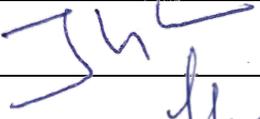
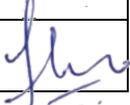




NEXTLEAP AERONAUTICS

Leap A10 Agricultural UAS Flight Manual

NLA-AGU-A10-FLT-MNL
Version: 7

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NEXTLEAP AERONAUTICS



Leap A10 Agricultural UAS Flight Manual

Version: 5

Published by: NextLeap Aeronautics Pvt. Ltd.



It is mandatory to read safety and security instructions before using the UAS

Safety & Security Instructions

Do's

1. As per MoCA, DGCA regulations only licensed and company trained pilots are allowed to operate the aircraft. Violation of this rule is a criminal offence.
2. The operator and pilot are strongly advised to read, understand and remember all applicable documents. They are helpful throughout the life cycle of the UAS.
3. It is pilot's responsibility to maintain the safety and security of UAS operations in full compliance with DGCA regulations, organization SOPs and manufacturer provided manuals, checklists and SOPs.
4. Exercise caution while handling, connecting and disconnecting batteries to avoid touching the terminals. There is a risk of electrical shock.
5. Respect the battery voltage operating limits. Not respecting battery level alerts and violating safe usage limits can result in battery damage, crash of the UAV and fire.
6. Caution must be exercised during take-off, landing phases and loitering mode, do not leave the aircraft in hover flight with full payload for long periods. This can overheat the motors and degrade battery performance over long term. Monitor the GCS for alerts.
7. The UA can be armed in Auto mode only after the GNSS HDOP has dropped below 2.0 and it has acquired stable 3D position lock.
8. The UA can be armed in Loiter mode only after the GNSS HDOP has dropped below 2.0 and it has acquired stable 3D position lock.
9. The UA may circle after take-off. This may happen due to bad compass offsets set during the compass calibration process.
10. User must strictly adhere to the 10L marking limit on the tank. Overfilling the tank is a safety hazard.

11. Use protective equipment such as gloves and safety goggles while handling concentrated agrochemicals.
12. When not in use, store the RC Unit in power off mode.
13. Before flying any mission ensure that battery level indicator LEDs indicate fully charged battery state.
14. Google maps may not show a recent image of the area, so always survey and visually inspect for obstacles and include them in the plot for safe operation.
15. Fly cautiously under windy conditions, follow SOP.
16. Allow the motors and battery to cool down for five minutes before performing checks.
17. Depending on the type of payload dispensed, clean the UA before inspection to limit exposure to chemicals. This will also prolong the life of UA components and reduce maintenance costs arising due to chemical corrosion.
18. The UA lacks shock absorbers on the landing gear structure. Reduce the throttle gently to zero when UAS at its terminal stage of landing. The pilot must exercise caution and land the aircraft gently till touchdown. After landing, inspect the landing gear for any dent, damage, kink, decay, crack etc.

Don'ts

1. Never operate the aircraft beyond defined operational limits.
2. Do not manipulate security measures, open tamper proofing, it will lead to violation of operating procedure and invalidate warranty.
3. Never operate the aircraft beyond certified operational limits.
4. Do not open tamper proofing, it will lead to violation of operating procedure and invalidate warranty.
5. Do not fix a leaking tank full of agrochemicals. Drain the contents into another container before troubleshooting.

6. User must not attempt replacement or removal of tank at any point of time. The tank replacement or removal must be done by the OEM only.
7. Do not move the mobile phone/tablet more than 5 meters from the RC.
8. Do not create mission plan and set waypoints outside the geofence.
9. Do not push the battery and continue to fly below critical voltage. This can result in permanent damage to the battery, violation of operating procedure and invalidity of warranty.
10. Do not operate the UAS at night, it is not certified for night operations.
11. The Bluetooth has a limited range of a few meters. Never take the phone more than five meters away from the RC. If the UA is in flight, loss of connection between the RC and GCS Application will trigger RTL.
12. Don't use the RC if the unit is heating up too much, there is smoke during operation or while charging the unit.

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1. Introduction

This document is the Flight Manual (FM) for agricultural Unmanned Aircraft System (UAS). The UAS is designed with the objective of supporting agricultural spraying operations for pesticides, fertilizers, automating workflows and supporting analytics for operations. The FM provides a brief on the UAS architectural elements, the Unmanned Aircraft (UA) subsystems, the UA Control System (GCS), operational limits, aircraft setup, pre-flight checks, post flight checks, handling and storage operations.

The UAS operation is subject to Ministry of Civil Aviation (MoCA), Directorate General of Civil Aviation (DGCA) regulations. Therefore, it is mandatory to follow the training program prepared by NextLeap Aeronautics, read this FM, Troubleshooting Manual and follow the prescribed procedure before handling and flying the UA. General and specific precautions have also been provided on the FM and it is the operator's responsibility to observe and follow them meticulously.

The UAS design incorporates several safety and security features for the system, operators and the environment in compliance with DGCA certification requirements. The UA operations are monitored. It is mandatory to follow and fly the UA within the prescribed framework. Any unlawful usage is a punishable offence under the law. The operator is responsible for ensuring own & others, environmental, infrastructure and safety & security of the system without exception.

1.1 Abbreviations

DGCA	Directorate General of Civil Aviation
EKF	Extended Kalman Filter
FUS	Firmware Update Software
GCS	Ground Control Station
GNSS	Global Navigation Satellite System
LED	Light Emitting Diode
MMC	Mission Management Computer
MoCA	Ministry of Civil Aviation
OEM	Original Equipment Manufacturer
PWM	Pulse Width Modulation
RPM	Rotations Per Minute
RC	Radio Control
RTL	Return to Launch
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UI	User Interface
UID	Unique Identifier

1.2 Definitions

3D Position

3D position refers to the position of aircraft in 3D space specified by latitude, longitude and altitude above ground level.

Battery

A generic term for one or more cells electrically connected in series and/or parallel with or without monitoring and protection circuitry for charging and discharging.

Charging

The application of electric current to battery terminals, which results in a Faradic reaction that takes place within the battery that leads to stored electro-chemical energy.

Command and Control (C2) Link

The data link between the UA and the remote pilot station for the purpose of managing the flight.

Controlled Airspace

Airspace of defined dimensions within which air traffic control service is provided in accordance with the airspace classification. Controlled airspace is a generic term which covers ATS airspace Classes A, B, C, D and E as described in ICAO Annex 11, Para 2.

Electric Shock Hazard

A potential for exposure of persons to hazardous voltage circuit through direct contact from openings in protective enclosures and/or insufficient insulation between hazardous voltage circuits and accessible parts.

Electrical System

The system of components, circuits, and related elements of the UAS. The system comprises the battery system, motors and motor controllers, protection/safety circuits addressing electrical, fire and explosion hazards, and associated on board electronics.

Explosion

A violent release of energy that produces projectiles or an energy wave from the UA and results in the UAS' contents being forcibly expelled through a rupture in the enclosure or casing.

Fire

The sustained combustion of the UAS' contents as evidenced by flame, heat and charring or other damage of materials.

Fully Charged Battery

A battery that has been charged per the manufacturer's specifications to its full state of charge (SOC).

Fully Discharged Battery

A battery, which has been discharged, according to the manufacturer's specifications, to its specified end of discharge voltage (EODV).

Geofencing

Geofencing is a firmware feature in a software program that uses the global positioning system to keep the UA within defined geographical boundaries.

Inspection

Inspection describes the regular checking of a product to make sure it meets specified criteria. Fire extinguishers, for example, need regular inspections to ensure they are safe for use. Examination of a product, process, service, or installation or their design and determination of its conformity with specific requirements or, based on professional judgment, with general requirements.

Operator

A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Payload

All components of equipment on board the unmanned aircraft that are not needed for the flight or its control. Its transport aims exclusively to fulfil a specific mission.

Remote Pilot

A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time.

All UA pilots are Remote Pilots.

Restricted Area

The airspace of defined dimensions above the land areas or territorial waters of India within which the flight of aircraft is restricted.

Prohibited Area

Airspace of defined dimensions, above the land areas or territorial waters of India within which the flights are not permitted at any time under any circumstances.

Segregated Airspace

The airspace of specified dimensions allocated for exclusive use to a specific user(s).

Unmanned Aircraft (UA)

An aircraft, which is intended to operate with no pilot on board.

Unmanned Aircraft System (UAS)

An aircraft and its associated elements, which are operated with no pilot on board.

1.3 Document Legends



This symbol indicates a situation or condition in which the pilot is required to exercise caution to minimise and/or eliminate exposure to safety incident.



This symbol indicates a situation or condition in which attention is paramount and user/pilot must not violate specified guidelines and rules specified in the documentation or MoCA regulations.



This symbol indicates a procedural note for the pilot.



This symbol indicates recommendation to the pilot for efficiency and safety risk reduction.

1.4 Applicable Documents

Following documentation is not part of flight manual as they are not relevant to flying the UA. They are ground based procedures, so cannot be part of flight manual. They are however important to handling, maintenance, care of the UAS and its components. It is an obligation on the part of operator to follow procedures described in the documents in following sections.



The operator and pilot are strongly advised to read, understand and remember all applicable documents. They are helpful throughout the life cycle of the UAS.

1.4.1 Logistics and Disposal

The operator is advised to refer and thoroughly read Leap A10 Logistics & Disposal Manual (NLA-AGU-A10-LOG-MNL.pdf). This manual describes the procedure for handling, storage, transportation and disposal of UAS.

1.4.2 Flight Logbook

The operator is advised to refer and thoroughly read the Leap A10 Agricultural UAS Flight Logbook (NLA-AGU-A10-FLT-LBK.pdf). This flight logbook is to be filled before and after each flight. It is mandatory to maintain all records of operations as per DGCA regulations.

1.4.3 Battery Charging Procedure

The operator is advised to refer and thoroughly read the Leap A10 UA Battery Charging Procedure (NLA-AGU-A10-BAT-CHG-SOP-3.0.pdf). The operator/pilot must follow the battery charging procedure as described in the referenced manual.

1.4.4 Battery Logbook

The operator is advised to refer and thoroughly read the Leap A10 Agricultural UAS Battery Logbook (NLA-AGU-A10-BAT-LBK.pdf). The operator/pilot must record and maintain the full battery charging records as per format in the referenced document.

Leap A10 Agricultural UAS Battery Logbook



2. Battery Maintenance Log

Battery Serial Number:																		
Manufacturer's Serial Number:																		
Sr. No.	Date	Charging Mode	Start Time	Initial Voltage (V)	Initial Individual Cell Voltages (V)					Duration (minutes)	Final Voltage (V)	Final Individual Cell Voltages (V)					Name of Operator	Signature
1																		
2																		
3																		

Figure 1: Battery Charging Logbook Template

The details of the table and data to be recorded thereof are described in the Battery Logbook.

1.4.5 GCS Software Process

The operator is advised to refer and thoroughly read the Leap A10 Agricultural GCS Software Installation Procedure (NLA-AGU-A10-GCS-SWR-PRS.pdf). The operator/pilot must read the GCS software download and installation manual. The GCS Application usage procedure is covered in this Flight Manual.

2. System Introduction

2.1 UAS Architecture

The Unmanned Aerial System (UAS) is comprised of two segments: UA in the air segment and the Ground Control Station on the ground segment. Figure 2 below presents the UAS (see definition) architecture elements and human participants in the system. The following section presents a brief overview of the architectural blocks.

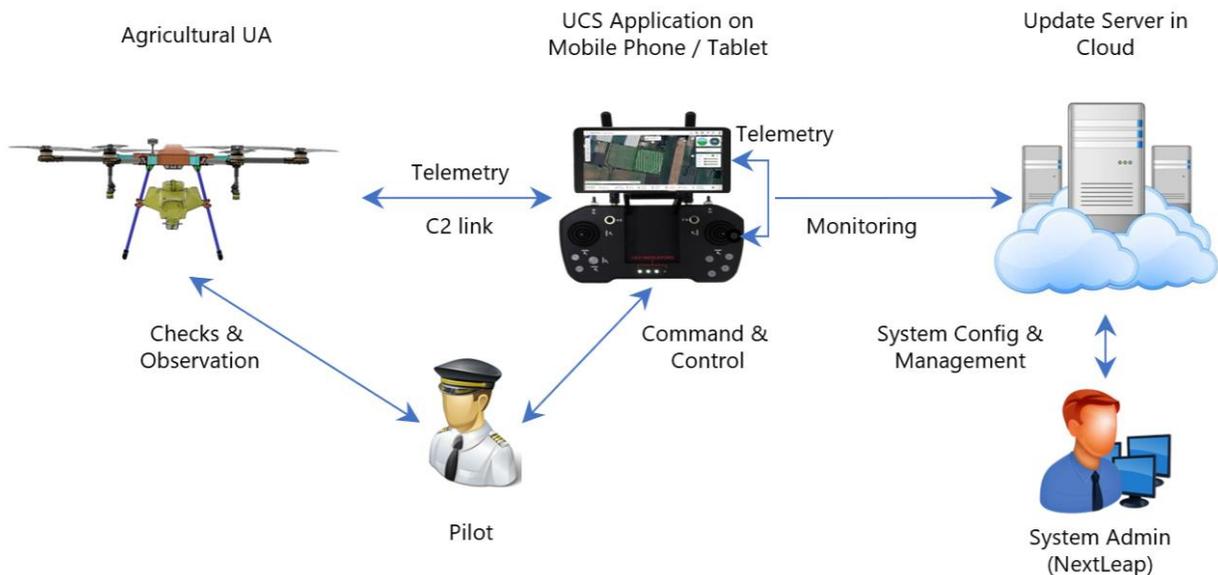


Figure 2: UAS Architecture

2.2 Architecture Description

2.2.1 Agricultural UA

The UA is a remotely piloted hexa-UA. The UA hosts and integrates several electrical, mechanical and electronic subsystems to deliver agricultural payload while respecting regulations and functional constraints as defined by the specifications. The UA hosts the Mission Management Computer which is secured through hardware and software security measures. More details on the UA are provided in section 3. The pilot controls the UA using a Radio Control or the GCS Application on the Mobile Phone.

2.2.1.1 UA Specification

Parameter	Data
UAS Category	Rotorcraft
UAS Sub-category	RPAS
Class	Medium
Empty Weight	Refer section 2.2.1.3
Maximum Take Off Weight (MTOW)	27.51 kg
Max Dimensions (L x B x H)	2026 x 1822 x 716.4
Operational Speed	2.5 m/s
Max Speed	10 m/s
Wind Resistance	<= 5 m/s (in flight)
Maximum operating altitude	25 m above ground
Propulsion type	Fully Electric
Propulsion Configuration	VTOL + Cruise
Launch & Recovery	Vertical Take-off and Landing (VTOL)
Payload	10L
Ground Control Station	RC Unit, Mobile Phone ^[1] , GCS Application ^[2]
RC Communication Link	2.4GHz, 20km
Flight Modes	Auto, Loiter and RTL
Endurance	22 minutes 22 seconds

Table 1: Agricultural UA Specification

[1] Mobile phone is not supplied with the UA. The operator must arrange it.

[2] GCS Application must be downloaded from the Google Play Store. The name of the application is "AeroGCS Green" OR Scan the QR code below.



2.2.1.2 Dimensions

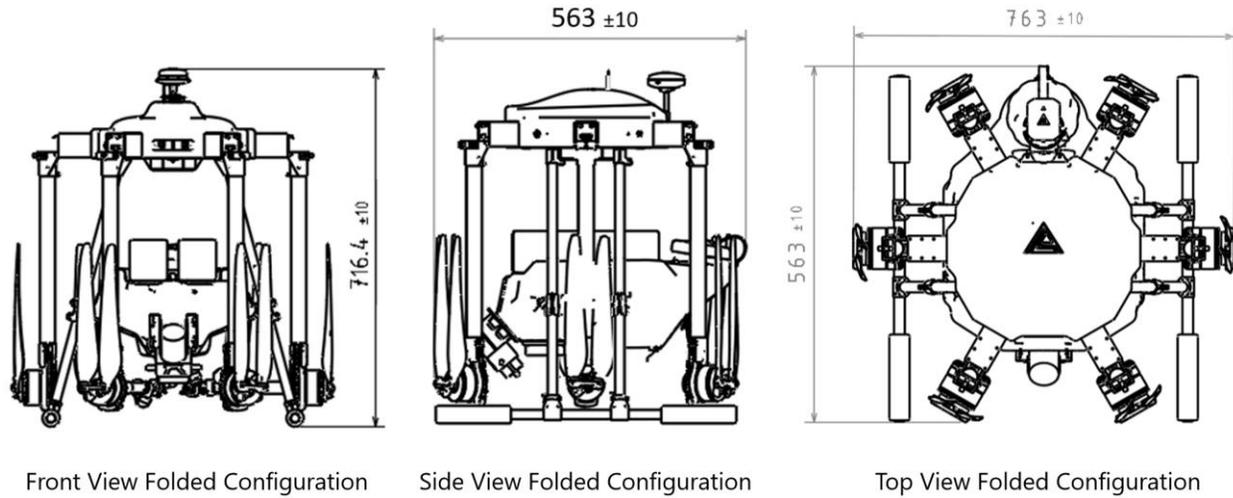


Figure 3: Leap A10 Folded Dimensions

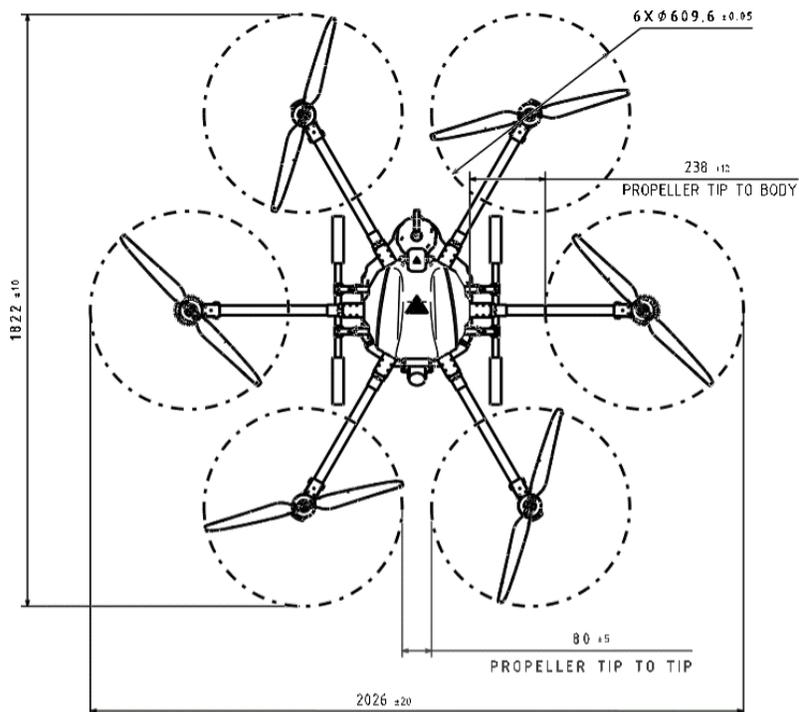


Figure 4: Leap A10 Fully Deployed Dimensions

2.2.1.3 Weight

Description	Nominal value(kg)
Mass without battery and without payload	9.69
Mass of the batteries	5.32
Mass with integrated battery, but no payload	14.92
Mass with batteries, pump, tank and spraying equipment (Flat Jet)	17.17
Mass with batteries, pump, tank and spraying equipment (Centrifugal Jet)	17.23

Table 2: Different Weights of the UA

2.2.1.4 Operational Limits

The UA shall be operated respecting following design limits:

Parameter	Limiting Value
Max Speed	10 m/s
Wind Resistance	<= 5 m/s (in flight)
Maximum operating altitude	25 m above ground
Maximum payload	10 L
Maximum take-off mass	27.51 kg
Maximum endurance with full payload	22 mins 22 sec
Maximum positive pitch angle	20°
Minimum negative pitch angle	-20°
Maximum positive roll angle	20°
Maximum negative roll angle	-20°
Maximum obstacle detection range	20 m
Maximum flight range	1.5 km
Maximum RTL altitude	24 m
Maximum RTL speed	5 m/s

Table 3: Operational Limits



Never operate the aircraft beyond defined operational limits.

2.2.1.5 Firmware and Parameter Updates

2.2.1.5.1 Firmware Update

The firmware is secured against remote updates, on-field updates through hardware and software tampering avoidance mechanisms. The system does not support on-field or operator side firmware updates. Firmware updates can only be performed by NextLeap Aeronautics' premises by appointed staff in secure environment.



Do not manipulate security measures, open tamper proofing, it will lead to violation of operating procedure and invalidate warranty.

2.2.1.5.2 Non-Modifiable Parameters

The operational limit parameters listed in section 2.2.1.4 and other aircraft performance related parameters cannot be modified by the user as no application, tool, procedure is provided for this operation.

2.2.1.5.3 Modifiable Parameters

The pilot plans field operations. This requires setting up a few parameters within defined range. Sometimes, the pilot will need to perform sensor calibrations, the calibration parameters will be determined by the UA and set automatically. Refer section 4. Ground Control Station (GCS) to know more about mission planning and parameter setting operations.

2.2.2 Ground Control Station (GCS)

Ground Control Station (GCS) is the complete set of ground-based hardware and software systems used to control Unmanned Aircraft (UA) as shown in Figure 5: Ground Control Station. The GCS used by NextLeap Aeronautics consists of a Radio Control (RC) Unit, Mobile Phone and a GCS application.

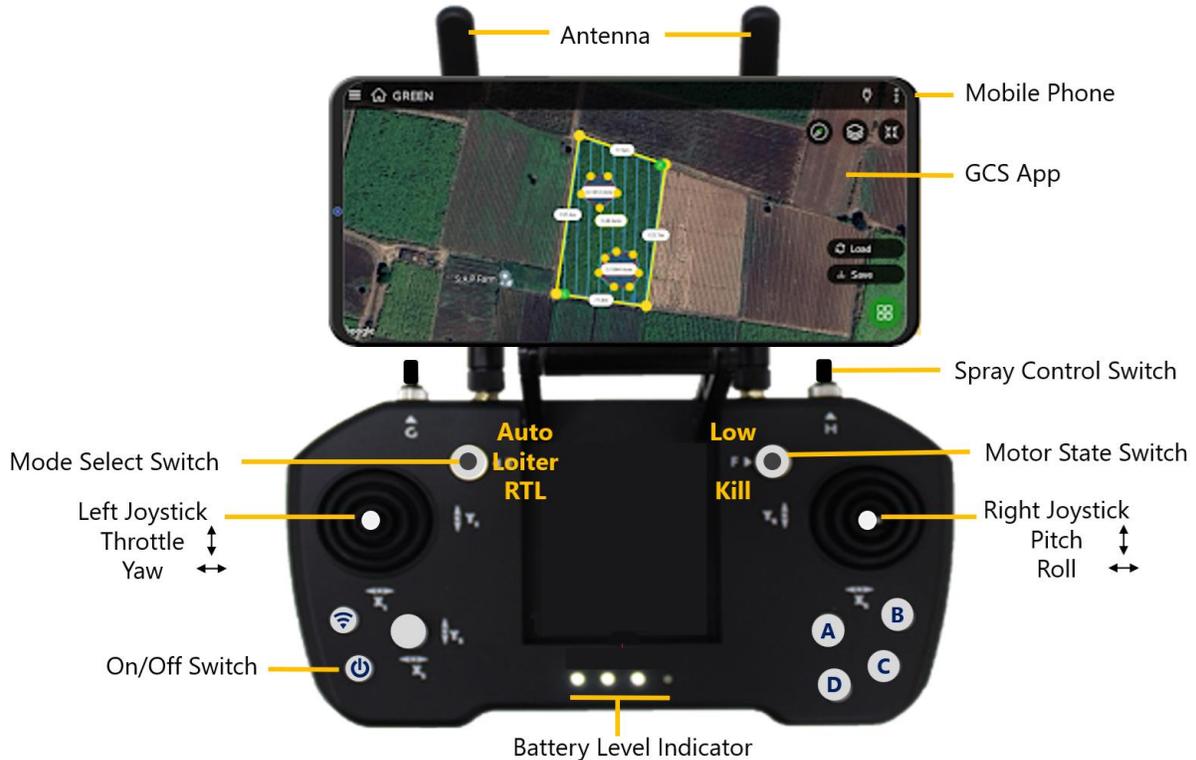


Figure 5: Ground Control Station

1. **The Radio Control Unit:** The RC unit houses the joysticks, the quick access buttons, LED indicators, telemetry transceiver, a Bluetooth device and the 2.4GHz transmitter for command and control. The Pilot controls the manual flight functions with joysticks and quick access buttons, which are used to switch flight modes.
2. **Mobile Phone:** The mobile phone hosts the GCS application. It is also connected to the RC via a Bluetooth channel to receive video and telemetry data. The video and data are displayed on the GCS application. The location and Bluetooth function must be turned on to use the GCS application and connect the phone/tablet to the RC.
3. **GCS Application:** The GCS application is a drone mission planning and operations management software. GCS allows pre-flight checks and pre-arming checks to ensure safety. The GCS application is described later in the document.

2.2.2.1 GCS Specification

Parameter	Data
RC Name	T12 Transmitter
Number of channels	12 channels
Frequency	2.400-2.4833GHz
Modulation	FHSS
Maximum Range	20 km
Locked Range	1.5 km
Weight	0.560 kg
Dimension (L x B x H)	225mm x 123mm x 35mm
Working voltage	3.7V (1s Li-ion)
Working Current	130 mA
Duration	25 hours
Battery Capacity	4000 mAh
Charging	Micro-USB port

Table 4: RC Unit Specifications

2.2.3 Update Server

The Update Server allows secure configuration management, data collection and relay to required external interfaces to required organizations and stakeholders. The Update Server is a very important function of the overall system where it holds the latest firmware binaries. Update server helps to manage all binaries of various signed firmware and manages all authentication of GCS software before allowing connection. It securely communicates with GCS system and helps to upgrade firmware securely using digital certificates.

2.2.4 System Admin

This is the operator of the cloud-based Update Server. The System Admin follows a standard operating procedure for performing requested updates and management of data in the cloud.

2.2.5 Pilot

The Pilot performs UA operations in the field and provides feedback on operations and to maintenance team for repairs. The Pilot uses the RC and GCS application to perform mission.



It is pilot's responsibility to maintain the safety and security of UAS operations in full compliance with DGCA regulations, organization SOPs and manufacturer provided manuals, checklists and SOPs.

2.3 Testing & Certifications

- The UA is certified at NABL accredited lab for following environmental operating conditions for temperature and humidity:
 - Cold test as per IEC60068-2-1 at minus 10°C for 4 hours.
 - Dry heat test as per IEC60068-2-2 at 55°C for 4 hours.
 - Damp test as per IEC60068-2-78 at 40°C, 93% RH for 16 hours.
- The UA is certified as per IEC 60068-2-27 at NABL accredited lab. The UA was subjected to 3 shocks of 5g for 30ms, half sine, in all three axes.
- The UA is certified at NABL accredited lab for EMC and successfully demonstrated compliance to Level 2 tests as per IEC 61000-4-3.
- The UA lacks any kind of Ingress Protection; it is not IP rated.
- The UA is not certified for night operations as it lacks necessary equipment and qualification.
- The UA is not certified to be operated in HIRF environments.



Never operate the aircraft beyond certified operational limits.

3. Leap A10 Agricultural Unmanned Aircraft

This section explains the aircraft construction in brief for the general awareness of the pilot for understanding and handling purposes.

- Structure
- Electrical System
- Propulsion System
- Navigation System
- Flight Control System
- Communication System
- Payload

3.1 Construction

All structural components of aircraft are designed respecting requirements in the DGCA certification document. The structure is composed of several subassemblies made from carbon fibre, metal, plastic parts joined by screws and appropriate glue. Some of these parts are removable. For example, the spraying subassembly needs to be removed for stowing and storage. The structure has been subjected to shock and vibration testing by NABL accredited labs to assure that the design meet needs of use, handling and transportation.



Figure 6: Leap A10 Agricultural Unmanned Aircraft

3.1.1 Primary Structural Elements (Critical Components)

The primary structural elements are listed below (Class 1). All the Primary Structural Elements are also critical components

No.	Name	Part No	Quantity	Material
1	Carbon Fiber Tube	NL_AGU_A10_1011	6	Carbon Fiber
2	Carbon Fiber Tube Rectangular	NL_AGU_A10_1012	6	Carbon Fiber
3	Folding Mechanism	NL_AGU_A10_FM0001	6	Aluminium 6061 T6
4	Landing Gear Tube	NL_AGU_A10_4001	4	Aluminium 6061 T6
5	Landing gear skid tube	NL_AGU_A10_4003	2	Carbon Fiber
6	Landing gear mount	NL_AGU_A10_4004	4	Aluminium 6061 T6
7	Landing gear tank mount	NL_AGU_A10_4005	4	Aluminium 6061 T6
8	Bottom Plate	NL_AGU_A10_2021	1	Carbon Fiber
9	Top Plate	NL_AGU_A10_2022	1	Carbon Fiber

Table 5: Primary Structural Elements List



The UA lacks shock absorbers on the landing gear structure. Throttle must not be suddenly reduced to zero when UAS at its terminal stage of landing. The pilot must exercise caution and land the aircraft gently till touchdown. After landing, inspect the landing gear for any dent, damage, kink, decay, crack etc.

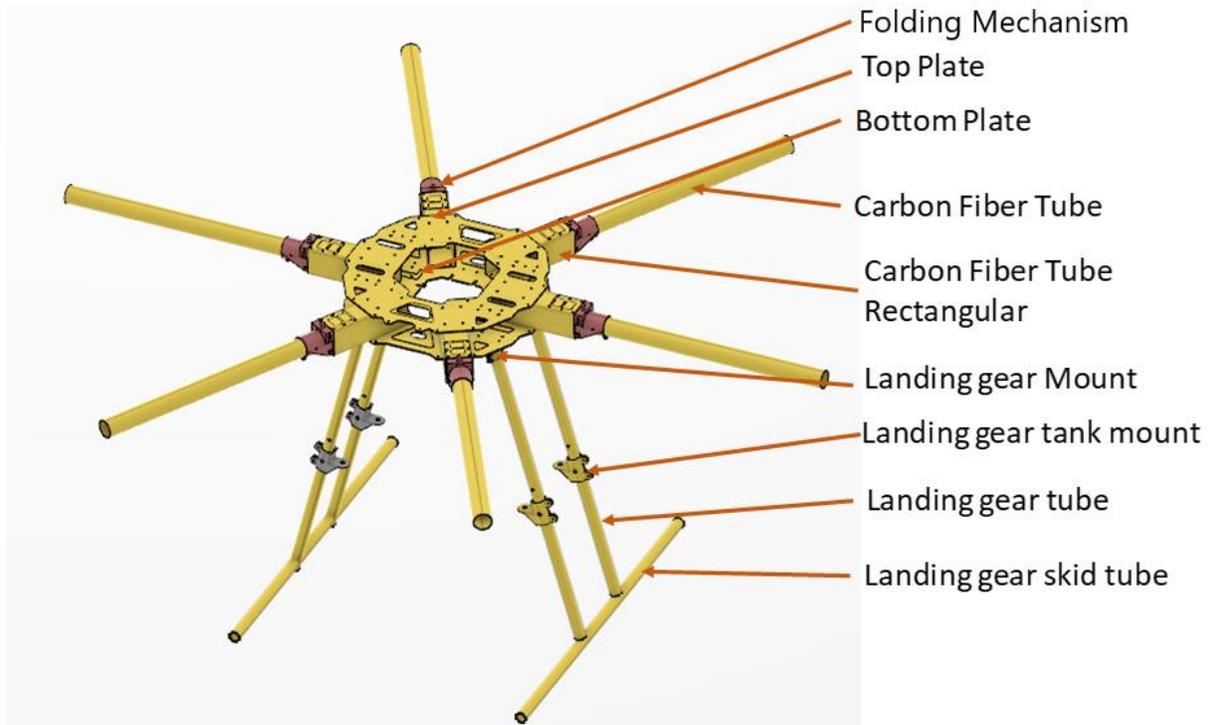


Figure 7: Primary structural elements

3.1.1.1 Prevention Against Deterioration of Strength

Deterioration of metallic materials, often referred to as corrosion or degradation, is a natural process that occurs when metals react with their environment. This deterioration can have a significant impact on the mechanical, structural, and aesthetic properties of metallic materials. There are several mechanisms by which metallic materials can deteriorate against which protection is available. These are described in the following sections.

3.1.1.1.1 Galvanic Corrosion

Galvanic corrosion occurs when two dissimilar metals are in contact with each other in the presence of an electrolyte (e.g., saltwater). The more anodic metal (the one that gives up electrons more easily) corrodes faster, while the more cathodic metal is protected. The max recommend difference is 0.25 V.

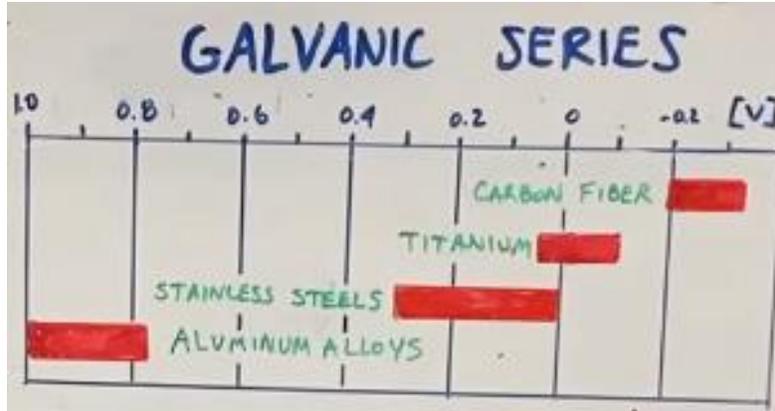
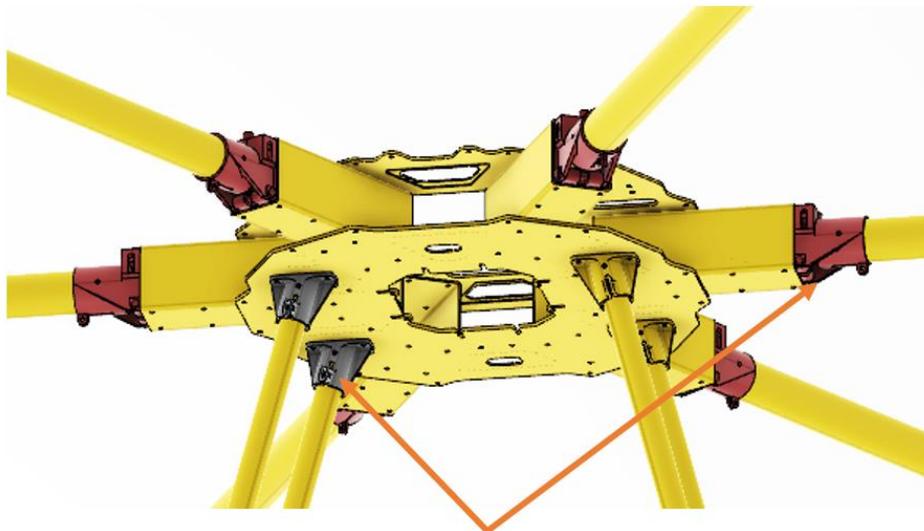


Figure 8: Galvanic corrosion chart.

Dis-similar metal combination	Criteria for acceptance
Aluminum to Carbon Fiber	Anodization of Aluminum
Aluminum To steel	Anodization of Aluminum
Steel to Carbon Fiber	Potential difference not greater than 0.25 V

Table 6: Galvanic Corrosion Table

The following picture shows the major interface portion between Carbon Fiber and Aluminum. Stainless steel is only used in fasteners which interface with both Carbon and Aluminum.



Aluminium to Carbon interfaces

Figure 9: Galvanic Corrosion Zone

3.1.1.1.2 Wear and Tear

The folding mechanism for the motor arms is the part which will be subjected to constant wear and tear. To counter this, Stainless steel hinges and locking pins are used by the supplier in these parts to prevent wear.

The landing gear skid which also faces constant impact load during every landing is also prone to wear and tear. To mitigate this risk, the landing gear skids are protected with a thick rubber-based cover to cushion the landings. Further, the condition of the cover will be inspected regularly before the flight to verify its condition and replaced if necessary.

List of parts which will be subjected to wear and tear with the mitigation strategies for each is given in Maintenance Manual-7, Table 3: Component Wear Mitigation Strategies, Page No. 14.

3.1.2 Tamper Proofing

The tamper proof casing has a “Do Not Open” Sticker on it. The user shall never open this tamper proof casing. Void tape is used to identify tampered conditions. If the tamper proof casing is found to be tampered, manufacturer will not hold any responsibility of the UA and warranty would be void.

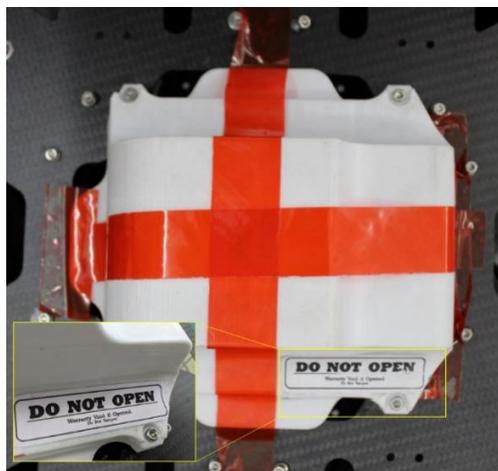


Figure 10: Hardware tamper proof



Do not open tamper proofing, it will lead to violation of operating procedure and invalidate warranty.

3.1.3 Life of Components

UAS components have different rated lives depending on the structural integrity of the component and the usage of the component. Certain components undergo high stresses during the UAS operation as compared to other components. Components that undergo high stresses are called critical components, failure of which may cause catastrophic damage and so, lives of these components are as significant. Lives of critical components and primary components are given in below table. Refer to maintenance manual for component replacement procedure once the lifespan of the components is over.

Component	Life
Battery	269 Charging Cycle
Propeller	500 Flying hours
Motor with ESC	
Landing Gear	10,000 Landings and Take-offs
Airframe	9000 hours

Table 7 Life of components

3.2 Electrical System

The Leap A10 is powered by Lithium-ion batteries at 43.2V (nominal), which is stepped down for required subsystem voltages. The batteries have a capacity of 25200mAh. The electrical system power consumption is monitored using voltage and current monitoring sensors. This monitoring data is transmitted to the GCS via telemetry and appropriate audio-visual alerts are triggered along with failsafe actions.

Parameter	Value
Battery chemistry	Lithium Ion
Configuration	6S6P
Capacity	25200 mAh
Discharge rate	11C
Nominal voltage	21.6V
Charge current	25A
Charging Modes	Balance Charge / Storage / Charge
Cooling type	Air

Charging voltage	25.2V
Safe discharge voltage	18V
Storage temperature	-20°C to +35°C
Connector type	AS150U

Table 8: UA Battery Specification



Exercise caution while handling, connecting and disconnecting batteries to avoid touching the terminals. There is a risk of electrical shock.



Respect the battery voltage operating limits. Not respecting battery level alerts and violating safe usage limits can result in battery damage, crash of the UAV and fire.

3.3 Propulsion System

The Leap A10 is an electrically propelled UA. It consists of:

1. 6 brushless DC motors for VTOL & cruise
2. 6 electronic speed controllers (ESCs) integrated in the motor assembly.
3. 6 foldable 61 cm diameter propellers.

The 6 motors and propeller combination provide sufficient thrust for the UA to lift with 10 litres of dispensable liquid payload. The propulsion subsystem is used to produce lift for vertical take-off, landing and forward flight. The subsystem additionally provides attitude control (roll, pitch and yaw) in longitudinal, lateral and vertical axes. See Figure 4: Leap A10 Fully Deployed Dimensions for a view of propellers mounted on motors.



Caution must be exercised during take-off, landing phases and loitering mode, do not leave the aircraft in hover flight with full payload for long periods. This can overheat the motors and degrade battery performance over long term. Monitor the GCS for alerts.

3.4 Navigation & Guidance System

The UA uses a Mission Management Computer (MMC), which integrates redundant Inertial Measurement Unit (IMU), a GNSS with magnetic compass and an internal barometer. The GNSS, IMU, Compass and Barometer form the navigation system for the UA. Algorithms help improve accuracy of position determination and maintain high integrity of the navigation system data. The guidance subsystem uses the position and heading data from the navigation algorithm's output, considers the pilot inputs, environmental sensor's data and then generates the next position output to guide the aircraft on required trajectory.

3.5 Flight Control System (FCS)

The FCS takes the input from the guidance algorithms, aircraft's current orientation and attitude and then determines the direction in which the aircraft should move and the rate desired by the pilot or automatically to achieve the required position and attitude. The FCS algorithms translate this data into outputs for ESCs, which then action the motors and propeller assembly to achieve the required heading and attitude. The UAS supports 3 flight modes: AUTO, Loiter and Return to Launch (RTL).

3.5.1 Autonomous (AUTO) Mode

In AUTO mode the UA flies a flight plan automatically. A flight plan is required to fly in AUTO mode. This flight plan can be created before flight from the GCS and uploaded to the UA. After successful power on self-tests, pre-flight and arming checks, the UA can be set to operate in AUTO mode. This is selectable on RC using the Mode Select Switch. See Figure 23: Ground Control Station for the switch and switch movement direction.

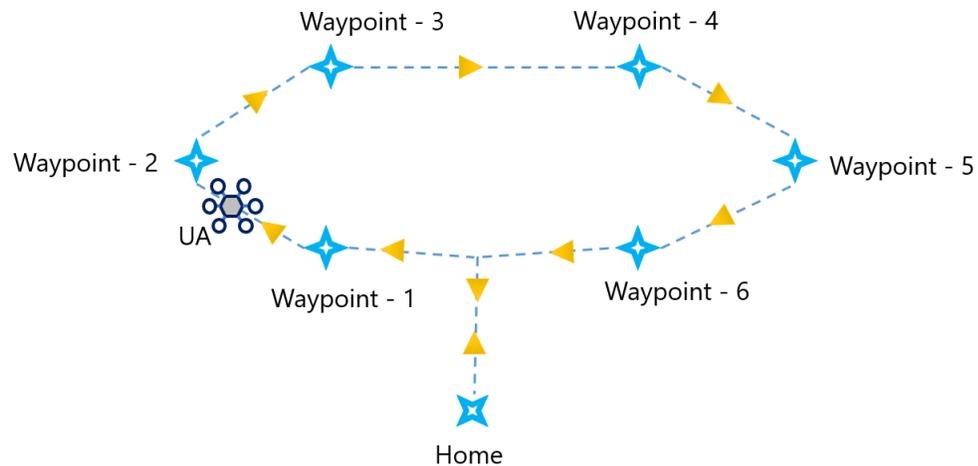


Figure 11: Flight in AUTO mode

AUTO mode navigates between each waypoint in a straight line and as it approaches each waypoint follows a smooth curving path towards the next waypoint (S-Curve). The guidance function controls the path as it approaches a waypoint to be within the predefined radius of each waypoint. The speed around the waypoint is managed as necessary according to set mission command. AUTO mode incorporates the altitude control and position control.



When starting the mission while the UA is on the ground ensure that the throttle is down, then switch to the Auto flight mode and then raise the throttle. The moment the throttle is raised above zero, the UA will begin the mission.



When the AUTO mission from in air, the mission will begin from the first command the moment the flight mode switch is moved to AUTO. If the first command in the mission is a take-off command and the UA is already above the take-off command's altitude the take-off command will be considered completed and the UA will move onto the next waypoint.



The UA can be armed in Auto mode only after the GNSS HDOP has dropped below 2.0 and it has acquired stable 3D position lock.

During an AUTO mission, the pilot can retake the control from the autopilot by returning the flight mode switch to Loiter. If the pilot then switches to AUTO again, the mission will resume from the last command.

During the mission the pilot's roll, pitch and throttle inputs are ignored but the yaw can be overridden with the yaw stick. This allows the pilot to for example aim the nose of the UA in certain direction. The autopilot will attempt to retake yaw control as the UA passes the next waypoint.

Missions should normally have an RTL as their final command to ensure the UA will return after the mission completes. Alternatively, the final command could be a LAND with a different location. Without a final RTL or LAND command the UA will simply stop at the final waypoint and the pilot will need to retake control with the RC.

Remember that when using RTL, the UA will return to the "home" position which is the location where the UA was armed.

As the UA touches down at the end of the mission the UA disarms but sometimes the UA may not sense the landing and the pilot may need to hold the throttle down and take-off in Loiter and then manually disarm the UA.

3.5.2 Loiter (Semi-Auto) Mode

The Pilot can select to operate the UA in Loiter mode. This is selectable on RC using the Mode Select Switch. See Figure 23: Ground Control Station for the switch and switch movement direction. In this mode the UA maintains its 3D position (current location, heading and altitude) in space. The pilot may fly the UA in Loiter mode as if it were in a more manual flight mode and when the sticks are released, the UA will slow to a stop and hold position.

- Horizontal position can be adjusted with the Roll and Pitch control sticks with the maximum horizontal speed being 10m/s. When the pilot releases the sticks, the UA will slow to a stop.
- Altitude can be controlled with the Throttle control stick.

- The heading can be set with the Yaw control stick.



The UA can be armed in Loiter mode only after the GNSS HDOP has dropped below 2.0 and it has acquired stable 3D position lock.



The UA may circle after take-off. This may happen due to bad compass offsets set during the compass calibration process.

3.5.3 RTL Mode

RTL mode (Return to Launch mode) navigates UA from its current position to hover above the home position and land. RTL mode is selectable on RC using the Mode Select Switch. See Figure 23: Ground Control Station for the switch and switch movement direction.

RTL mode requires a reliable position estimate to work properly, provided by GNSS and compass. Default pre-arm checks will ensure that requirements are met. RTL will command the copter to return to the home position, meaning that it will return to the location where it was armed. Therefore, the home position is always supposed to be your UA's actual GNSS take-off location, unobstructed and away from people.

Within 20 feet of the ground and Radar Altimeter installed and enabled, the UA in RTL mode will follow the ground profile to arrive back home. If Radar Altimeter is not working, the MMC uses a barometer derived altitude and if the air pressure is changing in flight area, the UA will follow the air pressure change rather than actual altitude.

3.6 Communication System

The UA integrates an RC receiver, telemetry system and a video transmitter on-board to enable the command and control (C2) link. The system is limited to work within 1.5 km of UA flying range. The radio and telemetry system implements failsafe features to return the UA back to launch location in case of loss of contact with the GCS for specified duration.

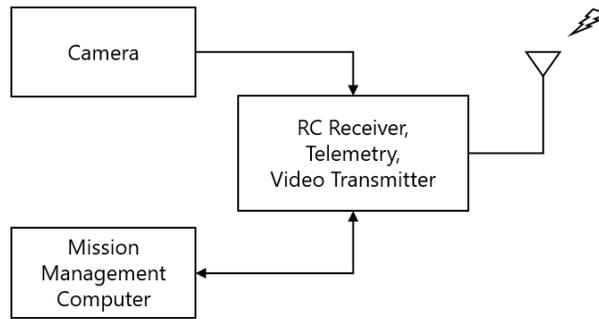


Figure 12: On-board Communication Architecture

3.7 Flight Data Recording

The UA is equipped with an integrated flight data recorder. All the pilot inputs, flight modes, flight profile of the aircraft and sensor inputs and system outputs are recorded. These flight logs are obtained by NextLeap Aeronautics for analysis in case of unsafe event and for UA performance analysis on field operations.

3.8 Payload

The UAS is designed with the objective of supporting agricultural spraying operations for pesticides, fertilizers. The UAV has a payload capacity of 10kg. The UA can carry 10 litres of dispensing liquid in the payload tank. The payload is dispensed via two different kinds of sprayers: flat jet nozzle and the centrifugal atomizer. This is an interchangeable set of assembly set. See instructions on how to change it in section on Spraying Management.

The GCS application receives audio-visual alerts when the spray liquid is finished, and it is also triggers a failsafe function to return the UA to launch coordinates.

3.8.1 Spraying Management

User has a choice in flying the Leap A10 either with centrifugal atomizer or with flat jet nozzle depending on the application for which the UA is being flown. In the out of the box state of the UA, it is equipped with centrifugal atomizers. Follow the steps to switch between the two spraying methods.

In case centrifugal atomizers are used during operation, no flat jet nozzles should be mounted. Moreover, exactly two centrifugal atomizers should be mounted on motor 1 and 2 only.

Similarly, in case flat jet nozzles are used during operation, no centrifugal atomizers should be mounted. Moreover, exactly four flat jet nozzles should be mounted on motor 3, 4, 5 and 6 only.

Both centrifugal atomizer set and flat jet nozzle set come with the tubes and connectors attached. It is recommended not to separate the tubes, connectors and spray device (flat jet nozzle or centrifugal atomizer). If removed, follow the schematics given in Figure 13 & Figure 17, respectively, to reattach).

While installing the spray device, no agrochemical tubes should be left overhanging, especially in vicinity of any radar. Rather, all the tubes should be routed through the Arm Clamps and LG Clamps that are present on the carbon fiber tubes and landing gear tubes.

3.8.1.1 Switching from Centrifugal Atomizer to Flat Jet Nozzle

Flat jet nozzles should be mounted on motor numbers 3, 4, 5 & 6. The steps would also involve unmounting the centrifugal atomizers from motor numbers 1 & 2.

1. Follow the schematic given in Figure 13 below (for Step 1 to 3) and remove the agrochemical tube connectors 8-6 (Connector 2A & Connector 2B in the schematic) from the Tube C and Tube D side respectively. Refer to Figure 14 to remove the tubes from connectors (this process is valid for every connector).

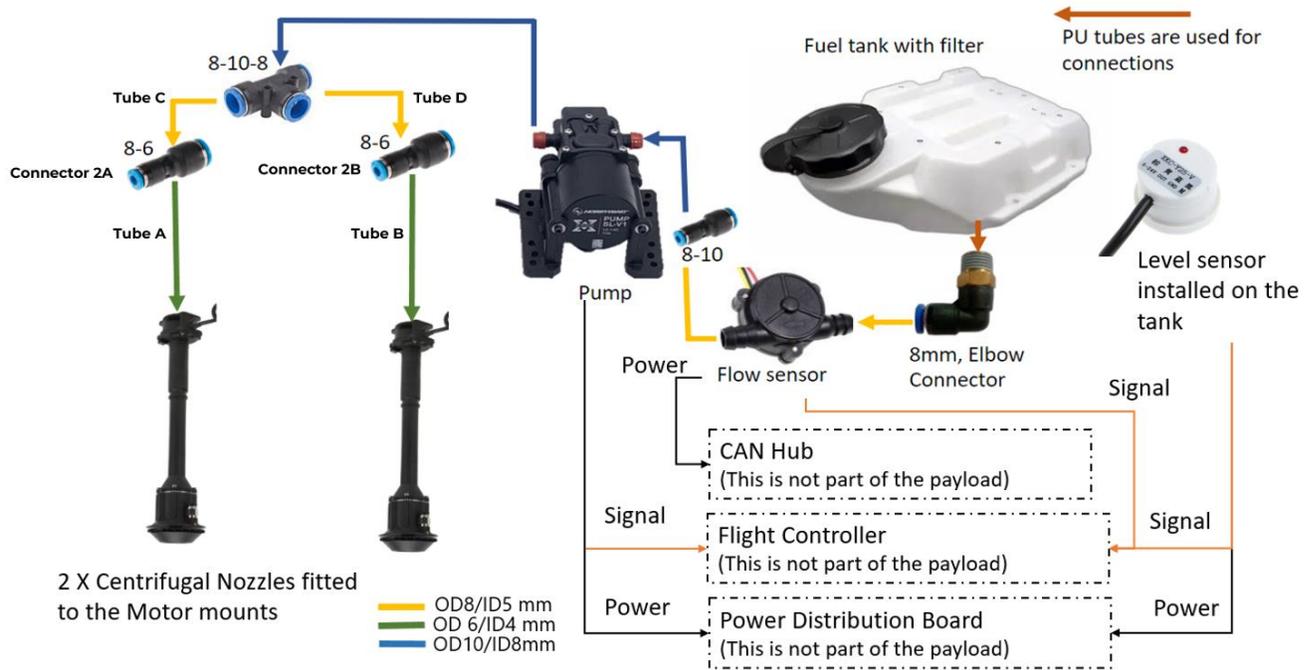


Figure 13: Centrifugal atomizer spray system schematic

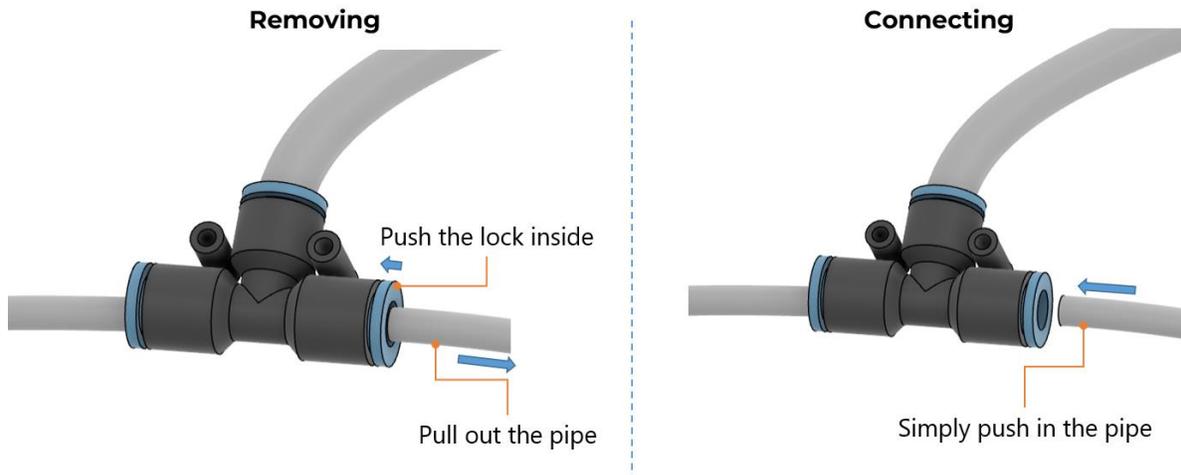


Figure 14: Removing and connecting agrochemical tubes from connectors.

2. Disconnect both the centrifugal atomizers from the signal connections present on the carbon fiber tubes of motor 1 and 2. To do so, rotate the cover lock in counter clockwise direction fully and pull out the connections.

3. Unbolt the two M3 screws present on the bottom of the centrifugal atomizers on each unit and remove the centrifugal atomizer sets.

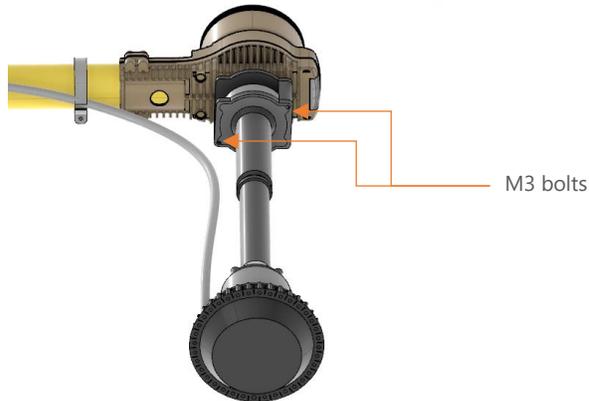


Figure 15: Centrifugal Atomizer fastener location

4. Mount the flat jet nozzle sets on motor 3, 4, 5 and 6. Bolt the two M3 screws present on the bottom of the flat jet nozzle on each unit. (Follow the schematic given in Figure 17 (for Step 4 onwards)).

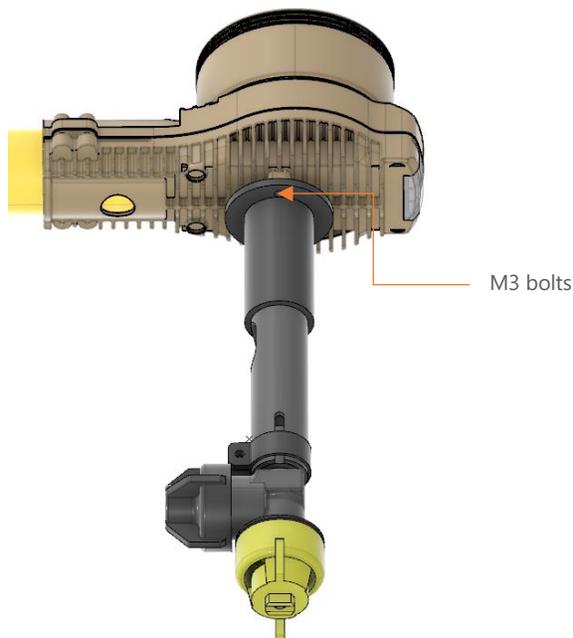


Figure 16: Flat jet nozzle fastener location

5. Connect agrochemical tube connectors 8-8-8 (Connector 3X and 3Y) to Tube C and Tube D respectively. Refer to Figure 14 to connect the tubes to connectors (this process is valid for every connector).
6. Ensure that Tube W & Tube X are connected to Connector 3X and Tube Y & Tube Z are connected to Connector 3Y. Route all the tubes through respective Arm Clamps of the nearest carbon fiber tubes and nearest landing gear tubes wherever possible.

3.8.1.2 Switching from Flat Jet Nozzle to Centrifugal Atomizer

Centrifugal atomizers would be mounted on motor numbers 1 & 2. The steps would also involve unmounting the flat jet nozzles from motor numbers 3, 4, 5 & 6.

1. Follow the schematic given in Figure 17 below (for Step 1 & 2) and remove the agrochemical tube connectors 8-8-8 (Connector 3X & Connector 3Y in the schematic) from the Tube C and Tube D side respectively. Refer to Figure 14 to remove the tubes from connector.

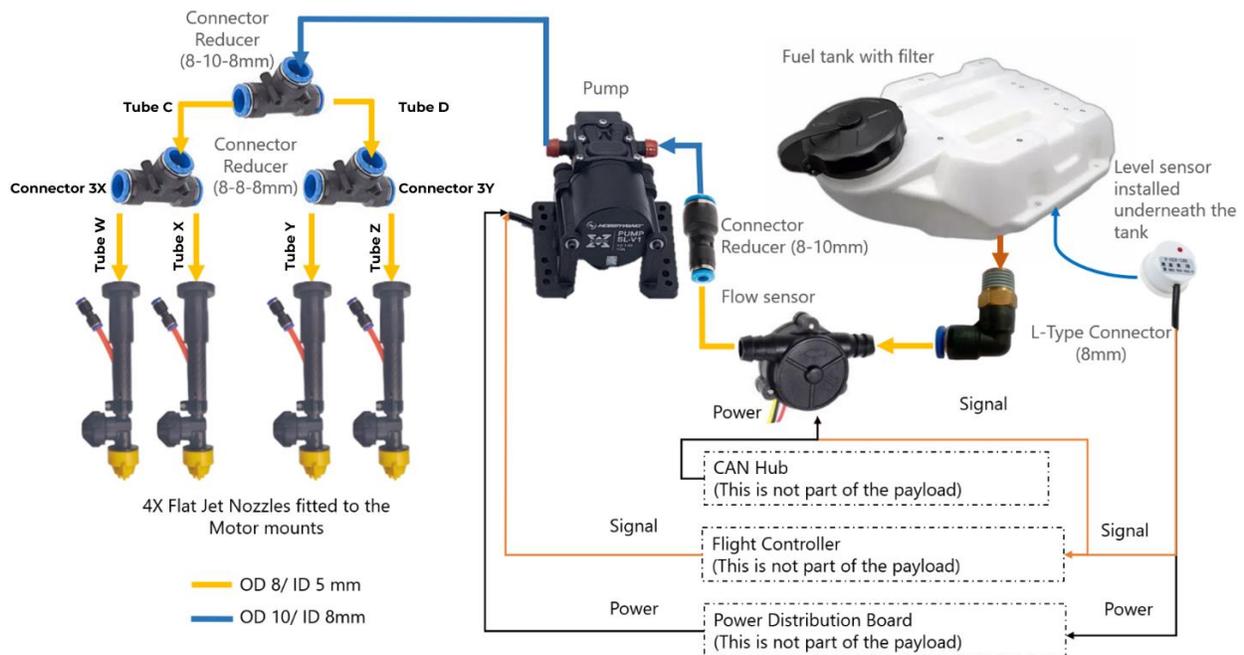


Figure 17: Flat jet nozzle spray system schematic

2. Unbolt the two M3 screws present on the bottom of the flat jet nozzles on each unit and remove the centrifugal atomizer sets.
3. Mount the centrifugal atomizer sets on motor 1 and 2. Bolt the two M3 screws present on the bottom of the centrifugal atomizers on each unit. (Follow the schematic given in Figure 13 (for Step 3 onwards)).
4. Align the connector before connecting as shown in Figure 18. Connect the centrifugal atomizer signal connection by plugging in and locking by rotating the lock cover.

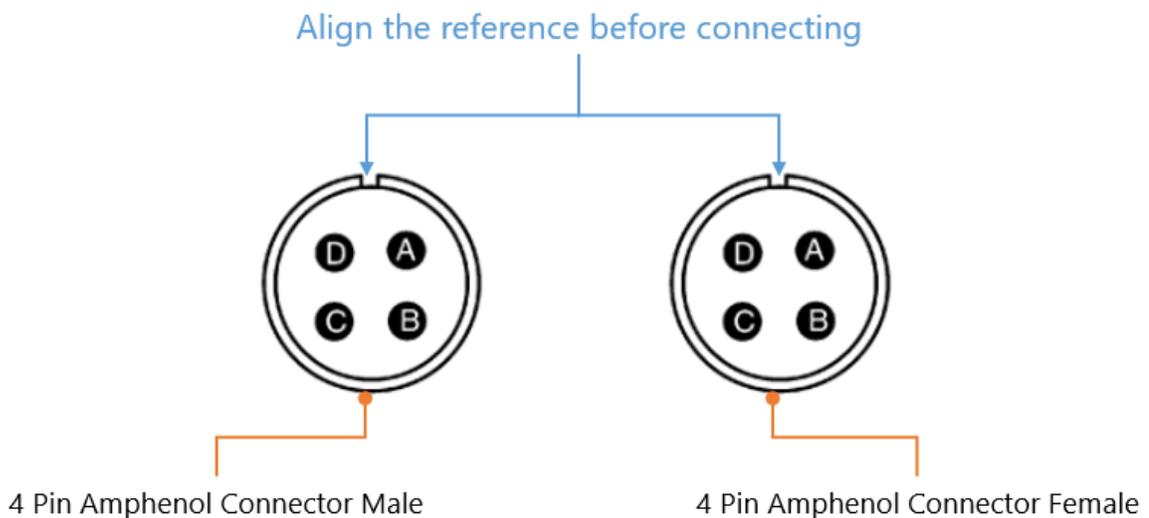


Figure 18: Centrifugal Atomizer signal connector alignment

5. Connect agrochemical tube connectors 8-6 (Connector 2A & 2B) to Tube C and Tube D respectively. Refer to Figure 14 to connect the tubes to connectors.
6. Ensure that Tube A and Tube B are connected to Connector 2A and Connector 2B respectively.

3.8.2 Use Cases

Flat jet nozzles and centrifugal atomizers are both widely used in various agricultural applications where spraying of liquid fertilizers and pesticides is required. Each type of nozzle has its advantages and is suited to specific requirements.

3.8.2.1 Flat Jet Nozzles

This section lists the advantages of using a flat jet nozzle. These are used largely for broadcast spraying, where foliar penetration and coverage are not essential. Flat jet nozzles can be used for a variety of spraying applications, including foliar fertilization, insecticide application, herbicide spraying, and fungicide treatment. The best operating pressure for flat fan nozzles is 15 – 30 psi, which produce coarser droplets that are not susceptible to drift. They have the following characteristics and advantages:

- **Uniform Coverage:** Flat jet nozzles produce a wide, flat spray pattern, ensuring uniform coverage of the target area. This uniformity is essential for effective distribution of fertilizers and pesticides across crops.
- **Precision Application:** The flat spray pattern of these nozzles allows for precise application of chemicals, minimizing overspray and drift. This precision helps reduce chemical wastage and ensures that the right amount of product is applied to the target area.
- **Optimized Drift Control:** Flat jet nozzles are designed to minimize spray drift, which is crucial for preventing off-target contamination and ensuring the safety of neighbouring crops, water sources, and wildlife.
- **Broad Spray Width:** Flat jet nozzles are designed to produce a wide, flat spray pattern, making them ideal for applications where coverage over a large area is needed. This could include tasks like washing or coating surfaces evenly.
- **Efficient Coverage:** Due to their design, flat jet nozzles efficiently distribute liquid over a broader area minimizing liquid waste, achieving uniform coverage is important.
- **Swath Change:** The flat jet nozzle offers adjusting the spray angle which affects flow rate, allowing for customization based on specific application requirements.
- **Spray Pattern:** Flat jet nozzles allow changing the spray pattern and coverage. Proper pressure regulation is necessary to maintain consistent performance.

3.8.2.2 Centrifugal Atomizers

This section lists the advantages of using a centrifugal atomizer for agricultural spraying of pesticides and fertilizers. These are used largely for broadcast spraying, where foliar penetration and coverage are essential. Here are some characteristics and advantages of centrifugal atomizers.

- **Fine Spray:** The centrifugal atomizers produce a finer spray compared to flat jet nozzles. This makes them suitable for applications where creating a mist or fine droplets is necessary, such as in humidification, cooling, or certain chemical processes.
- **Atomization Efficiency:** Centrifugal atomizers utilize high-speed rotation device to atomize the liquid into small droplets, ensuring efficient use of the liquid material. This can be advantageous in applications where minimizing liquid consumption or achieving precise droplet sizes is crucial.
- **Uniformity:** Centrifugal atomizers can produce a highly uniform spray, making them suitable for applications where consistent droplet size and distribution are required for desired outcomes.
- **Versatility:** Centrifugal atomizers offer versatility in terms of droplet size control and spray pattern adjustment, allowing for adaptation to different application needs.
- **Less Sensitive to Pressure:** Unlike flat jet nozzles, centrifugal atomizers are less sensitive to variations in pressure, which can provide more consistent performance across a range of operating conditions.

In summary, the choice between flat jet nozzles and centrifugal atomizers depends on the specific requirements of the application. Flat jet nozzles excel in providing broad coverage efficiently, while centrifugal atomizers are preferred for producing a fine spray with precise droplet control. Selecting the appropriate nozzle type is essential for achieving desired spray characteristics and optimizing the efficiency of various industrial processes.

3.8.3 Tank Filling

The tank on Leap A10 is destined to be filled with water or water-soluble pesticides, herbicides and fertilizers. The tank installed on the UA has a capacity of 11.4 L of agrochemical, but, due to payload weight restriction, the UA payload tank must be filled with a maximum of 10 L of agrochemical mix. The 10L capacity level markings is visible by a black line present on all sides of the tank. See Figure 18: 10L marking on the tank.



Figure 19: 10L marking on the tank

The liquid level must not be above the marking while filling the tank. The tank's translucent nature allows monitoring the mix level from outside.



User must strictly adhere to the 10L marking limit on the tank. Overfilling the tank is a safety hazard.



Use protective equipment such as gloves and safety goggles while handling concentrated agrochemicals.

1. Place the UA on a level ground so that during tank filling, the 10 L capacity marking would be levelled.
2. Prepare the agrochemical in a container before starting the filling procedure.

3. Loosen the battery straps and remove the batteries from the UA and keep them in a safe area, preferably in a battery case/bag.
4. Open the tank cap by rotating it in counter-clockwise direction.
5. Carefully pour the agrochemical in the tank, preferably using a funnel.
6. Ensure that the 10L mark on the tank is not crossed.
7. Close the tank cap by rotating in clockwise direction. Ensure the tank cap is firmly closed to avoid spillage of agrochemical.
8. Clean the vicinity of the tank mount. Ensure that droplets of agrochemical are not left over any part of the UA.
9. Place the batteries on the battery plate and fasten the battery straps firmly such that the batteries are secure on their place.
10. Make sure that the tank is not leaking. If leakage is found, follow guidelines given in next section.

3.8.3.1 Handling Leakage

Certain concentrated agrochemicals used for spraying may react with the tank and cause wall thinning. This may become a cause for leakage of liquid from the tank. The wall thinning can be avoided and prevented by cleaning the tank regularly and draining the spray system with clean water.



Do not fix a leaking tank full of agrochemicals. Drain the contents into another container before troubleshooting.



User must not attempt replacement or removal of tank at any point of time. The tank replacement or removal must be done by the OEM only.

The following procedure to detect a leak in spraying system is in no way is intended to be a repair/maintenance procedure. In all leak cases, the tank will need replacement, however, it must be ensured that it is indeed the tank which has the defect and not the tubing or other connecting subassemblies.

Follow these steps to detecting a leaking tank.

1. Two people are required for this troubleshooting process.
2. Fixing a tank full of agrochemicals is not advised for safety reasons. Drain the tank contents into another container.
3. Fill the tank with water.
4. After filling the tank with water, clean tank surface and all tubing, connection mechanisms with a dry cotton cloth to remove any droplets or traces of liquid spillage during the tank filling process.
5. Observe the surface of the tank, its bottom and connection mechanisms for any hint of leak. If the leakage is found in tubes and connectors, removing, cleaning & reconnecting the connector, or temporarily fixing the leak with a leak proof tape may help fix the issue if the leak proof tape is available. However, the user is advised to immediately contact the manufacturer for spare parts.
6. Fill the tank completely to 10L capacity, clean wipe the external surface and connectors with a dry cotton cloth and leave the UA for couple of hours. Check the surface under the UA for trace of water pool or check the tank water level with reference to the level marking. If there's trace of water, pool of water below the UA, or if the level is below 10L mark, there is a leak. If it is a minor leak, a leak proof tape can temporarily fix the issue. In addition, the user must contact NextLeap Aeronautics for tank replacement.

3.9 Safety Features

Safety features consists of features which enhance the safety of the UAS, operational environment and ensure respect of regulations. The following safety features are discussed in the subsections of this section.

- Return to launch

- RC failsafe
- GCS failsafe
- Geofence breach
- Battery low or critical
- Detect and Avoid
- Vibration failsafe

3.9.1 Return to Launch (RTL)

RTL is a failsafe flight mode, which is engaged automatically by the MMC firmware on detection of a condition in which safety and security may be jeopardized. The RTL is a safety behaviour which sets the Auto flight mode and flies the UA back to the launch coordinates provided its navigation systems are working correctly. For Leap A10, the RTL is configured to trigger under following conditions:

- When the payload being dispensed finishes, i.e. payload tank is empty, the RTL is triggered immediately.
- When the UA experiences RC loss, the RTL is triggered immediately.
- When the UA experiences GCS Application datalink loss, the RTL is triggered after 5 seconds allowing the GCS application to re-establish contact with the UA.
- When the UA experiences low battery voltage of 37.2V, the RTL is triggered immediately.
- In case of terrain change if the UA breaches the defined vertical geofence at 25m altitude above launch location, the RTL is triggered immediately.

Section 7 provides message displayed on the GCS in each case and subsequent sections also highlight in brief.

When an RTL is triggered, the flight mode changes to “RTL” and a message pops-up on the screen stating the reason for the RTL. RTL mode then automatically navigates UA from its current position, where RTL is triggered, to hover above the home position and land. RTL mode requires a reliable position estimate to work properly, this requirement is

satisfied by GNSS and compass. Default pre-arm checks will ensure a 3D GNSS lock. The behaviour of RTL mode is controlled by parameters, and these have been already configured for Leap A10's application purpose as listed above. The RTL flight altitude is set at 24m. If the UA is below the RTL altitude, it will climb to 24m altitude AGL, then follow the straight-line path back to launch coordinates. If the UA altitude is higher than 24m, it will descend to the set altitude before returning home.

The RTL is performed using the shortest return path to the launch coordinates. This is straight line path from the point where the RTL was triggered to the launch coordinates. The shortest direct return path rather than planned path is chosen because any of the above event can occur at a variable instance of time and depending on flight conditions that day. For instance, in case of low battery voltage, expecting the vehicle to follow a required path may not be possible. It can lead to critically low battery voltage and landing the UA in the middle of the field, thus potentially jeopardizing crop, and UA safety. Therefore, shortest direct flight path for RTL is the best chance of recovering the UA. In the meantime, if the link is restored, the pilot can intervene to take action according to situation.

3.9.2 RC

The UA is configured for RC Failsafe. This means that UA has the settings and is prepared to handle the situation if the link to RC is lost. The loss of radio link is triggered after the configured safe delay expires (which is set to **5 seconds** by the manufacturer). The failsafe is triggered if any of these conditions occur:

- The pilot turns off the RC transmitter.
- The vehicle travels outside of RC range and signal is lost.
- The pilot forces the throttle channel below a safe threshold throttle limit from the transmitter.
- The receiver loses power (unlikely).
- The wires connecting the receiver to the autopilot are broken (unlikely).

The transmitter is selected such that it can detect the loss of contact with RC and communicate to the MMC. When the MMC firmware detects this condition the RC failsafe condition will be triggered immediately.

When a radio failsafe is triggered, the UA is configured via parameters to perform an RTL. The UA will continue landing if already in a landing phase.

- If the UA is disarmed, no failsafe will take place.
- If the UA has landed and is armed, it will immediately disarm.

3.9.3 GCS Application

The UA is configured for GCS Application Failsafe. This means that UA has the settings and is prepared to handle the situation if the link to UCA Application link is lost. The GCS failsafe monitors the time since the last MAVLink heartbeat signal from the GCS application. If no heartbeat is received for the configured number of seconds, the GCS failsafe event will trigger. When no GCS Application is ever connected, the GCS failsafe will remain inactive regardless of parameter settings.

The following situations can cause a loss of GCS Application MAVLink heartbeat, triggering a GCS failsafe event:

- The operator turns off or otherwise disconnects the GCS Application.
- The operator's RC and mobile phone/tablet hosting the GCS Application are separated beyond the Bluetooth device range.
- The UA travels beyond the range of the GCS telemetry radios.
- The GCS telemetry radio on either end loses power.
- Wires connecting the GCS telemetry radio to the autopilot or ground equipment become disconnected.

When a GCS Application failsafe is triggered, the UA is configured via parameters to perform an RTL. Following will happen when GCS Application failsafe is triggered:

- If the UA is disarmed, no failsafe will take place.

- Continue landing if already in a landing phase.
- If the UA has landed and is armed, the UA will immediately disarm.

If the failsafe clears (i.e. GCS reconnects and MAVLink heartbeat is restored) the UA will remain in its failsafe mode. It will not automatically return to the flight mode that was active before the failsafe was triggered. If the pilot wished to re-take control in Loiter he/she would need to change the flight mode switch to another position and then back to Loiter. This can be done via the re-connected GCS also.



Do not move the mobile phone/tablet more than 5 meters from the RC.

3.9.4 Geofence

A geofence is a virtual fence or a perimeter around a physical location. This is purely a digital implementation of the fence. The objective of having a fence is to define a geographical area where the UA operation is allowed or prohibited.

The UA can manage two different types of geofence designs: Circular and Polygon.

By default, the UA height is limited to 25m. The operating altitude can be specified by the pilot to set desired altitude up to 25m, this is the ceiling. The UA does not go any higher than this. An active GNSS with good accuracy is required to achieve the geofencing behaviour.

Circular Geofence: In the circular geofence a radius is specified around to keep UA inside or around an obstacle to keep UA outside of designated area. A cylindrical shape geofence is constructed with vertical geofence limit. See definitions below for inclusion and exclusion zone.

Polygon Geofence: In the polygon geofence the pilot must define the geographical coordinates of the points using which the virtual fence will be created by the GCS Application and uploaded to the firmware. obstacle and a cylindrical shape geofence is constructed.

Using these two types of fences, two types of zones can be defined: Inclusion Fence, Exclusion Fence. A mission plan can have multiple inclusion and exclusion zones.

- **Inclusion Fence:** Inclusion Fence is an area defined to contain the UA in flight. When this fence is defined, UA remains within the boundary of defined fence.

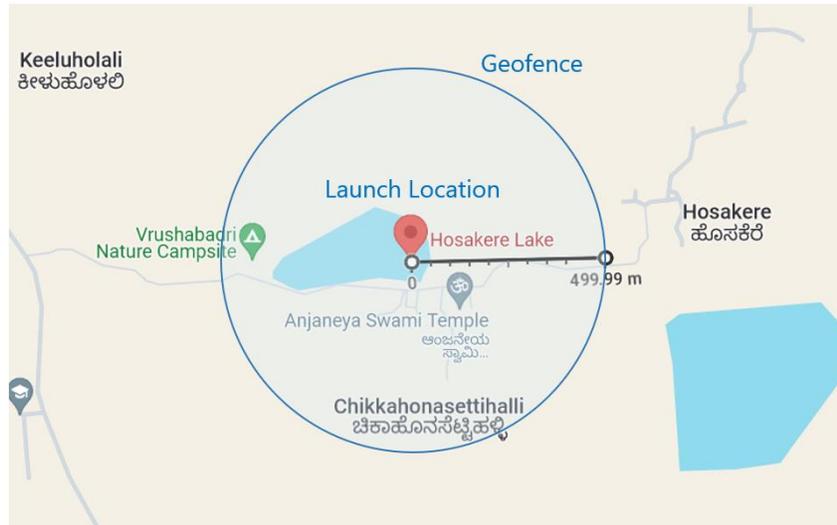


Figure 20: Circular Geofence

An example of inclusion type circular geofence, shown in Figure 20: Circular Geofence, has a radius of 500m having center at launch location at Hosakere Lake.

- **Exclusion Fence:** Exclusion Fence is an area defined to exclude from the flight path when the UA is flying. The UA treats this as an obstacle and avoids this by following a path around the defined area.
- **Altitude restriction:** When the altitude constraint is imposed, the UA remains below the specified altitude in within inclusion zone.

The GCS application allows to specify a safety margin distance around the actual fence. This is the margin distance, which can be useful if GNSS accuracy falls on a cloudy day. The UA will remain inside the defined fence. For Inclusion Fence, this margin is defined on the inside of actual fence and for Exclusion Fence, the safety margin is defined outside the actual fence.

3.9.5 Battery

The battery failsafe is configured to do two actions in two different states. The two states are:

- **Low Voltage:** When the low battery voltage failsafe is triggered. Following will happen:
 - The UA buzzer will play a loud low-battery alarm.
 - LEDs will flash yellow.
 - “Low Battery!” will be displayed on the GCS application.
 - The UA will perform RTL.
- **Critical Voltage:** The critical battery voltage level is less than low voltage level. When this voltage level is recorded for 5 seconds or the estimated remaining capacity has dropped below a configurable threshold, the UA will land immediately to avoid damaging the battery.

The pilot can re-take control of the UA by changing the flight mode switch to another mode.



Do not push the battery and continue to fly below critical voltage. This can result in permanent damage to the battery, violation of operating procedure and invalidity of warranty.

3.9.6 GNSS

The EKF failsafe monitors the health of EKF (the position and attitude estimation system) to catch problems with the vehicle’s position estimate (often caused by GNSS glitches or compass errors) and prevent “flyways”.

The EKF failsafe triggers when any two of the EKF “variances” for compass, position or velocity are higher than the threshold value for 1 second.

The EKF calculates these “variances” by comparing the results from multiple sensors. For example, if the GNSS position suddenly jumps but the accelerometers do not show a sudden acceleration, the EKF variance for position would climb (i.e. become less trustworthy).

When the EKF failsafe is triggered

- An audio-visual alert will sound at the GCS Application.
- “EKF Failsafe” will appear on the GCS Application if telemetry is connected.
- In autonomous modes that require GNSS (i.e. Loiter, RTL, Auto) the UA will switch to Land mode. This is a “pilot controllable” landing meaning the pilot will have control of the roll and pitch angle but the vehicle will descend at the configured descent rate. The UA will land and finally disarm its motors.
- An EKF failsafe error will be logged.

EKF failsafe recovery happens when GNSS performance improves.

- The EKF failsafe is cleared when GNSS performance improves and a message “EKF failsafe cleared” is displayed on the GCS.

3.9.7 Detect and Avoid

The Leap A10 UA is designed to fly for agricultural operations of spraying fertilizers and pesticides. Therefore, it is equipped with an Obstacle Detection Radar, Radar Altimeter and a Camera. These subsystem elements and functions are described in the following subsections. Then a dedicated section describes the Detect and Avoid function.



In case obstacle detection radar fails, GCS will display “PRX No Data” or “RngFnd No Data”. Pilot is recommended to switch to camera based flying in manual mode.

3.9.7.1 Camera & Lights Module



Figure 21: Camera and Lights Integrated Module

The UA is equipped with an integrated camera and lights module. The camera has a 720p HD live video output. The live video feed is sent and made available to the pilot via the video transmitter in the communication subsystem. The camera forms an essential component of the detect and avoid function alongside the obstacle detection radar. The camera enhances situational awareness for the pilot. The camera works as a parallel redundant source of information for obstacle avoidance. The pilot can visually observe the obstacle, the nearby area and make decisions on how to avoid the obstacle.

3.9.7.1.1 Lights

The lights are based on LEDs assembly. They are powered directly using a separate cable from the PCDM. The lights are used when night or early morning operations are required, for instance in case of locust invasion. The lights provide visibility and help the pilot navigate visually. However, this UA is not certifiable for night operations due to absence of flashing strobe lights.



Do not operate the UAS at night, it is not certified for night operations.

3.9.7.2 Obstacle Detection Radar

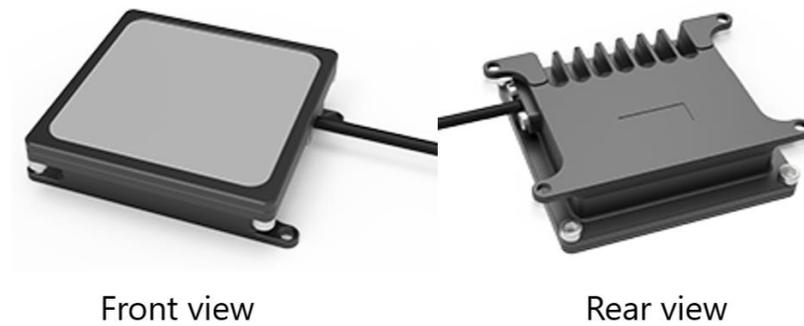


Figure 22: Obstacle Detection Radar

Obstacle detection radar is used to measure the relative distance between the UA and the obstacle in the direction of flight. The ODR uses the 77GHz to 81 GHz band. This allows it to work in all-weather conditions including daylight, high temperature, fog, dust, wind and night. is long, the signal transmission is fast and stable.

The high sensitivity and long detection distance range allows the radar to detect electric wires, small trees with a trunk of 10 cm, people, and telephone poles etc. The versatile nature of radar provides excellent obstacle detection function at all speeds.

The UA uses only one radar facing the direction of flight. To detect obstacles in another direction it must first turn in the desired direction to make observations.

Using a single radar has advantages in terms of UA weight, power consumption and cost of the UAS. The most critical here is the Design to Cost factor and with a single radar it is easy to meet the functional and performance requirements for agricultural applications.

3.9.7.3 Radar Altimeter

The RA is a height measuring millimeter wave radar. It works in the 77-81GHz frequency band and provides less than 2cm height measuring accuracy. Its small size, high sensitivity, low weight, stable performance and easy integration with MMC via CAN hub make it a suitable choice for the agricultural UA application.

The radar can detect the height of both the crops and the ground surface at the same time. It can be used in various complex terrain environments, and this enables the MMC

to provide the terrain following feature. The MMC uses altitude information from RA to keep the UA above the preset height for the spraying operation. The RA also helps in implementation of terrain failsafe.

3.9.7.4 Detect and Avoid

The Detect and Avoid Function is implemented in two ways using two different sensors.

- **Radar based detect and avoid:** The radar based detect and avoid functions only in Loiter flight mode. The ODR scans the area in the direction of flight in 34° horizontal FoV and 6° vertical FoV. The radar's observation data is sent to the MMC. The MMC firmware using data derived from the radar, informs the pilot on the GCS about the presence of an obstacle and the UA comes to a stop in flight. The audio-visual alert is triggered on the GCS Application. Even if the pilot tries to push the throttle the aircraft maintains its position at the configured distance from the obstacle. The pilot must maneuver the UA flight path away from the obstacle to continue. The fully automated detect and avoid function will be available in the next version of firmware.
- **Camera based detect and avoid:** The visible spectrum camera based detect and avoid function is available in all modes of flight and as a redundant backup to the radar-based obstacle detect and avoid function. The camera video feed is available on the GCS Application. The pilot must always view it to ensure that UA is flying in safe conditions. On detection of an obstacle in flight path the pilot can maneuver the aircraft and change its flight path to avoid the obstacle and continue with the mission plan.
- **Avoiding obstacles in Auto mode:** The design team has consulted field operators of agricultural drones. Based on feedback, it was concluded that the operators are not using automated collision avoidance function because there are alternatives.
 - One method is to just plan exclusion zones around obstacles. This method works best because dynamic obstacles in agricultural fields are rare. All the

trees, bore wells, electric poles and infrastructure are already present and known. The GCS application allows creation of exclusion zones around known obstacles in the field. The exclusion zone in the plot helps the MMC firmware to pre-plan the path and execute planned and known maneuvers thus ensuring safety of the UA, infrastructure, crops and environment. We recommend this method of operation.

- The second method is configuration based in which the AP is configured to stop and slide when it comes across an obstacle in the flight path. The pilot may then choose to either change to Loiter flight mode or just fly around the obstacle in either case.
- **Terrain following/avoidance:** The Radar Altimeter is used to maintain a precise constant height above the crops for spraying operations. This also has the advantage of avoiding any terrain collisions due to changing geological features. The aircraft is then able to adapt its height AGL and follow the terrain, thus avoiding collision.

3.9.8 Vibration Failsafe

Vibration Failsafe is a little different than other failsafes because it does not initiate a flight mode change or RTL. When vibration failsafe becomes active, it changes the algorithm which controls altitude and climb rate in altitude control modes.

Excessive vibration levels (more than 60m/s/s) can lead to the accelerometers saturating (i.e. going beyond the range that the sensor can measure). This leads to “clipping” and means the EKF cannot accurately calculate its climb rate or vertical acceleration. This can lead to the vehicle becoming unable to control its climb rate and, in severe situations, can lead to the vehicle climbing rapidly at full throttle. When the vibration failsafe triggers the following will happen:

- “Vibration compensation ON” will appear on the GCS Application.

- The vehicle will not change mode but its altitude hold will be less accurate than normal. The vehicle may overshoot its altitude targets and/or respond more slowly to pilot input.

Recovery from the failsafe happens as follows:

- Vibration failsafe will deactivate 15 seconds after the EKF returns to normal.
- "Vibration compensation OFF" will be displayed on the HUD.

4. Ground Control Station (GCS)

The GCS consists of an RC Unit and a mobile phone running a GCS Application. The GCS application is explained in multiple sections in the FM in the context of use. The RC Unit provides the features to control the UA, set flight modes, spraying mode, battery status indicators and support for installing a mobile phone or tablet. The GCS application runs on the mobile phone. The mobile phone connects to the UA via the RC unit using a Bluetooth connection through which the telemetry and video information is relayed.

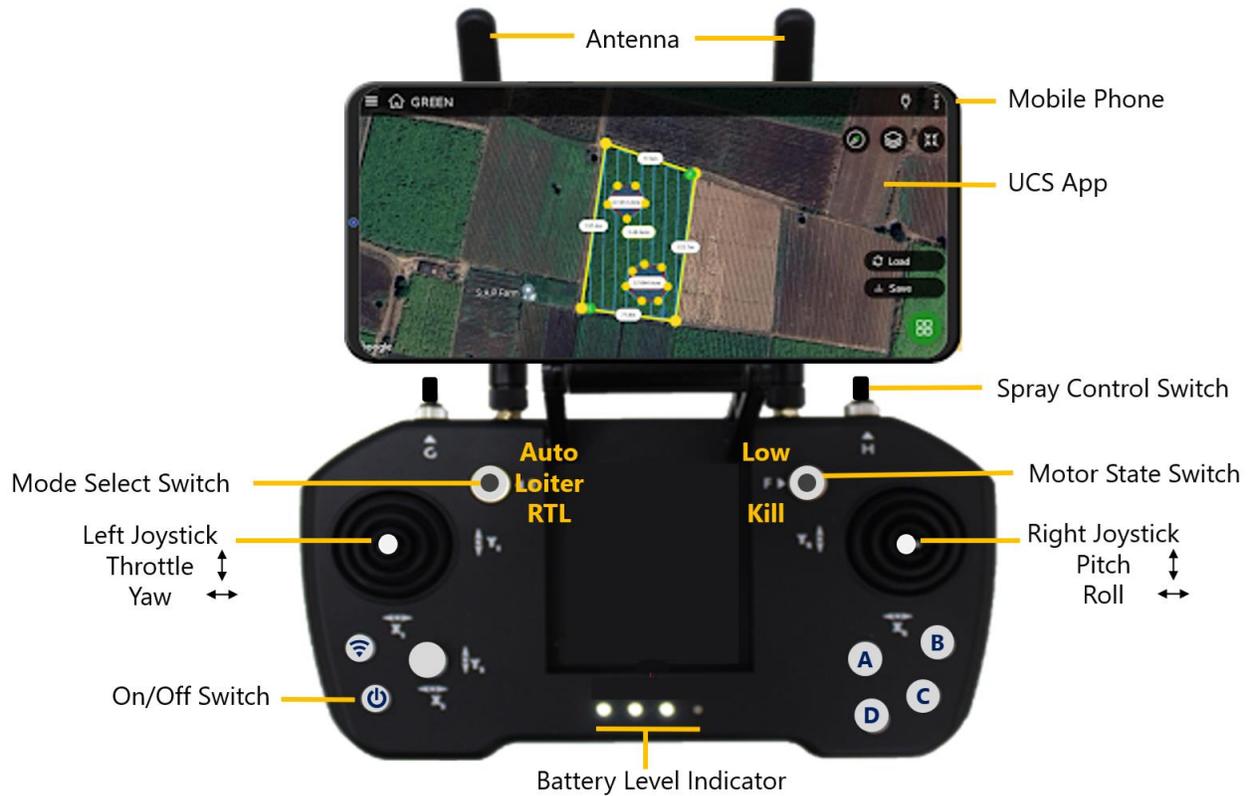


Figure 23: Ground Control Station

 To ensure safe and efficient operation, it is ideal to remember positions of buttons, switches, their corresponding states and practice them.

4.1 Radio Control Unit

The Radio Control unit is part of the GCS. Its features are described below.

- On/Off Switch:
 - Switching On: Press the On/Off switch shortly, do a second press and hold the button pressed to power On the RC. An intermittent beep is heard after power up. Now the device is ready to pair with the UA receiver. The beep stops once the connection with receiver is established.

- Switching Off: Press the On/Off switch shortly, do a second press and hold the button pressed to switch Off the RC.



When not in use, store the RC Unit in power off mode.

- Battery Level Indicator: The battery level LEDs indicate the state of charge of the internal battery. Pressing the power button shortly lights up the LEDs indicating the state of charge of the battery.

Battery Level LEDs ● On ○ Off				State of Charge
●	●	●	●	76% - 100%
●	●	●	○	51% - 75%
●	●	○	○	25% - 50%
●	○	○	○	0% - 24%

Figure 24: Battery Level Indication



Before flying any mission ensure that battery level indicator LEDs indicate fully charged battery state.



Stop using the RC if the unit is heating up too much, there is smoke during operation or while charging the unit.

- Mode Change Switch: This is a tri-state switch mapped to 3 modes: Auto, Loiter and RTL.



In case pilot is not able to switch flight mode using mode change switch, it is recommended to immediately trigger RTL or Land from GCS.

- **Motor State Switch:** This switch provides control on the motor state to set a low RPM state after arming and a zero RPM (motor kill) if it is required to stop them in emergency.
- **Spray Control Switch:** This switch controls the sprayer state and actions the pump to On and Off.

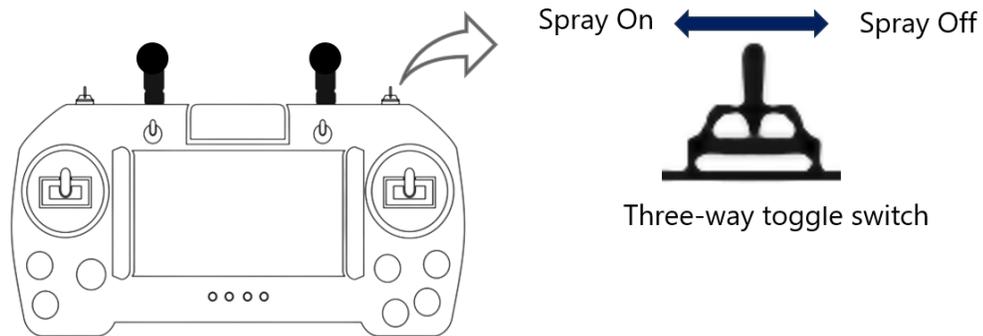


Figure 25: Spray Control Switch

- **Left Joystick:** The left joystick is mapped to two functions: Throttle and Yaw control.
Throttle Control: Moving the left joystick up increases the throttle and moving it down decreases the throttle.
Yaw Control: Moving the left joystick left yaws the aircraft to the left and moving the joystick right yaws the aircraft to the right.

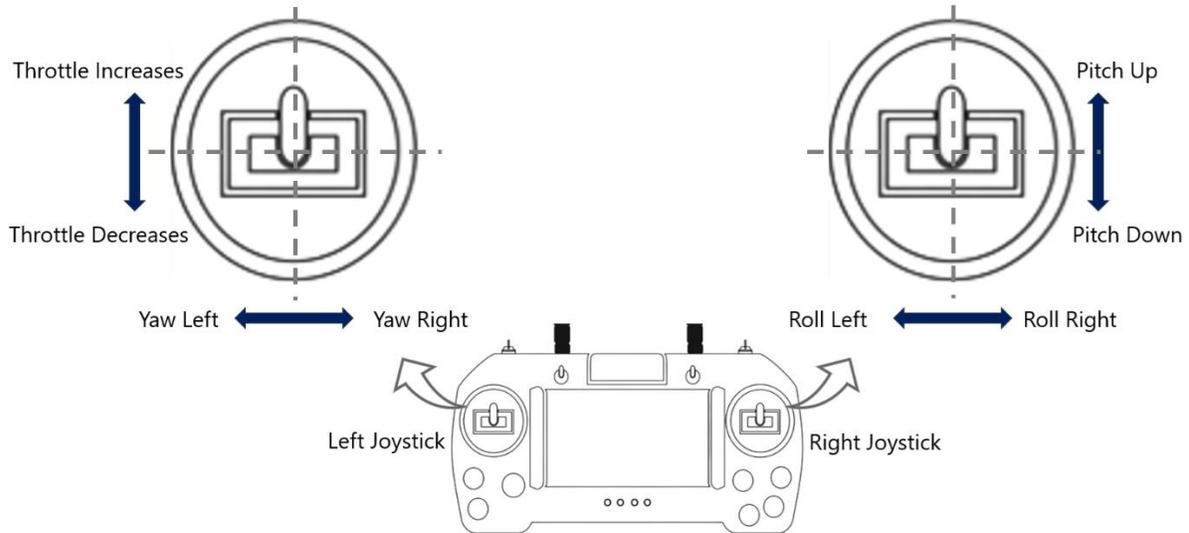


Figure 26: RC Joystick Controls

- **Right Joystick:** The right joystick is mapped to two functions: Pitch and Roll control.
 - Pitch Control:** Moving the right joystick up pitches the UA down and moving the stick down pitches the UA up.
 - Roll Control:** Moving the right joystick left rolls the UA left and moving the stick right rolls the UA right.



In case pilot is not able to control UA as per desire using control sticks, it is recommended to immediately trigger RTL or Land from GCS.

- **Mobile Phone Holder:** The RC Unit provides an extensible mobile phone holder. This is shown in Figure 27 by yellow coloured area. It can be extended in horizontal direction to install the mobile phone. It can be rotated also to suite the usage.

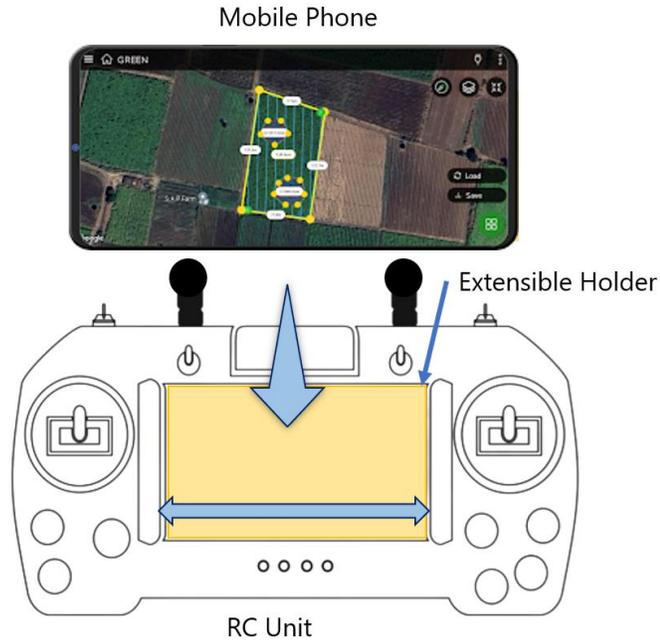


Figure 27: RC Unit's Mobile Phone Holder

- Connecting to Mobile Phone: Switch on the mobile phone's Bluetooth. The T12 RC appears as T12_NNN, where NNN is a number. Example: T12_889. Select this and the phone will attempt to connect to the RC via Bluetooth connection.

4.1.1 RC Usage Recommendation



Figure 28: RC Antennae Position Recommendation

4.2 GCS Application

The GCS application is an important component in the UAS architecture. The application runs on an Android mobile phone or tablet. It enables multiple functions required for UAS operation and monitoring. It connects to the RC Unit via mobile phone's Bluetooth connection and streams live telemetry and video data providing updates as the UA flies and performs its mission.

4.2.1 Introduction

4.2.1.1 Availability

The application must be downloaded from the Google's Play Store. Search for AeroGCS Green on Play Store and install the latest version. AeroGCS Green requires Android version 10 and above.

The software version being used at the time of documentation was AeroGCS Green 1.39 (Version number subjected to change)

4.2.1.2 License

One license per mobile phone application installation will be provided by NextLeap Aeronautics. The application must be installed and used with provided credentials. Enter the email address and License key provided to you. After entering the details click on "Activate" button to activate your app.

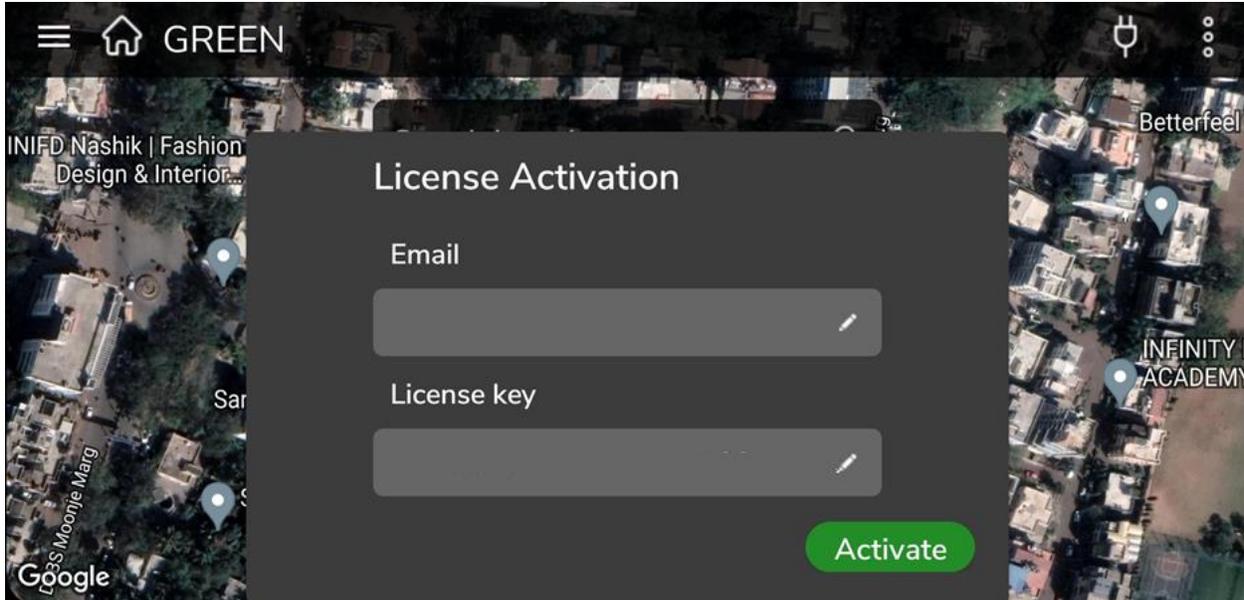


Figure 29: GCS Application License Activation

When a new version of AeroGCS GREEN is available, the app alerts the user to act. The user must keep the application updated to avoid security issues.

4.2.1.3 Use Case

AeroGCS GREEN is a UA management and mission planning and execution software. Its wizard capabilities help the pilot to perform tasks efficiently without laptops on the field. Plan everything using your mobile device.

In agriculture, spray operations are performed to apply fertilizer and pesticides to have healthy crops. It takes a lot of time to apply these chemicals and water by manual labour. The UA based sprayers work automatically, enabling farmers the ability to finish tasks quickly and easily. In addition, sprayers have a much wider range of coverage compared to human effort. The GCS application helps in achieving all this through planning and execution.

Post spraying operation, automated log collection of missions helps the user and operators collect and concentrate data on a cloud server. The cloud server has functions to perform analytics on acquired data. This helps operators and governments to monitor crops and take appropriate actions.

4.2.2 Application Dashboard



Figure 30: UA Dashboard Introduction

GCS Application Dashboard is the application’s home page where the user arrives after signing up. See Figure 30: UA Dashboard Introduction.

- Selecting  icon provides access to the list of Projects. An existing project can then be selected by selecting the project name.

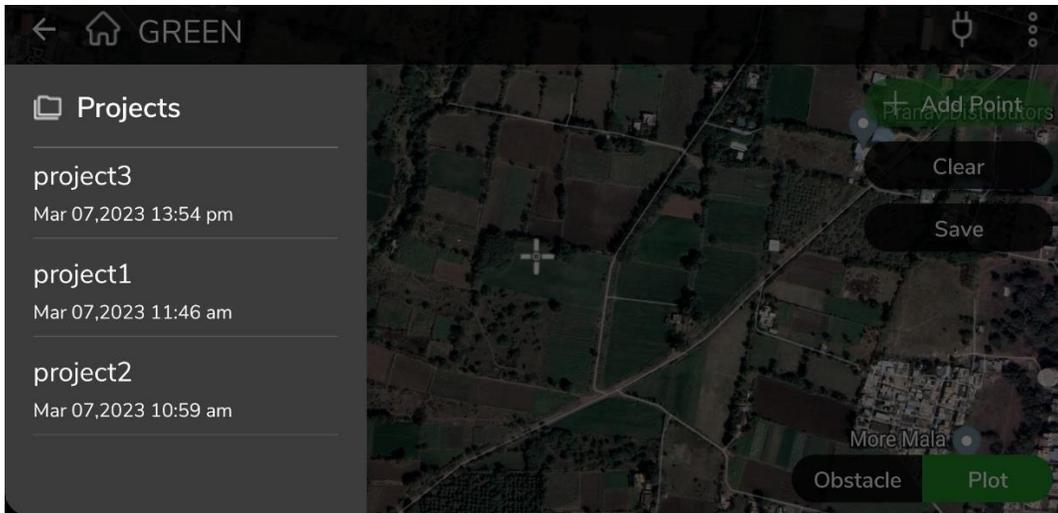


Figure 31: Projects List

Selecting a project name in the list provides access to its Plans and Plots. shows the details of the selected project such as the total area covered in acres and the mission completeness percentage.

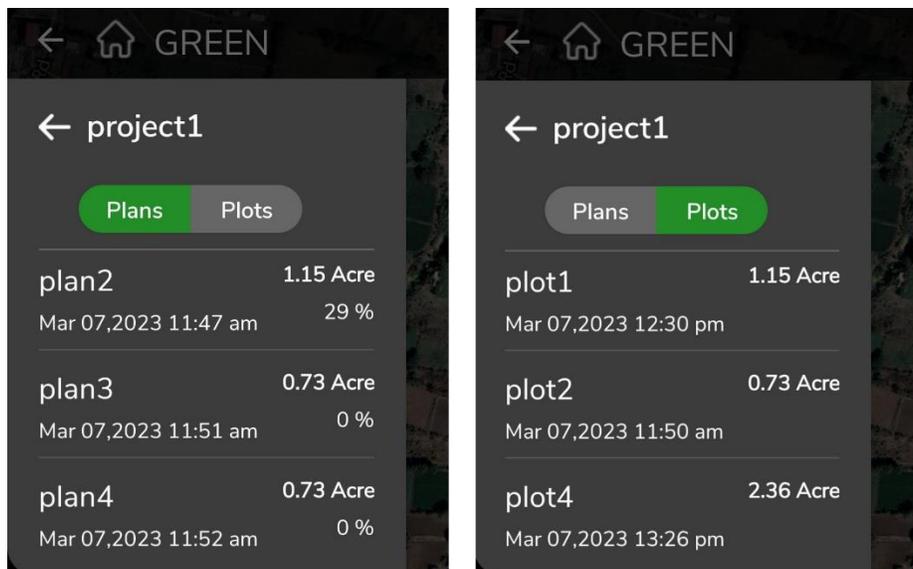


Figure 32: Projects and Plots Access

Selection of a plan or plot shows the following screen.



Figure 33: Plan/Plot Details

- UA Battery Voltage: The UA battery voltage is displayed at the location indicated in Figure 30: UA Dashboard Introduction. Follow recommendations for battery voltages.
- UA Speed: The UA speed is displayed at the location indicated in Figure 30: UA Dashboard Introduction. See operational specifications for speeds in section 2.2.1.
- UA Flight Mode: The UA flight mode is displayed at the location indicated in Figure 30: UA Dashboard Introduction. See operational specifications for flight modes in section 2.2.1.
- GNSS Satellites in View: The number of satellites as visible to GNSS receiver are displayed at the location indicated in Figure 30: UA Dashboard Introduction.
- UA Altitude: The UA's current altitude is displayed at the location indicated in Figure 30: UA Dashboard Introduction.
- UA Connectivity: The GCS Application's connection status to the RC is displayed by  icon at the location indicated in Figure 30: UA Dashboard Introduction. When the application is not connected to the RC, the icon is greyed out .

- Cloud & Sync Settings: The cloud and sync settings are accessed by selecting  icon. The setting is used to upload necessary data to the cloud.

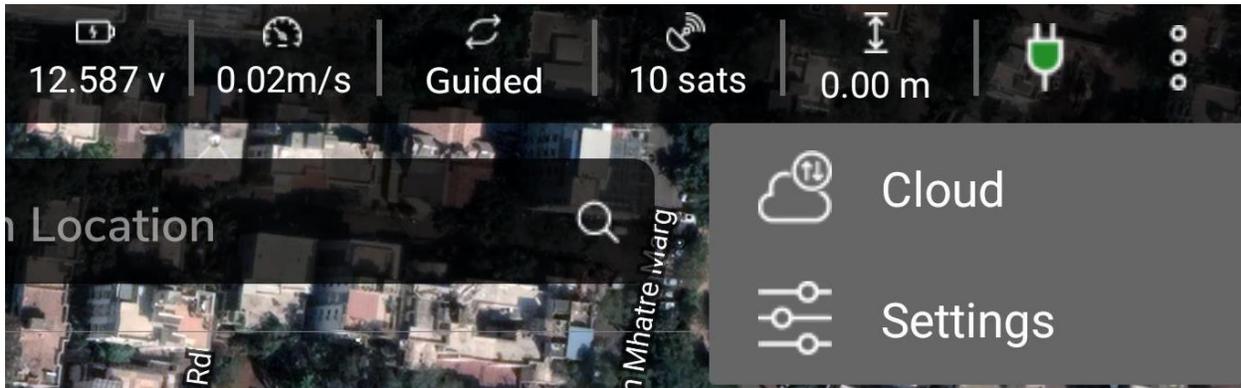


Figure 34: Cloud Sync and Settings

- Settings: Settings provides access to UA settings, where specific system parameters can be set to achieve desired behaviour. This is described in the UA Settings section.
- UA Heading: The  icon shows UA's current heading at the location indicated in Figure 30: UA Dashboard Introduction. The value is not displayed.
- Map Layers: The application uses google maps. The pilot can select  the normal map or satellite view by selecting the Map Layers icon. The satellite view image provided by google may not be recent.
- UA Focus:  Selecting this icon puts the UA location at the center of the screen to focus on the UA.
- Selecting the  icon provides quick access to project list and creation screen.

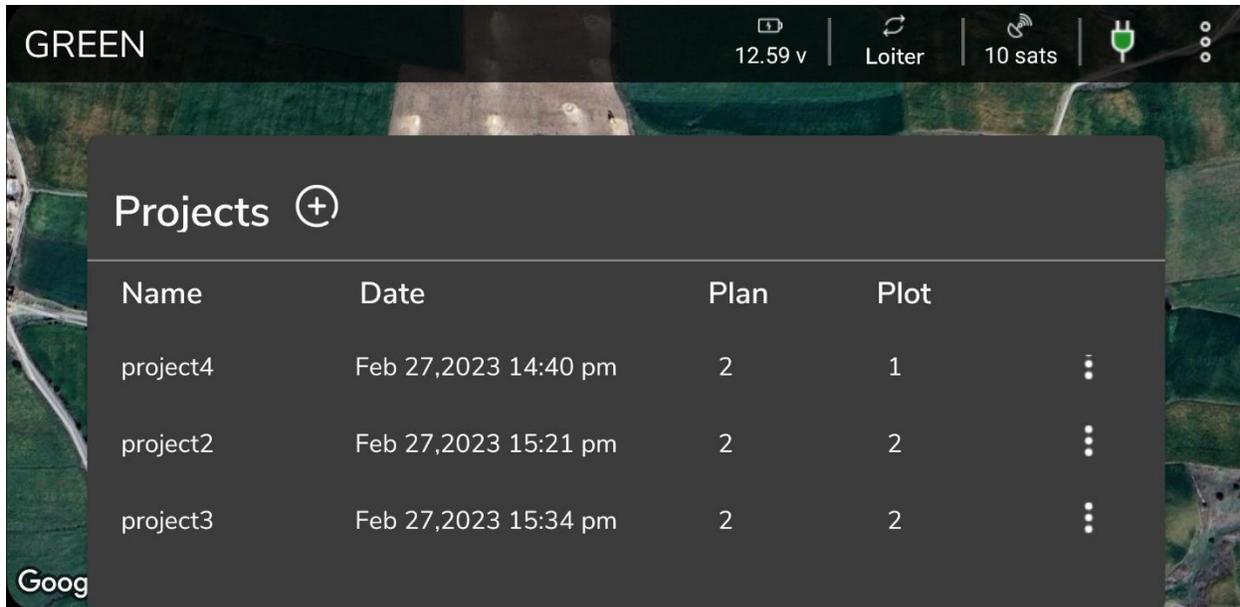


Figure 35: Project List & Creation Screen

4.2.3 Connecting to UA

To have an incident or RTL (triggered due to communication loss) free flight a reliable connection between the UA and GCS is essential. A reliable connection ensures that UA is connected to the GCS all the time, all the commands and plans will be followed by the UA and the GCS will continue to receive telemetry data.

Select  on the dashboard icon to access connection settings with the UA. The application connects to the RC using the phone's Bluetooth. Ensure that phone's Bluetooth is turned On. Select the Bluetooth option under Comm Link Type.

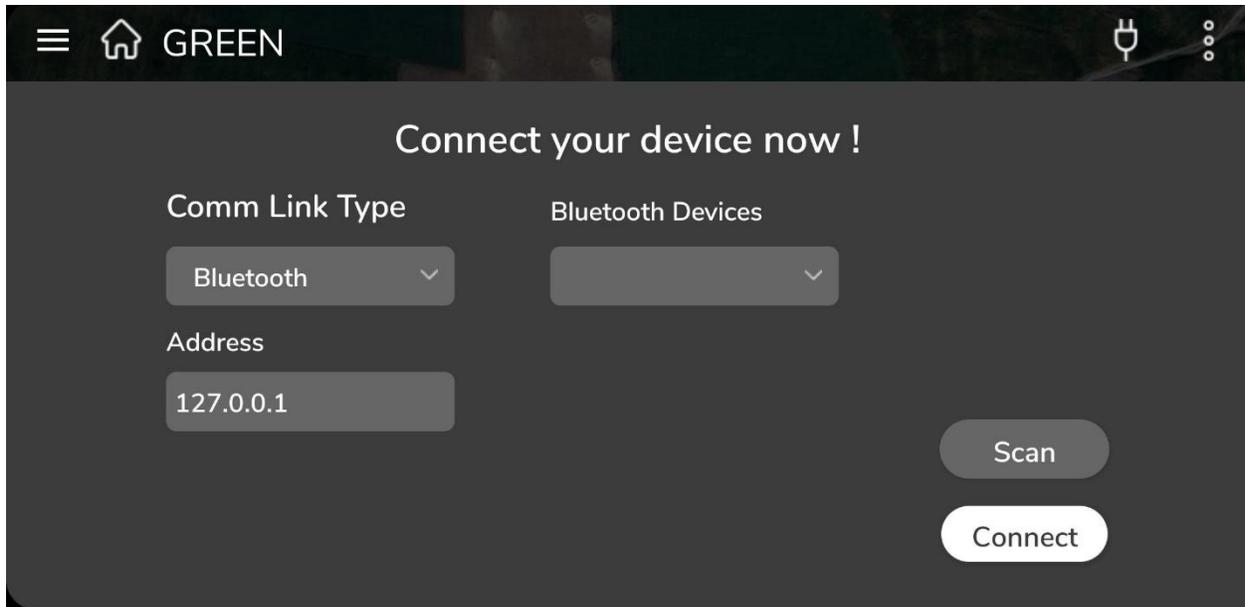


Figure 36: Connecting to the UA via RC

Now, select Scan to search for RC's Bluetooth connection as shown in Figure 36. Select the RC's Bluetooth device through the list. Allow to access the location of your mobile.

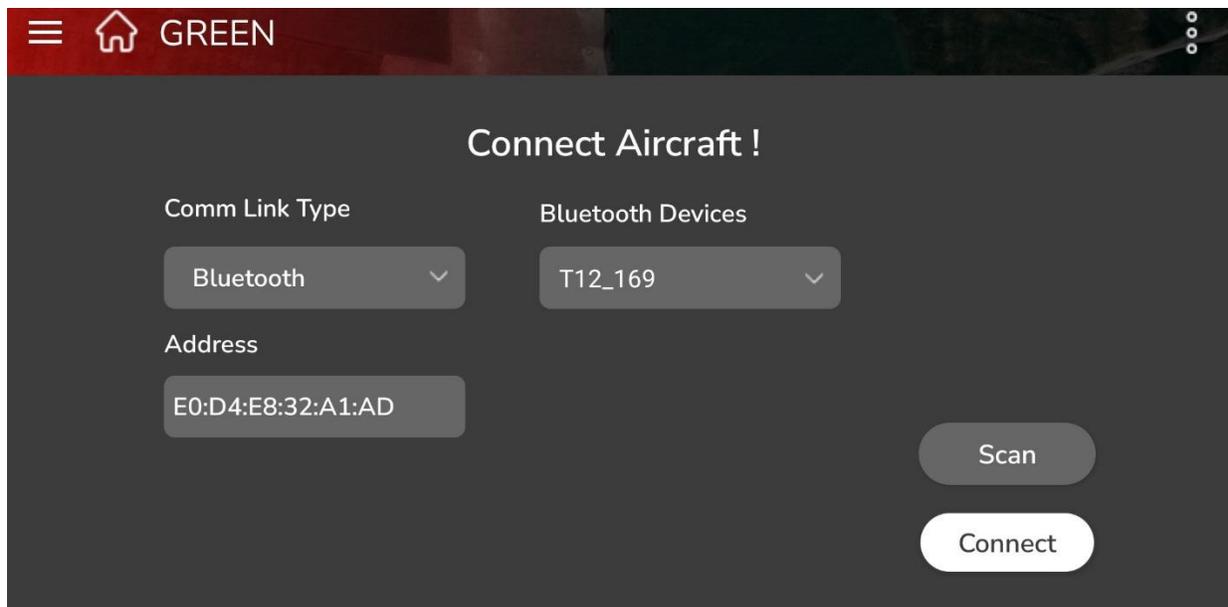


Figure 37: RC's Name Selection in Bluetooth Devices



The Bluetooth has a limited range of a few meters. Never take the phone more than five meters away from the RC. If the UA is in flight, loss of connection between the RC and GCS Application will trigger RTL.

The  will turn green  to show that connection between RC and GCS Application is successful.

4.2.4 UA Settings

UA Settings must be initialized before operating. It is essential to set mandatory parameters to have safe flight. To open the UA settings, select the three dots icon on the top right-hand corner of the dashboard. Then select "Settings" option from the pop up.

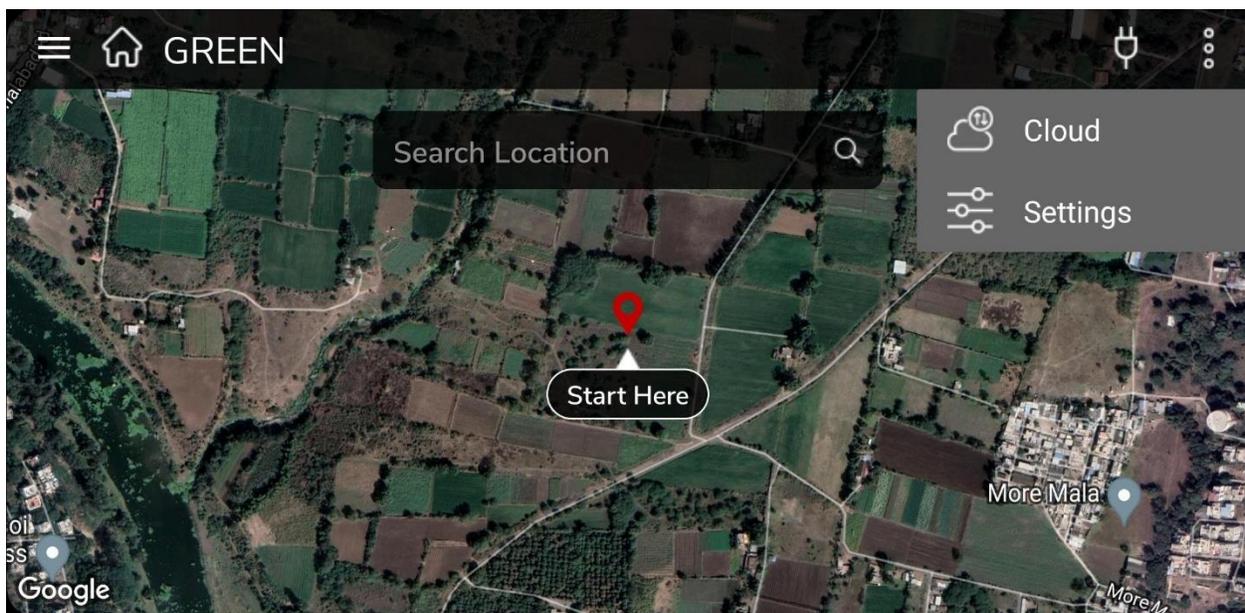


Figure 38: UA Settings Access

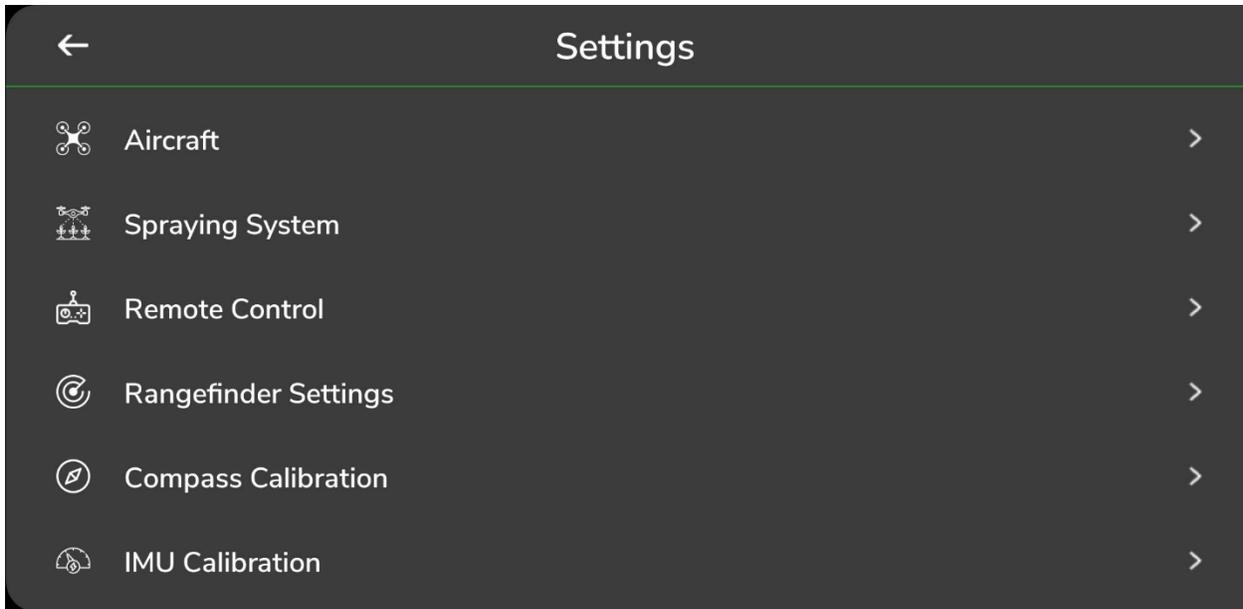


Figure 39: UA Settings - I

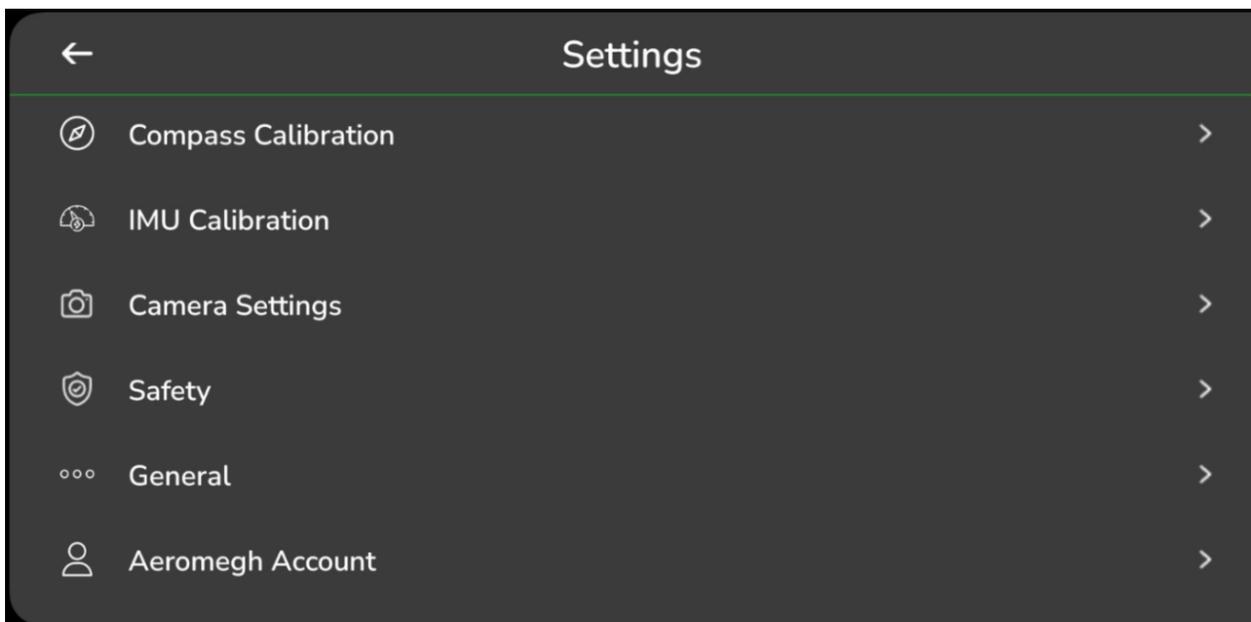


Figure 40: UA Settings – II

4.2.4.1 Aircraft Settings

The image below shows Aircraft Settings UI.

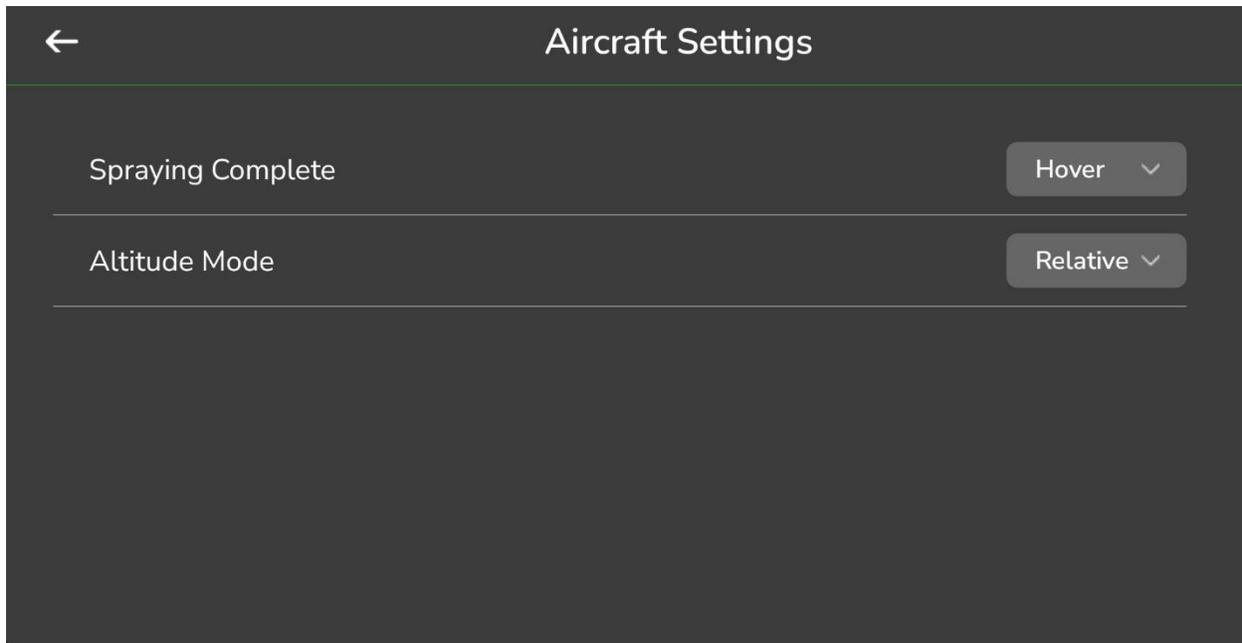


Figure 41: Aircraft Settings UI

The following image presents an introduction to settings screen layout and parameters related to aircraft.

- **Spraying Complete:** This setting allows the pilot to set the UA behaviour when spraying is complete: RTL, Land or Hover.
- **Altitude Mode:** The pilot can set the altitude mode to either Relative or Terrain. This setting applies to all flight modes (Auto, Loiter).
 - **Relative Mode:** The UA target altitude is set relative to the altitude to follow the set altitude.
 - **Terrain Mode:** The UA target altitude is set according to the terrain data. This feature allows the UA to climb or descend to maintain a specified distance above the terrain using SRTM data (aka terrain altitude data) provided by the GCS using a mapping service such as Google maps. To follow terrain data, the pilot must enable the parameters such as Enable Terrain and Terrain Follow. Before enable

Follow Terrain Data the pilot must select the location of Drone. The Terrain parameter enables the terrain functionality and generates the Terrain folder on the MMC SD Card. Terrain follow parameter enables the terrain mode in RTL and Land mode. User can also set the radius using in Terrain Radius Text box and this radius is used to download the terrain file. When user enables the Follow Terrain Data option, the GCS will generate and download the terrain file and that file is automatically get uploaded to the SD Card.

4.2.4.2 RC Settings

The RC needs to be setup correctly to control the UA. The first thing is to setup buttons and calibrate the joysticks. The RC buttons are explained in section 4.1. Select the "Calibrate" button to calibrate the RC for roll, pitch, yaw, and throttle controls. Then follow instructions on the UI.

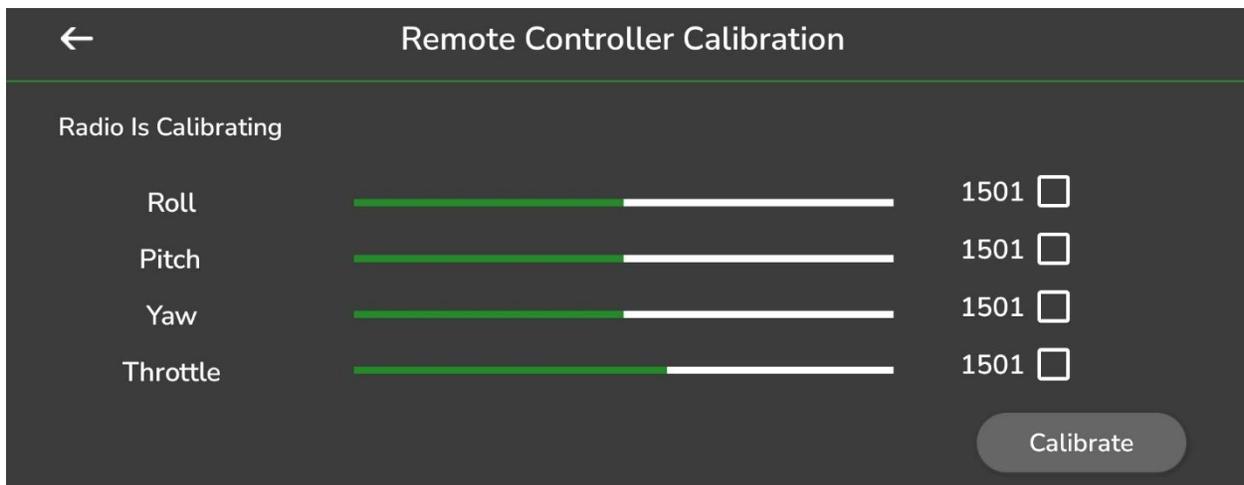


Figure 42: RC Calibration (Not calibrated view)

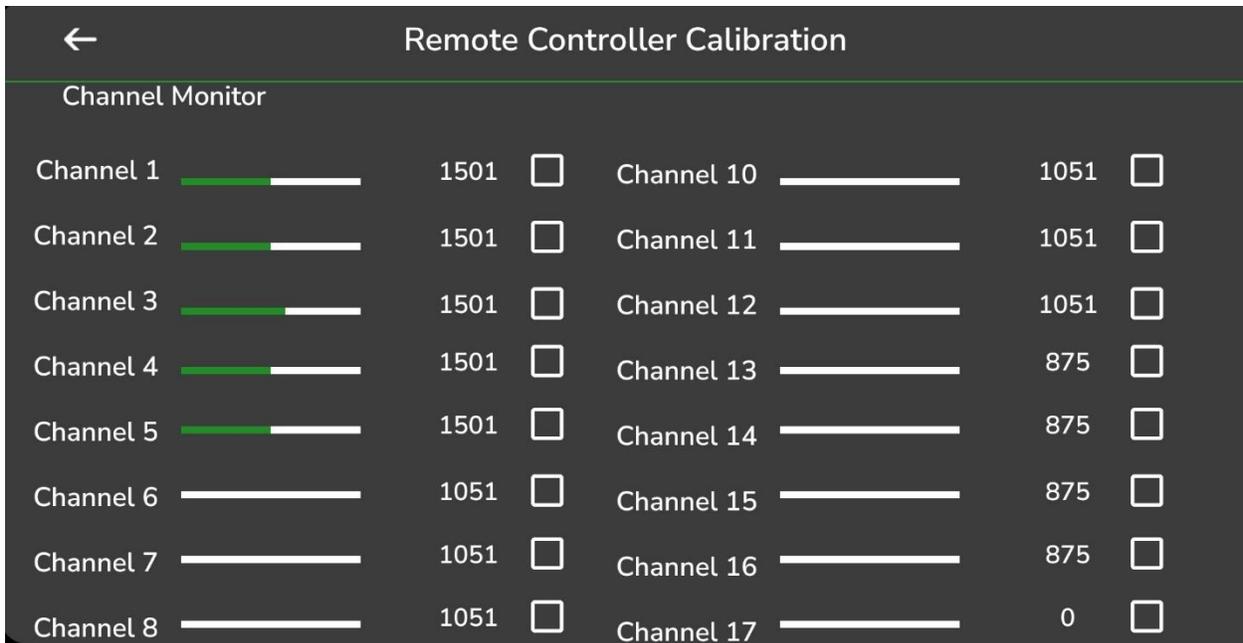


Figure 43: RC Calibration (Calibrated view)

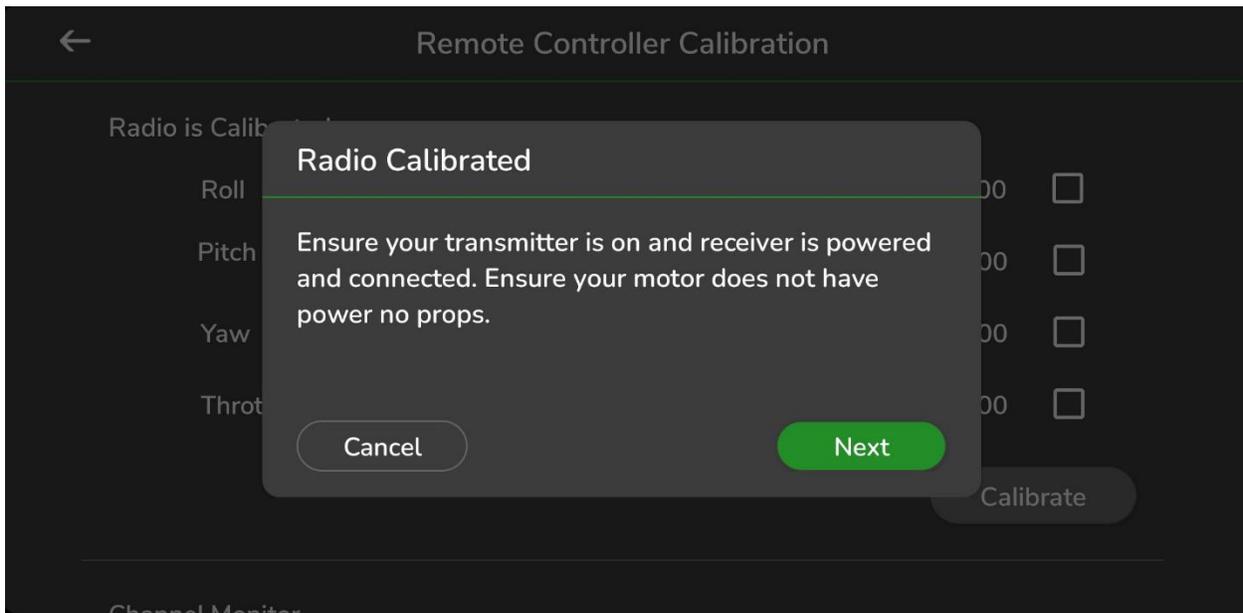


Figure 44: RC Calibration View After Selection of Calibrate Button

Once the calibration is done it will display all the values collectively as shown in the image.

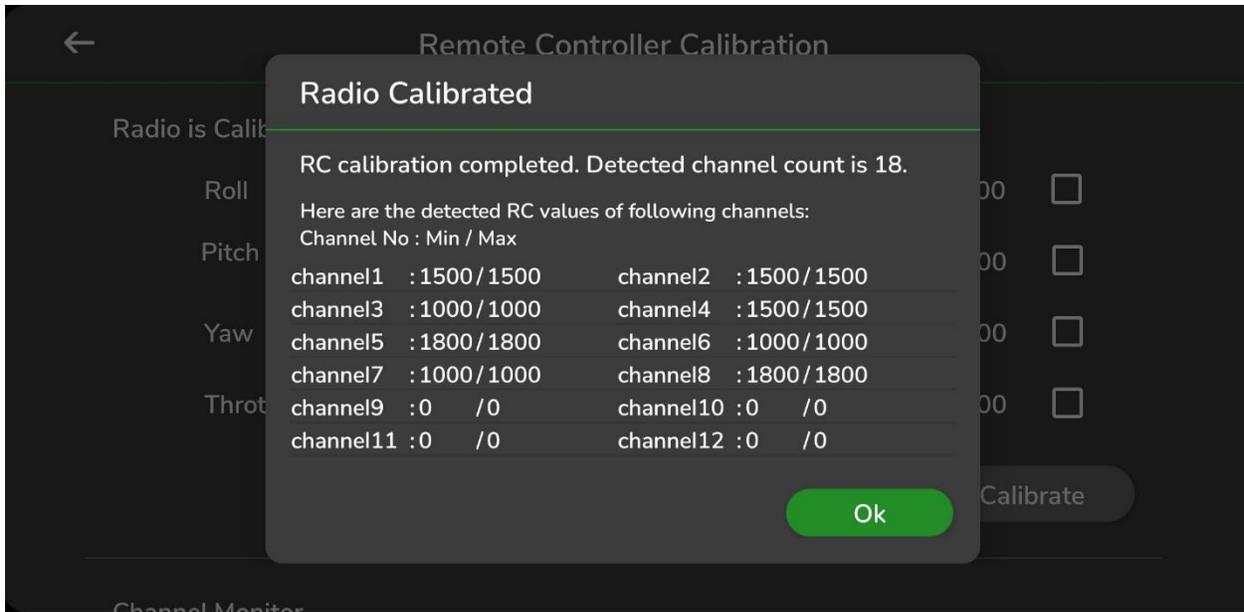


Figure 45: Calibration Completed View

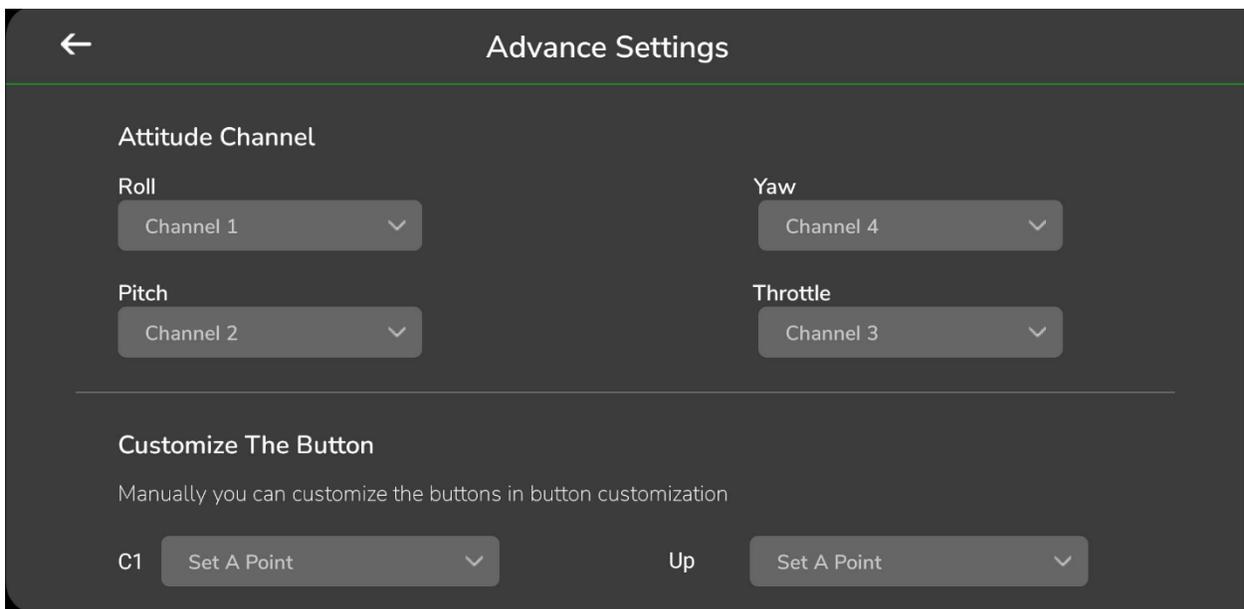


Figure 46: Advanced Settings - I

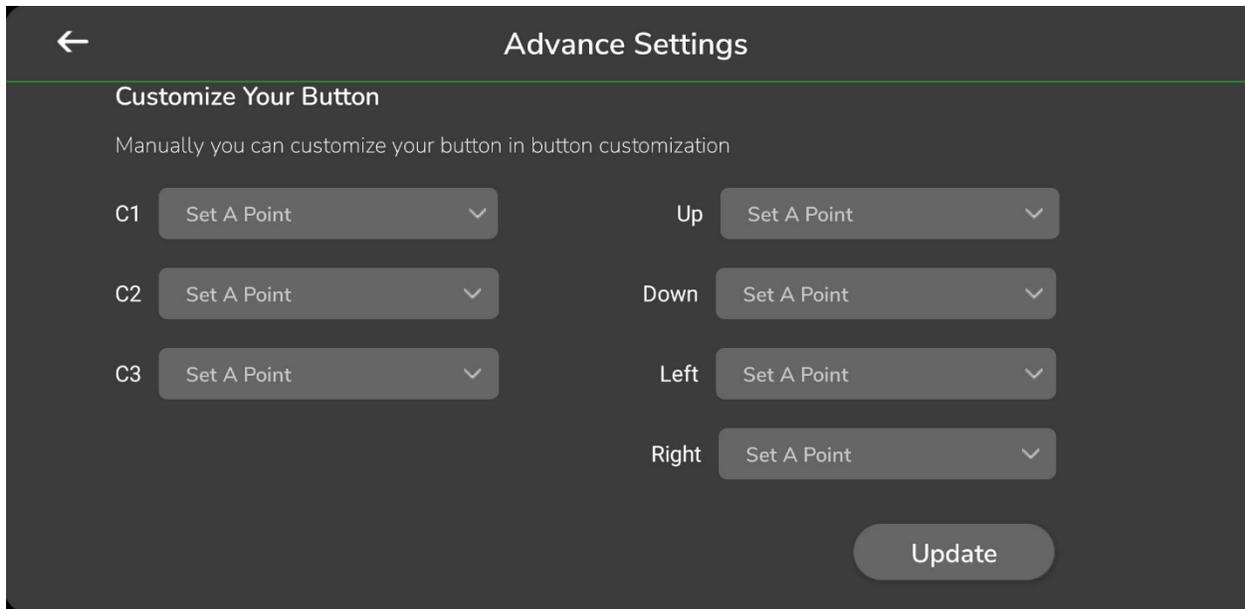


Figure 47: Advanced Settings - II

4.2.4.3 Compass Calibration



It is recommended to perform a compass calibration when the UAS is operated on a field which is at a distance of more than 15 Kilometres than the launch point of previous flight.

After selecting Compass Calibration, follow the on-screen instructions. Select "Start" button to start the calibration procedure. Lift the UA and holding by the arms at designated spots, gently rotate the UA in all axes. Calibration progress will be displayed as rotation around each axis is completed. After successful completion of compass calibration, a message will be displayed.

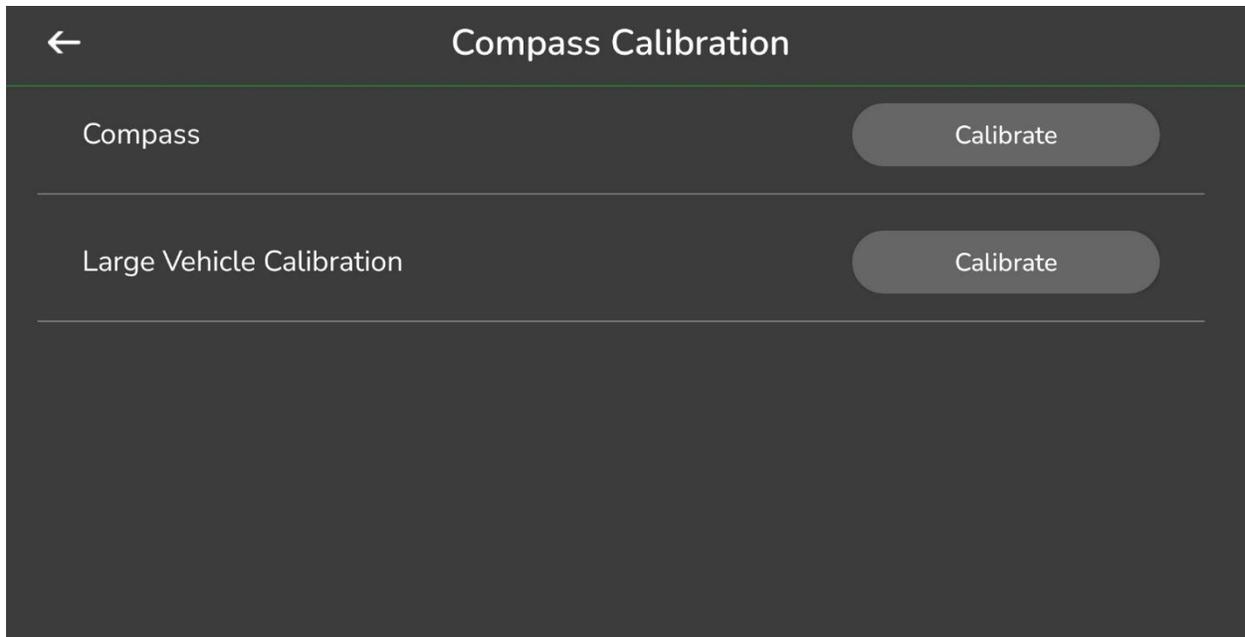


Figure 48: Compass Calibration Interface

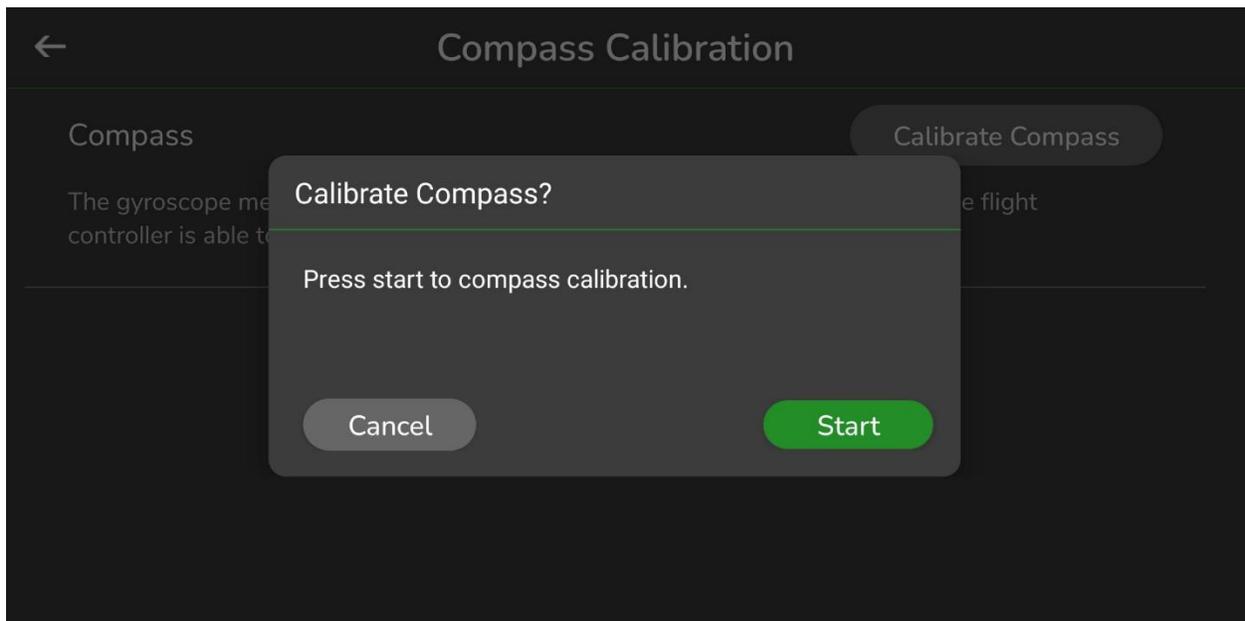


Figure 49: Compass Calibration, Normal Process

4.2.4.4 Large Vehicle Calibration

Large or heavy vehicles are impractical to rotate on all axes. This feature allows a fairly accurate calibration when GNSS fix is available on the autopilot and the UA's current

heading is known. The current heading can be derived using a known landmark reference or external compass. The heading should be TRUE but not MAGNETIC.

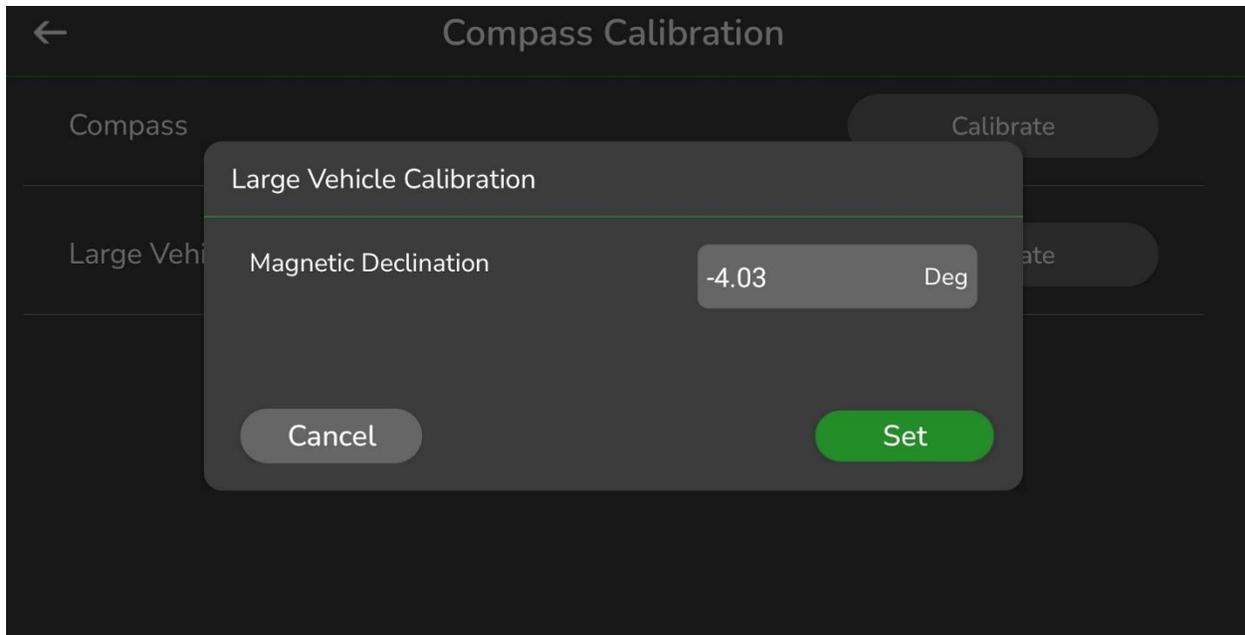


Figure 50: Large Vehicle Compass Calibration

4.2.4.5 IMU Calibration

The IMU calibration page allows access to calibrate Accelerometer, Barometer, and Level Horizon sensors. Each of these sensors has a Calibrate button associated with it. Select Calibrate for the sensor to be calibrated and follow the on-screen instructions.

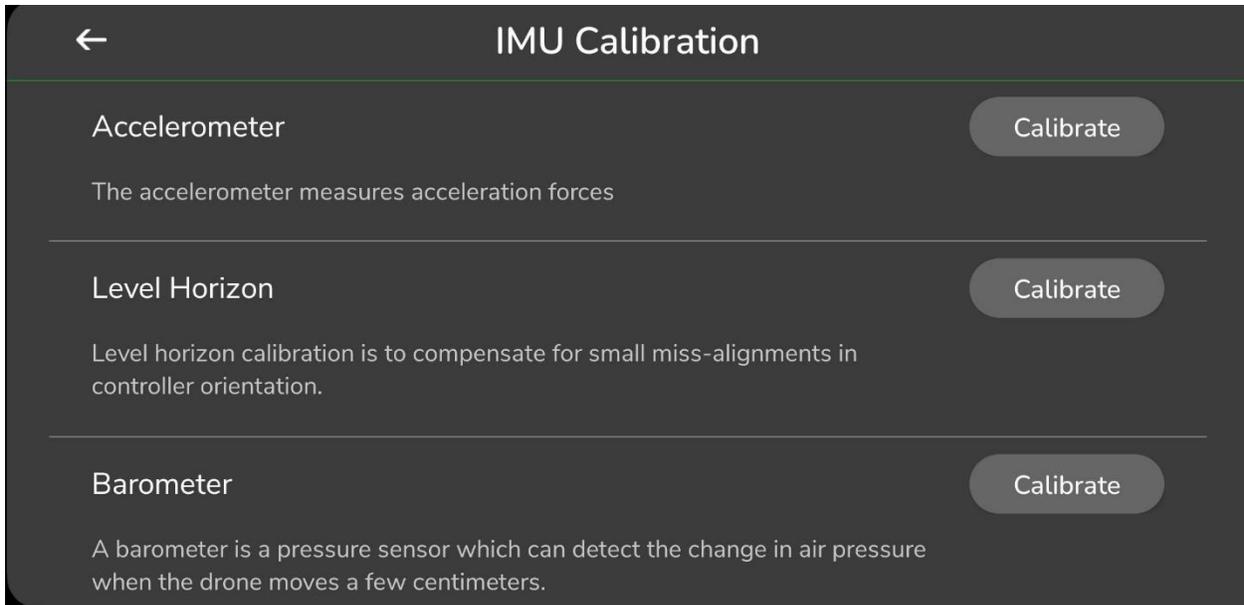


Figure 51: IMU & Sensors Calibration Panel



Figure 52: IMU & Sensors Calibration Screen

4.2.4.6 Spraying Settings

Spraying System settings provide access to the pilot to set spraying parameters, which are controlled through the pump, tank, and few emergency settings.

4.2.4.6.1 Configuration

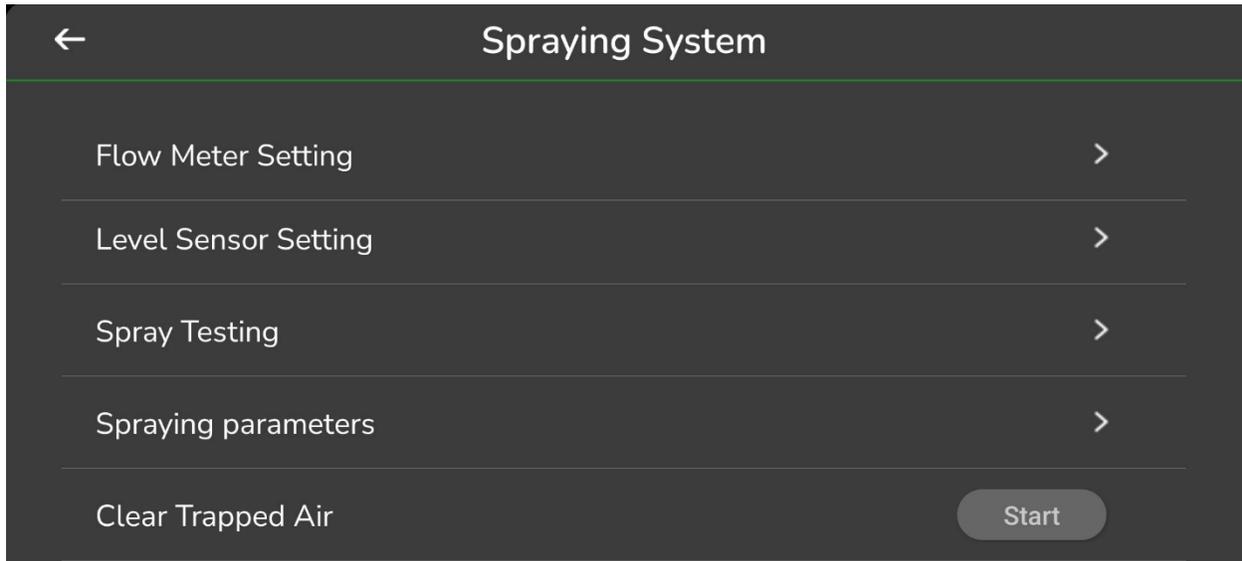


Figure 53: Spraying System Settings

- **Flow meter Settings**

- **Flow Sensor:** Select the YF-S201 flow sensor from the drop-down list as shown in the image below.
- **Liquid Tank Capacity:** Set the tank capacity to 10000ml (ten thousand ml).
- **Battery Current Pin:** Select AUX5 from the drop-down list.

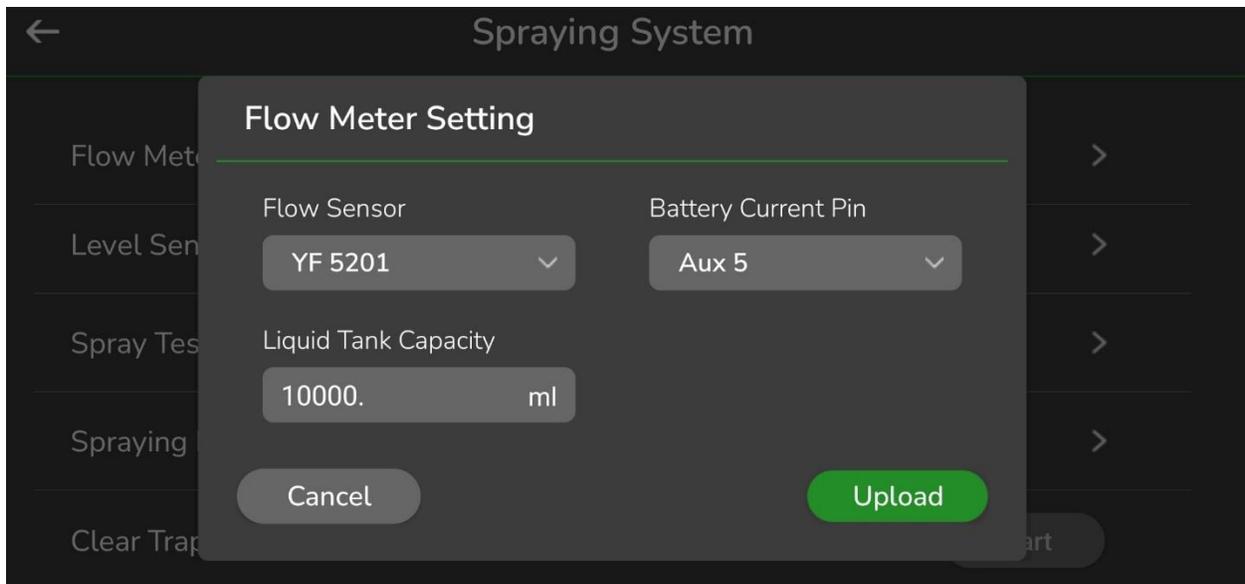


Figure 54: Flow Rate Sensor Settings

- **Level Sensor Settings:** Select the AUX 6 sensor input pin for XKC-Y25-NPN as connected to the MMC from the dropdown list. Click Upload after selection and follow on-screen instructions.

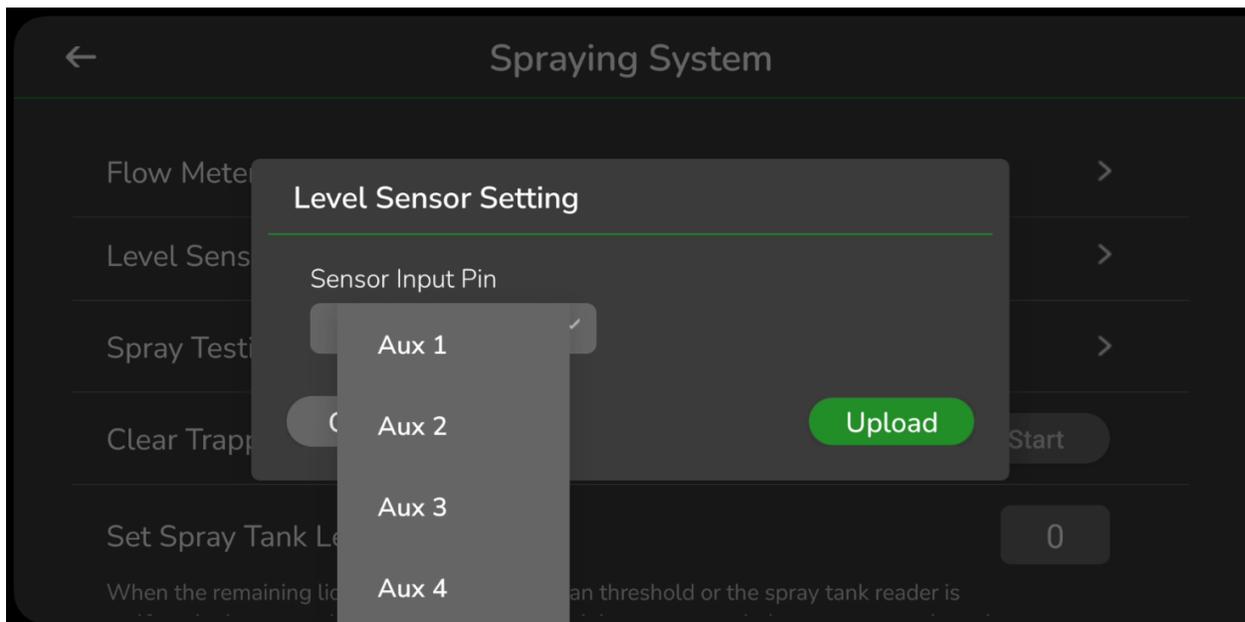


Figure 55: Level Sensor Setting

- **Centrifugal Atomizer Settings:** Select the AUX 6 sensor input pin for XKC-Y25-NPN as connected to the MMC from the dropdown list. Click Upload after selection and follow on-screen instructions.
 - **SPRAY_SPINNER:** Set the speed of spray spinning in 'cm/s'.
 - **SPRAY_SPEED_MIN:** Set the minimum speed of spraying in 'ms'.

4.2.4.6.2 Spray System Testing

The spray system can be tested on ground without flying the UA. Ensure that the tank is filled with liquid and the pump is on.

Select the Spray Testing option and follow on-screen instructions.

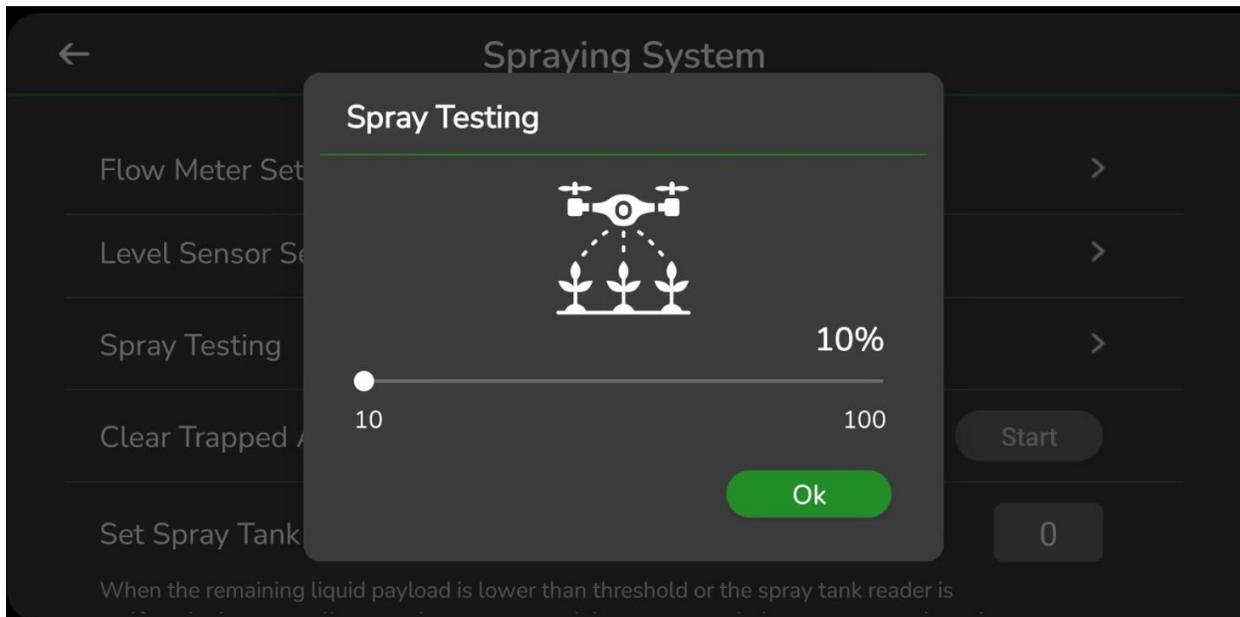


Figure 56: Spray Testing Configuration

The percentage of spraying volume can be updated with the slider. Select a value and click "Ok" to test.

4.2.4.6.3 Clearing Trapped Air

Sometimes the spraying system may stop functioning due to air pockets in the tube assembly. This blockage can be cleared automatically using the setting from GCS

application. Select the “Clear Trapped Air” in Spray System Testing and follow the on-screen instructions.

4.2.4.6.4 Spray Tank Level

Set the level of liquid in Spray Tank. When the remaining liquid payload is lower than threshold or spray tank reader is malfunctioning, manually enter the exact remaining amount to ensure normal operation.

4.2.4.6.5 Empty Tank Threshold Actions

Setting “Empty Tank Threshold Actions” will raise a warning message when the payload in the spray tank drops to the preset threshold. The user can set the empty threshold action as follows:

- **RTL:** Return to Launch after the level of liquid in the tank crosses the threshold level.
- **Hover:** Hover when the liquid in the tank crosses the threshold level.
- **None:** Assign no action on crossing the level of the liquid in the tank.



Figure 57: Empty Tank Threshold Action

4.2.4.6.6 Flow meter Error Alert

Setting this option generates an alert on the GCS Application when there is a large difference between standard and active flow levels. The user can set a minimum of 1% to a maximum of 20%.

4.2.4.6.7 Calibrate Pump Flow

Any fluid flow device must be calibrated to ensure correctness in the measurement system and configured alerts. Calibrate the pumps before spraying operation, change in the type of nozzle, or pump.

Access the UI and select the option to Calibrate Pump Flow. Before calibrating ensure that air has been discharged manually. Then pour 1 litre of water into the spray tank. Click on the 'Start' button to start the calibration process.

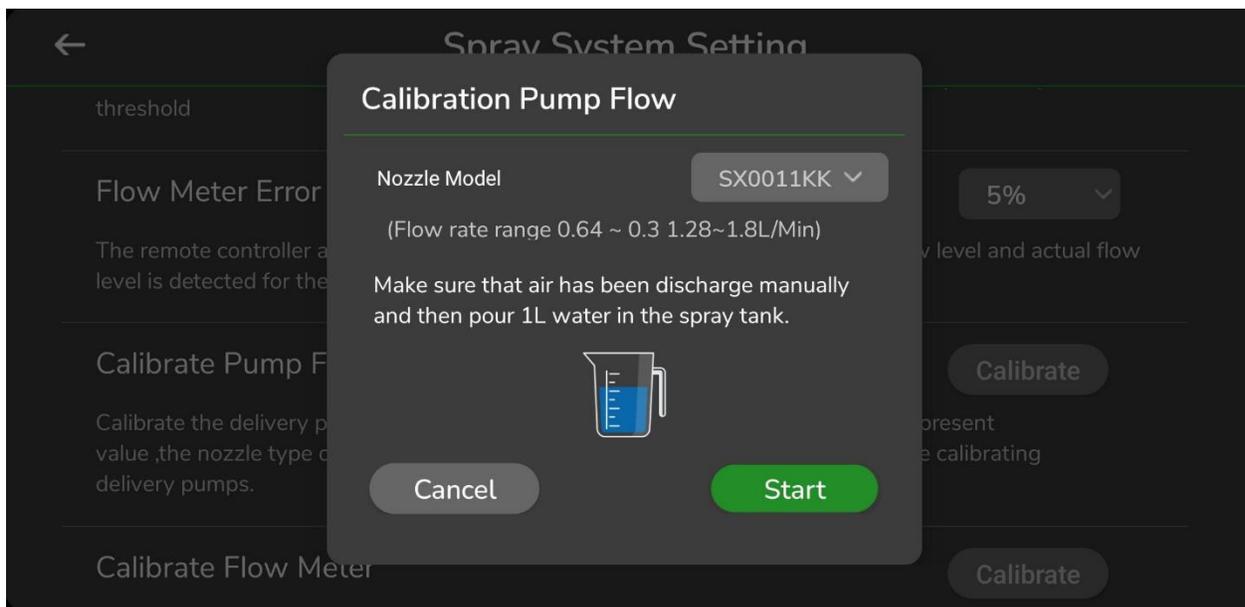


Figure 58: Pump Calibration View - I

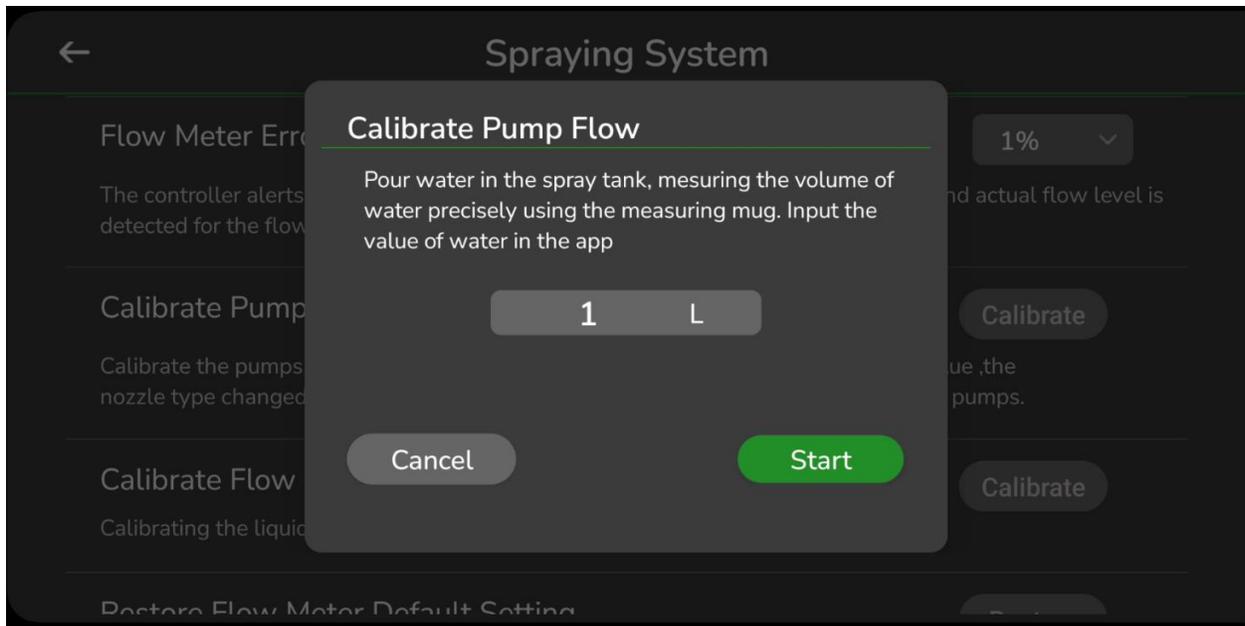


Figure 59: Pump Calibration View – II

Wait till the calibration is completed. After the completion of the process, click on the 'Done' button to finish.

4.2.4.6.8 Calibrate Flow Meter

Calibrating the liquid level ensures the accuracy of the remaining payload. After releasing air from spray assembly, pour the water into the tank. Select the capacity of a tank from the drop-down menu and click on the 'Start' button to start the process of flow meter calibration. Follow the instructions on the screen. Select Stop as soon as the tank is empty.

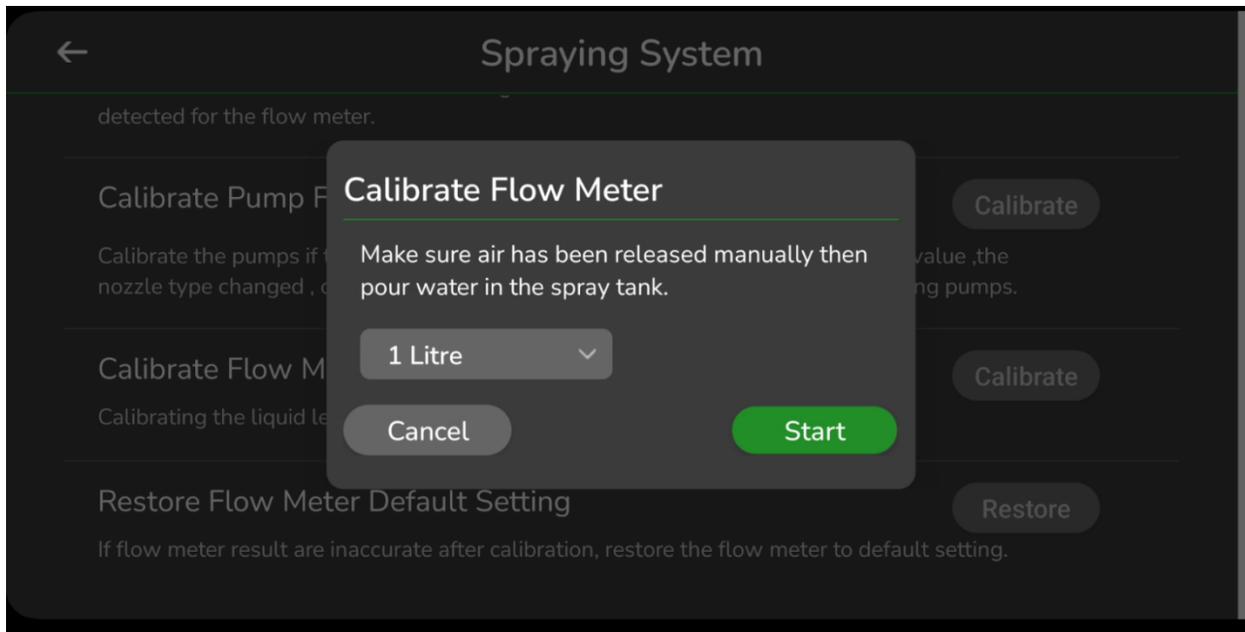


Figure 60: Flow Meter Calibration Screen

4.2.4.6.9 Restore flow Meter Default Setting

If the flow meter is giving inaccurate results after calibration, then restore the flow meter settings to test default settings. Calibration can be reperformed if results are not favourable. If there is still an issue, then flow meter may have manufacturing issues.

4.2.5 General Settings

General Settings provides access to select the operational language as shown in the image below.



Figure 61: General Settings

About provides access to application information.

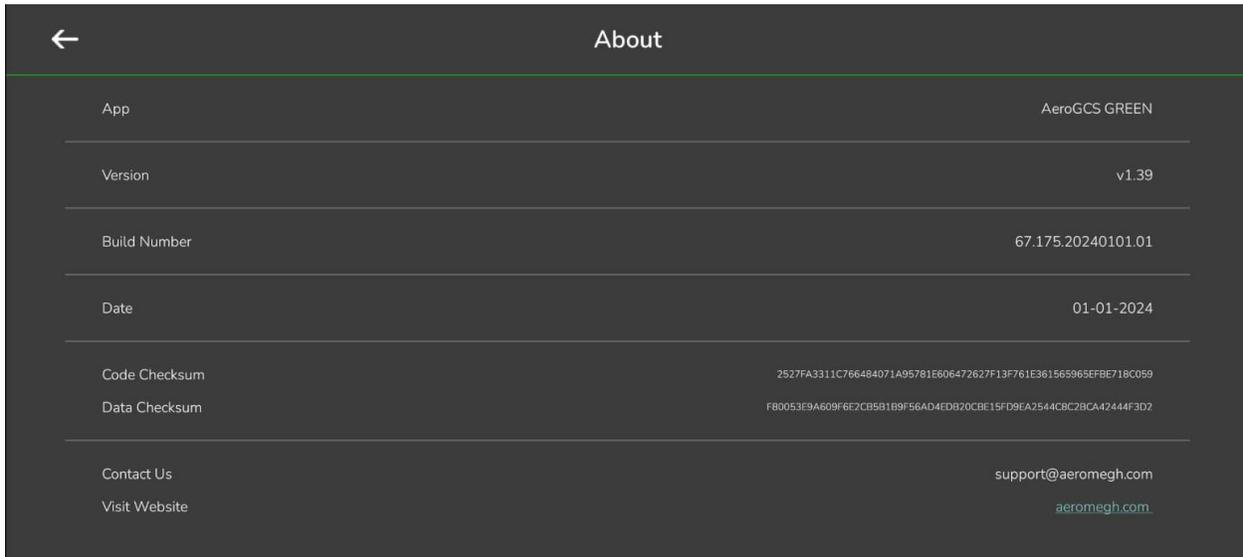


Figure 62: Application Information

4.2.6 Projects and Reports Editing

A Project is a collection of plans and plots with proper settings of parameters necessary to have a smooth and safe flight. Click on the Home icon to access the Projects panel. Then click on the  icon to start defining a new project. A project needs a plot to be defined using which the UA performs the spraying operation. The first step is to select the flying method.

There are two ways, the UA can be operated: Automatic and Manual (In this mode the pilot controls the aircraft and the aircraft maintains a stabilized 3D position in space.).

- **Automatic:** In this method, the user can plot a field plot on Google Maps.
- **Manual:** In this method, the user can mark the field plot on the map by using RC/Mobile or UA. Arm the drone for marking accurate positions on the field. Disarm the motors after marking the exact area.

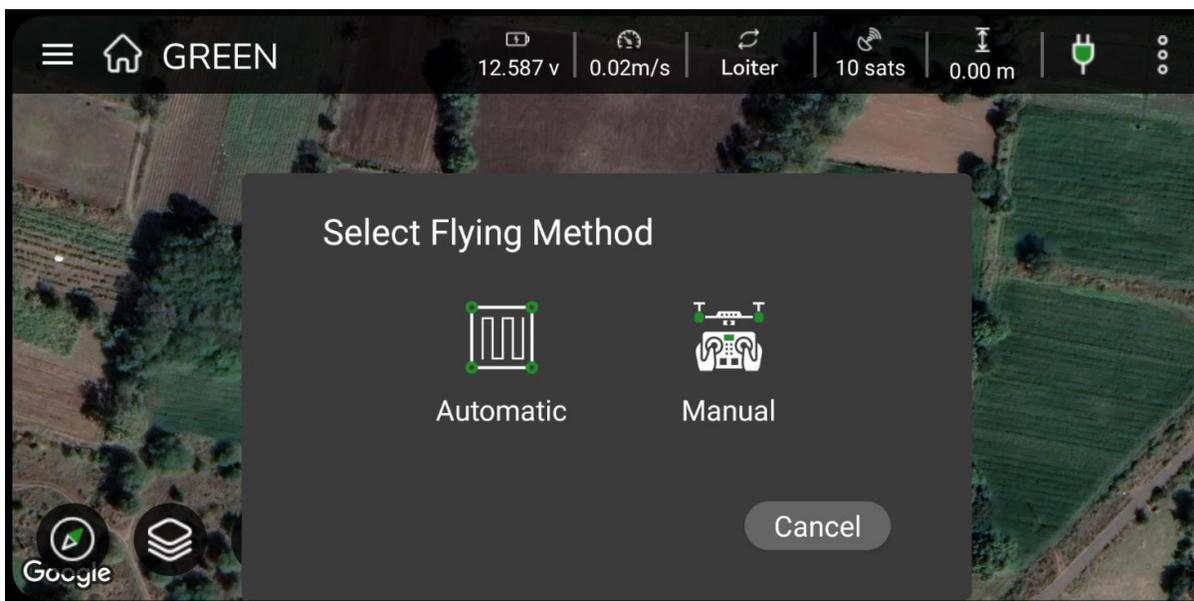


Figure 63: Flying Method Selection

4.2.6.1 Automatic Method

The Automatic method allows the user to select an option: RC/Mobile, Drone, Map, Import KML to create a plot. A Plot is defined as an area over which the UA will be operated.

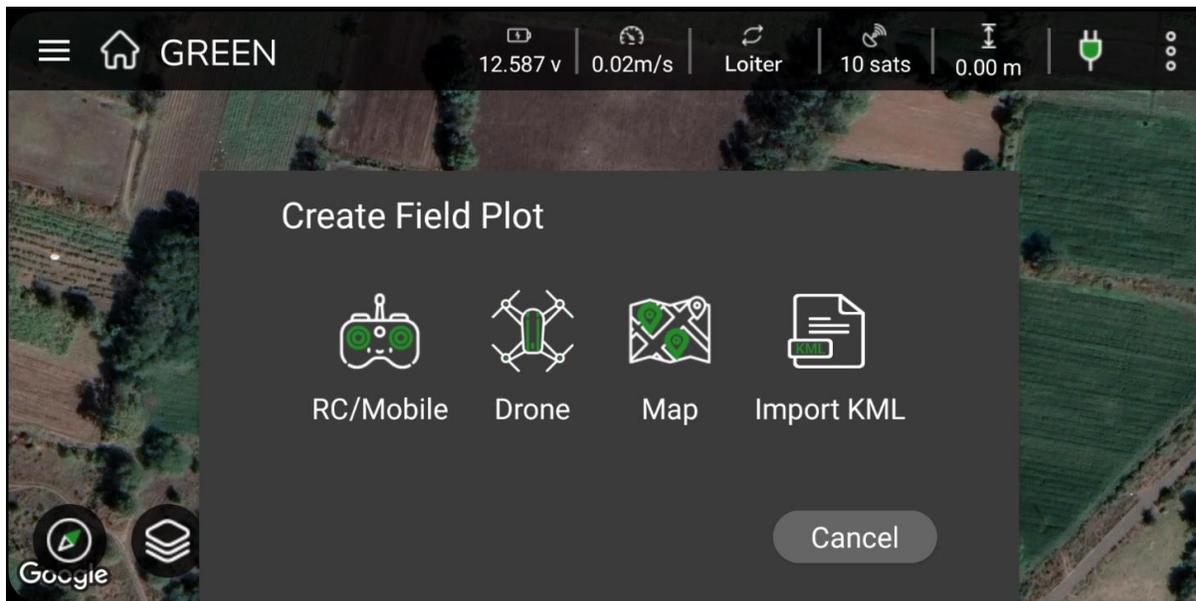


Figure 64: Plot Creation Method

1. **RC/Mobile Method:** In this method the user is required to carry the RC and mobile/tablet to the actual location on the field. The boundary points are marked by moving to the specific location. Click on the "Add Point" button to add it to the field plot. Mark the entire field plot by reaching the exact locations. Save that plot and use it for flying the drone. The accuracy of the plotting area will be improved with this method. Set all the parameters as per requirements and save the plan.
2. **Drone Method:** In this method the boundary is marked with the help of a UA flying in the air. Fly a drone in the specified area. Hover the drone at a particular position to mark it as a point for a field plot. Click on "Add Point" button on the GCS Application and move further to mark other points. Save the plot and proceed for creating a plan
3. **Map:** Use the location on Google Maps to set the position and create a field plot using the map functionality. This method offers various features like 'Add point', 'Clear', and

'Save' options. The pointer and the background moving on the Google Maps screen give precise field plotting.

4. **Import KML:** If the pilot knows how to work with Google Map's KML files, this option is very useful. The pilot can import KML files for a field plot. After selecting the right option, add points to the plot by using the 'Add Point' option. Navigate on the map to mark the points. When you are done with marking all the points then 'Save' the plot.

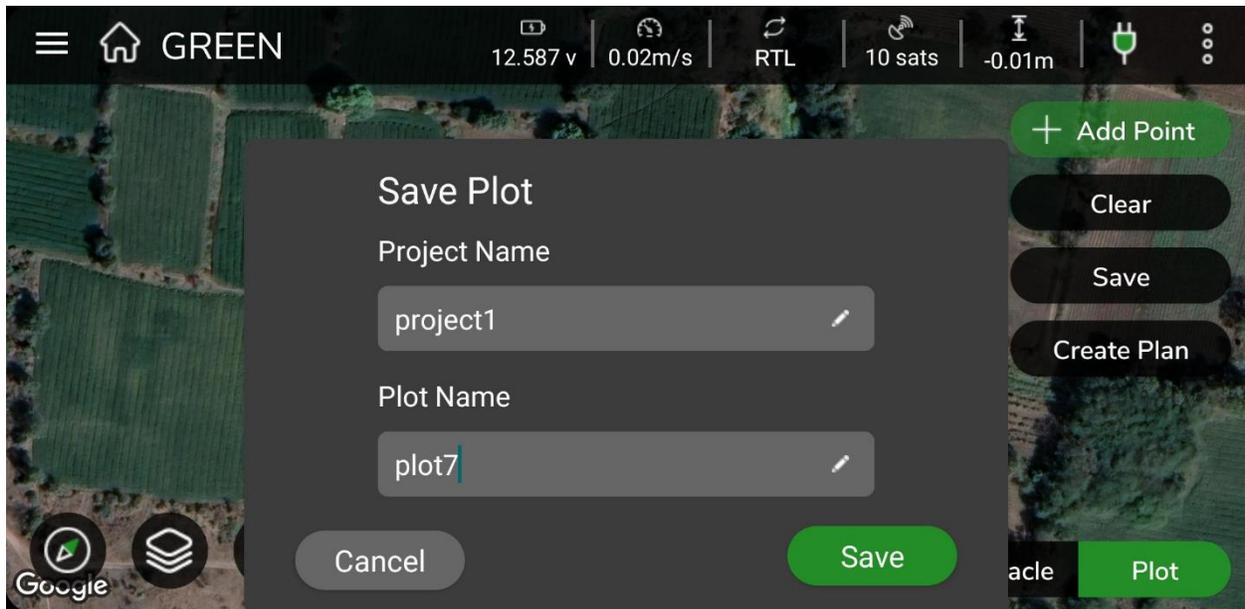


Figure 65: Saving a Plot

4.2.6.1.1 Setting up the Plan

A **Plan** is the way, the operation will be performed on a Plot. A plan is created by selecting 'Create Plan' button. The spraying map will be displayed on the screen with the parameter setting options window as shown in the following image.

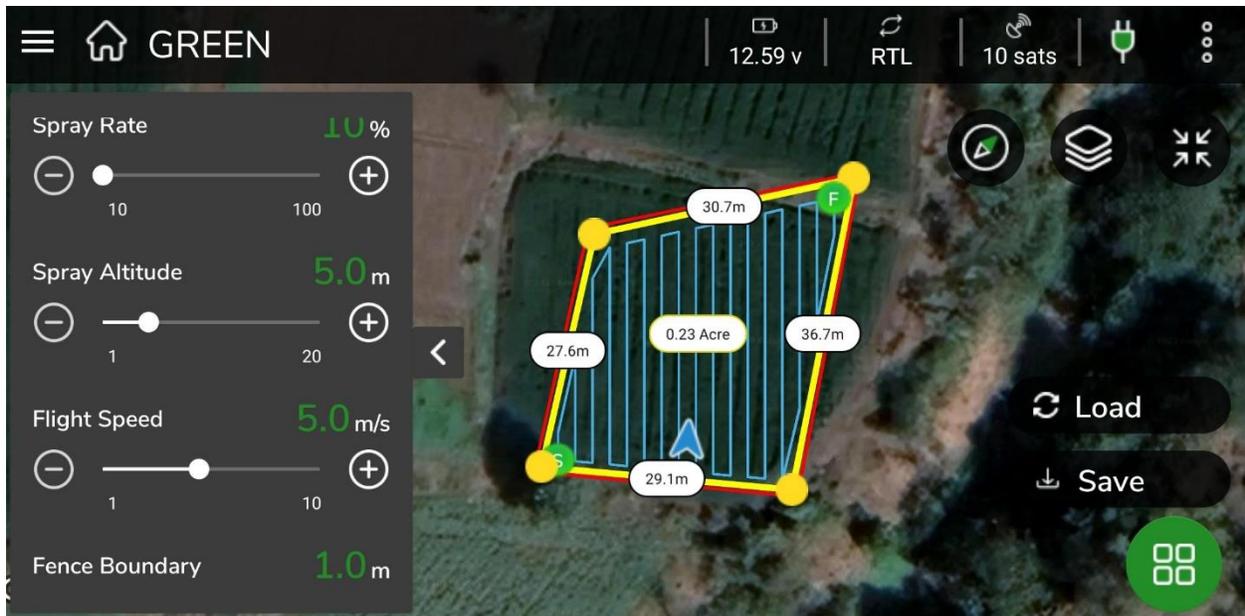


Figure 66: Defining Plan Parameters

The screen displays all the dimensions of the plan, which includes the calculation of the area in Acres. The list of parameters that are to be changed is displayed on the left-hand side of the screen as shown in the image. The sliders are provided through which the user can adjust these values. The plan created has a fence marked outside of the plan indicated by a red line as shown in the image. This fence can be adjusted as per need.

- **Spray Rate:** The rate of spraying can be adjusted from 10% to 100% by using the slider.
- **Spray Altitude:** The altitude from which the spraying operation needs to be performed be adjusted from 1 meter to 20 meters.
- **Flight Speed:** The flight speed can be adjusted from 1 m/s to 10 m/s.

- **Fence Boundary:** Adjust the fence boundary from 2 meters to 10 meters. The fence boundary is intended prevent the UA from flying into (exclusion) or out of (inclusion) zone by triggering a failsafe action like RTL or in some cases, plan paths around the boundaries. When flying in Loiter mode and Object Avoidance is set up, the UA will stop before breaching the fence.



Figure 67: Defining Plan Parameters – 2 (Fence Adjustment)

Save the changes. The saved plan is available for edition at a later point in time. Saved plans are synced to the cloud server.

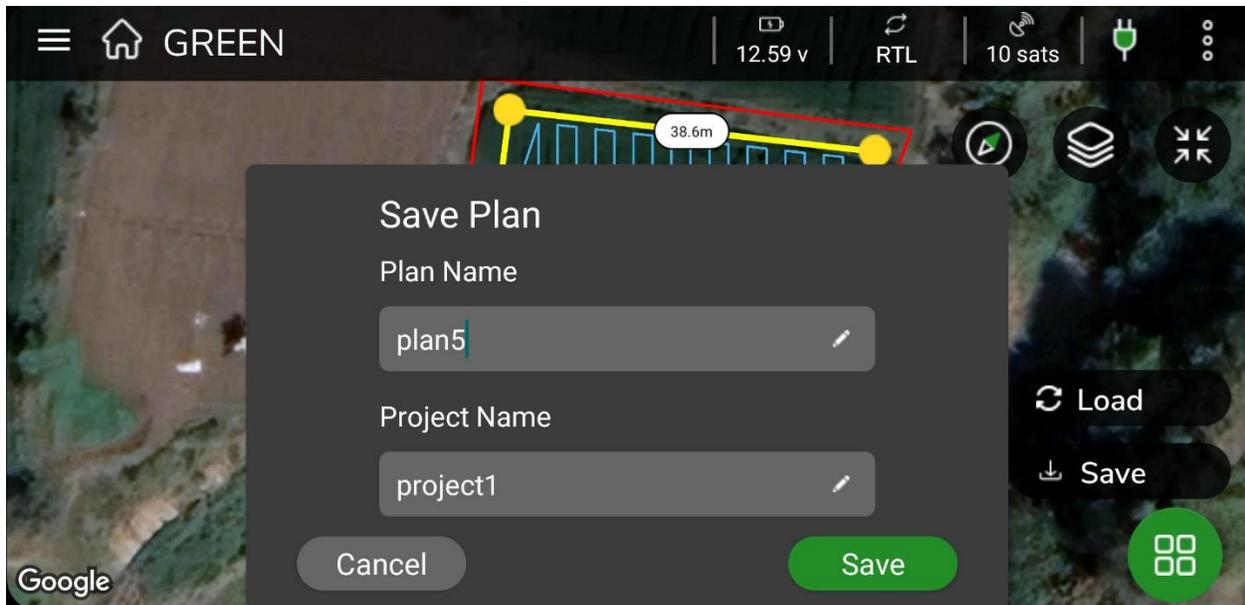


Figure 68: Saving a Project with a Plan

4.2.6.1.2 Plan Splitting

Battery powered UAs have limited flying time, which makes it difficult to complete a large area in a single flight.

The first step is to Plot the area for spraying. Plan for obstacle avoidance. The estimated time required will be calculated and displayed on the screen as shown in the following image. Based on the power of the battery and the area to be covered, the pilot may decide to use the plan-splitting functionality.

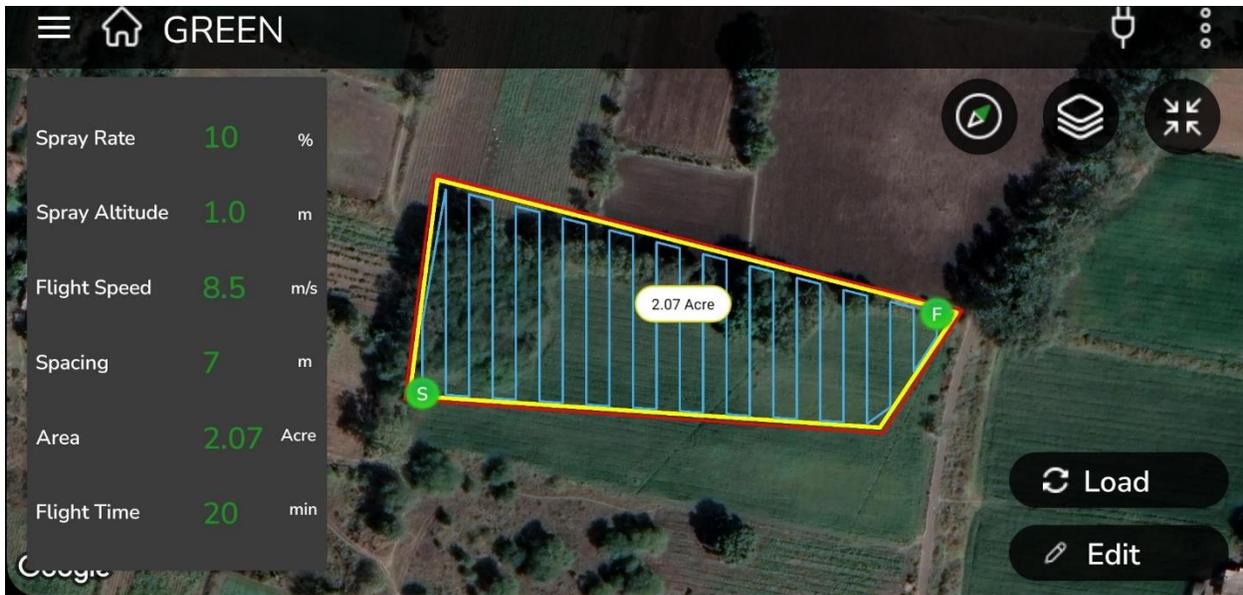


Figure 69: Split Plan Function

Select the Edit option to access "Plan Splitting".



Figure 70: Plan Splitting

Select the percentage of plan splitting from the start position or from the finished position according to your requirements. Change the position of the slider to set the desired percentage. The 'blue' lines here indicate that this portion of the plan will not be

considered for flight by the UA. The portion indicated by the 'yellow' colour indicates the area over which the UA will fly. Split the larger plan into smaller plans as shown in the above image, Save these plans separately.

Plan can be split into two parts as shown in the image. The user can set different speeds, and altitudes of the drone to operate in these areas. This type of flexibility will be helpful when there is different crop available in the planned area.



Figure 71: Plan After Splitting

The split plan will be displayed on the fly view as shown in the above image.

4.2.6.2 Manual Method

The pilot can fly the UA manually in Loiter mode using the RC. The track of manual flight can be observed on the screen.

Click on the "Arm"  icon to Arm the aircraft and start the flight. This is indicated with "Arming Motors" message on the screen as shown in the image below. The manual flight can be traced from the Fly View of GCS Application as shown in the following image.

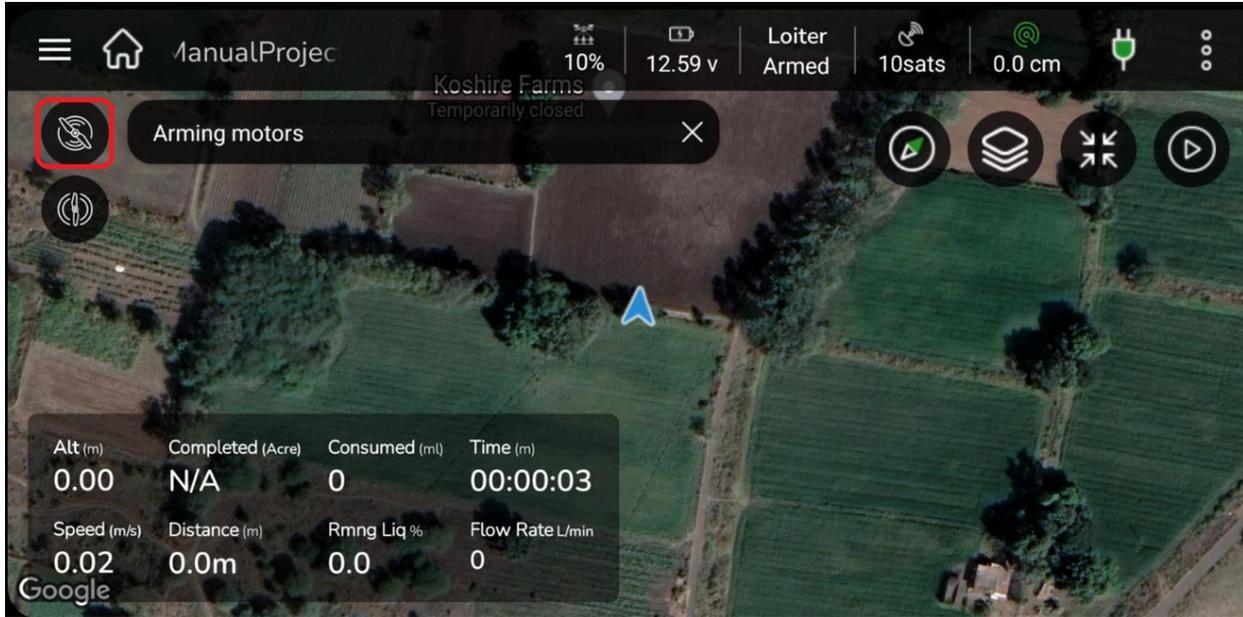


Figure 72: Manual Flight Project Creation

4.2.7 Editing Existing Projects

Select the "Home menu" to open existing projects. Select a project of choice to open from a displayed list. Then select the plan to be edited. The search box can be used to find a particular plan or plot.

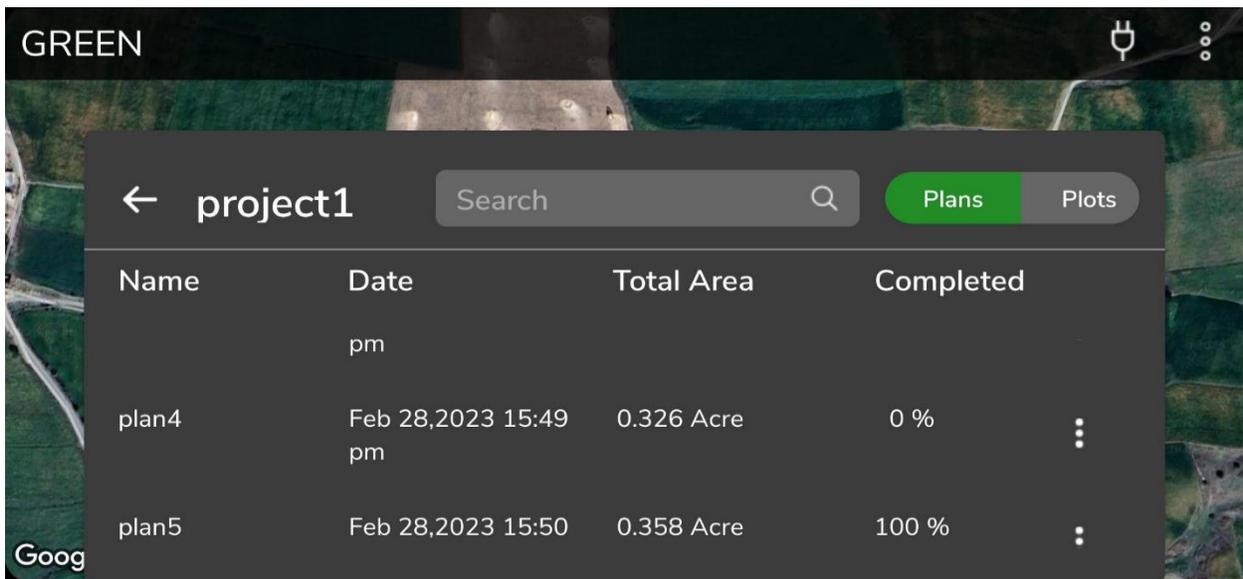


Figure 73: Project, Plan Screen

4.2.7.1 Plan Edition

In the Plan Display click Edit to begin editing. The list of parameters is displayed on the left-hand side of the screen. The modifications in the parameters are done by using the sliders. The following parameters can be altered by using respective sliders.



Figure 74: Plan Display



Figure 75: Plan Edition Window

 icon can be used to access and adjust the settings of parameters, route adjustments, etc.



Figure 76: Plan Editing Options

This option provides a setting of following:

- Parameter:** Spray amount, spray rate, spray altitude, flight speed, spacing between lanes and fence boundary can be adjusted.
- Waypoints:** The 'Adjust Waypoints' screen will pop up on the screen's left side. Select a waypoint that you want to adjust. After getting selected, the colour of the waypoint changed to Green from yellow. Adjust the location of the waypoint with the arrows present on the screen. After adjusting the waypoint press on Ok button. The changes will be stored.



Figure 77: Waypoints Editing

- **Spacing:** Move the slider to change the spacing between the rows of the plan. The minimum spacing allowed is 2 m and the maximum spacing is 10 m.

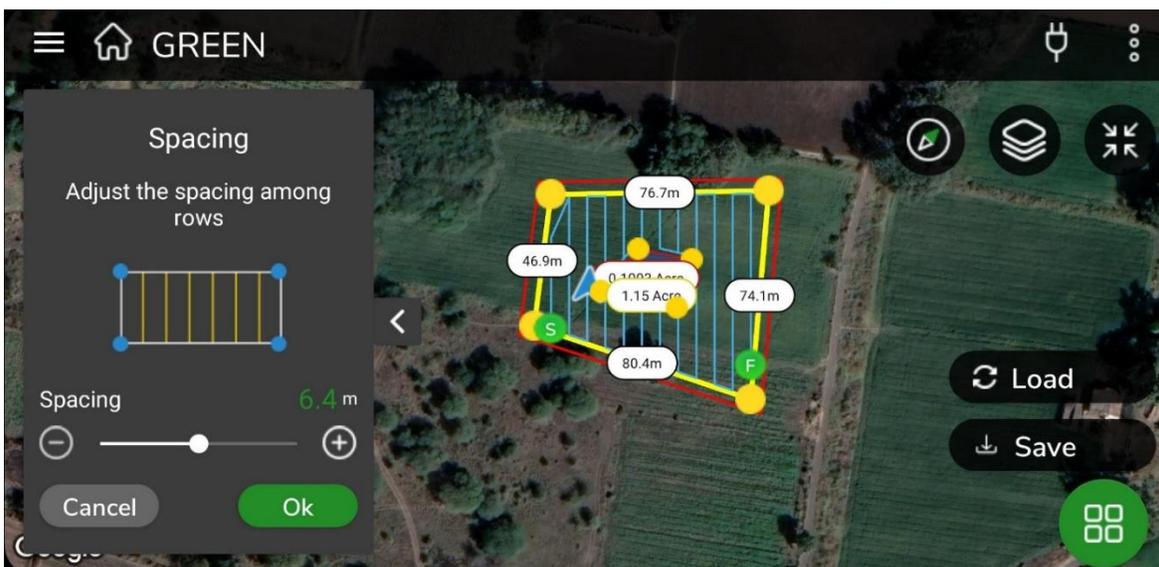


Figure 78: Spacing Edit view

- **Indentation:** Select the edge or side of the plan to adjust the indentation. The colour of the selected edge will turn Green as shown in the following image. The user can set the indentation from 1 m to 10 m.

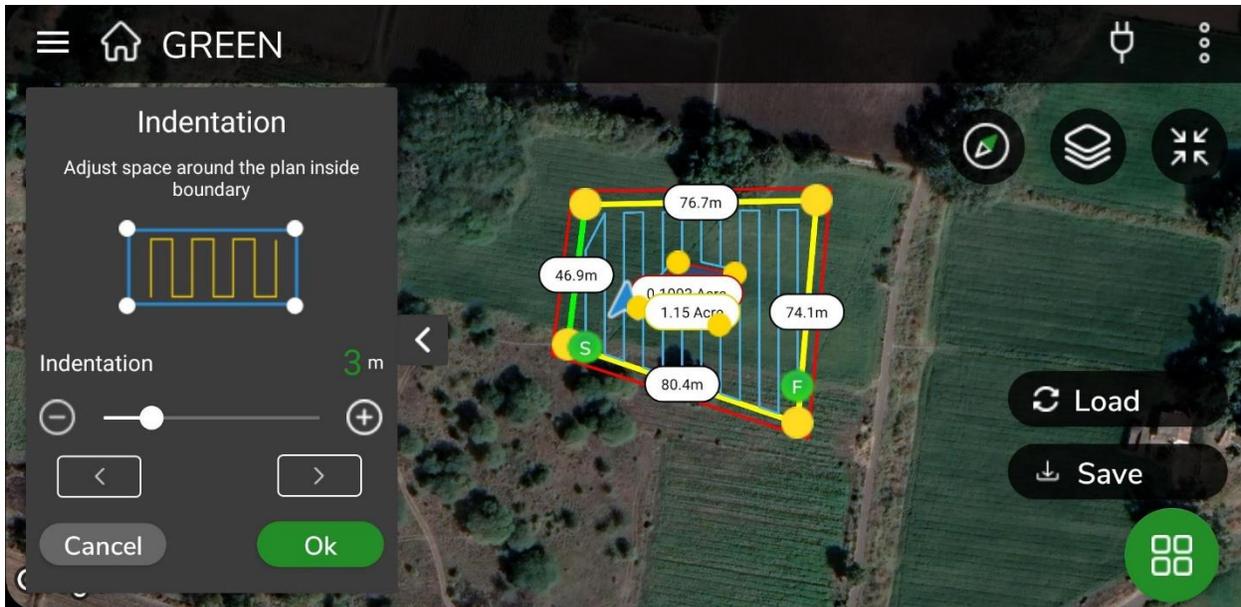


Figure 79: Indentation Editing

- **Obstacle Boundary:** Use the slider to change the spacing around the obstacle. The spacing can range from 0 m to 10 m.

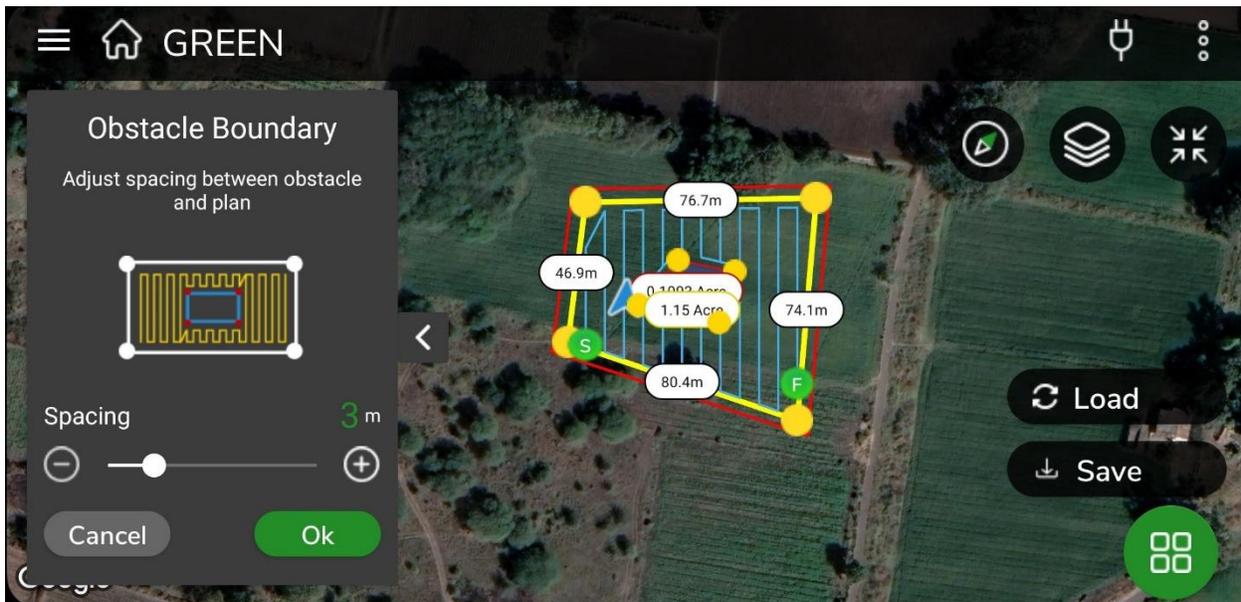


Figure 80: Obstacle Boundary Editing

- **Route Adjust:** The Route Adjust option is used to change the orientation of the flight pattern over the spray area. Use the slider to set the orientation. This can be helpful in windy conditions.



Figure 81: Route Pattern Editing

All these altered parameters can be saved into the existing plan or the user can save these by creating a new plan. Save the changes to the existing plan and click on the "Load" button to fly the UA.

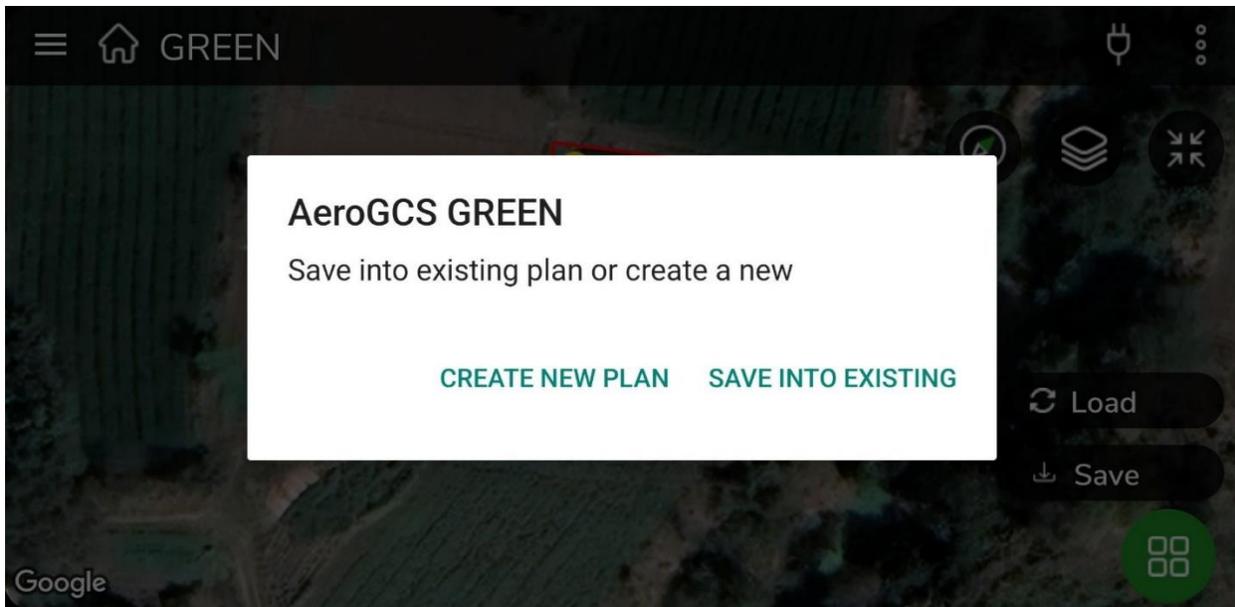


Figure 82: Saving Options for Edited Plan

 If the flight is not completed and has a resume point marked, the plan parameters cannot be edited and change attempt will be ignored by the application.

4.2.7.2 Plot Edition

This functionality provides the editing of a plot on the map. The user can select a specific plot from the list and then move on with editing a plot.



Figure 83: Plot Edition

Clicking on Edit Plot shows the following screen.



Figure 84: Edit Plot options

Now, the user has several options to modify if required such as:

- **Add Point:** Allows the user to add waypoints to the existing plot.
- **Clear:** Deletes the earlier points and obstacles after user confirmation on a dialog. If all the points are to be deleted then select "Yes", else select "No" button.

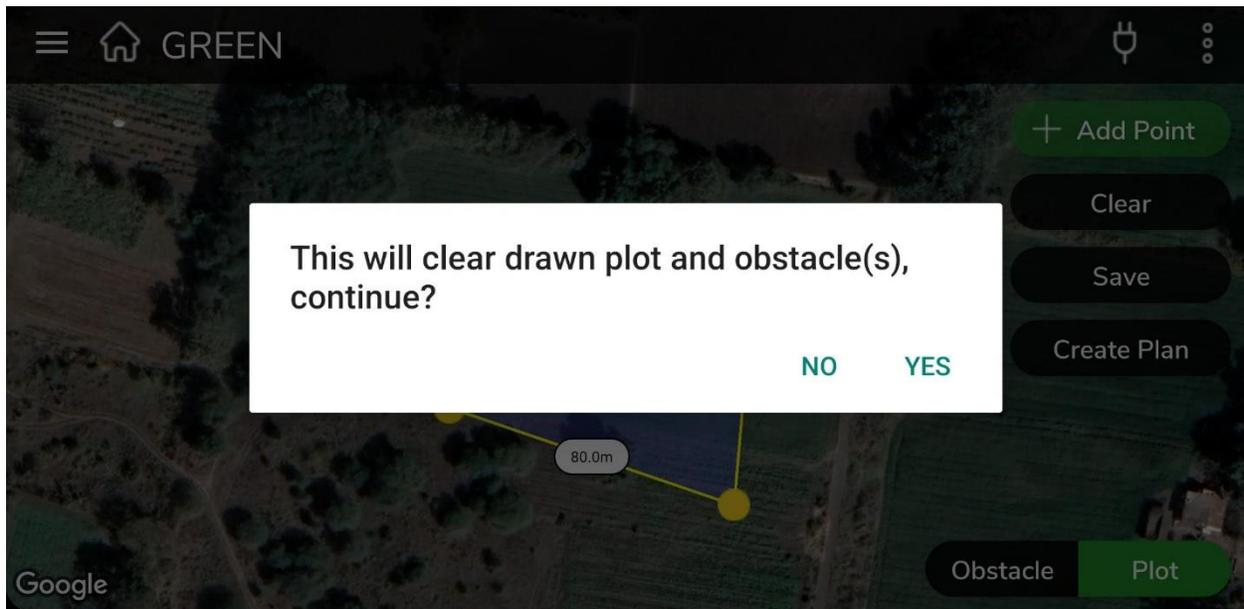


Figure 85: Plot Clear Operation

- **Save:** Save all the changes by clicking the "Save" button. While saving a plot application asks whether to "Create new Plot" or "Save into Existing Plot".
- **Create Plan:** This button creates a plan based on a plot. Now the user may be able to modify the parameters, spacing, indentation, etc. if required. Save all the changes by selecting "Save" button.
- **Obstacle:** This option allows the user to mark the obstacles on the plot shown on the screen. Follow the instructions appear on the screen. After marking an obstacle plot save the plot with "Save Obs" button as shown in the image below.

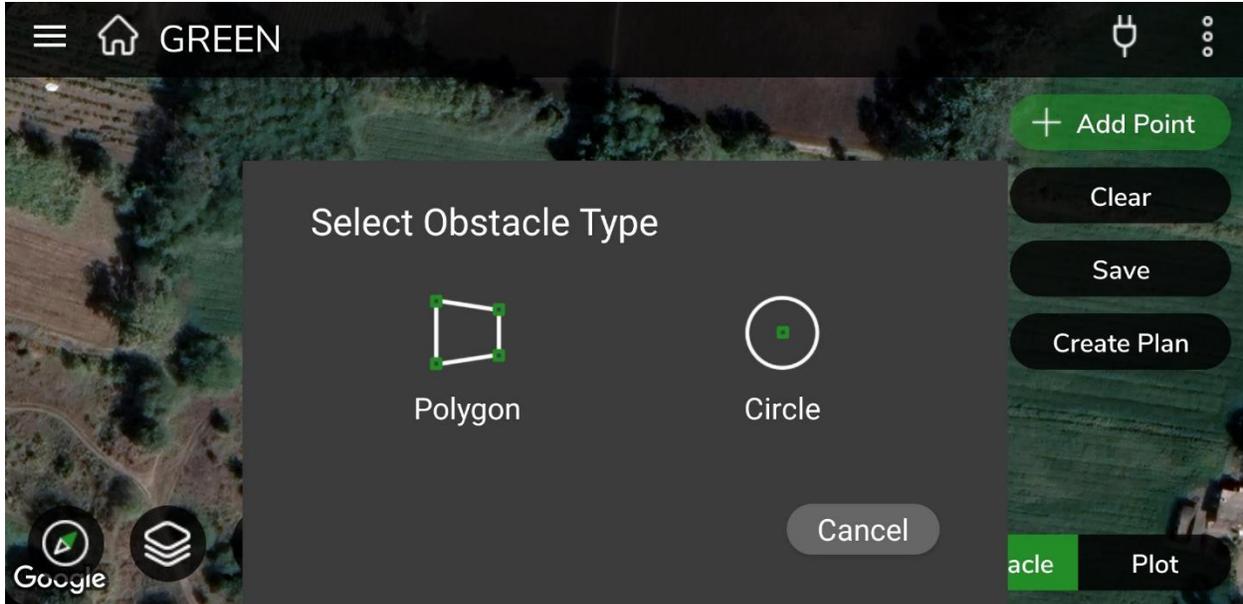


Figure 86: Obstacle Type Definition

Obstacle avoidance functionality is helpful in defining obstacle presence areas and avoid trees, electric poles other static obstacles. Save the plot with all these modifications.



Google maps may not show a recent image of the area, so always survey and visually inspect for obstacles and include them in the plot for safe operation.



Figure 87: Saving Obstacles with Plan

There are 2 types of obstacle shapes available: Polygon and Circle. If you don't want to add an obstacle then select the "Cancel" button.

- **Polygon Obstacle:** Mark the obstacle plan by adding points to the plot. Save all the obstacle points by clicking on the "Save Obs" button. Save the plot by clicking on the "Save" button.

The area of the obstacle plan marked will be displayed on the screen. The portion marked as an obstacle plan will be avoided during the flight. The points of an obstacle plan can be adjusted precisely to avoid the concerned area.

Create the plan with an obstacle plan and adjust the parameters if required. The pilot can adjust obstacle boundaries by selecting the option "Obstacle boundary" from the pop-up.

- **Circle Obstacle:** Select the area where the circle obstacle is to be added and select that area to have a circle obstacle marked as shown in the image below. Click on the "Add Circle" button to add the circular obstacle plan to the plan.



Figure 88: Addition of Circular Obstacle

The circle obstacle will be added to the plan which must be saved by selecting the "Save Obs" button. After saving the obstacle plan, save the entire plan. Multiple circular obstacle can be added to a plan on a plot. Save the first obstacle plan and create another one to handle the multiple obstacles plans as shown. These circle obstacles will be useful to avoid spraying in the well-like structure.

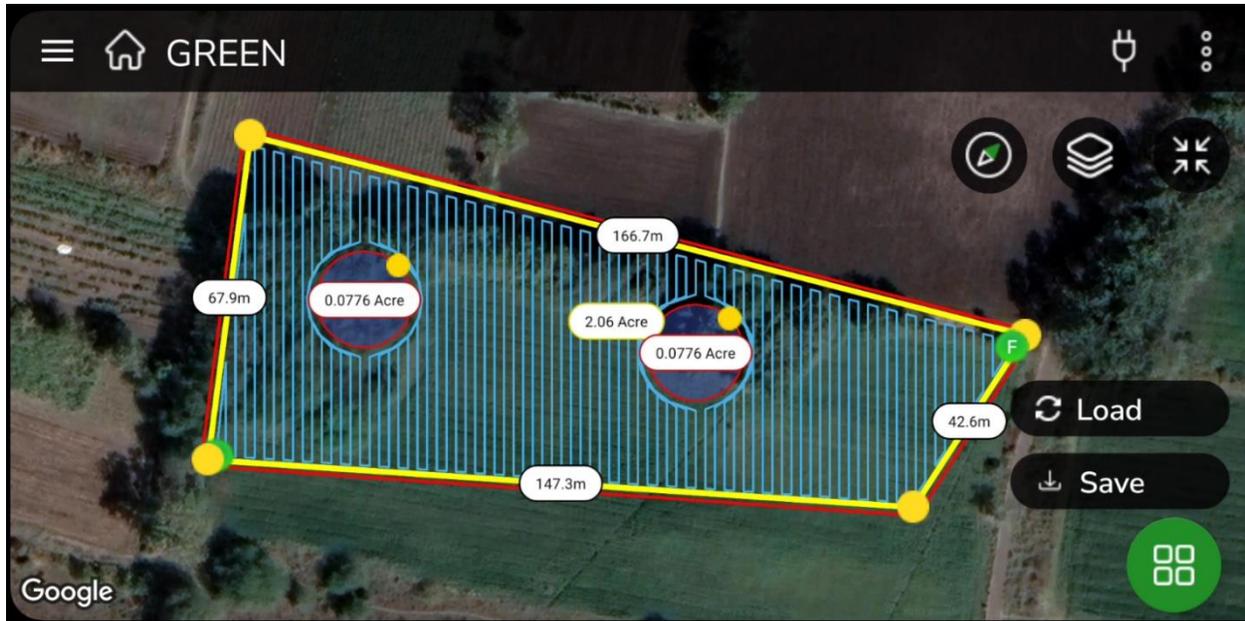


Figure 89: Multiple Circular Obstacles

- **Delete the Obstacle Plans:** The pilot can delete obstacle plans which are not required. To delete an obstacle plan, select the obstacle plan to be deleted. The selected plan will be indicated with green colour and the user will have two new buttons appeared on the screen as shown in the following image. The selected obstacle plan will be deleted after select the "Delete" button. To abort the operation of deletion, select the "Cancel" button. No obstacle plan will be deleted.

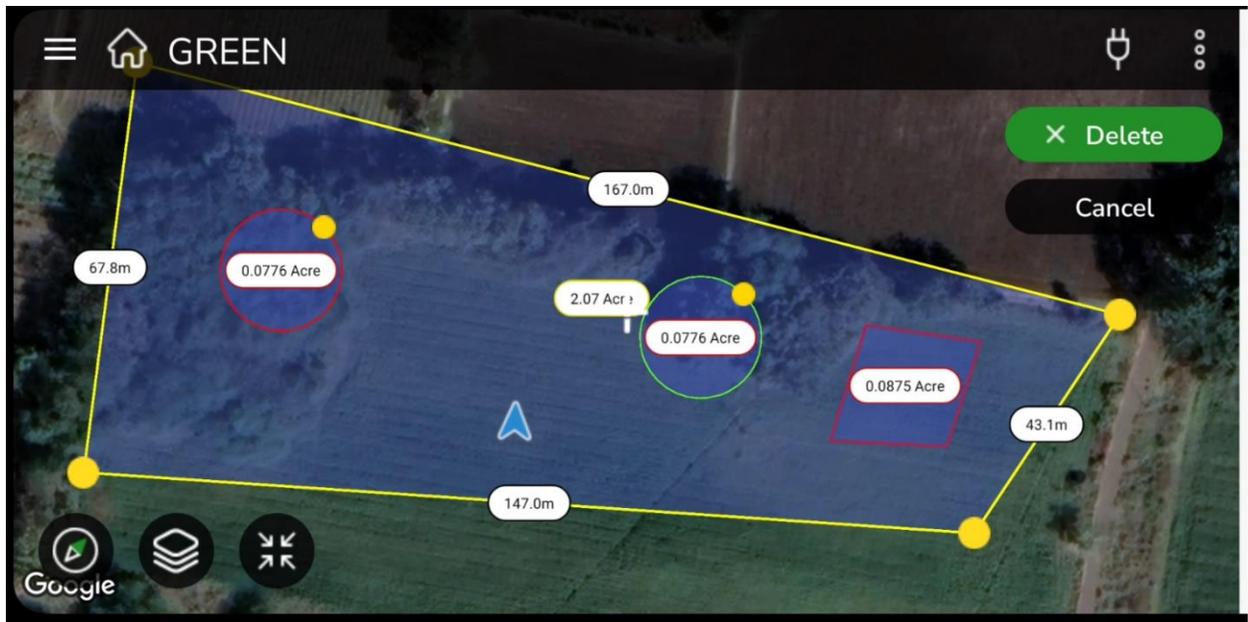


Figure 90: Delete Obstacle

4.2.7.3 Project Renaming

Open the list of projects and select the three dots icon on the right to see the options of 'Rename' and 'Delete' as shown in the image. Select the 'Rename' option to rename the project in that row.

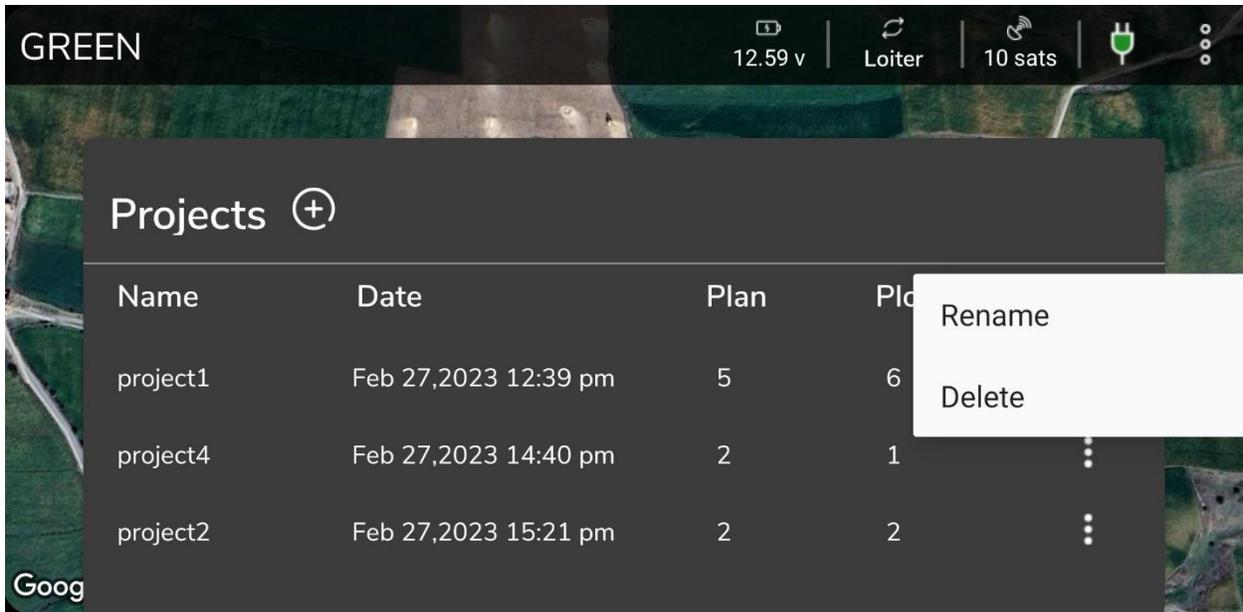


Figure 91: Project Rename & Edit Options

The following dialog will be displayed on the screen with a field to edit the project name. Provide a suitable name to the project and select the "Ok" button to save.

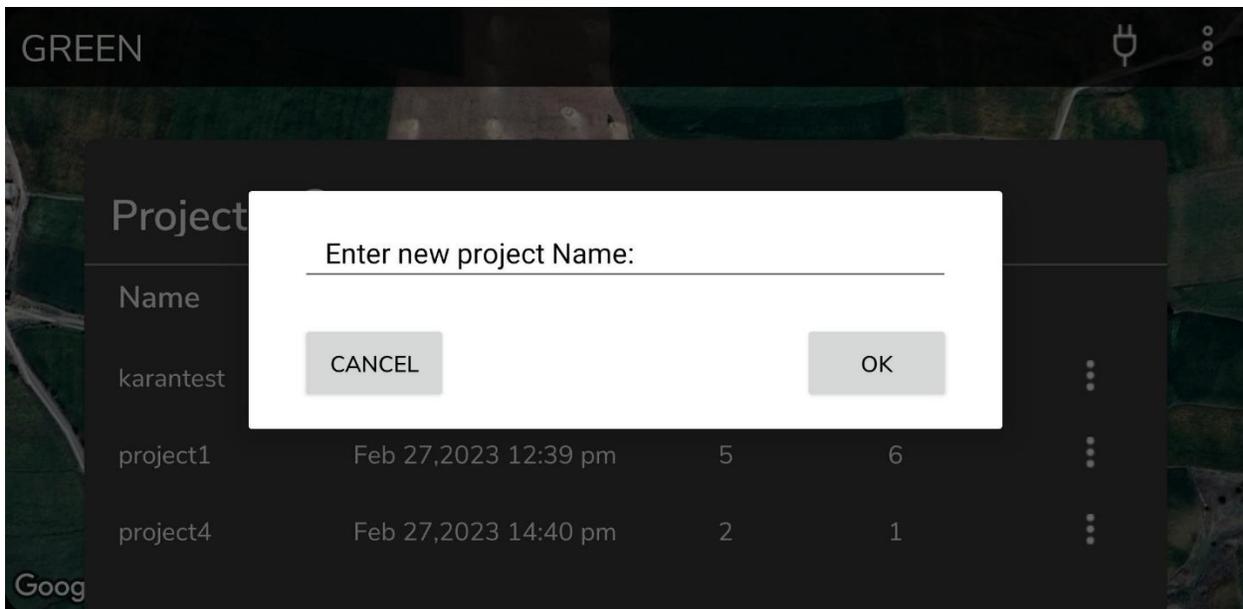


Figure 92: Project Rename Dialog

4.2.7.4 Project Deletion

Open the list of projects and select the three dots to see the options of 'Rename' and 'Delete' as shown in the image. Select the Delete option to delete the project in that row.

When a project is deleted all the plots and associated plans in the project will also be deleted and cannot be retrieved. There is no undo option.

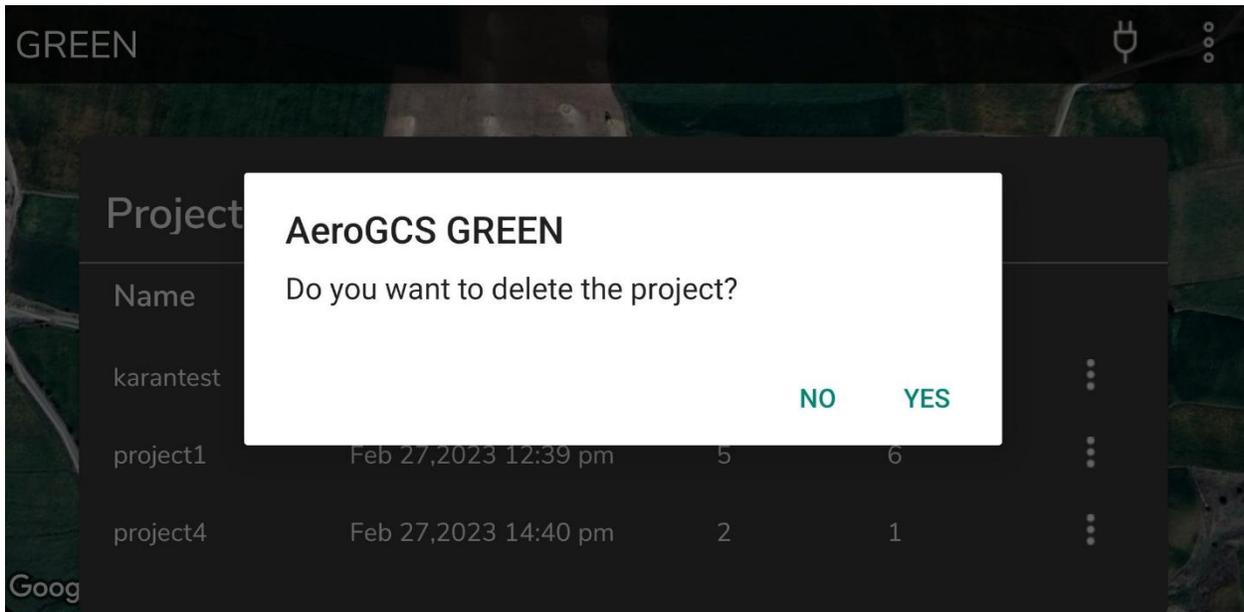


Figure 93: Project Delete Confirmation Dialog

It is also possible to delete only a specified plan or plot from a project.

- Delete a Plot: Open the projects list and select the project to be edited. Select the Plots tab on the top right. Then select the three dots icon on the right in the rows below with Plot names to view options.

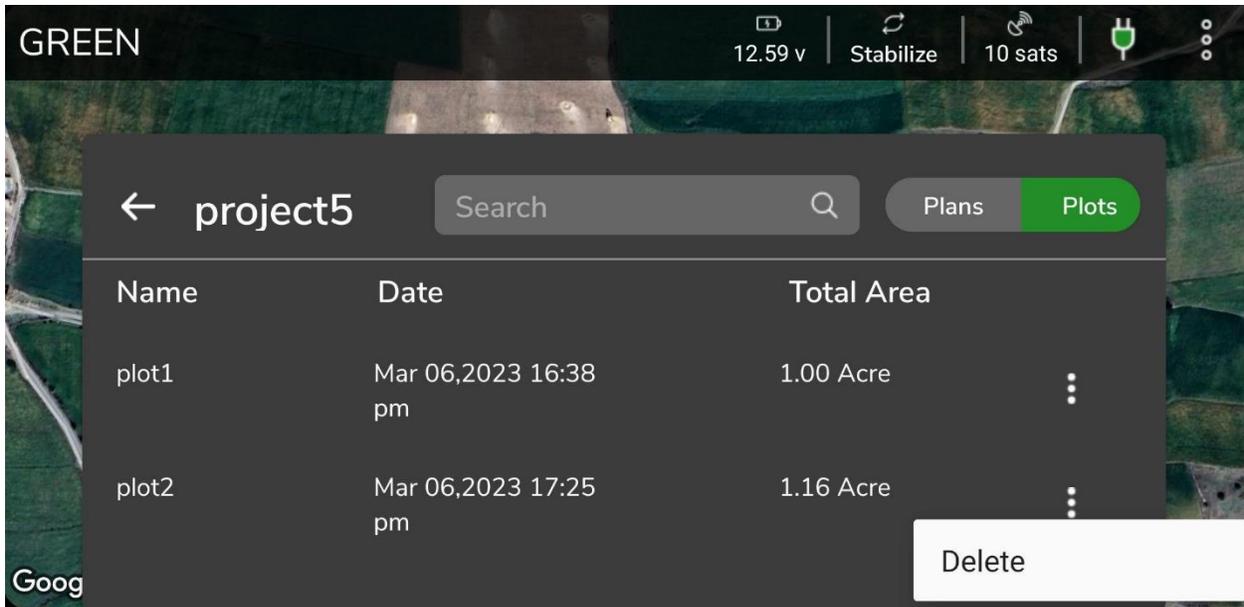


Figure 94: Plot Delete Option

Confirm the operation to delete the plot.

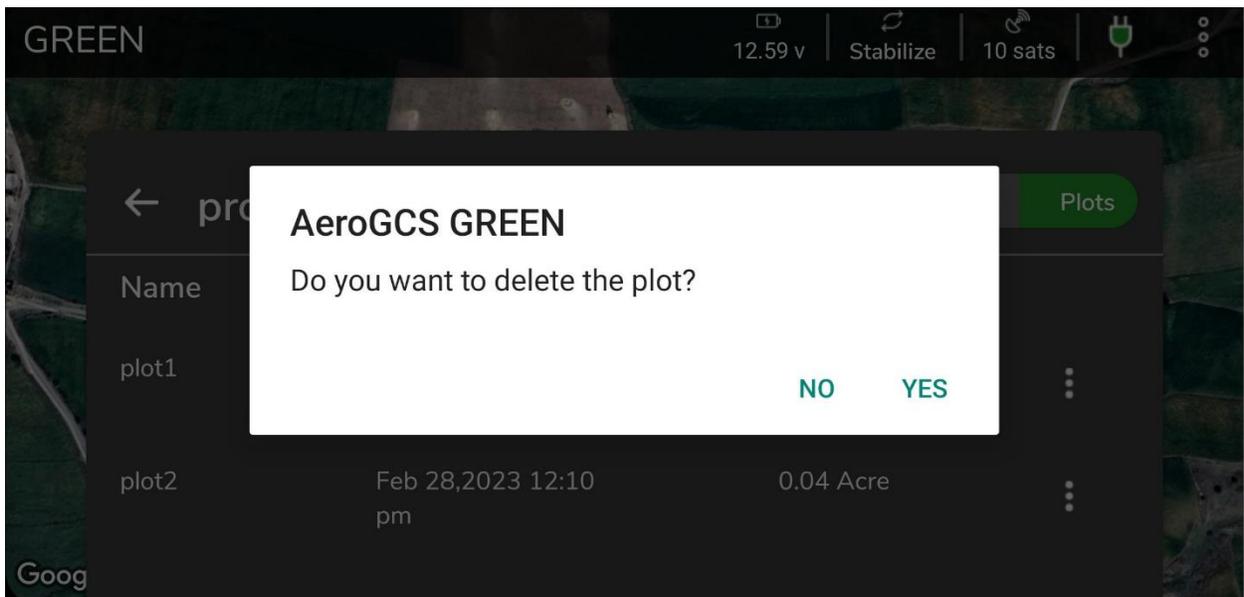


Figure 95: Plot Deletion Confirmation Dialog

- Delete a Plan: Open the projects list and select the project to be edited. Select the Plans tab on the top right. Then select the three dots icon on the right in the rows below with Plan names to view options.

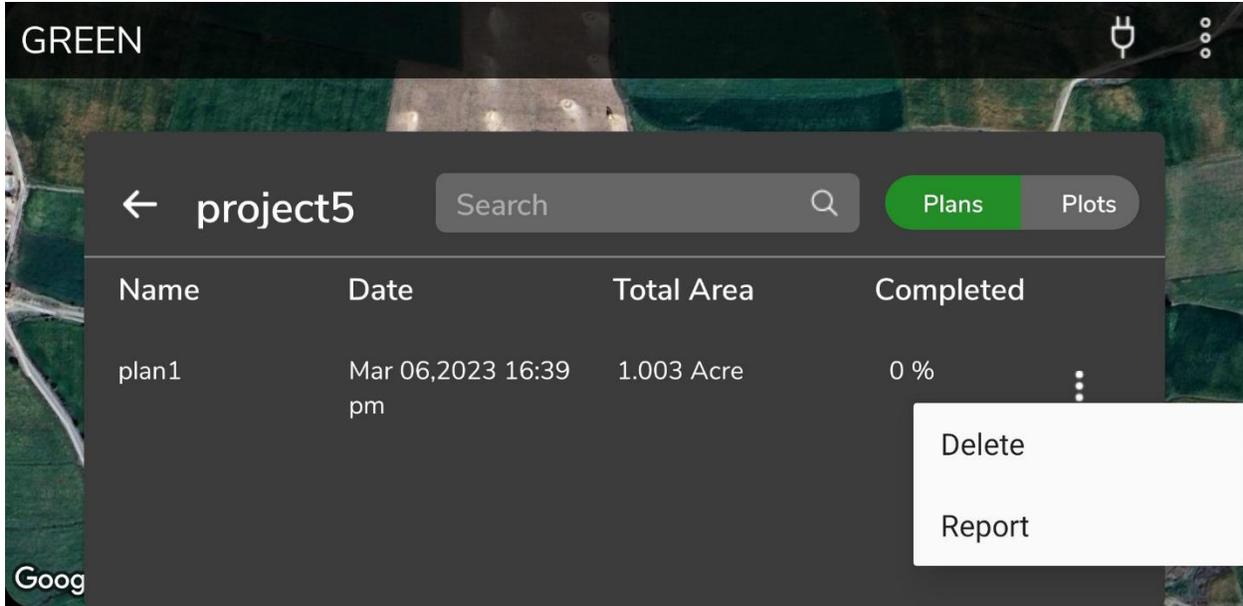


Figure 96: Plan Delete Option

Confirm the operation to delete the plot.

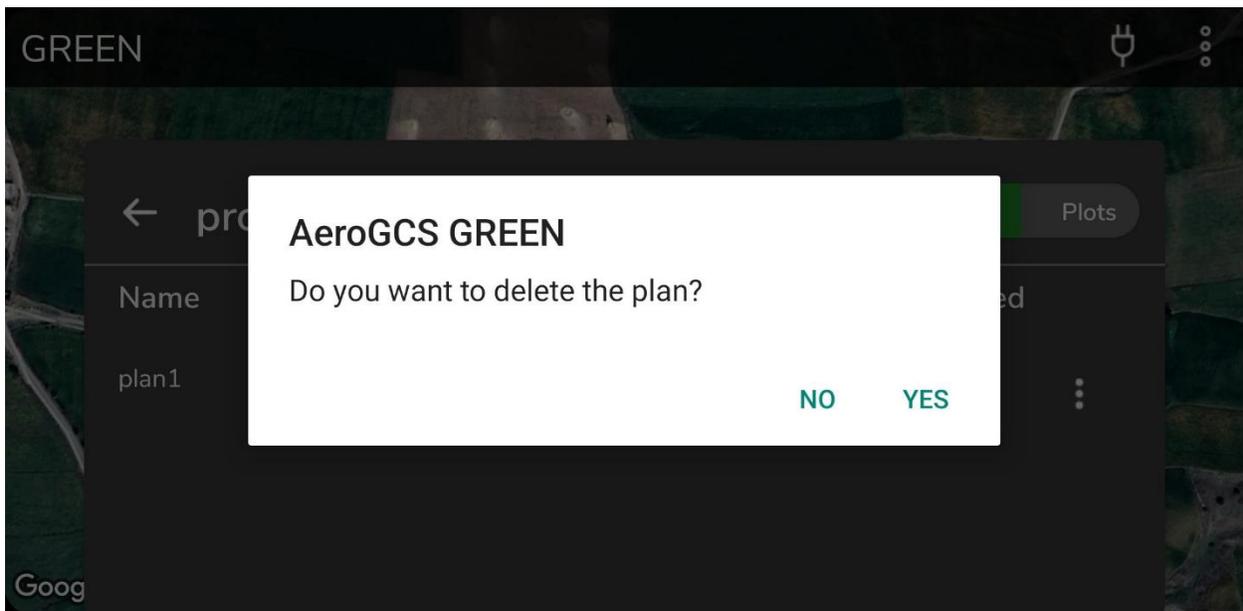
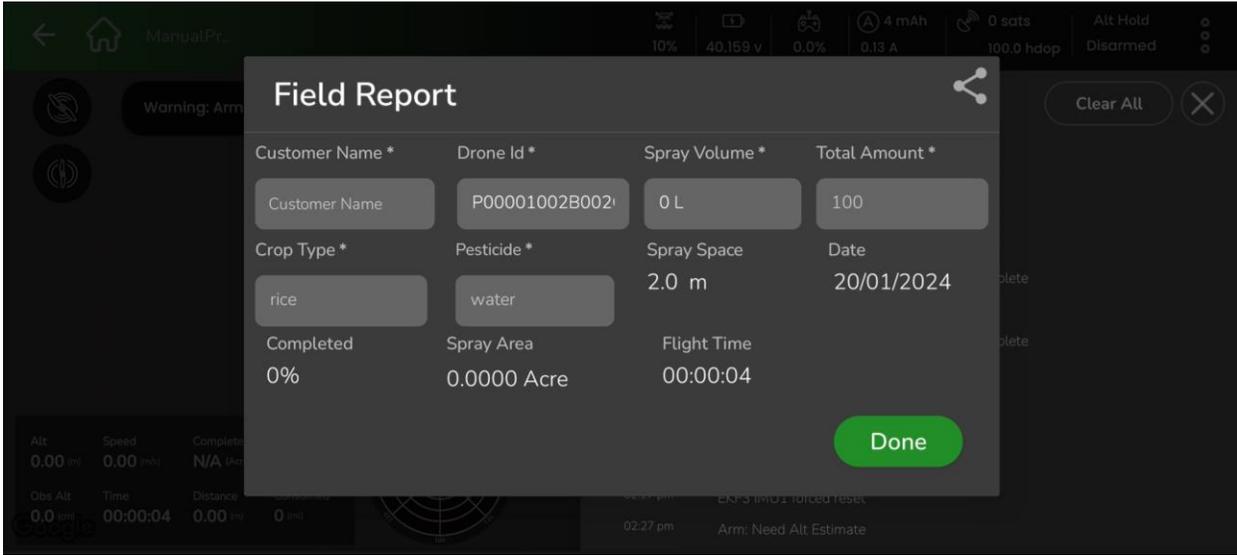


Figure 97: Plan Delete Confirmation Dialog

4.2.8 Field Spraying Report

Field Report will be automatically generated after the successful completion of flight. The user must enter the details as shown in the image below. The field report can be synchronized with cloud server.



Customer Name *	Drone Id *	Spray Volume *	Total Amount *
Customer Name	P00001002B002	0 L	100
Crop Type *	Pesticide *	Spray Space	Date
rice	water	2.0 m	20/01/2024
Completed	Spray Area	Flight Time	
0%	0.0000 Acre	00:00:04	

Figure 98 : Field Report

The following data can be updated for the report:

- **Date of flight:** This is auto filled by the app.
- **Area covered by the flight:** It is automatically calculated and displayed on the screen.
- **Drone ID:** The identity number of a drone is required to maintain the record of a drone. The registration number will be considered as the identity number of a drone.
- **Completion Status:** The status of the flight is displayed as the percentage of flights completed. The value will be determined automatically through AeroGCS GREEN. Based on the percentage of completion, it is indicated that the flight is completed or has a resume remark. A resume remark is used in case of emergency. The flight can be completed from the resume marked on the plan. It will help to reduce the time of flight.

- **Customer Name:** Enter the name of the customer for which the flight was conducted if you want to change it. Otherwise, the name of the customer will be accepted as per the registered one.
- **Spray Volume:** This is a capacity of a tank attached to a drone.
- **Total Amount:** The total amount is which the pilot going to charge to the customer/farmer.
- **Crop Type:** This is required to cross-verify for altitude values.
- **Pesticide:** Enter the details of the pesticide used for spraying.
- **Spray Space:** The value of spray space is based on the spacing allotted while setting parameters before actual flying.
- **Flight Time:** Total time taken to complete the flight. This will be calculated automatically by the application.

After filling in the necessary data in the report click on the "**Done**" button. The report will be saved for the respective plan. The same report can be shared through different options such as Gmail, WhatsApp, etc. and synced to the cloud server for monitoring and analysis purposes.

4.2.9 Aural & Visual Warning During C2 Link Loss

The GCS application prompt distinct aural and visual signals upon the loss of a communication link which ensures timely pilot awareness and response. Validation during flight tests reinforced the effectiveness of these alerts, contributing significantly to enhanced safety in the event of communication link failures. The GCS alerts the pilot with aural signal of "Communication link loss. Drone Disconnected" for once and continuous visual signal of "Communication link loss. Drone Disconnected".

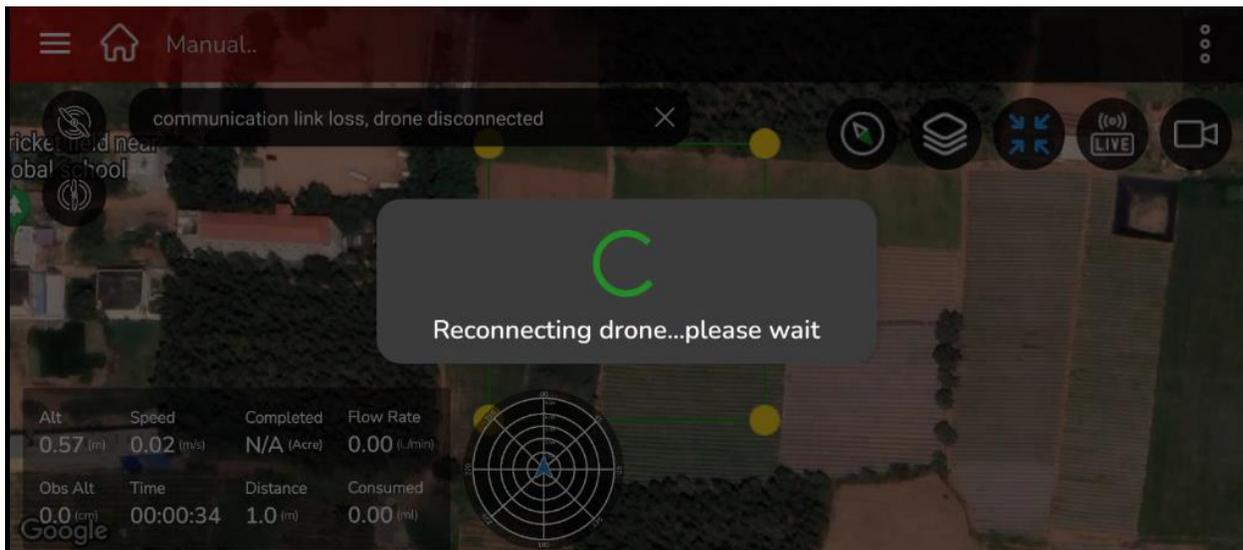


Figure 99 Visual Warning during C2 Link Loss

5. Field Tools

5.1 Battery Tester

The battery tester is used on field to test the battery voltage. The battery tester works for batteries between 1S and 8S. It automatically detects the voltage of each lithium battery cell and the total voltage. It has reverse connection protection.

When the voltage is lower than the set value, the buzzer will sound and the red LED light will flash; the set value is 3.3V, press the button to change the voltage set value, and automatically save the user's current set value.



Figure 100: Battery Tester

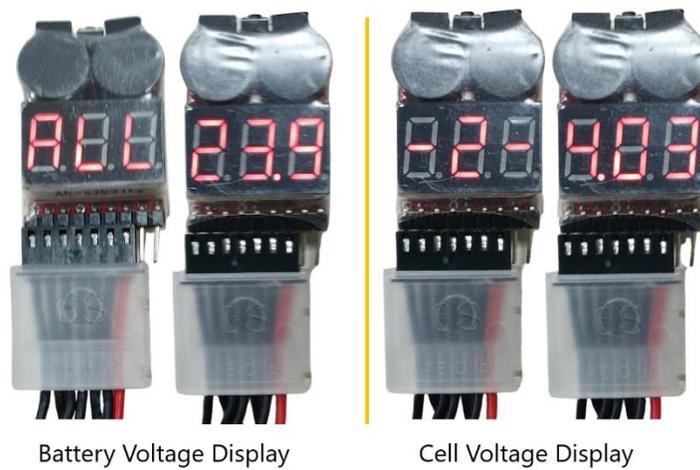


Figure 101: Battery and Individual Cell Voltage Display

5.2 Mechanical Toolkit

A toolkit is provided along with the UAS to tighten any loose parts or perform field maintenance to ensure airworthiness.

6. Flying the UA

6.1 Required Systems & Equipment

Depending on the needs of the day's activities, following are required for the UA flight.

Item Name	Status
Leap A10 UA	Mandatory
RC Unit	Mandatory
Mobile Phone with GCS Application Installed (Not Supplied)	Mandatory
Anemometer	Mandatory
Ph meter	Mandatory
Toolkit	Mandatory
Fire Extinguisher (Not Supplied)	Mandatory
Dispensable liquid payload (Not Supplied)	Based on need

Table 9: Required Systems & Equipment for Flight

6.2 Flight Preparation

It is assumed that UA is taken out of the box following the guidelines and recommendations in Leap A10 Logistics & Disposal Manual.

6.3 Pre-flight Checks

Flying a UA must be done in compliance with regulations and company SOPs to ensure safety and security of the systems, people, infrastructure and environment. The subsections describe the procedure and checklist to be followed before each flight. Post flight checks are mandatory before every flight.

6.3.1 Pre-flight Check Procedure

1. **Meteorological Conditions Check:** Before even taking out the UAS to perform operations, it is mandatory to check meteorological conditions. It must be ensured that conditions are right according to operational specifications and limitations of the UAS.
2. **Location Check:** Since the UAS is designed for agricultural operations, it is pilot's responsibility to survey the operation location, understand the operating constraints and then plan for the flight. A proper spraying plan must consider all observations of the operational environment to ensure safety, security of people, infrastructure and environment. The area must be cleared of people, animals, UAs or other obstacles if they can be moved.
3. **Physical Inspection:** At the location after unloading the UA, perform a physical inspection of the UA.
 - a. Check that there is no physical damage on any part of the UA.
 - b. Motors and propellers are clean.
 - c. Straighten the arms and ensure that they're locked in place.
 - d. The sensors installation is safe.
 - e. The spraying assembly is installed and connected properly.
4. **Battery Checks:** Battery serves as the power source to the UA systems. Before the battery is installed on the UA it is necessary to make checks on the state of the battery.
 - a. Connect the battery tester to the battery as per documentation in section 3.3.1.
 - b. Note battery voltage in the Battery Logbook. It must be between above 23.1V, the nominal battery voltage. Fully charged battery voltage can be 25.2V for a new battery. If the battery voltage reading is less than 23.1 V for fully charged battery, it indicates a problem with the battery. It must be replaced with another healthy battery.

- c. Note individual cell voltages in the Battery Logbook. The cell voltage for a fully charged cell is 4.2V. The cell voltage must not be less than 3V. If the tester is reading less 3V for any of the cell, it is damaged. The battery must not be used.
 - d. If the batteries are healthy, install them. Check that they are properly installed and secured.
5. **RC Checks:**
- a. Power on the RC, it will connect automatically to drone and beep. The beep indicates that the RC and drone are paired.
 - b. Ensure that RC is fully charged.
 - c. Check the signal strength. The signal strength value at UA receiver side must be 100% as received on telemetry data.
6. **PoST Checks:** When both the batteries have been connected to the UA, the MMC will run power on self-test to ensure the integrity of installed components. On failure, the GCS application does not connect to the UA.
7. **Pre-arm Checks:** The pre-arm checks are part of preflight checks and ensure that critical systems and configuration is correct for the aircraft to fly safely. Following pre-arm checks must pass:
- a. RC calibration,
 - b. Accelerometer calibration,
 - c. Compass calibration,
 - d. Gyro calibration,
 - e. AHRS check
 - f. Barometer check
 - g. Motors test,
 - h. battery level test,
 - i. GNSS
 - j. MMC Board voltage check

- k. Mission check
- l. Safety switch check
- m. Logging check
- n. Systems check
- o. Rangefinder data check

If any of the check fails, follow the respective procedure to resolve the failure and reperform pre-flight checks.

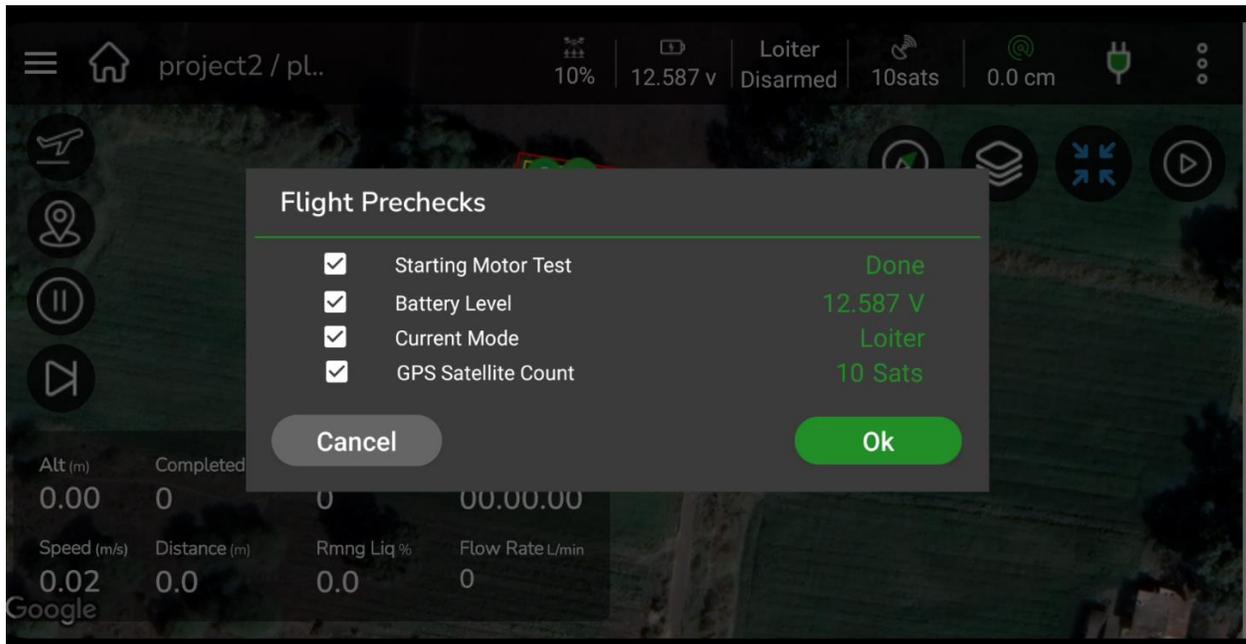


Figure 102: Pre-flight Checks

On successful completion of pre-flight checks, the UA is ready to fly.

6.3.2 Pre-flight Checklist

The full pre-flight checklist is based on the procedure described in 4.3.1. It is available in Appendix A for use before each flight. This checklist must be fully completed and filed along with the flight logbook, with its reference number.

6.3.3 Flying in Windy Conditions

Multi-copters have special behaviours when flying in windy conditions. The crop spraying is also not effective under windy conditions as the spraying liquid droplets can fly to other areas thus spreading it over undesired areas. It is recommended to follow operator SOP for spraying under windy conditions.

The UA attitude and orientation will change depending on wind conditions to maintain set speed. In strong headwinds, the UA may pitch down so much that the front radar will trigger a collision warning with the ground. In this case change the mode and fly in Loiter mode.

The tailwinds can increase the speed of the aircraft. The max speed of the UA is limited to 5m/s, so an alert will be triggered in this case.



Fly cautiously under windy conditions, follow SOP.

6.4 Post-flight Checks

Post flight checks are important to ensure that the UAS is in good condition after flight. These checks allow to determine maintenance, cleaning and care actions. Post flight checks are mandatory after every landing.

6.4.1 Post Flight Checks Procedure

These checks are conducted after a full power down of UA and the RC. This is necessary to avoid any incident during the inspection process.



Allow the motors and battery to cool down for five minutes before performing checks.



Depending on the type of payload dispensed, clean the UA before inspection to limit exposure to chemicals. This will also prolong the life of UA components and reduce maintenance costs arising due to chemical corrosion.

1. **Flight Log:** Ensure that flight logs and required data have been uploaded to monitoring server. This operation can be performed while waiting for motor and batteries to cool off before handling them.
2. **Visual Inspection:** Check that there is no physical damage on any part of the UA.
 - a. Check the motor support arms for any physical damage.
 - b. Check the motors and propellers.
 - c. Inspect the batteries and ensure that there is no bulging, leaking, smoke from the batteries.
 - d. Check that spraying system is still mounted and nothing has come off lose.
 - e. Check that there is no leak in the spraying system.
 - f. Check that all visible nuts and parts are still holding good.
3. **Battery Checks:** Remove the batteries from the UA and perform checks.
 - a. Connect the battery tester to the battery as per documentation in section 3.3.1.
 - b. Note battery voltage in the Battery Logbook. If the battery voltage reading is less than 18 V describe the reason in the logbook.
 - c. Note individual cell voltages in the Battery Logbook. If the tester is reading less 3V for any of the cell, it is damaged. Note the cell number and voltages in the battery logbook.
4. **RC Checks:** Check that RC is also being clear of any damage.
5. **Anomaly Record:** All anomalies have been noted in the Flight Logbook and where maintenance is required comments have been mentioned.
6. **Pre-flight and Post flight checklists:** Both pre-flight and post flight checklists have been completed.

7. Messages, Warnings and Troubleshooting

Visual warnings are displayed by the GCS in top left side of the screen in a black bounding box. Aural warnings are exact audio description that read the visual warning being displayed.

Sr. No.	Component causing warning	Visual and Aural warning	Description
1	RC/ Command and control	"RC not calibrated"	The message indicates that RC calibration has not been performed, there is a problem with the calibration data or RC is faulty. Check the RC configuration and the RC to troubleshoot the problem.
		"RC calibrating"	This information message is displayed when RC calibration is in progress and some other operation is requested on GCS.
		"Throttle (RC% value) is not neutral"	This information is displayed when the pilot by mistake sets a high throttle input on RC during pre-arm. Throttle check enabled is set for this warning and it requires throttle input to be set to zero.
		"VTOL Fwd Throttle is not zero"	This message appears for take-off case when required throttle value is zero but channel input outside 2% of minimum tolerance.
		"Radio Failsafe"	This message appears when RC contact is lost with the UA. The aircraft performs an RTL.
		"Radio + Battery Failsafe Continuing Landing"	This message appears when radio failsafe is active and battery critical failsafe is triggered. The aircraft lands.
		"Radio Failsafe Disarming"	This message appears if UA is armed on ground and RC failsafe is triggered.
		"Radio failsafe on"	When pre-arm check is enabled this information is presented to inform the

			pilot that radio failsafe is enabled. Radio failsafe setting cannot be modified
		“Radio Failsafe Cleared”	When pre-arm check is enabled this information is presented to inform the pilot that radio failsafe is enabled. Radio failsafe setting cannot be modified.
		“Radio Failsafe Cleared”	The message appears when RC connection is restored to UA after a radio failsafe.
2	Barometer	“Baro not healthy”	This message is displayed when the barometer sensor reports that it is unhealthy. This is a sign of a hardware failure.
		“Alt disparity”	The message is triggered when barometer derived altitude data disagrees with the inertial navigation data (i.e., Barometer and Accelerometer) altitude estimate by more than 1 meters. This message is normally short-lived and can occur when the autopilot is first plugged in or if it receives a hard jolt (i.e., dropped suddenly). If it does not cleared automatically, the accelerometers may need to be recalibrated or there may be a barometer hardware issue.
3	Compass	“Compass not healthy”	The compass sensor is reporting that it is unhealthy which a sign of a hardware failure is.
		“Compass not calibrated”	The compass calibration is not done. The compass offset parameters are zero or the number or type of compasses connected has been changed since the last compass calibration was performed.
		“Compass offsets too high”	The primary compass’s offsets lengths are larger than 500. This can be

			caused by metal objects being placed too close to the compass. If only an internal compass is being used (not recommended), it may simply be the metal on the board that is causing the large offsets and this may not actually be a problem, in which case you may wish to disable the compass check.
		“Check mag field”	The sensed magnetic field in the area is 35% higher or lower than the expected value. The expected length is 530 so it’s > 874 or < 185. Magnetic field strength varies around the world, but these wide limits mean it’s more likely the compass calibration has not calculated good offsets and should be repeated.
		“Compasses inconsistent”	The internal and external compasses are pointing in different directions (off by >45 degrees). This is normally caused by the external compasses orientation being set incorrectly.
		“Compass calibration running”	The message appears when compass is being calibrated and pilot selects another operation on the GCS.
		“Compass calibrated requires reboot”	This message appears after compass has been calibrated and MMC requires reboot.
4	GNSS	“GPS Glitch”	The GPS is glitching and the UA is in a flight mode that requires GPS (i.e., Loiter, Auto, RTL) and/or the cylindrical fence is enabled.
		“Need 3D Fix”	The GPS does not have a 3D fix and the UA is in a flight mode that requires the GPS and/or the cylindrical fence is enabled.
		“Bad Velocity”	The UA’s velocity (according to inertial navigation system) is above 50cm/s. Issues that could lead to this include the UA moving or being dropped, bad

			accelerometer calibration, GPS updating at below the expected 5hz.
		“High GPS HDOP”	The GNSS’s HDOP value (a measure of the position accuracy) is above 2.0 and the UA is in a flight mode that requires GPS and/or the cylindrical fence is enabled. This may be resolved by simply waiting a few minutes, moving to a location with a better view of the sky or checking sources of GNSS interference. The GPS HDOP is visible on the GCS UI. The pilot should monitor this value and understand the impact of this message to take action.
		“GPS 1 failing configuration checks”	Pre-arm GNSS check failure message. This could indicate a potential configuration issue or hardware failure.
		“GPS Glitch or Compass error”	This message is displayed when there is a GPS or compass glitch and EKF cannot estimate the source of error.
		Glitch cleared	This message appears when GNSS glitch is cleared by restoration of GNSS signal quality and HDoP is in acceptable range.
5	Inertial Navigation System	“Leaning”	The message indicates that the UA is leaning to one side during calibration. Make UA level and calibrate.
		“INS not calibrated”	Some or all the accelerometer’s offsets are zero. The accelerometers need to be calibrated.
		“Accels not healthy”	One of the accelerometers is reporting it is not healthy which could be a hardware issue. This can also occur immediately after a firmware update before the board has been restarted.
		“Accels inconsistent”	The accelerometers are reporting accelerations which are different by at least 1m/s/s. The accelerometers need to be re-calibrated or there is a hardware issue.

		“Gyros not healthy”	One of the gyroscopes is reporting it is unhealthy which is likely a hardware issue. This can also occur immediately after a firmware update before the board has been restarted.
		“Gyro cal failed”	The gyro calibration failed to capture offsets. This is most often caused by the UA being moved during the gyro calibration (when red and blue lights are flashing) in which case unplugging the battery and plugging it in again while being careful not to jostle the UA will likely resolve the issue. Sensors hardware failures (i.e., spikes) can also cause this failure.
		“Gyros inconsistent”	Two gyroscopes are reporting UA rotation rates that differ by more than 20deg/sec. This is likely a hardware failure or caused by a bad gyro calibration.
		“Temperature cal running”	The message appears if user tries to arm while temperature sensor is performing calibration. Arming is not allowed while doing temp calibration.
		“Heater Temp Low”	This message appears when IMU temperature is lower than desired setting. This message clears off as the temperature is stabilized at the level setting. Low IMU temperature leads to reduced performance, so it is worth the wait.
		“Heater: Out=value Temp=value”	IMU reporting outside temperature outside and inside temperature when there is a difference above set threshold for doing thermal compensation.
		“3D Accel calibration needed”	This message informs the user that 3D calibration is required for INS.

		“Accels calibrated requires reboot”	Accelerometers have calibrated and MMC requires reboot. Recycle the UA power.
6	Radar Altimeter	“No rangefinder”	Message from pre-arm check when using RA for RTL.
		“RTL_ALT > RNGFND_MAX_CM”	Check message result when RTL altitude is set higher than RA’s max range.
		“Rngfnd No data”	This message is displayed when terrain radar data is not available due to a fault.
7	Obstacle Detection Radar	“PRX No data”	This message is displayed when Obstacle Detection Radar is faulty.
8	Mission Management Computer	“Check Board Voltage”	The board’s internal voltage is below 4.3 Volts or above 5.8 Volts. This is a serious problem and the battery must be carefully checked before flying.
		“Board ‘voltage’ out of range [low-high]V”	Measured board voltage is lower than the value within acceptable threshold: low range to high range V
		“IOMCU is unhealthy”	IO MCU health check status.
9	Navigation	“Need Alt Estimate”	System is unable to compute altitude. EKF altitude estimate must be computed for removing navigation errors.
		“EKF compass variance”	EKF's compass variances are below failsafe threshold.
		“EKF position variance”	EKF's position variances are below failsafe threshold.
		“EKF velocity variance”	EKF's velocity variances are below failsafe threshold.
		“EKF height variance”	EKF's height variances are below failsafe threshold.
		“EKF attitude is bad”	The gyros are suffering a bias issue. Recalibrate gyros.
		“EKF3 IMU n switching to compass m”	This message appears when EKF3 algorithm switches from one IMU to another and one compass to another

			as a source of data. 'm' and 'n' are numbers 1, 2, 3.
		"EKF3 refusing set origin"	This message appears if a wrong position initialization is likely to occur to sensor and pilot data mismatch. The system prevents accidental setting of EKF origin with an invalid position or height or causing upsets from a shifting origin.
		"GPS and AHRS differ by xm"	The EKF algorithm checks AHRS and GPS positions and if they are not within 10m of each other this message is triggered. "x" is distance and unit is meters.
		"AHRS: waiting for home"	This message means that AHRS is not yet initialized. It is waiting for GNSS to provide position. This might indicate issue with GNSS satellite availability, the message appears after a configured timeout. It is automatically cleared when GNSS acquires fix and AHRS is initialized.
		"Vibration compensation ON"	When excessive vibration happens and has persisted for at least 1 second, the vibration compensation controller switches to compensation mode. This message is only for information.
		"Vibration compensation OFF"	The vibration compensation is turned off after 15 seconds. This message notifies the user that vibration compensation is off now.
10	Geofence	"Fence enabled, need position estimate"	Information for the pilot that need GNSS I required as fence is enabled.
		"Need Position Estimate"	If circular or polygon fence is enabled we need GNSS based position for navigation.
		"Fence Breached"	The fence breached message appears when the geofence limit of 1.5km is crossed. In Auto mode the aircraft will

			not breach the geofence. In Loiter mode however, if the UA is pushed, it will trigger an RTL action.
11	Flight Modes	“RTL: rangefinder unhealthy, using alt-above-home”	This message is displayed when the rangefinder (radar altimeter) is unhealthy. The aircraft uses the altitude above the launch coordinate as reference. The aircraft switches automatically to RTL mode.
		“RTL: unexpected error calculating target alt”	The aircraft switches automatically to RTL mode when there is an unexpected error in target altitude computation.
		“Mode change to AUTO RTL failed”	This message is displayed when UA is unable to perform RTL mode change.
		“Mode change to AUTO RTL failed: No landing sequence found”	This message is displayed when UA is unable to set RTL mode due to absence of landing sequence.
		“Auto: Missing Takeoff Cmd”	Aircraft rejects switching to auto mode if landed with motors armed but first command is not a take-off. This is a precaution to reduce chance of flips.
		“Auto mission changed, restarted command”	This message is displayed when aircraft is flying a mission, and aircraft restarts the current command if it is a waypoint or spline waypoint command.
		“Auto mission changed but failed to restart command”	This message is displayed when aircraft fails to restart mission for some reason.
		“Mode change to Mode-Name failed: reason”	This message is displayed when the aircraft is unable to set the required flight mode. Mode-name is the name set by pilot, reason is the reason due to which the failure occurred.
12	Throttle	“Throttle below failsafe”	Check throttle setting, it must be above failsafe throttle value.
13	Motors	“Check MOT_PWM_MIN /MAX”	Pre-arm check message when motor minimum PWM value is lower than minimum acceptable value and motor

			maximum PWM is greater than maximum PWM acceptable output values.
		“Motor Emergency Stopped”	Pre-arm check message informing the pilot to move the motor emergency stop switch out of its position for flight.
		“Motors: N”	Check motor number, there is an issue with the motor.
14	Parameter checks	“Ch7 & Ch8 Opt cannot be same”	Auxiliary Function Switches are set to the same option which is not permitted because it could lead to confusion.
		“Check FS_THR_VALUE”	The radio failsafe PWM value has been set too close to the throttle channels (i.e., ch3) minimum.
		“Check ANGLE_MAX”:	The ANGLE_MAX parameter which controls the UA’s maximum lean angle has been set below 10 degrees (i.e., 1000) or above 80 degrees (i.e., 8000).
15	Battery/Power Monitor	“Prearm: Battery below minimum arming voltage”	This message appears if battery voltage is below the set minimum arming voltage. Replace the battery with a charged battery.
		“Battery Failsafe Disarming”	This message is displayed when the UA is armed, on ground and the battery reaches a critical voltage threshold.
		“Battery Failsafe Continuing Landing”	This message is triggered on the GCS when battery failsafe is active and pilot tries to switch mode. The aircraft ignores the input and continues landing.
		“Battery low voltage failsafe”	This message appears if battery voltage is below the set low voltage threshold. Replace the battery with a charged battery.
		“Battery critical voltage failsafe”	This message appears if battery voltage is below the set critical voltage. Replace the battery with a charged battery.
		“Bad Battery”	Ensure that the hardware configuration and wiring on the aircraft is correct. e.g.

			Autopilot, current and voltage sensor. This may also happen due to bad hardware pin configuration. This issue may arise due to bad battery connection also.
16	Data Logging	“Logging failed”	Logging pre-armed was enabled but failed to write to the log.
		“No SD Card”	Logging is enabled, but no SD card is detected.
17	Safety Switch	“Hardware safety switch”	Hardware safety switch has not been pushed.
18	System	“Failed to load bootloader into memory”	Message sent by system when it is unable to load bootloader.
		“Failed to find key signature”	Message sent by the system when it is unable to find the firmware signature key.
		“Internal errors (0xx)”	An internal error has occurred. Report this error to NextLeap Aeronautics Pvt. Ltd.
		“Param storage failed”	A check of reading the parameter storage area failed.
		“KDECAN Failed”	KDECAN system failure.
		“DroneCAN Failed”	DroneCAN system failure.
19	Mission	“No mission library present”	Mission checking is enabled, but no mission is loaded.
		“No rally library present”	Rally point checking is enabled, but no rally points loaded.
		“Missing mission item: xxxx”	The required mission item is missing.
		“Flight plan update rejected”	The message sent by MMC software when it rejects flight plan update.
		“Mission upload timeout”	The message sent by MMC software when mission cannot be uploaded because it is too big or system is busy with other high priority tasks or link issue.
		“Flight plan received”	Message sent by MMC software when flight plan is received.

		“Out of memory for upload”	This is a message sent by MMC software when geofence polygon points definition upload failure occurs.
		“Fence upload timeout”	This message is sent by the MMC software when fence upload fails due to system being busy with other priority tasks or link issue.
		“Error replacing item (id)”	The message is displayed on the GCS when geofence item change fails. The id of the item appears in the brackets.
20	Ground Control Station	“GCS failsafe on”	Message appears while pre-arm check is running for GCS failsafe check.
		“GCS Failsafe”	This message is triggered when GCS failsafe gets activated due to data link loss. The aircraft performs an RTL.
		“GCS Failsafe Disarming”	This message is displayed when aircraft is on ground and GCS failsafe is triggered. The aircraft immediately disarms.
		“GCS Failsafe Cleared”	When GCS failure is cleared by restoring connection after loss of link with GCS.
		“GCS + Battery Failsafe Continuing Landing”	This message is displayed when GCS and Battery failsafe are active and pilot tries to switch flight mode. The aircraft continues to land.
		“GCS Failsafe Continuing Landing”	This message is displayed when GCS failsafe is active and pilot tries to switch flight mode. The aircraft continues to land.

Table 10: GCS Messages, Warnings and Trouble Shooting

7.1 Motor Visual Warnings

The following table illustrates motor visual warnings, their corresponding meanings, and the recommended solutions.

Sr. No.	Visual Warning	Meaning	Solution
1	Single short flash	Over-voltage	Replace the battery (Voltage below 63V).
2	2 short flash	Under-voltage	Replace the battery (Voltage higher 18V).
3	3 short flash	Over-current	<ul style="list-style-type: none"> • Check the motor for foreign objects and check the propeller, then power on again. • Contact after-sales service.
4	Single long flash	Throttle lost	<ul style="list-style-type: none"> • Check connection between signal line to the flight controller. • Check whether the remote controller and flight controller are turned on.
5	Single long flash + Single short flash	Throttle not reset to zero	This problem occurs during the rotation of the motor. Please check the aircraft battery and circuit. There could be a short circuit on the circuit.
6	Single long flash + 2 Short flash	ESC Mosfet over-heated (Over 110°C)	Cool down the propulsion system and power on again.
7	Single long flash + 3 Short flashes	ESC Capacitor over-heated (Over 110°C)	Cool down the propulsion system and power on again.
8	Single long flash +4 Short flashes	Stall protection	<ul style="list-style-type: none"> • Restart after the throttle is reset to zero. • Please check if there is any foreign matter in the motor, remove the foreign matter before starting.
9	2 long flashes	ESC open-circuit	<ul style="list-style-type: none"> • Please check whether the motor circuit is intact. • Contact after sales service.
10	2 long flashes + Single short flash	ESC short-circuit	<ul style="list-style-type: none"> • Please check whether the motor is in good condition. • Contact after sales service.

11	2 long flashes + 2 Short flash	Motor short-circuit	<ul style="list-style-type: none"> • Please check whether the motor is in good condition. • Contact after sales service.
12	2 long flashes + 3 Short flash	Phase A operational amplifier is abnormal	<ul style="list-style-type: none"> • Disconnect and reconnect the battery on to return to normal. • Contact after sales service.
13	2 long flashes + 4 Short flash	Phase B operational amplifier is abnormal	<ul style="list-style-type: none"> • Disconnect and reconnect the battery on to return to normal. • Contact after sales service.
14	3 long flashes	Phase C operational amplifier is abnormal	<ul style="list-style-type: none"> • Disconnect and reconnect the battery on to return to normal. • Contact after sales service.

Table 11: Motor Visual Warnings and Trouble Shooting

Appendix A: Pre-flight Checklist

PREFLIGHT CHECKLIST				
Date		Flight Log Reference		
UAV UIN		RC ID		
Pilot ID		Battery ID		
No.	Category	Check	Y/N (Yes/No)	Notes
1	Meteorology	Are the meteorological conditions suitable for UA operation?		
2	Environment	Is the operational area clear of <ul style="list-style-type: none"> • low lying trees • poles and power lines • flocks of birds, animals, people, • UAs 		
3		Is Takeoff zone clear of people?		
4	Physical Inspection	Are the UA arms opened and locked in place?		
5		Are all UA propeller securing guards removed?		
6		Are all propellers are securely attached?		
7		Are propellers attached as per the right direction of rotation?		
8		Are all required parts installed on the UA?		
9		Is the correct spraying assembly installed as per required operation?		
10		Are all sensors (radar, camera, GNSS, flow, level sensors) installed and secure?		
11		Is the UA (all parts inclusive) free of visible physical damage?		
12		Is UA free of wear or damage to connecting joints?		
13	Batteries	Are batteries free of damage, leak and swelling?		
14		Are the batteries compatible to UA?		

15		Is each battery voltage between 23.1V and 25.2V?		
16		Is each cell voltage for both batteries between 3.85V and 4.2V?		
17		Are batteries installed correctly and secure?		
18		Are batteries connected correctly?		
19	PoST Check	When both batteries have been connected a successful power on sound is heard?		
20	RC Check	Is the RC fully charged?		
21		Is the RC to UA receiver connection beep heard?		
22		Is the radio receiver signal strength 100%?		
23		Are all assigned channels responding to RC commands?		
24		Is the motor state switch set to low position?		
25		Is the spray control switch set to off position?		
26		Is the Mode Select Switch set to desired mode Loiter/Auto?		
27		Is the GCS Application free of error and warnings related to RC?		
28	Calibration Checks	Is RC Calibrated?		
29		Are accelerometers calibrated?		
30		Are gyros calibrated?		
31		Is Compass Calibrated?		
32		Is ESC Calibration done?		
33		Is level Calibration done?		
34	Spraying system checks	Is liquid flow rate sensor calibrated?		
35		Is liquid level sensor calibrated?		
36		Is the spray system free of leaks?		
37	Failsafe Checks	Is RC failsafe enabled and checked?		
38		Is GCS failsafe enabled and checked?		
39		Is battery failsafe enabled and checked?		
40		Is spraying failsafe enabled and checked?		
41		Is geofence failsafe enabled and checked?		

42		Is EKF failsafe enabled and checked?		
43		Is Vibration failsafe enabled and checked?		
44	Pre-arm Checks	Is UA armed?		
45		Is there any error/warning reported on GCS Application?		
46	Logbook Update	Is the Battery Logbook updated?		
47		Is the Flight Logbook updated?		

Appendix B: Post-flight Checklist

POST FLIGHT CHECKLIST				
Date		Flight Log Reference		
UAV UIN		RC ID		
Pilot ID		Battery ID		
No.	Category	Check	Y/N (Yes/No)	Notes
1	Data retrieval	Is the flight log and required data uploaded to monitoring server?		
2	Physical inspection	Is landing gear secure and free of damage?		
3		Are the motor support arms free of physical damage?		
4		Are the motors and propellers free of physical damage?		
5		Are the batteries free of bulging, leak and smoke?		
6		Is the spraying system still secure and nothing has come off lose?		
7		Is the spraying system free of leaks?		
8		Are all visible nuts and parts are still holding good.		
9		Battery	Are the batteries disconnected?	
10	Is each battery voltage above 18V?			
11	Is each cell voltage above 3V?			
12	RC Checks	Check that RC is also is clear of any damage.		
13	Logbooks Check	Is the Flight Logbook updated?		
14		Is the Battery Logbook updated?		
15		Are anomalies recorded in the Flight Logbook and where maintenance is required comments have been mentioned?		
16		Are preflight and post flight checklists completed?		