere gratitude to all those who provided us with the possibility to complete this amazing report. We would also like to thank our supervisor "**Dr. Emad ud Din**" for their unwavering support and guidance throughout the project.

We must also recognize the guidance provided by other advisors, as well as the feedback given by the panel during our last project presentation. Their constructive input enabled us to make significant improvements and present our work with a clear and practical approach. Once again, we appreciate the efforts of all those who helped us in completing this project.

Team Lead's Signature

Supervisor's Signature

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ABBREVIATIONS

Table 1- Abbreviations of the words used in the report

ACH	Air Change per Hour
a-Si	Amorphous – Silicon Solar Cell
CIS	Copper Indium Gallium Selenide Solar Cell
CdTe	Cadmium Telluride Solar Cell

CHAPTER 1: INTRODUCTION

The project owes its conception to the soldiers of Pakistan who risk their lives out on the field for demining operations – missions whose purpose is to clear an area of landmines. Areas suspected of landmines are old battlefields or bordering territories of suspected terror groups. Enemies are capable of deploying many kinds of lethal explosives from basic IED's that are fatal for foot mobiles, to anti-tank mines that can even immobilize armored vehicles.

Sweeping an area of landmines currently involves manual detection, where foot mobiles use specialized gear for protection and detectors on prongs (mainly metal detectors) for detecting the mines. This is an effective method but involves a great amount of risk by placing the soldiers in dangerously close proximity to the mines. And there have been instances of mines exploding in such operations, causing fatal injuries to the soldiers involved, leaving them paralyzed or worse.

We hope to develop a reliable countermeasure or a bypass to the conventional method, by introducing an automated detection method by employing a mine-detection drone. The drone will be composed of a metal detector suspended by a scissor mechanism. The scan patterns of the detector will be analyzed to calculate the points where mines have been detected and pinpoint the marks by GPS. This will only leave the detonation which can be done safely from a distance as the position of mines is ascertained.

Problem: To prevent military personnel casualties by providing an alternate means to conventional demining

Solution: An automated mine-detection drone.

Objectives:

- Design and development of scissor mechanism
- Design and Deployment of Metal Detector with mechanism
- Deployment of whole system with a Drone

Figure 1 - Traditional method of sweeping

CHAPTER 2: LITERATURE REVIEW

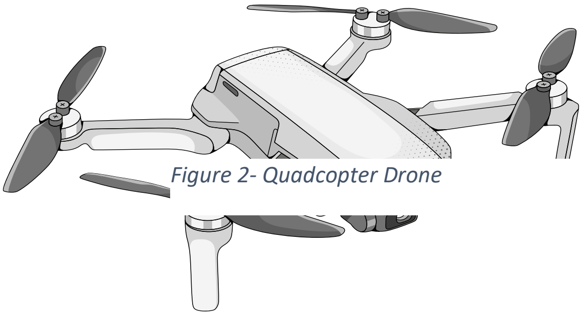

Figure 2- Quadcopter Drone

2.1 Scissor mechanism

The scissor mechanism is used in scissor lifts, which are essential pieces of equipment in various industries for lifting and positioning heavy loads and personnel at elevated heights. The mechanism works by using a set of cross-braced arms that move up or down to raise or lower the platform. Scissor lifts are employed in a wide range of industrial environments, including construction, warehousing, manufacturing, transportation, and maintenance. They can be powered by different sources such as electric, hydraulic, diesel, or pneumatic, and come in various types, including rough terrain, electric, and pneumatic scissor lifts. The choice of scissor lift depends on the specific application and working environment. The scissor lift mechanism is designed to improve productivity, enhance safety, and save money in various industrial and commercial settings

2.1.1 A Historical Perspective and Engineering Evolution

The scissor mechanism, a fundamental mechanical structure, has played a pivotal role in the evolution of engineering applications across various industries. Dating back through history, its inception can be traced to simple mechanical devices designed for lifting and extending purposes. Over time, this seemingly straightforward mechanism has undergone significant development, becoming a versatile and widely utilized engineering solution.

Historical Development:

The origins of the scissor mechanism can be identified in ancient civilizations where basic principles of leverage were applied for lifting heavy loads. Simple devices resembling the fundamental structure of scissor mechanisms were employed for tasks such as lifting water from wells or aiding in the construction of architectural marvels. In these early applications, the scissor mechanism embodied the essence of mechanical ingenuity, providing a straightforward yet effective means of achieving mechanical advantage.

As engineering knowledge advanced, so did the sophistication of scissor mechanisms. Historical records indicate the use of more intricate scissor-like structures in various forms, including devices for artistic pursuits, medical instruments, and early mechanical engineering endeavors. The Renaissance period, in particular, witnessed a surge in the exploration of mechanical principles, contributing to the refinement and diversification of scissor mechanisms.

Evolution in Engineering Applications:

The evolution of scissor mechanisms gained momentum during the industrial revolution, marking a transformative period for engineering applications. With the advent of precision engineering and manufacturing, scissor mechanisms found their way into an array of industries, each demanding specific functionalities and adaptations.

In automotive engineering, scissor mechanisms became integral components of lifting systems in vehicle maintenance. Their ability to provide stable and controlled vertical movement made them indispensable in the design of hydraulic lifts and automotive scissor jacks. This application not only showcased the mechanical prowess of scissor mechanisms but also highlighted their relevance in enhancing operational efficiency.

Furthermore, scissor mechanisms found applications in the burgeoning fields of aerospace, medical devices, and manufacturing. Their adaptability, compact design, and ease of integration into various systems contributed to their widespread adoption. In the medical field, for instance, scissor mechanisms became crucial components in operating tables, enabling precise adjustments to accommodate diverse surgical procedures.

The engineering evolution of scissor mechanisms also saw advancements in materials and manufacturing techniques. Traditional metal constructions evolved to include lightweight alloys, and with the advent of modern manufacturing methods, such as 3D printing, scissor mechanisms could be custom-designed with intricate geometries and increased structural integrity.

Explore the design principles behind scissor mechanisms, including the choice of materials, member lengths, and configurations. Discuss how these design choices impact the mechanism's functionality and efficiency.

2.1.2 Types of Scissor Lifts

There are several types of scissor lifts, each designed for specific applications:

1. **Hydraulic Scissor Lifts**: Powered by a hydraulic system, these lifts are suitable for a wide range of applications, from building repairs to heavy-duty industrial sectors

2. **Diesel Scissor Lifts**: These lifts are commonly used on construction sites and outdoor environments due to their ability to reach heights of up to 60 feet. They are powered by traditional diesel fuel

3. **Electric Scissor Lifts**: Ideal for indoor spaces due to their silent, emission-free operation, electric scissor lifts are a popular choice for tasks that require working at height in environments with insufficient ventilation

4. **Rough Terrain Scissor Lifts**: Specifically designed for outdoor terrain, these lifts are equipped with heavy-duty tires and additional safety mechanisms, making them ideal for work sites with slopes and uneven surfaces

5. **Pneumatic Scissor Lifts**: Running on air pressure, these lifts are a sustainable option for companies looking to minimize their carbon footprint. They do not emit hazardous fumes, making them suitable for a variety of surroundings

Each type of scissor lift has its own unique features and is suitable for specific applications, ranging from indoor to outdoor use, and from light to heavy-duty tasks

2.1.3 Applications in Various Industries:

Scissor lifts have a wide range of applications in various industries. They are used for tasks that require working at height or elevating a work piece. Some of the applications of scissor lifts in industry include:

1. **Aircraft maintenance**: Scissor lifts are used in the airline industry to reach every part of the plane safely and easily.

2. **Workstations**: Scissor lifts can be used as workstations to lift heavy objects and move them from one position in the factory to another, reducing human error and saving time.

3. **Machine tending tasks**: Scissor lifts are well suited for machine tending tasks in the factory. They can be stationed next to manufacturing equipment at the same height to ensure that they feed raw materials onto the machines.

4. **Healthcare industry**: Scissor lifts are used in hospitals to move patients and medical equipment.

5. **Transporting items within the factory**: Scissor lifts are used to move items from one point to another within the factory.

6. **Construction industry**: Scissor lifts are used in construction for tasks such as building repairs, accessing materials stored at height in a warehouse facility, and heavy-duty industrial aerospace, energy, entertainment, transport, and advanced manufacturing sectors.

7. **Warehousing**: Scissor lifts are used in warehouses to streamline inventory processes, including loading and unloading pallets and lifting and retrieving heavy goods from shelves.

2.1.4 Other Mechanisms That Could Be Considered

Several mechanisms can perform tasks similar to those achieved by a scissor mechanism, depending on the specific requirements of the application. The choice of mechanism often depends on factors such as load capacity, precision, speed, and spatial constraints. Here are a few alternative mechanisms that can be considered for tasks similar to those performed by a scissor mechanism:

1. **Lever Systems:**

Levers are simple machines that consist of a rigid bar (lever arm) that pivots around a fixed point (fulcrum). Lever systems can be employed for lifting and moving loads, providing mechanical advantage based on the lever's configuration.

2. **Linkages:**

Linkages are assemblies of rigid bodies (links) connected by joints. Depending on their arrangement, linkages can achieve a variety of motions, including linear, oscillatory, and complex paths. For lifting applications, a four-bar linkage or a slider-crank mechanism might be considered.

3. **Hydraulic Cylinders:**

Hydraulic cylinders utilize fluid pressure to generate linear motion. These cylinders are often used in lifting systems and can provide significant force and precise control. The application of hydraulic systems can be advantageous in scenarios requiring high load capacities.

4. **Pneumatic Systems:**

Similar to hydraulic systems, pneumatic systems use compressed air to generate linear or rotational motion. Pneumatic cylinders can be employed for lifting applications in situations where hydraulic systems are not suitable due to specific environmental or safety considerations.

5. **Scissor Lift Table:**

While a scissor mechanism is itself a form of a scissor lift, dedicated scissor lift tables may use variations or additional features to cater to specific lifting needs. These tables often incorporate multiple scissor mechanisms to achieve higher lifting capacities and stability.

6. **Screw Jacks:**

Screw jacks consist of a threaded screw mechanism and a nut. Rotation of the screw causes linear motion of the nut, allowing for controlled lifting or lowering of loads. Screw jacks can provide mechanical advantage and are suitable for lifting heavy loads at a slow pace.

7. **Rack and Pinion Systems:**

Rack and pinion systems involve a gear (pinion) that engages with a toothed bar (rack). This mechanism is often used in linear motion applications, where the rotation of the pinion translates to linear movement of the rack. It can be employed for lifting or adjusting the position of loads.

8. **Telescopic Lifts:**

Telescopic lifts consist of nested sections that can extend or retract, providing variable height adjustments. These lifts are often used in applications where a range of lifting heights is required, such as in aerial work platforms.

2.1.5 Comparison with Other Mechanisms:

1. **Lever Systems:**
    - *Advantages:* Simple, lightweight.

- *Disadvantages:* Limited in reach and lifting height compared to scissor mechanisms.

2. **Linkages:**
    - *Advantages:* Versatile motion capabilities.
    - *Disadvantages:* May require complex designs for specific tasks; limited in lifting capacity compared to scissor mechanisms.

3. **Hydraulic Cylinders:**
    - *Advantages:* High force and precision.
    - *Disadvantages:* Bulkier, more complex, and may require a hydraulic power source.

4. **Pneumatic Systems:**
    - *Advantages:* Clean operation, suitable for certain environments.
    - *Disadvantages:* Lower force compared to hydraulic systems; may not be suitable for heavy loads.

5. **Scissor Lift Table:**
    - *Advantages:* Provides a stable platform for lifting; can handle heavy loads with a relatively compact design.
    - *Disadvantages:* Limited to vertical motion; may require additional modifications for specific drone-mounted applications.

6. **Screw Jacks:**
    - *Advantages:* Simple design, suitable for slow and controlled motion.
    - *Disadvantages:* Limited speed; may not be ideal for applications requiring rapid deployment or retraction.

2.1.6 Why Scissor Mechanism is Better for Lowering a 2kg Payload Attached to a Drone:

1. **Compact Design:**
    - The scissor mechanism offers a compact design, making it suitable for drone applications where space is limited. Its vertical motion can be easily accommodated within the confined space of the drone's payload area.
2. **Stability:**
    - Scissor mechanisms inherently provide a stable lifting platform. This stability is crucial when lowering sensitive equipment such as a metal detector, ensuring controlled and steady deployment.
3. **Controlled Vertical Motion:**
    - The scissor mechanism excels in providing precise and controlled vertical motion. This is essential for lowering a 5 kg metal detector with accuracy, minimizing the risk of impact or damage during deployment.
4. **Lightweight Construction:**
    - Compared to some alternatives like hydraulic systems, scissor mechanisms can be designed with lightweight materials. This is advantageous for drone applications, where minimizing additional weight is crucial for maintaining flight stability and duration.

5. **Ease of Integration:**
    - Scissor mechanisms can be seamlessly integrated into the payload system of a drone. Their relatively simple design and vertical motion make them compatible with the specific requirements of lowering equipment from aerial platforms.

6. **Reliable Load Handling:**
    - Scissor mechanisms are well-suited for handling moderate to heavy loads, making them an appropriate choice for lowering a 2kg payload. The distributed support across the scissor structure contributes to the reliable handling of the load during descent.
7. **Minimal Power Requirements:**
    - The straightforward mechanical design of scissor mechanisms results in lower power requirements compared to more complex alternatives like hydraulic or pneumatic systems. This is advantageous for maintaining energy efficiency in drone applications.
8. **Cost-Effective Solution:**
    - Scissor mechanisms are often cost-effective to manufacture and implement. This is beneficial for drone applications where cost considerations are essential, allowing for an efficient solution without compromising functionality.

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2.1.7 Energy Efficiency and Sustainability:

Efforts to enhance the energy efficiency and sustainability of scissor mechanisms have become imperative in the context of growing environmental awareness and the push towards greener engineering solutions. Researchers and engineers have undertaken studies to investigate and implement design modifications that contribute to reduced energy consumption and environmental impact.

1. Materials and Weight Optimization:

- Research has explored the use of lightweight materials with high strength properties in scissor mechanism construction. Utilizing materials that offer a favorable strength-to-weight ratio helps in reducing the overall weight of the mechanism, contributing to energy efficiency and ease of operation.

2. Friction Reduction:

- Efforts have been directed towards minimizing friction within the scissor mechanism. This includes the use of low-friction materials, lubrication techniques, and precision engineering to reduce energy losses during extension and retraction. Lowering friction contributes to smoother motion, less wear on components, and improved energy efficiency.

3. Efficient Actuation Systems:

- Researchers have investigated the integration of more energy-efficient actuation systems. This involves optimizing motor types, exploring regenerative braking mechanisms, and employing advanced control algorithms to ensure precise and controlled motion while minimizing energy consumption during both ascent and descent phases.

4. Smart Control Systems:

- The implementation of smart control systems has been a focus area. These systems incorporate sensors and feedback mechanisms to adapt the operation of the scissor mechanism based on real-time conditions. By dynamically adjusting parameters like speed and force, energy efficiency is improved, particularly in applications with variable loads.

5. Recyclable Materials:

- Sustainable design practices involve the consideration of recyclable materials in the manufacturing of scissor mechanisms. Studies have explored the feasibility of using materials with minimal environmental impact and end-of-life recyclability, aligning with broader sustainability goals.

6. End-of-Life Considerations:

- Researchers have examined the environmental impact of scissor mechanisms at the end of their operational life. This includes evaluating options for disassembly, recycling, or repurposing components to minimize the ecological footprint associated with the disposal of obsolete mechanisms.

7. Life Cycle Assessments (LCA):

- Comprehensive life cycle assessments have been conducted to evaluate the environmental impact of scissor mechanisms from production to disposal. LCA studies provide insights into potential areas for improvement, guiding the development of more sustainable design and manufacturing practices.

2.1.8 Safety Considerations:

Ensuring safety is a paramount concern in the design, implementation, and operation of scissor mechanisms, especially given their diverse applications across industries. A thorough understanding of potential hazards and the incorporation of safety features are essential to minimize risks and create a secure working environment. Here are key safety considerations associated with scissor mechanisms:

1. Overload Protection:

- Scissor mechanisms should incorporate overload protection mechanisms to prevent exceeding their specified load capacity. This can include the integration of limit switches, load sensors, or other devices that automatically halt operation when load limits are surpassed, reducing the risk of structural failure.

2. Emergency Stop Systems:

- An emergency stop (E-stop) system is crucial to immediately halt the operation of the scissor mechanism in case of unforeseen circumstances or emergencies. This feature is typically integrated into the control system and should be easily accessible for quick response.

3. Structural Integrity and Material Selection:

- Ensuring the structural integrity of the scissor mechanism is fundamental for safety. Thorough stress analysis and appropriate material selection, considering factors like fatigue resistance and durability, contribute to the longevity and safety of the mechanism.

4. Guarding and Enclosures:

- Physical guarding or enclosures around the moving parts of the scissor mechanism can prevent accidental contact and reduce the risk of injury. Transparent materials may be used to maintain visibility while providing protection.

5. Limit Switches and Position Sensors:

- Limit switches and position sensors are essential safety features that help define the travel limits of the scissor mechanism. They play a critical role in preventing overextension or over retraction, safeguarding against potential hazards associated with exceeding the mechanical limits.

6. Operator Training and Awareness:

- Proper training for operators is imperative to ensure safe operation. Training programs should cover the correct use of controls, emergency procedures, and an understanding of the scissor mechanism's operational limits. Operator awareness contributes significantly to accident prevention.

7. Load Distribution and Stability:

- Even load distribution across scissor members is crucial for stability and safety. Properly balanced loading prevents uneven stress on individual members, reducing the risk of structural failure and ensuring stable vertical motion.

8. Regular Inspection and Maintenance:

- Regular inspection and maintenance routines are essential for identifying wear, damage, or potential issues before they escalate. during operation.

2.2 Drone

Several designs were considered and then dropped keeping in view several aspects. Some of the designs considered (and rejected or adopted) have been mentioned as follows:

2.2.1 Camber Morphing Wings based on Compliant Corrugated Structures (Dropped)

These wing structures had the merit of changing the camber angle by moving the trailing edge. The trailing edge was moved by the rear spar, which in turn was mobilized by a servomotor each for a wing. In this way, we could change the camber angle of the foil/wing according to the flying phase. The efficiency and flight performance could be optimized in this way. The compliant ribs incorporate the use of 3D printing (using PLA or preferably ABS for its ductility and strength). With the use of stringers, the whole mechanism proved capable of bending but resistant to buckling (bending due to axial forces rather than lateral forces). This eliminates the risk of bending under the action of aerodynamic forces which are

dominant mostly at the front, and rear in the case of counter-vortex. The wing will bend only when the rare spar is moved.
The compliant mechanism is covered with a latex sheet, which has been pre-tensioned to up to 5% to prevent loose fitting and consequent aerodynamic underperformance. The latex sheet is attached with epoxy and provides a continuous, smooth path for the air streams to flow. Unlike flaps and ailerons, where discontinuity occurs, no vortex generation happens in gaps and thus no portion of the lift is compromised to drag. In order to further strengthen the wing's, double corrugated structures have also been devised, whereby one layer is stacked upon another and then joined. The aerodynamic performance of both single and double-corrugated wings is almost the same, so where strength is an overwhelming concern, double-corrugated structures can be used actively.

Infeasibility as per our requirements:
There were, however, certain considerations that rendered such a versatile wing into an unfeasible application. Firstly, to move the rear spar a powerful servo motor had to be used, which added to the weight of the craft. Two powerful servo motors could be a considerable addition of weight. It also proved to be a challenge to house the servos in the fuselage, given that the fuselage was already congested with servos for other purposes as well as controllers and other equipment. Secondly, it was resolved that adding ailerons would provide better functionality since it would use lighter, less powerful servos, and moreover, it would be better at providing control for maneuvers. The morphed wing on the other hand, due to the rigidity of the ribs and stringers used, would not be able to provide morphing at only particular sections of the wing which means the wing would have to be morphed as a whole with a uniform angle throughout spanwise compromising the individual functions of flaps and ailerons.

2.2.2 Fairey Rotodyne (Dropped)

Fairey Rotodyne VTOL was also considered as a base model for our design. It features a large (helicopter) propeller atop an otherwise fixed-winged type airframe. The main advantage of this model is that it greatly reduces the power required during the take-off and landing phases of the flight. Although both these phases cumulatively account for about 60 seconds during the flight, still they expend about one-third of the power required for the flight. Using large helicopter propellers reduces such power requirements sufficiently. The advantage over usual conventional tiltrotor and tilt-wing VTOLs is that no actuators would have to be used for rotating rotors and wings. Additionally, fewer moving parts directly translate to lesser susceptibility to failure.

Infeasibility as per our requirements:
However, there were certain setbacks in the design. First and foremost, although the plane eliminated the need for a tilting mechanism, using a helicopter propeller configuration would have been in itself a design challenge. Mimicking a miniature helicopter swashplate or equivalent mechanism could prove to be very complicated and over-engineered. Moreover, the Fairey Rotodyne was designed to be an intra-city passenger aircraft, which gave more consideration to its spaciousness and urban airspace traffic adaptability, rather than speed and maneuverability. As such, the Rotodyne model was not a very suitable guide for aerodynamic design parameters for our drone.
Another setback was that due to such large propellers, noise pollution is also an issue. There is also a potential need for a counter-rotating top propeller in order to render the aircraft stable from torque if the complicated rudder and elevator systems are not to be used at the tail. The addition of a second propeller would also add significant noise. The propeller would also not be functioning in the cruise phase of the flight, essentially rendering them to be redundant, which can be counted as an additional weight during most of the flight time. Last but not the least, in the original design of the Rotodyne, the propellers at the wings have

been placed near the fuselage. This means short diameter rotors would have to be used, which would provide less thrust.

2.2.3 Quadcopter Configuration (Incorporated into Design)

The original Quadcopter design features a pair of twin rotors. To increase thrust-to-weight ratio, the stability, and to get more sensitive controls. By using 4 rotors, the team has essentially provided our craft with the pitch, yaw, and roll controlling capability of a quadcopter drone. Thus, the control has also gotten immensely simplified. All 4 rotors will be able to control all dimensions of movements.

2.2.3.1 Control Mechanism for Motors

The UAS design will also incorporate basic control systems for better control while cruising.

- A set of 4 motors will be used that will run the vehicle.
- A controller will be used to control and coordinate the movement.

2.2.3.2 Frame Design & Material

The frame serves as the foundation of the quadcopter and affects its overall stability and weight distribution. Design factors such as geometry, material selection (e.g., carbon fiber, aluminum, or composite materials), and construction techniques impact the drone's durability, aerodynamics, and weight.

The aerodynamic body of a quadcopter drone, meticulously constructed from lightweight and high-strength carbon fiber composite materials, plays a pivotal role in optimizing its flight performance and efficiency. Carbon fiber's exceptional strength-to-weight ratio and inherent rigidity allow for the creation of a streamlined structure that minimizes air resistance while maintaining structural integrity. This design approach not only enhances overall stability and control but also maximizes the drone's endurance and maneuverability. The utilization of carbon fiber in the quadcopter's body underscores a commitment to cutting edge materials science, enabling the drone to navigate through challenging environmental conditions with heightened agility, reduced energy consumption, and extended operational range.

2.2.3.3 Motor and Propeller Selection

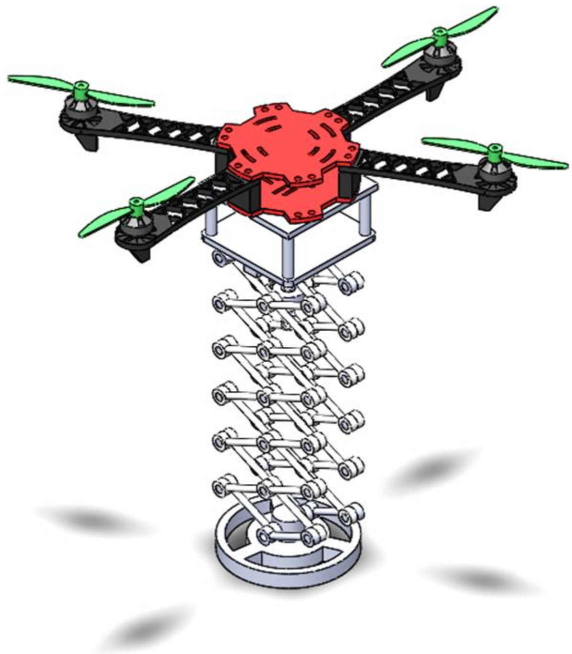
The choice of motors and propellers significantly influences the drone's thrust-to-weight ratio, lift capabilities, and maneuverability. Calculations involving motor torque, Kv rating, and propeller size should align with the quadcopter's weight and payload requirements. We have used 340 kV motors.

2.2.3.4 Flight Controllers and Sensors

A sophisticated flight controller equipped with accelerometers, gyroscopes, barometers, and magnetometers is essential for stable flight and accurate sensor data. Integration of GPS and IMU (Inertial Measurement Unit) sensors contributes to precise positioning, altitude control, and navigation.

2.2.3.5 Power Distribution

Efficient power distribution and battery management systems ensure a consistent power supply to the motors and onboard electronics. Battery selection, capacity, voltage, and discharge rate influence flight duration and overall drone performance. We have used 22000 mAh batteries.



Conceptual Design

Figure 3- Conceptual design of the mechanism attached to the drone

CHAPTER 3:

METHODOLOGY

3.1 Design methodology of Scissors mechanism

During the design phase, a systematic approach was formulated to engineer a drone that meets the specified mission requirements. The design methodology encompasses the delineation of design requirements, careful selection of propulsion system of drone and the mechanism to lift lower the metal detector.

So, the whole design section is divided into 2 main parts first for drone and second for the scissor’s mechanism.

This section will comprise of the design methodology of the scissor mechanism and its design requirements that will be engineered to complete its mission.

3.1.1 Identification of Design Requirements

Design Requirement for Scissor Mechanism on UAV with Metal Detector:

1. **Deployment Efficiency:**

The scissor mechanism must enable swift and efficient deployment of the metal detector from the UAV, ensuring minimal time delay in the detection process.

2. **Compactness and Portability:**

The scissor mechanism should be designed to maintain the overall compactness of the UAV, allowing for ease of transportation and launch in diverse operational environments.

3. **Stability and Precision:**

The scissor mechanism must provide stable and precise control during the descent of the metal detector, ensuring accurate positioning and reliable detection capabilities in various terrains.

4. **Adjustability and Adaptability:**

The scissor mechanism should be adaptable to varying altitudes and terrains, allowing for adjustments to optimize metal detection performance based on the specific characteristics of the operational area.

5. **Material Durability:**

The materials used in the construction of the scissor mechanism must be durable and resilient to environmental factors, ensuring longevity and reliability over multiple deployment cycles.

6. **Integration with Drone Systems:**

The scissor mechanism should seamlessly integrate with the UAV's control system, allowing for coordinated operation and precise control of the metal detector throughout the mission.

7. **Sensor Compatibility:**

The scissor mechanism must be designed to support the attachment and functionality of the metal detector, ensuring compatibility and optimal performance of the sensing equipment during the detection process.

8. **Power Efficiency:**

The scissor mechanism should be designed with a focus on energy efficiency, ensuring that the power consumption during the deployment and retraction of the metal detector is minimized to extend overall mission endurance.

9. **Quick Retrieval Capability:**

The scissor mechanism must facilitate quick and reliable retrieval of the metal detector, allowing for rapid extraction and safe return of the UAV after completing the mission.

10. Safety Features:

Incorporate safety mechanisms to prevent accidental deployment or retraction, ensuring secure handling and minimizing the risk of damage to both the UAV and the attached metal detector.

11. Ease of Maintenance:

Design the scissor mechanism for easy maintenance and replacement of components, reducing downtime and simplifying field repairs when necessary.

By addressing these design requirements, the scissor mechanism will enhance the UAV's capabilities in metal mine detection missions, ensuring effectiveness, reliability, and safety during deployment and retrieval processes.

3.1.2 Metal Detector Integration Parameters

In addition to the scissor mechanism, specific parameters related to the metal detector integration are considered:

1. **Detector Sensitivity and Range**: Determining the metal detector's ability to detect mines at different depths.
2. **Power Supply**: Designing a power supply system to ensure continuous operation of the metal detector during the mission.
3. **Data Communication**: Establishing communication protocols between the metal detector and the drone's onboard systems.
4. **Integration with Scissor Mechanism**: Ensuring seamless integration of the metal detector with the selected scissor mechanism.

3.1.3 Overall Flow of Scissor Mechanism Integration

A structured approach is followed, including conceptual design, preliminary design, and detailed design phases for the scissor mechanism integration. Iterative reviews are conducted after each phase to validate the design against the defined requirements.

3.1.4 Scissor Mechanism Configuration Selection

Based on a comprehensive review of existing scissor mechanisms and their applications, a configuration is selected that best suits the specific requirements of attaching a metal detector to a drone. The decision matrix methodology is employed to evaluate different scissor mechanism configurations based on the following factors:

- **Mechanism Stability**: Ensuring stability during deployment and retrieval.
- **Payload Capacity**: Ability to support the weight of the metal detector.

- **Compactness**: The mechanism's ability to remain compact for integration with the drone.
- **Ease of Control**: Factors affecting control and maneuverability.
- **Durability**: Resistance to wear and tear during operational use.

A weighted decision matrix is created to assign importance to each factor, and the configuration with the highest weighted average is selected for further design and integration.

3.1.5 Selection Criteria for Scissors Mechanism Components

The initial consideration for the scissor mechanism involved the use of aluminum. However, due to concerns related to weight, this option was reconsidered and subsequently canceled. In its place, a more lightweight and versatile material was chosen to meet the design requirements.

1. Material Choice:

The selected material for constructing the scissor mechanism is 3D printed PETG (Polyethylene Terephthalate Glycol). PETG is chosen for its favorable combination of strength, flexibility, and reduced weight compared to aluminum. The 3D printing process allows for intricate and customized designs, enabling the fabrication of complex geometries required for the scissor mechanism.

2. Infill Percentage:

The 3D printed parts are designed with an infill percentage ranging between 80-100%. This high infill ensures that the PETG parts exhibit enhanced structural integrity, providing the necessary strength and stability for the scissor mechanism.

3. Weight Reduction:

The transition from aluminum to 3D printed PETG results in a significant reduction in weight. The use of PETG with high infill reduces the overall weight of the mechanism by half, bringing it down to a mere 1kg. This weight reduction contributes to improved portability and operational efficiency.

4. Customization and Complexity:

3D printing allows for the creation of intricate and customized components tailored to the specific requirements of the scissor mechanism. This capability is crucial for achieving the desired dimensions, tolerances, and geometries necessary for optimal functionality.

5. Cost-Efficiency:

PETG is chosen not only for its mechanical properties but also for its cost-effectiveness in comparison to certain metal alloys. This ensures that the scissor mechanism can be produced with a balance of performance and economic viability.

Material selection is a critical aspect of the design process, impacting the overall performance, weight, and cost of the mechanism. The adoption of 3D printed PETG aligns with the design goals, offering a lightweight yet robust solution for the construction of the scissor mechanism. The combination of material properties, customization capabilities, and cost considerations make PETG a suitable choice for this application.

3.1.6 Design Specifications of Scissor Mechanism

The scissor mechanism under consideration is designed with specific dimensions and operational requirements to achieve a desired extension and compression. These specifications are crucial in ensuring the functionality and reliability of the mechanism.

1. **Length of Single Member:**
   - The length of each individual member within the scissor mechanism is set at 6 inches. This parameter defines the basic unit length for constructing the linkage.

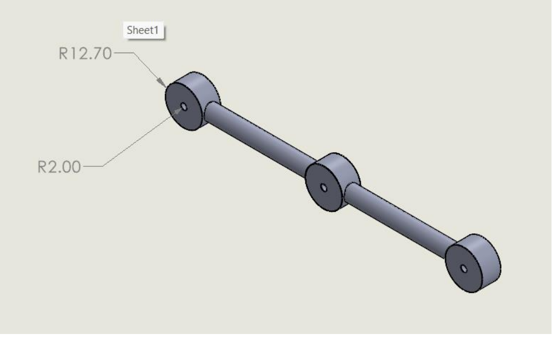


Figure 4- Single member of the scissor mechanism

2. **Length of First and Last Members:**
   - The first and last members of the scissor linkage have a unique length, each measuring 3 inches. This distinctive length ensures proper alignment and contributes to the overall structural integrity of the mechanism.
3. **Required Extension:**
   - The scissor mechanism is designed to achieve a specific extension of 24 inches. This extension is the result of the coordinated movement and extension of all individual members in the linkage.
4. **Fully Compressed Length:**
   - The scissor mechanism starts from a fully compressed state with a length of 6 inches. This compressed length serves as the baseline for the extension and
   - retraction capabilities of the mechanism.
5. **Total Members in 1 Linkage:**
   - Each scissor linkage is composed of a total of 12 members, distributed as 5 full-length members and 2 half-length members. This configuration imparts the necessary flexibility and rigidity to the mechanism.
6. **Lead Screw Connection:**
   - When the total length of the scissor mechanism reaches 24 inches, a lead screw connection is introduced. This connection is positioned 4

inches below the top point of the fully extended mechanism. The lead screw plays a critical role in stabilizing and maintaining the extended position.

7. **Power Screw Operation:**
   - The lowering action of the scissor mechanism is facilitated by a power screw. The power screw engages with the lead screw, enabling controlled and precise descent. The linear speed of this descent is specified at 1 inch per second, ensuring a smooth and controlled retraction.

Understanding and adhering to these design specifications is essential for achieving the desired performance and functionality of the scissor mechanism, providing a basis for successful implementation in various applications

3.1.7 Structural Analysis and Optimization

Figure 5- Finalized CAD design of the whole design made on Solidworks

The structural integrity and performance of the scissor mechanism were rigorously evaluated through advanced simulation using Ansys software. This analysis aimed to assess the response of the mechanism under operational loads, specifically considering a payload of 5kg in addition to the inherent weight of the mechanism itself (1kg). The obtained results provide crucial insights into the mechanical behavior of the system.

Von Mises Stress:

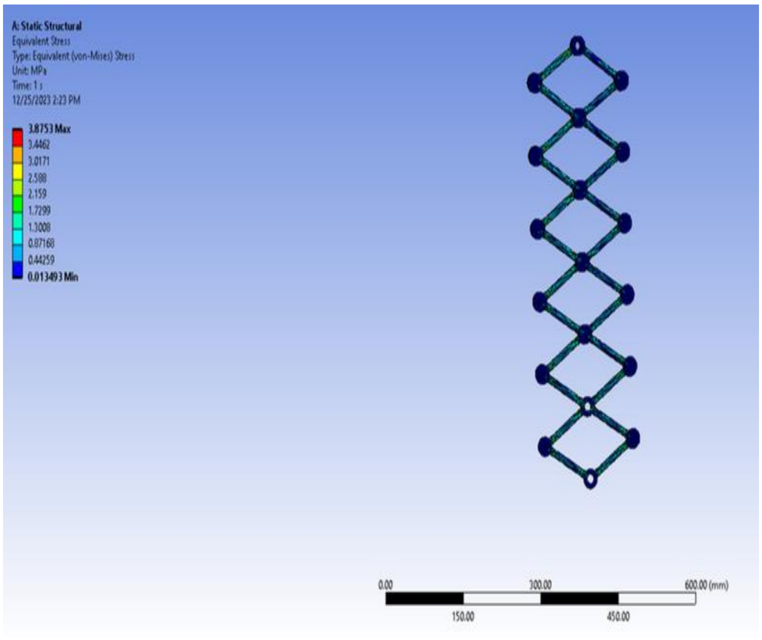


Figure 6- Von mises calculated on ANSYS software

Maximum Von Mises stress: 3.86 MPa

Minimum Von Mises stress: 0.013 MPa

Von Mises stress is a measure of the combined effect of different types of stress on a material. The results indicate that the scissor mechanism, under the specified loads, experiences stress levels within acceptable limits. The maximum stress observed is 3.86 MPa, ensuring that the material is well within its yield strength.

Elastic Strain:

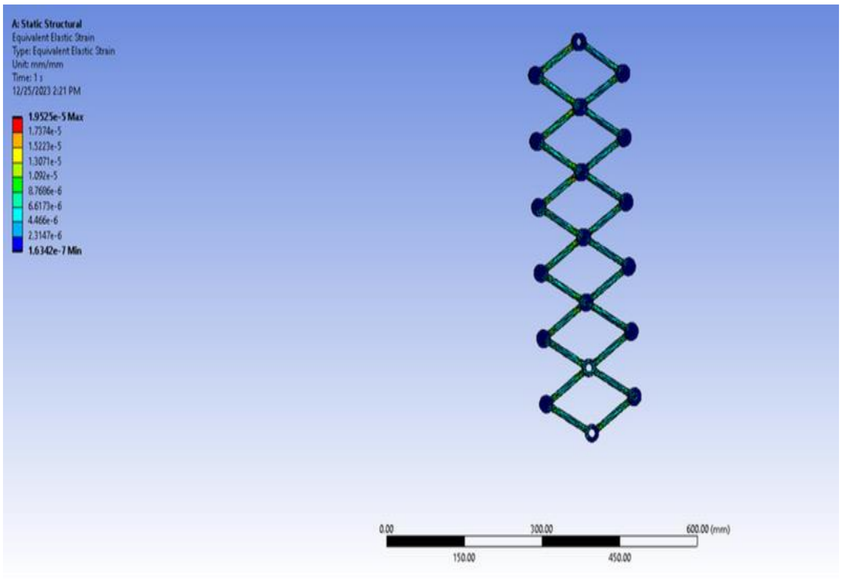


Figure 7- Elastic strain calculated on ANSYS software

Maximum Elastic Strain: 1.9e-5

Minimum Elastic Strain: 1.6e-7

Elastic strain measures the deformation of the material under load and provides insights into its elastic properties. The obtained results indicate minimal elastic strain, signifying that the scissor mechanism exhibits excellent elastic behavior and returns to its original shape after the applied loads are removed.

Total Deformation:

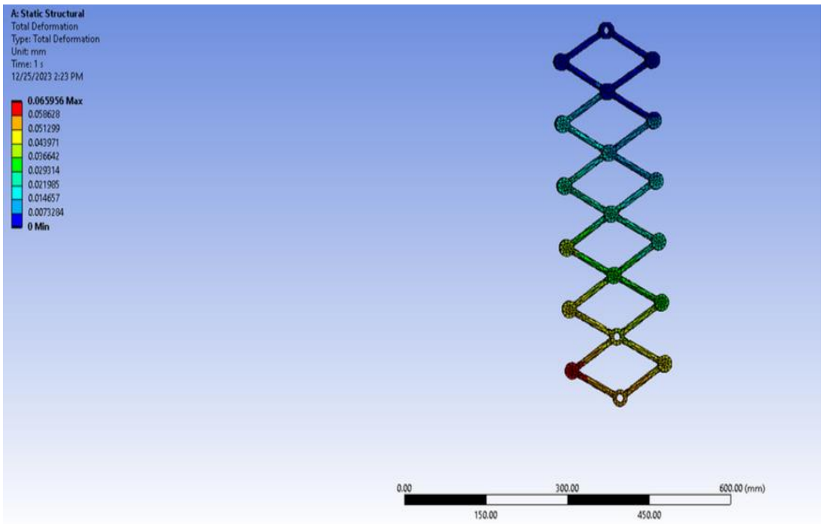


Figure 8- Total deformation calculated on ANSYS software

Maximum Total Deformation: 0.065 mm

Minimum Total Deformation: 0 mm

Total deformation represents the overall displacement of the mechanism under the specified loads. The results show that the scissor mechanism experiences a maximum deformation of 0.065 mm, which is well within acceptable limits and ensures that the mechanism maintains its structural integrity during operation.

The structural analysis using Ansys software validates the design and material choices made for the scissor mechanism. The results demonstrate that the mechanism can effectively withstand the anticipated loads, providing a reliable and robust solution for its intended application. The combination of 3D printed PETG material and careful design considerations contributes to the successful performance of the scissor mechanism under real-world conditions.

3.1.8 Integration of Control Systems

The control systems for the scissor mechanism are seamlessly integrated, employing a combination of motorized actuation, position feedback sensors, and a robust control algorithm. The key components and functionalities of the control system, along with their respective power and control sources, are detailed below:

Motorized Actuation:

The scissor mechanism is actuated by a NEMA 17 stepper motor, chosen for its precision and torque characteristics. This motor serves as the primary driver for the power screw, enabling controlled vertical movement.

Position Feedback Sensors:

To ensure accurate control over the scissor mechanism's position, position feedback sensors are integrated. These sensors, such as encoders or potentiometers, provide real-time information about the extension or retraction of the mechanism.

Control Algorithm:

The control algorithm, implemented on an Arduino Uno microcontroller, governs the motorized actuation system. This microcontroller processes input signals from position feedback sensors and calculates the necessary control signals to drive the NEMA 17 motor effectively.

User Interface:

User interaction and control are facilitated through the Arduino Uno microcontroller, which can incorporate a user interface, such as a control panel or touchscreen. Operators can set parameters, monitor the status, and control the scissor mechanism through the user interface.

Emergency Stop and Safety Features:

The control system incorporates an emergency stop mechanism, controlled by the Arduino Uno. This ensures the immediate halting of the mechanism in case of unforeseen circumstances, enhancing overall safety.

Communication Protocols:

The communication between the Arduino Uno and the NEMA 17 motor is established using common protocols suitable for microcontroller-motor interaction. This may involve pulse-width modulation (PWM) or other relevant protocols for efficient communication.

Power Supply and Distribution:

Both the NEMA 17 motor and the Arduino Uno are powered by a 24-volt battery supply. An efficient power supply and distribution system ensure reliable operation, with the battery

serving as a portable and accessible power source.

Integration with Overall System Architecture:

The control system is designed to seamlessly integrate with the overall architecture of the scissor mechanism. Compatibility with the 24-volt battery supply, coordination with other subsystems, and adherence to industry standards are essential aspects of this integration.

Testing and Calibration:

Rigorous testing and calibration procedures are conducted to verify the performance and reliability of the integrated control systems. This includes validating the coordination between the Arduino Uno, NEMA 17 motor, and the overall scissor mechanism under various operating conditions.

Documentation and User Manuals:

Comprehensive documentation and user manuals are provided, outlining the integration of the control systems. These documents guide users, maintenance personnel, and system integrators, ensuring proper usage, troubleshooting, and maintenance of the system powered by a 24-volt battery supply.

The integration of the control systems, driven by a NEMA 17 motor and an Arduino Uno microcontroller, provides a robust and efficient solution for the precise control of the scissor mechanism, emphasizing safety, reliability, and user-friendly operation.

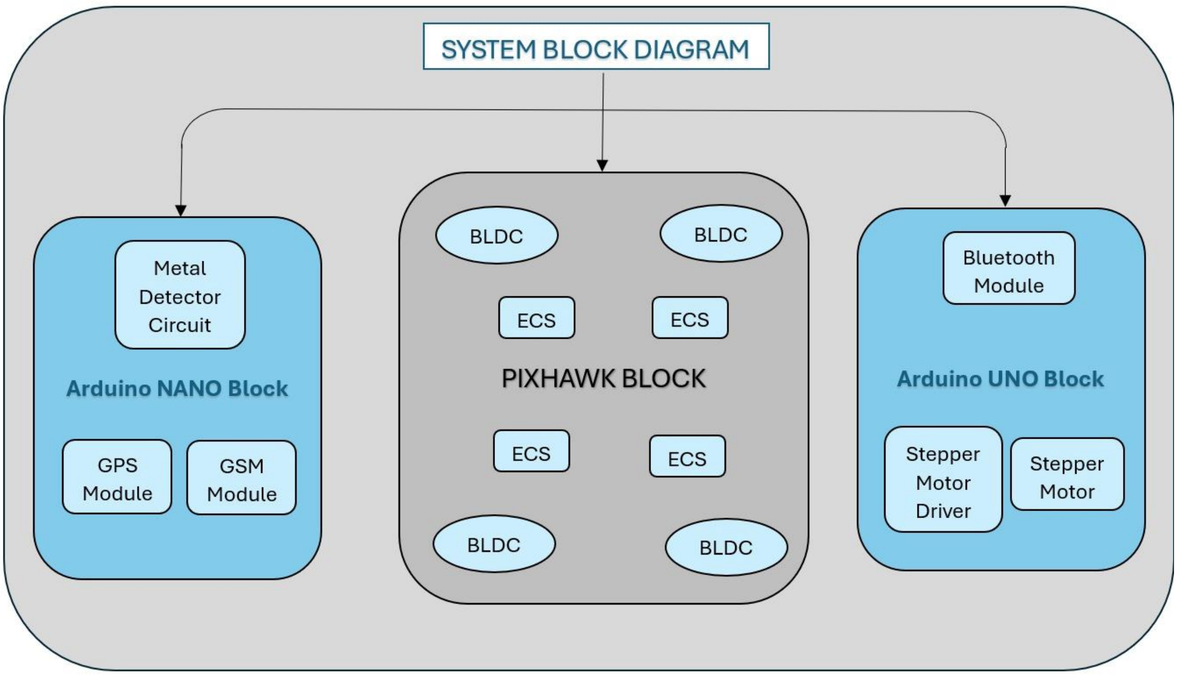


Figure 9- The system Block Diagram of the whole Project

3.1.9 Prototyping and Testing Strategies

The prototyping and testing phase is a critical step in the development of the scissor mechanism, ensuring that the design and control systems are translated into a functional and reliable system. The approach involves a systematic process that includes the fabrication of 3D printed components and the testing of electronics, culminating in the assembly and evaluation of the complete mechanism.

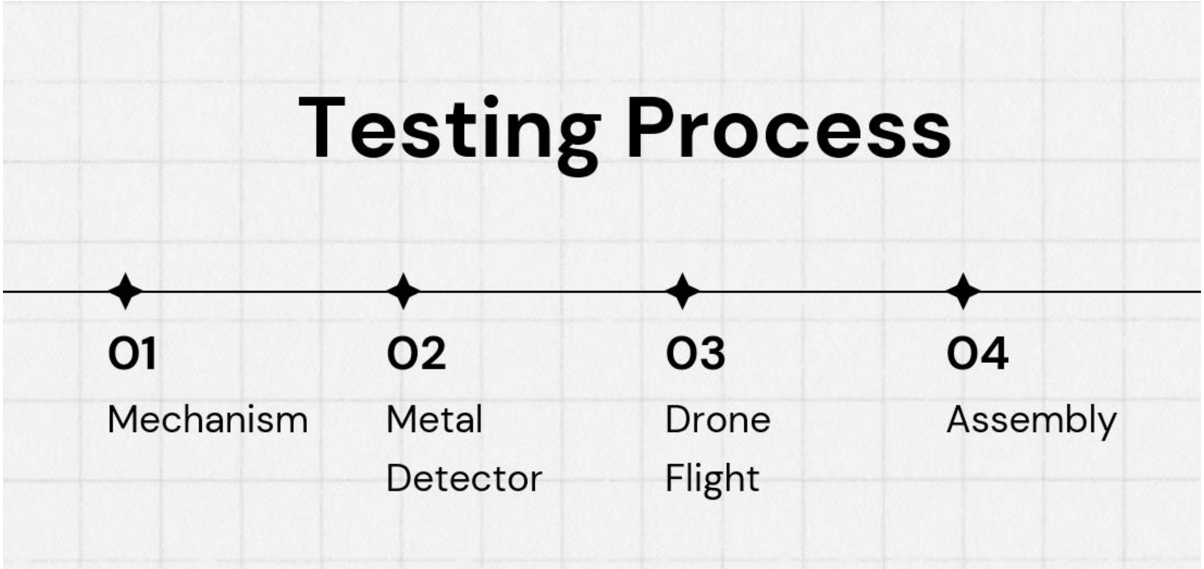


Figure 10- The step by step Testing phase

Documentation of Prototyping Process:

Throughout the prototyping and testing phase, detailed documentation is maintained. This documentation includes records of design changes, test results, and any modifications made during the iterative refinement process. A comprehensive log provides valuable insights for future development, troubleshooting, and scaling.

The prototyping and testing strategies outlined above ensure a systematic and thorough approach to validate the scissor mechanism's functionality, reliability, and safety. This iterative process allows for refinement and optimization, leading to a final product that meets or exceeds the intended design specifications.

3.1.10 Conclusion and Future Directions

Similar to the overall drone design process, specific design reviews are conducted for the scissor mechanism integration:

1. **Conceptual Integration Review (CIR)**: Evaluating the conceptual design of the scissor mechanism and its compatibility with the metal detector.
2. **Preliminary Integration Review (PIR)**: Assessing the preliminary design, ensuring stability, and addressing any potential challenges in deployment and retrieval.
3. **Final Integration Review (FIR)**: Verifying the detailed design, including material selection, manufacturing processes, and integration with the drone.

By following this comprehensive design methodology, the integration of a scissor mechanism for metal mine detection becomes a systematic and well-considered part of the overall drone design.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Testing: Mechanism

The scissor mechanism is connected to a lead screw which rotates to open and close the mechanism. The motor used is the NEMA17 motor which has been integrated with a Bluetooth circuit. This allows the mechanism to be opened and closed via Bluetooth.

The mechanism was tested multiple times to verify its working, its ability to carry the load and the time it takes to open and close.

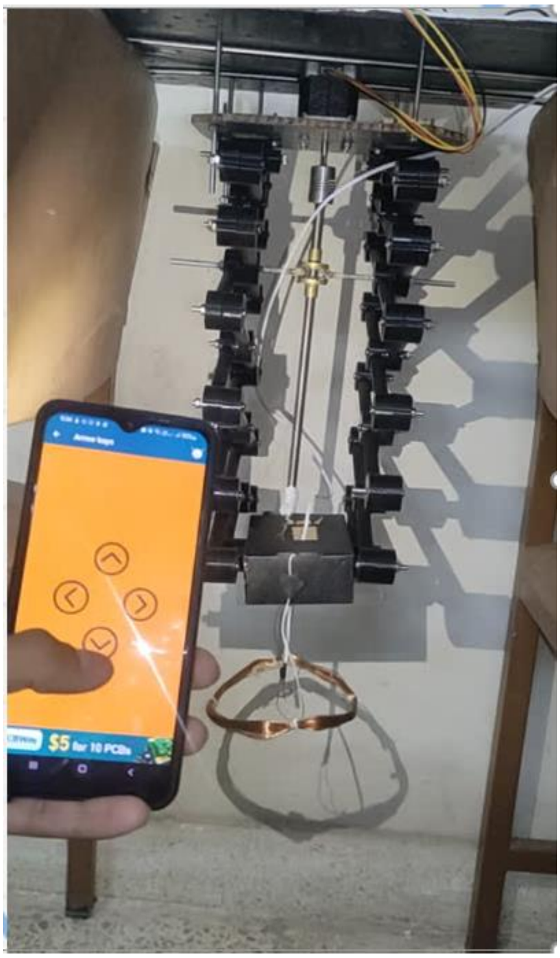


Figure 11- The testing of the Scissor mechanism controlled from phone application

The following results were concluded from this test:

Table 2- The Data acquired for the testing of the Scissor mechanism

Average Time to Open	12s
Average Time to Close	12s
Motor RPM	60
Payload	1.5kg

Working: **Successful**

4.2 Testing: Metal Detector

The metal detector circuit involves buck converters, GPS, GSM and a copper coil. When current passes through the copper coil, it produces a magnetic field. When a metallic object enters that magnetic field, it changes the magnetic flux which in turn produces emf. This change in magnetic flux lets the detector know that a metallic object is in range. The GPS module figures out the coordinates and the GSM module sends the location of the metal detected to a cell phone. This allows us to accurately pin point the latitude and longitude of mines buried in a mine field.

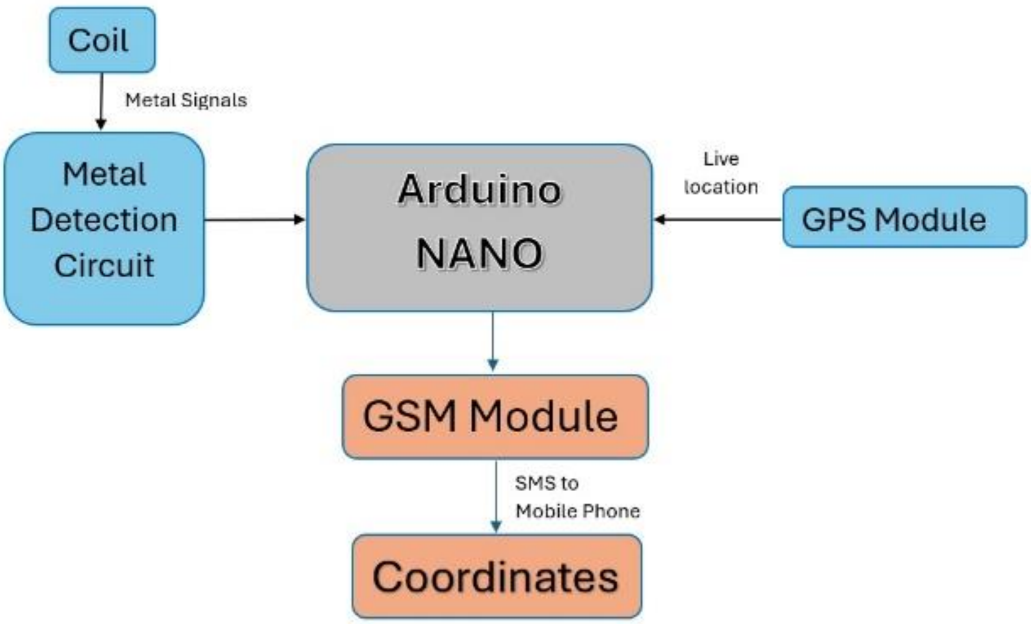


Figure 12- The Flowchart that shows how everything is connected

The test was conducted to verify the working of the system and its accuracy.

The following results were concluded from this test:

Table 3- The table shows the data acquired from the testing of the metal detector

Detection Range	4-6 in
Coil Diameter	5 in

Location	Accurate
Time to send location	2-5s

Working: **Successful**

4.3 Drone Flight

The drone flight was tested to verify its working, its ability to carry payload and to operate autonomously.

The payload used for testing was 4kg which is much higher than the actual payload of the mechanism.

Figure 13- Testing of the flight and payload of the Drone

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The project is concluded with a successful fabrication of a scissor mechanism using the material PETG. The mechanism operates through a lead screw connected to NEMA17 motor which is operated via Bluetooth.

The mechanism has the ability to extend up to 2ft below the drone and help in identifying the location of the mines. The mechanism is also integrated with a metal detector system which conveys the location of the mines using a GSM module.

The recommendations for the project are:

- Develop a drone based the design which has been made.
- Improve the metal detector strength and accuracy by using a better metal detector.
- Move towards modern ways of identifying mines like the GPR. The metal detector mechanism is detachable and hence allows other systems to be put in place.

REFERENCES

[1] Alberto Sigala (2020). Applications of Unmanned Aerial Systems (UAS): A Delphi Study Projecting Future UAS Missions and Relevant Challenges

[2] Batra, N., Kimball, D. F., Sheehan, T., & Co, B. V. (1986). *Early Evaluation of the V-22 Osprey Through Piloted Simulation*. Retrieved 4 15, 2022, from https://vtol.org/store/product/early-evaluation-of-thev22-osprey-through-piloted-simulation-1464.cfm

[3] Driggers, M. (2018). *Spraying and Surveying Applications of Drones to the Precision Agriculture Industry: Writing Prototype Software to Automatically Fly a Drone for Survey or Spray Purposes*.

https://scholarexchange.furman.edu/scjas/2018/all/47

[4] Escareno, J., Salazar, S., & Rondon, E. (2013). *TwoRotor VTOL Mini UAV: Design, Modeling and Control*.

[5] Katz, K., Helicopters, B., & Poulin, R. (1991). *Flight Testing the Avionics System of the V22 Osprey*. https://vtol.org/store/product/flight-testing-theavionics-system-of-the-v22-osprey-982.cfm

[6] Khateb, A. H., Rahim, N. A., & Selvaraj, J. (2013). *Cascaded DC-DC Converters as a Battery Charger and Maximum Power Point Tracker for PV Systems*.

https://ieeexplore.ieee.org/document/6529642

[7] Kohno, S., & Uchiyama, K. (2014). *Design of robust controller of fixed-wing UAV for transition flight*.

[8] Sage P., Design, Development, and Flight Test of a
Small-Scale Cyclogyro UAV *Utilizing a Novel CamBased Passive Blade Pitching Mechanism:*

[9] Anne, B. (2011). *Environmental-Friendly Biodegradable Polymers and Composites*.