Field Falcon: A Multirotor Drone for Assessing Farms Conditions After Severe Weather

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The Field Falcon project addresses critical challenges in modern agriculture, particularly those caused by unpredictable weather conditions and the growing need for efficient field assessments. Rising temperatures, heavy precipitation, and soil erosion necessitate frequent crop monitoring, consuming significant time and resources. To tackle these issues, the team proposes the Field Falcon, a cost-effective, user-friendly hexacopter drone designed for rapid post-weather damage assessment and crop health monitoring. With a 35-minute flight time and coverage of 5-10 acres per mission, the drone leverages advanced imaging technology and future AI integration to provide actionable data, enabling farmers to optimize resource allocation and decision-making. Its offline functionality and compatibility with existing farm management software ensure seamless integration into agricultural operations. Key challenges in deploying the Field Falcon include overcoming resistance to adopting drone technology, ensuring FAA compliance, and addressing potential costs for small-scale farms. However, the system's affordability, scalability, and adaptability to severe weather-prone regions present significant opportunities. The phased development plan includes prototype testing, user feedback incorporation, and large-scale production by 2030. By prioritizing sustainability and ease of use, the Field Falcon aims to revolutionize precision agriculture, offering a practical solution to enhance efficiency and resilience in farming practices.

I. Introduction

With the agricultural industry being responsible for 80% of the world's food supply, efficient and sustainable land management practices are vital to maintain a healthy and thriving farm. Farmers receive support with Land management from the USDA through the NRCS [1]. However, traditional methods of data collection and land management encompassing crop health and field conditions are time-consuming and labor-intensive. After severe weather, farmers need to be able to assess the conditions of their land and crops. The process of collecting agricultural data is inherently challenging, often requiring significant time to identify problem areas. Manually inspecting fields post-rainfall, assessing for mud, rock hazards, and monitoring soil conditions is impractical for many farmers due to time constraints and safety risks associated with operating heavy machinery in adverse conditions.

To reduce both the time required to survey farmland and the risk to machinery this paper introduces the Field Falcon, an autonomous Unmanned Aerial Vehicle (UAV) designed for surveying large swaths of land quickly and from a remote location. The Field Falcon will modernize farm management by streamlining data acquisition and analysis following inclement weather experienced on farms. The Field Falcon integrates a high-resolution camera and crop monitoring indices to acquire critical field condition data efficiently and safely after rainfall events. This collected data will be analyzed to create precise maps identifying areas with vegetation concerns, helping farmers optimize planting strategies and avoid equipment damage. The Field Falcon aims to improve efficiency, reduce risks, and ultimately enhance agricultural productivity and sustainability. This paper details the design, implementation, and validation of the Field Falcon system, focusing on key performance metrics, and highlighting the potential of autonomous UAVs for precision agriculture.

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II. Mission Overview

The Field Falcon system is designed to provide farmers with critical post-weather surveillance, enabling them to assess damage, detect terrain changes, make informed decisions on crop health, and to prevent farm equipment from getting stuck or sustaining damage. The system consists of three interconnected modules: the ground station, the payloads, and the multi-rotor vehicle. The Field Falcon is equipped with multiple onboard sensors that facilitate autonomous flight and data acquisition, including an accelerometer for stability, an altitude sensor for maintaining optimal flight height, a pressure sensor for environmental monitoring, and a GPS for precise positioning.

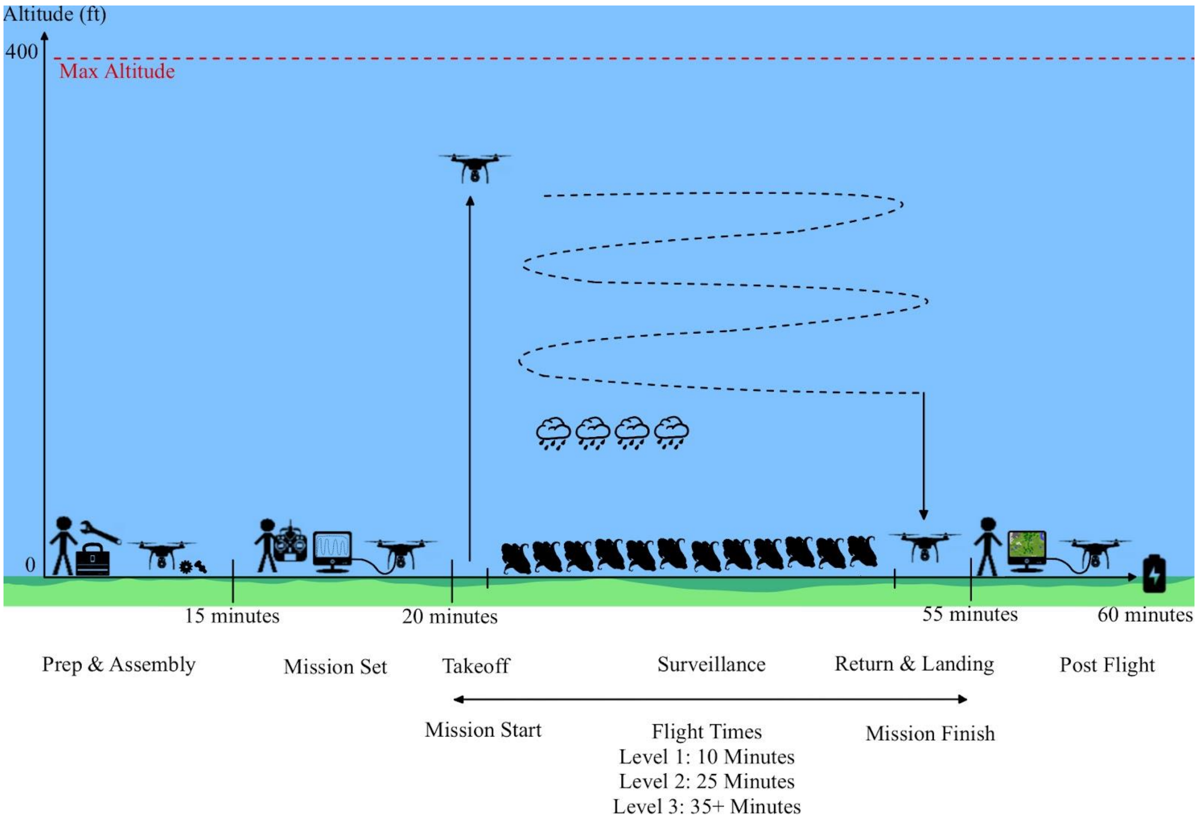

Fig. 1 Concept of Operations

Surveillance is the primary function of the Field Falcon, ensuring an accurate assessment of field conditions after heavy weather events or natural disasters. The onboard camera continuously captures real-time images and video, offering farmers a visual representation of the affected areas. This enables the identification of flood zones, erosion patterns, fallen debris, and damaged crops without the need for manual inspection. The drone autonomously follows a pre-defined flight path, systematically covering the designated area while adapting its altitude and speed based on environmental factors and mission requirements. The system processes the collected data in real-time, generating a detailed terrain and crop condition map, which can be accessed after data acquisition at the ground station.

Beyond visual imaging, the payload sensors enhance surveillance by gathering critical environmental data. An air quality sensor detects changes in atmospheric conditions that may indicate potential crop stress, while a sunlight sensor assesses light exposure, identifying shaded or overexposed areas that could impact growth. These combined capabilities allow for a multi-layered analysis, providing farmers with a comprehensive understanding of post-weather field conditions.

By seamlessly integrating aerial imaging, sensor-based data collection, and automated processing, the Field Falcon significantly improves the efficiency and accuracy of farm surveillance. It minimizes the time and labor required for post-disaster assessments, reduces the risk of equipment damage, and enables farmers to make faster, data-driven decisions to restore operations. When looking at the vehicle it is composed of various different systems, subsystems, and individual components.

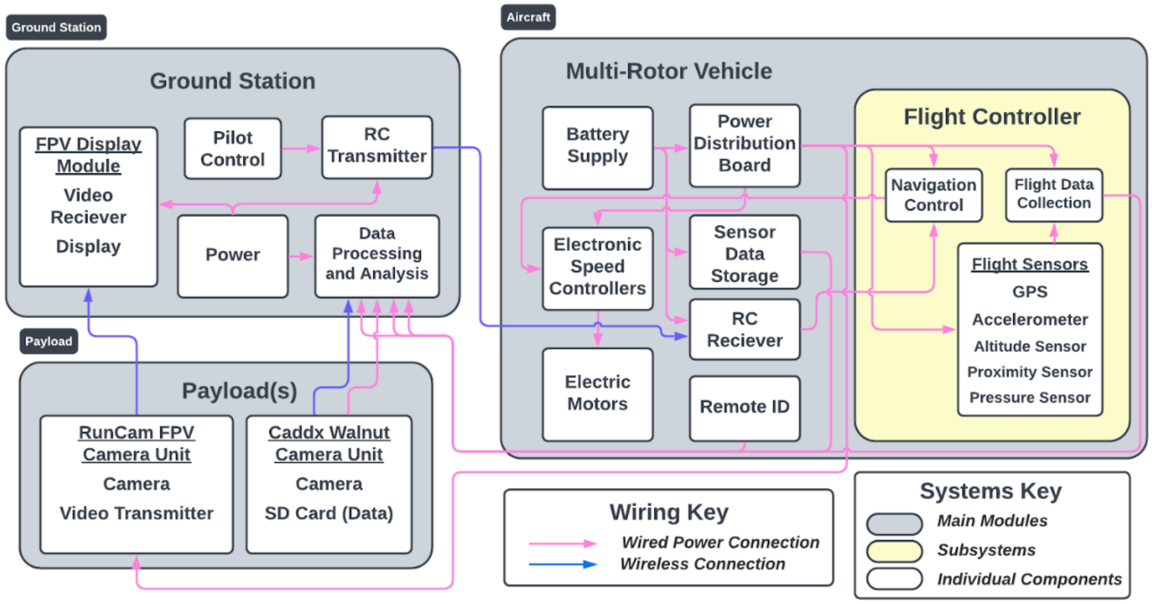

Fig. 2 Functional Block Diagram

Figure 2 details the interconnected subsystems of the Field Falcon. The Field Falcon is separated into three main modules: the ground station, the payload(s), and the multi-rotor vehicle. In the multi-rotor vehicle module or subsystem, the flight controller acts as the central electronic unit. The flight controller is responsible for receiving signals from the ground station through a radio control (R/C) transmitter, as well as sending output functions to the electronic speed controllers (ESCs) and motors. The flight controller also houses multiple on-board sensors, including an accelerometer, an altitude sensor, a pressure sensor, and a GPS. The use of various payload cameras will allow for adequate agricultural data and information to be collected and analyzed. More specifically, the on-board CADDX Walnut camera will allow for the collection of real-time RGB scale images of the field and crop conditions.

III. Final Design Specifications

Fig. 3 Functional Block Diagram

The Field Falcon is designed to survey landscapes in an agricultural context. Utilizing a compact and slim frame design to reduce weight while also incorporating a traditional multirotor configuration to provide a more stable flight, and propulsion mechanisms powered by brushless motors to ensure smooth and even power delivery. Structural elements prioritize lightweight durability, utilizing advanced composite materials to optimize endurance and enhance payload capacity without compromising integrity. Its integrated navigation and control systems offer intuitive handling and high accuracy. This comprehensive approach ensures that the Field Falcon meets the rigorous demands of modern agricultural and environmental applications.

A. Stability And Controls

1. Multirotor Configuration

With the Field Falcon's hexacopter design, it was decided that in order to ensure stability and controllability the drone would utilize a traditional, evenly spaced multirotor configuration where each motor arm is positioned on one corner of the hexagonal body of the drone. For this configuration, the propellers alternate their spinning direction (i.e. half of the rotors spin clockwise and the other half spin counterclockwise). By alternating the direction of the spin, it counteracts any adverse moments made by the propellers, making the drone more stable, as well as being able to adjust the spin rate of each motor to make precise maneuvers.

B. Electronics and Avionics

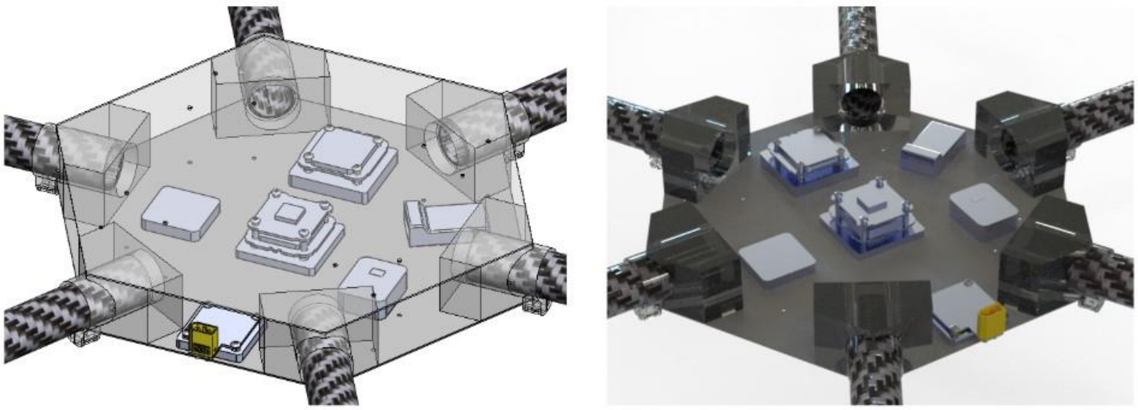

Fig. 4 CAD Model and Rendering of Electronics and Avionics

1. Power System

The electronic components and the propulsion system of the Field Falcon will be powered through the use of a Zeee 10000 mAh 4S Lithium Polymer battery [2]. This battery will allow for the necessary amps and power to be supplied to both the flight controller, as well as the components of the propulsion systems and imaging systems. Regarding battery specifications, the battery has a high discharge rating or "C" rating of 120C, meaning that it can handle a large amount of discharge requirements safely and without rapid battery degradation. Additionally, this battery provides a reduced weight as compared to other battery alternatives, weighing approximately 740 grams (1.63 lb), which is approximately 500 grams (1.10 lb) than 6S batteries with comparable specifications. When selecting the battery, it was vital to ensure that the endurance fell within the range of 10 and 35 minutes of flight time. As a method to calculate this flight time, Eq. (1) was used.

$$Flight\ Time = \frac{(Battery\ Capacity)(Battery\ Discharge\ Rate)(60)}{Average\ Amperage} \quad (1)$$

Upon referencing the performance table for the motor-propeller combination, both a maximum and minimum average amperage was calculated in accordance with thrust generation equivalent to the maximum weight of 10 pounds (4550 g). In addition to average amperage calculation, the discharge capacity rate of the battery, a value of 80% or 0.80 was chosen as this corresponds to the battery's available capacity before falling below the 20% threshold. This threshold is commonly chosen due to the fact that after falling below 20% battery capacity the battery can experience damage or degradation and more rapidly discharge. This yielded flight times of approximately 26 minutes and nine minutes for the lower and upper average amperage draws, respectively.

2. Flight Controller Hardware and Firmware

The Field Falcon will use the SpeedyBee F405 V4 [3] as its on-board flight controller hardware system. Unlike other comparable flight controllers, this hardware comes at a low price point, costing approximately $40. This flight controller features a multitude of on-board sensors, as well as compatibility with up to eight individual motors. The main on-board sensors offered by the controller include a battery level indicator, a built-in barometer and an inertial measurement unit (IMU) or gyroscope. The 4-level LED battery indicator can be used to monitor and check the overall battery health. In regard to how the indicator works, each LED relates to a 25 percent interval or range.

Based on these ranges, 4 LEDs being lit up indicate that the battery is between 75 and 100 percent, this trend continues until only one LED is on meaning that the battery is below 25 percent. Additionally, once below 25 percent the LED will begin blinking or pulsing as an indication that the battery level is below 10 percent. The SpeedyBee F405 V4 has compatibility with three main flight controller firmwares, ArduPilot, BetaFlight, and iNav, however, for this mission in specific ArduPilot has been chosen for the Field Falcon. ArduPilot navigation firmware or software allows for proper control over the Field Falcon during the entire mission plan, including the ability to complete autonomous, waypoint-to-waypoint missions. This firmware offers compatibility with Mission Planner software, allowing for the pilot and or team members to monitor real-time flight parameters, as well as some remote-controlled (R/C) inputs. Some of the flight parameters that can be displayed within the Mission Planner window include altitude, air speed, and battery voltage, in addition to pitch, roll, and yaw rotation or positions.

3. Electronic Speed Controllers (ESCs)

In order to limit the costs associated with ESCs, the Field Falcon will use two different 4-in-1 ESC units. These 4-in-1 ESC units are BL Heli_S 55A 4-in-1 ESC [3] modules. These ESC modules feature four individual sets of motor signal and power pads. Each set of power pads consists of three different soldering surfaces. These power and signal pads allow for the direct connection of the motor signal and power wires to the 4-in-1 ESC modules and therefore the hardware system of the flight controller. In addition to the availability of direct soldering connection points between the motors and ESC units, the 4-in-1 ESC modules feature soldering pads for the direct connection of the battery's power leads. Alongside the soldering pads of the 4-in-1 ESC module, it also offers a heat sink to mitigate and reduce the risks of shorting or overheating. These BL Heli_S 55A 4-in-1 ESCs specifically feature a heat sink that is capable of handling up to 220 amps of current during usage, as well as a maximum threshold of 280 amps of continuous current for ten seconds.

4. Remote ID

The remote ID module is vital to successful design and flight of the Field Falcon. This module is responsible for broadcasting the necessary parameters and defining characteristics of the drone. These characteristics and/or parameters include but aren't limited to drone ID, drone location and altitude, drone velocity, and launch location. The broadcasting of these parameters is required in accordance with both the FAA (Federal Aviation Administration). The Holy Stone Drone Remote ID Module [4] provides the necessary characteristics and capabilities described above. This module is a standalone unit or module that requires no external battery or power source and no external GPS unit. Through the application and bluetooth connection the drone's ID weight, etc. can be entered. Upon entering the necessary information, the drone's remote ID can be broadcasted for other nearby drone users to view.

5. Receiver and Transmitter

To operate the Field Falcon in flight, a FlySky FS-I6X transmitter [5] and a FlySky FS-IA6B [6] receiver will be used. The receiver is directly compatible with the transmitter and features six output channels, enabling proper communication and control of the Field Falcon multi-rotor vehicle. Once the receiver is bound to the transmitter, in-flight communication is established, allowing for full control over movements and the execution of mission plans.

6. GPS

In order to allow for proper tracking and the capacity or capability to complete autonomous missions, the Field Falcon will feature a GPS and/or compass. The GPS will be placed alongside the flight controller and allow for real time tracking of the Field Falcon's location. As mentioned previously, this ability to accurately track the vehicle's location will allow for the use of autonomous mission plans. The GPS used is the BZGNSS BZ-251 GPS [7] from SpeedyBee, which features a 5883 compass. This GPS module and/or unit specifically allows for the direct connection to the SpeedyBee F405 V4 flight controller and consumes minimal space on the drone's frame.

7. Camera

The camera is vital to the successful operation of the Field Falcon. This component provides the capability for FPV (first-person view) with low latency, allowing the operator to maintain precise control during flight. Additionally, the camera captures high-resolution images necessary for post-processing tasks, including generating vegetation indices to assess crop health and identifying hazardous areas such as rocky or muddy terrain. These features are essential for fulfilling the mission objectives and ensuring the Field Falcon performs effectively in its intended applications. To meet the camera requirements, the team has chosen the CADDXFPV Walnut Action Camera [8].

C. Propulsion System

1. Motor

The SunnySky V3506 motor [9] has an individual weight of 84 grams and an individual thrust of 1373 grams. It is rated for a 4-6S lithium polymer battery and 20-30 amp ESC. The motor boasts a maximum efficiency of 16.89 grams of thrust per watt. This 650 KV option can handle a maximum continuous current of 30 amps for 30 seconds and a maximum continuous power of 400 watts.

2. Propeller

The EOLO propeller [10] is constructed from high strength materials such as long carbon fiber filament and nylon PA66 to form carbon fiber reinforced nylon. This material design aids in abrasion and corrosion resistance, and has an extremely low water absorption rate, allowing it to perform in harsh environments. The propeller is 0.15 inches thick and has a hooked tip shape to reduce vortices. This propeller can also handle rotational speeds of up to 8500 RPM, therefore proving to be capable of handling the stress and forces applied by both the motor and drag.

IV. Manufacturing and Fabrication Process

Fig. 5 Finalized Drone Design Excluding Electronics and Motors

The primary objective of the body is to provide structural support to the drone while protecting electronic components. The body consists of two hexagonal carbon fiber plates, each measuring 300 mm in diameter. Both plates were cut from 300x300 mm square carbon fiber sheets using a wet saw in the designated carbon fiber cutting room. These plates are separated by six 3D-printed PETG blocks, positioned at each corner of the hexagon. PETG was selected for its strength and flexibility along with the material's higher compatibility with heat-set inserts compared to ABS. The blocks not only maintain spacing between the plates but also serve as mounting points for the drone’s arms. Each PETG block was printed with 15% infill and six wall loops for added strength. Heat-set inserts were embedded into pre-set holes within the blocks to accommodate M4 screws, which secure them to the top and bottom plates. The blocks were attached to the plates using these M4 screws.

A. Arms

The drone arms are composed of 1-inch diameter carbon fiber tubes, each cut to 12 inches in length using the same wet saw used for the plates. The arms are attached to the PETG blocks via 3D-printed ABS tube clamps. ABS was selected due to its high strength. These clamps were secured within holes inside the blocks using super glue, allowing the arms to be securely mounted while remaining removable for easier storage and transport. The clamps and blocks were made of separate materials to allow for the blocks to remain compatible with heat-set inserts while not compromising the strength of the clamps. Each clamp is sealed at the end to allow for even placement of all six arms, as well as protecting the ends of the carbon fiber tubes from wear.

B. Landing Gear

The landing gear consists of two skids made from the same 1-inch diameter carbon fiber tubing as the arms. The skids are connected to the drone’s body at a 30-degree angle using four 3D-printed ABS tube clamps that screw directly into the carbon fiber base with three M2 screws. The vertical tubes of each skid were cut to be 4.5 inches long, providing the drone with 3.9 inches of clearance, which is then increased to 4.9 inches by the T-connectors. The T-connectors secure the vertical tubes of the skids to the horizontal tubes. These connectors are 3D-printed from PETG, which was selected due to printing issues with ABS for these components. At the end of both horizontal tubes are end caps, which serve primarily as protective covers and balance aids. These end caps are printed from PLA for its lightweight properties. While the primary force holding the tubes in place is friction, M2 screws are used to directly fasten the tube clamps, T-connectors, and end caps to the tubes to prevent slipping.

C. Electronics System

The Field Falcon's main power source, the battery, is mounted on the top carbon fiber plate of the drone and secured with Velcro. To ensure the battery properly powers the entirety of the electronics and avionics, a power distribution board (PDB) is utilized. To efficiently facilitate power distribution across different levels, the PDB is located between the top and bottom plates. For secure connections, the electronic components were soldered directly to either the flight controller or the PDB.

In regard to wiring and the creation of connections between the electronic components, a general wiring diagram was constructed and precisely followed. Additionally, this diagram was broken down into multiple wiring diagrams, each illustrating the connection between two electronic components, including flight controller-to-ESC, flight controller-to-receiver, and flight controller-to-GPS wiring.

When mounting the flight controller and additional electronics, a connection was established between the components and the carbon fiber plate using 3D-printed mounts. After printing, M3 heat-set inserts of varying depths were installed with a soldering iron. These mounts secure the electronics between the two carbon fiber plates using Velcro. This layout provides protection while ensuring easy access for any necessary modifications or repairs.
Overall, this manufacturing approach ensures a lightweight yet robust structure, integrating high-strength carbon fiber components with precisely engineered 3D-printed parts. The modular design allows for easy assembly, maintenance, and future upgrades.

D. Propulsion System

The drone's propulsion system consists of six motors mounted on the ends of the arms. Each motor is attached using the hardware provided by the manufacturer and is secured to a PETG-printed motor mount. The motor mounts feature the same tube clamp design as the body attachments, allowing them to be securely affixed to the carbon fiber arms. PETG was selected for the motor mounts due to its high strength and melting temperature compared to PLA, along with its lower tendency to deform when heated compared to ABS. ABS was further ruled out for the motor mounts due to issues such as deforming and discoloration when exposed to direct sunlight for long periods. The motors drive two-blade propellers, specifically "EOLO Carbon Fiber Reinforced Nylon UAV Propellers 13x5 in." These propellers were chosen for their optimal thrust-to-weight ratio when paired with our motors. They are attached to the motors using the hardware provided.

V. Conclusion

The Field Falcon serves as the next step towards advancing safe, efficient, and cost-effective agricultural practices. Through the utilization of high-resolution image processing and data collection, the Field Falcon will provide farmers with accurate data on the conditions of their land following severe weather conditions, allowing them to identify hazardous conditions and obstacles, and make informed decisions to protect both the crops and equipment.

As technology progresses, it is imperative that agricultural practices are not left behind but are instead improved alongside of it. The Field Falcon not only provides an immediate solution for post-disaster field assessments but also lays the foundation for further advancements in precision agriculture. With potential future enhancements such as AI-driven analytics, multispectral imaging for advanced crop health monitoring, and integration with automated farm management systems, the Field Falcon can continue to revolutionize agricultural efficiency and sustainability.

By addressing key challenges such as affordability, scalability, and regulatory compliance, the Field Falcon demonstrates how modern UAV technology can bridge the gap between innovation and real-world applications. As adoption of autonomous aerial systems increases, the Field Falcon stands poised to play a pivotal role in the future of farming, ensuring that agricultural operations remain resilient, data-driven, and prepared for the evolving demands of food production in a changing world.

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References

[1] “Get Started with NRCS,” Natural Resources Conservation Service
Available: https://www.nrcs.usda.gov/getting-assistance /get-started-with-nrcs.

[2] Zeee 4S LiPo Battery 10000mAh 14.8V 120C EC5." Zeee Battery.
Available: https://zeeebattery.com/products/zeee-4s-lipo-battery-10000mah-14-8v-120c-ec5.

[3] Kofler, S., Beer, G., Carapinha, I., and Juancr, “SpeedyBee F405 V4 BLS 55A 30x30 FC&ESC Stack,” Speedy Bee
Available: https://www.speedybee.com/speedybee-f405-v4-bls-55a-30x30-fc-esc-stack/.

[4] “Holy Stone Drone Remote ID Module,” Holy Stone
Available: https://store.holystone.com/products/holy-stone-drone-remote-id-module.

[5] “FS-I6X,” FlySky Available: https://www.flysky-cn.com/fsi6x.

[6] “IA6B-Specifications,” FlySky Available: https://www.flysky-cn.com/ia6b-canshu.

[7] Meier, S., Massimo, B., Marcello, K, J., Bp, and Jensen, D., “BZGNSS BZ-251 GPS with 5883 Compass,” SpeedyBee
Available: https://www.speedybee.com/bzgnss-bz-251-gps-with-5883-compass/.

[8] “Caddx Walnut Action Camera*”*, Available: https://caddxfpv.com/products/caddx-walnut-action-camera.

[9] “SunnySky V3506 Motor.” *SunnySky USA,* Available: https://sunnyskyusa.com/products/sunnysky-v3506-motor.

[10] “EOLO Carbon Fiber Reinforced Nylon UAV propellers 13x5 inch,” *SunnySky USA* Available: https://sunnyskyusa.com /products/eolo-cn13-5-prop?srsltid=AfmB+OoruiunZHxyYIP3xP_1DKGmq2hOhfAYSEoz4W9LPlebfl76QU71.

Appendix

A. Design Requirements

The design requirements listed below are sub-requirements of the functional requirements. These additional requirements are specific missions selected by Team Future Flyers of America (FFA).

FR 1.0: The Field Falcon shall have a maximum all-up weight of 10 pounds.

- **DR 1.1:** The propulsion system shall provide thrust exceeding the total weight of the aircraft.
  - **Motivation:** Sufficient thrust is required to achieve lift-off and maintain stability during flight.
  - **Verification:** Thrust will be measured based on manufacturer data and validated through flight tests.
- **DR 1.2:** The airframe shall not exceed 5 pounds.
  - **Motivation:** A lighter airframe allows more weight for the payload and other systems.
  - **Verification:** The airframe will be weighed independently before full assembly.
  - **DR 1.2.1:** The landing gear shall support the UAS's weight during standard landings.
    - **Motivation:** Durable landing gear is needed to protect the payload and prevent damage.
    - **Verification:** Landing gear strength will be verified during ground testing.

FR 2.0: The Field Falcon shall maintain real-time communication with the ground station.

- **DR 2.1:** The UAS shall establish a dedicated communication channel to avoid interference.
  - **Motivation:** A stable communication channel is essential for uninterrupted control.
  - **Verification:** The channel's stability will be tested in both laboratory and field conditions.
  - **DR 2.1.1:** A telemetry handshake shall be established upon startup.
    - **Motivation:** Ensures the connection between the UAS and the ground station is active before takeoff.
    - **Verification:** Handshake verification will occur during initial testing.

FR 3.0: The Field Falcon shall use a battery as the power source.

- **DR 3.1:** The battery shall support at least 10 minutes of flight.
  - **Motivation:** Ensures the UAS can complete a standard mission duration.
  - **Verification:** Battery life will be measured through timed test flights.
  - **DR 3.1.1:** The battery shall power all critical systems, including propulsion and communication.
    - **Motivation:** Essential for sustained operations during flight.
    - **Verification:** Power distribution will be verified through system testing.

FR 4.0: The Field Falcon shall adhere to size restrictions, fitting within a 5 ft x 3 ft x 2 ft space when disassembled.

- **DR 4.1:** The UAS shall be modular and capable of partial disassembly to fit within the specified dimensions.
  - **Motivation:** Size constraints allow easy transport and meet customer specifications.

- **Verification:** The UAS dimensions will be measured and validated during assembly tests.

FR 5.0: The Field Falcon shall broadcast Remote ID as required by FAA regulations.

- **DR 5.1:** The Remote ID signal shall be detectable from a minimum distance of 400 feet.
  - **Motivation:** Ensures the UAS can be identified within the operational range.
  - **Verification:** Signal strength will be measured in line-of-sight tests.

FR 6.0: The Field Falcon shall be operable and assembled by no more than two persons.

- **DR 6.1:** Assembly time shall not exceed 5 minutes.
  - **Motivation:** Quick setup is crucial for timely mission initiation.
  - **Verification:** Assembly tests will be conducted under simulated mission conditions.

FR 7.0: The Field Falcon shall demonstrate stability in various agricultural environments and under standard flight conditions.

- **DR 7.1:** The UAS shall hover at a fixed point for at least 30 seconds.
  - **Motivation:** Hovering capability indicates control precision and system balance.
  - **Verification:** Hover tests will be conducted in a controlled environment.

FR 8.0: The Field Falcon shall stay within a budget of $1,000.

- **DR 8.1:** The UAS frame and components shall be sourced cost-effectively to stay under budget.
  - **Motivation:** Cost-effective sourcing is essential to allocate resources for mission-critical systems.
  - **Verification:** Parts list and budget report will be reviewed during financial audits.
- **DR 8.2:** The UAS shall not be a modified version of an existing multi-copter.
  - **Motivation:** A custom design ensures the project meets unique requirements and fosters innovation.
  - **Verification:** All components will be inspected and documented to confirm they are custom or new designs, rather than modifications of pre-existing multi-copter.
  - **DR 8.2.1:** The airframe shall be designed and manufactured in-house.
    - **Motivation:** In-house design and manufacturing contribute to project originality and allow for specific customizations.
    - **Verification:** Design files and manufacturing documentation will be reviewed to confirm in-house creation.
  - **DR 8.2.2:** System components, such as propellers and motors, may be purchased off the shelf.
    - **Motivation:** Some specialized components are beyond the project's design scope and can be sourced externally to meet budgetary and time constraints.
    - **Verification:** A parts list of off-the-shelf components will be maintained, detailing their cost and source.

FR 9.0: The Field Falcon shall incorporate modular and reconfigurable components for mission adaptability.

- **DR 9.1:** The payload system shall support multiple configurations.
  - **Motivation:** Flexibility in payload allows the UAS to carry different sensors or equipment.
  - **Verification:** Payload configuration will be verified during mission-specific testing.

B. Standard Operating Procedures

1. **Pre-Flight Preparation**
   - Internal team meeting to set a desired flight or mission plan. Details of the mission plan include desired flight time and location.
   - Inform the pilot (whether internal or external) two days in advance of the test flight. Inform them of the desired flight time, location, and flight plan.
   - Check weather conditions and assess the risks of any possible adverse weather conditions. This includes preparing any necessary failsafe or solutions to possible problems.
   - Charge the primary and secondary batteries in the Design Lab days prior to the flight test. This should be done in the range of one to three days prior to the flight test to ensure charging availability.
   - Arrive two hours prior to takeoff. Ensure the battery is fully charged and all necessary tools, kits, and parts on the "Flight Packing List" are collected.
2. **On-Site Preparation**
   - Remove the drone from the transport vehicle to prepare for assembly.
3. **Electronics Configuration:**

- Verify that the power distribution board (PDB) is secured to both its mount and the drone's body using fasteners and Velcro.
    - Ensure that the flight controller stack (flight controller and 4-in-1 ESC module) is secured to both its mount and the drone's body using fasteners and Velcro.
    - Check that the individual 4-in-1 ESC module is secured to both its mount and the drone's body using fasteners and Velcro.
    - Ensure that the GPS module is secured to the drone's body using Velcro.
    - Ensure that the receiver is secured to the drone's body using Velcro.
    - Verify that the Remote ID module is secured to the drone's body using Velcro.
4. **Motor Configuration:**
    - Connect individual motors to the 4-in-1 ESC module using bullet connectors attached to both the 4-in-1 ESC modules and motors.
5. **Battery Installation:**
    - Measure battery voltage with a multimeter and report the voltage on the Flight Test Card.
    - Verify that the battery voltage exceeds 14.8 V, as this is the voltage desired for flight.
    - Connect the battery to the frame of the drone's body using Velcro. Ensure that this connection is stable and secure.
    - Connect the battery to the power distribution board (PDB) and therefore the avionics and electronics.
6. **Arm Installation:**
    - Insert arms into the individual arm mounts on the drone's central body. Tighten the screws and ensure minimal arm movement.
    - Ensure that the motors and motor mounts are secured to the arms.
7. **Camera Installation:**
    - Verify that the camera is securely placed within the camera mount and oriented in the correct direction (proper mission configuration).
8. **System Functionality:**
    - Verify that Remote ID is being broadcast.
    - Arm the drone and ensure that the flight controller and motors respond to transmitter inputs, specifically from the throttle.
9. **Flight**
    - Clear the takeoff area to ensure safety. Clearance should be at least 15 feet from the drone.
    - Launch the drone and lift it to a stable hover.
    - Complete mission plan set up prior to flight.
    - Return the drone to the ground, ensuring no observers or operators are within 15 feet of the landing zone.
    - Return the throttle position to zero on the transmitter and disarm the drone.
    - Disconnect the battery from the PDB.
10. **Post Flight Data Processing:**
    - Remove the SD card from the CADDX Walnut Camera and transfer images to a personal laptop for image processing to be completed.
    - Run a Python script and code to generate various vegetation indices (VI, GLI, VARI).
11. **Inspection and Storage:**
    - Inspect all electrical components and connections to ensure they are secure and comparable to pre-flight conditions.
    - Return drone components and additional tools to the Design Lab.