DORIS Drone Operation & Assembly Manual

1. Introduction

- **Project Overview**: A heavy-lift quadcopter drone designed to pick up/carry/drop off various payloads up to 10 lb. (4.5 kg) using iFlight XING X4214 660KV motors and dual 6S LiPo batteries without direct human intervention.
- **Original Design & Build By**: Dylan Boeholt, Andre Bonillas, Connor Davidson, Jeremy Malmo, and Michael Zielinski (Boeing Capstone Project, 2024-2025)
- **Version**: v3.0 – April 2025
- **Purpose of Manual**: Guide users in assembly, operation, maintenance, and troubleshooting of the DORIS drone.

2. Safety Information

- **Pre-Flight Safety Checks**: Inspect structural components for cracks/compromised integrity, confirm firmware and calibrations, check battery voltage/charge.
- **Battery Charging and Handling Warnings**: Only charge with a balanced charger on a fire-safe surface. Never charge unattended.
- **Propeller Safety**: Install props after setup and calibration. Keep limbs and objects clear of spinning blades. Maintain 20 yards or more from drone during startup.
- **Personal Protective Equipment (PPE)**: Safety glasses and gloves recommended during assembly and soldering.

3. Assembly Instructions

3.1 Required Tools, Materials, and Software

- Tools:
  - Hex keys (2.5, 3, 5)
  - Socket set (10 mm, 5.5 mm)
  - Wrench set (10 mm, 5.5 mm)
  - Soldering iron and solder
  - Multimeter (for system checks, current draw, and continuity testing)
- Extra Materials:
  - Loctite/threadlock - for structural bolts

- Zip ties – for protection basket
    - Heat shrink – for crimped connectors
    - Electrical tape – to clean up/protect wires
- Software & Files:
    - CAD reference File: drone_assembly_v3.step
    - QGroundControl (QGC): mission control software
    - 3D STL Files: this folder contains all 3D-printable part files
    - 3D-printing slicer: if manufacturing 3D-printed parts in-house
    - SolidWorks: to view raw CAD files and assemblies

3.2 Purchased Components List

For a full purchased components list, please see the Bill of Materials in the Appendix.

3.3 Manufactured Components List

- MagSwitch Actuator Wheel: 3D-printed MagSwitch interface wheel with servo-based release, servo mounting provisions
    - Material: PLA or better
    - Quantity: 2
    - File Name: **Actuator_Wheel.stl**
- Payloads: 3D-printed payload holders for both camera and dumbbell weight
    - Material: PETG or better
    - Quantity: 1 each (or as desired)
    - File Names: **Drone_Payload_camera_bracket.stl, Drone_Payload_dumbell_bracket.stl**
- Payload Sub-Assembly: 3D-printed parts to secure MagSwitches and servos onto drone frame
    - Material: PETG or better
    - Quantity: 1 each
    - File Names: **Drone_Payload_bracket_1.stl, Drone_Payload_bracket_2.stl**
- Battery Bracket: 3D-printed bracket to hold batteries secure on the frame
    - Material: PETG or better
    - Quantity: 1 each
    - File Names: **drone_battery_holder.stl, drone_battery_hold_tab.stl**
- Arm Mounts: 3D-printed clamps designed to secure 20 mm x 30mm arms to the central plates
    - Material: TPU 95A

- Quantity: 16
- File Name: **ArmMount_Design2.stl**

- Motor Mount Arm Brackets: 3D-printed clamps designed to secure Motor Mount Plates to arms
  - Material: TPU 95A
  - Quantity: 16
  - File Name: **motormount_bracket_v3.stl**
- Motor Mount Plates: 3D-printed plates fitted to secure XING motors to the Motor Mount Arm Brackets
  - Material: ABS or better
  - Quantity: 8
  - File Name: **Motormount_plate.stl**
- Legs:
  - Material: ABS or better
  - Quantity: 4
  - File Name: **Arm_legs_V3.stl**
- Frame Plates:
  - Material: Fiberglass/resin/birch markerboard or carbon fiber
  - Quantity: 2
  - File Name: **Drone_Base_V3.stl**

3.4 Step-by-Step Assembly

3.4.1 Frame Construction

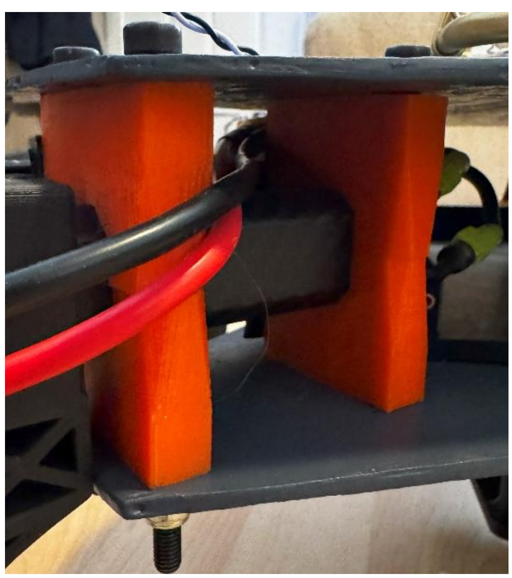
Materials and Components

- **Top and Bottom Frame Plates:**
  - Material: ¼" birch plywood, marine grade
  - Finish: Sealed with fiberglass resin (polyester or epoxy-based) for durability and weather resistance
- **Arms:**
  - Carbon fiber tubes, 20 mm × 30 mm cross-section (Octagonal)
- **Mounting Hardware:**
  - 3D-printed arm clamps (TPU 95A)
  - Threaded bolts with Loctite/threadlocker
  - Hex keys (2.5 mm, 3 mm)

Step 1: Frame Plate Fabrication

1. **Cutting Birch Plates**
    a. Laser-cut, CNC machine, or hand cut the birch plywood according to the supplied CAD profile (Drone_Base_V3.stl).
    b. Ensure clean edges and no splintering. If cutting manually, sand all edges smooth.
2. **Fiberglass Resin Sealing**
    a. Place cut birch plates on a flat, disposable surface.
    b. Cut out the same shape of fiberglass cloth
    c. Brush on a thin, even layer of fiberglass resin to all surfaces. This protects the wood against humidity and flexing under stress.
    d. Layer the fiberglass sheet on top of the resin, adhering it to the wood.
    e. Brush on a second layer of resin over the fiberglass, evenly sealing the fibers in.
    f. Compress between a flat hard surface to ensure the plate does not warp.
    g. Let cure for 4–6 hours (depending on resin used), then flip and seal the opposite side.
    h. Once fully cured, lightly sand with 400-grit paper for a smooth surface.
    i. (Optional) Apply a second coat for added waterproofing and strength.
    j. **Estimated Time:** 1–2 days total including curing time

Step 2: Arm Mounting



1. **Positioning Arms**

    a. Lay the bottom plate flat. Arrange the 4 carbon fiber arms in a symmetric cross pattern (90° separation).
    b. Insert arms between upper and lower frame plates through 3D-printed **Arm Mounts**.

2. **Securing Arms**
    a. Use 3D-printed **Arm Mounts** to hold arms firmly in place.
    b. Insert bolts through pre-drilled holes in the frame plates and into arm mounts.
    c. Apply Loctite to all bolts to prevent loosening from vibration.
    d. Torque bolts evenly to avoid skewed alignment.
3. **Check Alignment**
    a. Ensure all arms are level, equidistant, and are symmetric.
    b. Verify that the frame sits flush with no rocking or warping.

Tips & Warnings

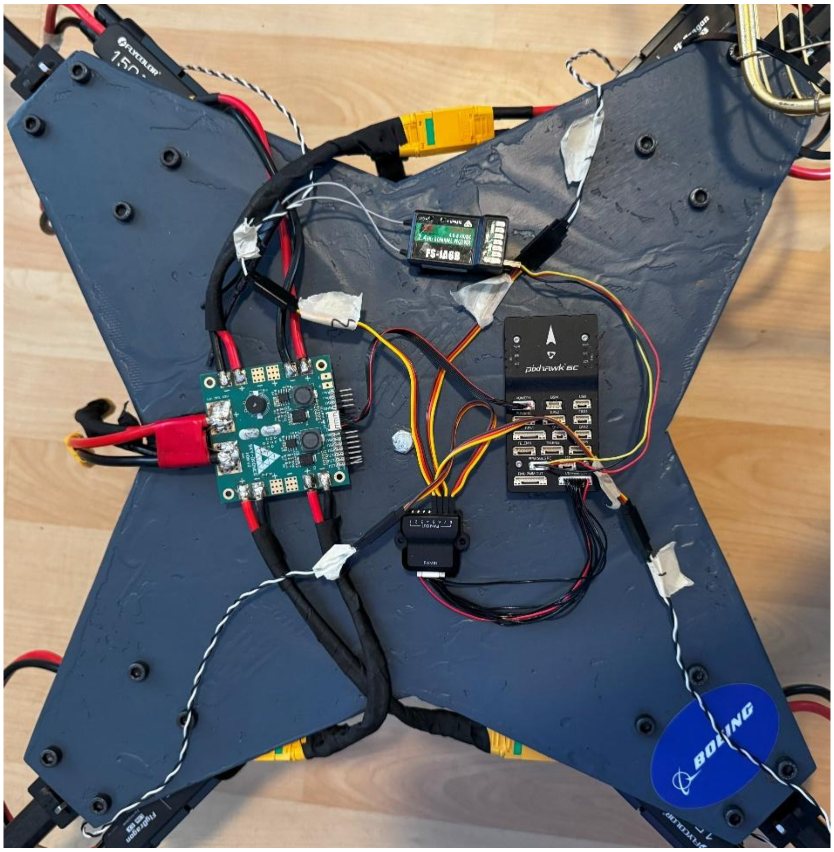
- Always wear gloves and safety glasses when applying resin.
- Work in a well-ventilated area when using fiberglass resins.
- Verify curing before handling to avoid resin fingerprints or surface damage.
- Do not over-tighten bolts—thread locker will secure them against vibration.

3.4.2 Motor Installation

    a. Mount iFlight motors to ends of each arm using the 3D-printed **Motor Mount Arm Brackets** and **Motor Mount Plates**. The plates should be oriented with the little protruding squares facing the arm (down for the top plate, up for the bottom plate). The farthest arm mount bracket from the center of the drone should be 4 inches from the end of the arm tube.

b. Run all three motor wires through the hollow arm toward the drone body.
c. Confirm each mount is tightened securely and motor alignment is true.
d. Check CW/CCW motor order for proper prop pairing (described in Electronics Setup section).

3.4.3 Electronics Setup



e. Battery, ESC, Motor, & PDB Setup

   i. Solder two 8-inch pieces of 12AWG wire (one red, one black) to an Amass XT90 male connector on their respective sides (red = positive, black = negative). Make two of these XT90 extensions.

   ii. Repeat the above, but with female XT90 connectors. Make 6 female extensions.

   iii. Solder the four **female** XT90 extensions to any four of the SmartAP Power Distribution Board ESC power pads. Make sure you note where the positive and negative wires are supposed to go.

   iv. Solder the two **male** XT90 extensions to the main battery power pads on the PDB. Also solder on the capacitor included with the PDB onto these pads.

   v. Solder a **male** XT90 connector to the power leads from each ESC (4 connectors total).

   vi. Crimp and heat shrink female tab disconnects (or other bullet-style connectors) to the end of the three ESC motor wires.

vii. Crimp and heat shrink male tab disconnects to the end of the three wires coming from the motors.

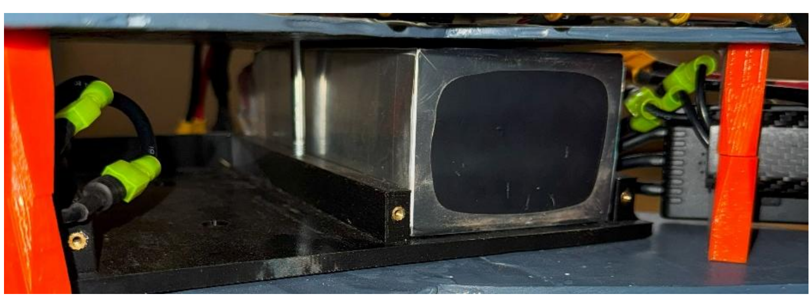
viii. Place ESCs on the sides of the arms at the front and back of the drone, secured with Velcro straps as shown in the figure below.

ix. The three ESC wires will be run to the opposite side of the drone to connect to the three motor wires that are run through the hollow arms. At this point, it does not matter what order the three wires are plugged in.

x. Place the PDB on top of the frame using Velcro with the power connectors hanging off the left side of the frame (where the batteries will slot in, and where their wires will be). This is shown in Figure 3.4.3.1 above.

xi. Install the 3D-printed **Battery Bracket** on top of the bolts for the payload system. This is a press fit but can be glued if desired.

xii. Install the batteries through the right side of the drone into the Battery Bracket with the wires going in first.



xiii.

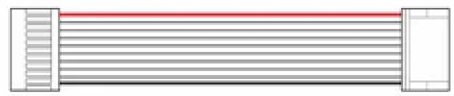
xiv. Screw in the front plate of the Battery Bracket using three M3x10mm screws to fully secure the batteries.

f. Flight Controller Connections

i. Velcro the Pixhawk 6C down to the right of the PDB with the top of the Pixhawk facing the front of the drone.

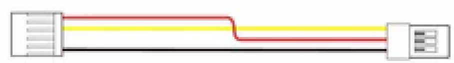
ii. Plug the 10-pin cable seen below into the I/O PWM Out port on the Pixhawk and the other end into the PWM splitter.

2x GHR 1.25mm 10 to 10 pin cable (PWM)



iii. Plug the 5-pin RC cable shown below into the PPM/SBUS RC port on the Pixhawk. The DuPont connector end plugs into the RC receiver in CH1/PPM following the +/-/S convention displayed on the receiver itself.

1x GHR 1.25mm 5 to DuPont 2.54 3 pin cable (RC)



iv. Take the 6-pin Molex PicoBlade to 6-pin JST-GH wire and switch the connections so that all wires go straight through (i.e. Pin 1 to Pin 1, Pin 2 to Pin 2, etc.). This wire comes with, for example, Pin 2 to Pin 8 as standard and this is incompatible with the Pixhawk.

v. Plug the JST-GH end of the above wire into the POWER1 port on the Pixhawk. Plug the PicoBlade end into the port on one side of the SmartAP PDB.

vi. If using a GPS like the M8N, plug the GPS cable into CAN1. GPS is optional for the basic configuration of the DORIS drone.

vii. The signal and ground wires (with DuPont connectors) from the ESCs need to be connected to the PWM splitter in the orientation indicated on it. Channels 1-4 are the default unless changed in QGC. The order at this point does not matter and will be addressed later. DuPont extension wires may be required to allow the ESC wires to reach far enough.

g. Flight Controller Programming

i. First, download QGroundControl, there are both Apple and Windows versions. There is no mobile version.
ii. Using a USB-C cable, plug into the Pixhawk with QGC open.
iii. From here, follow the guide found in the PX4 documentation: https://docs.px4.io/main/en/config/
iv. For the frame selection, use "Generic Quadcopter".
v. With a brand new Pixhawk, PWM channels 1-4 should be active and work appropriately, but if they do not, navigate to the "Motors" tab in QGC and change the motor channels to channels that work.
vi. After following the guide and performing all required and optional calibrations (acceleration, ESC, etc. – found under "Sensors" in QGC), the flight controller is ready.
vii. Under the "Power" tab, input 6 for the number of battery cells.

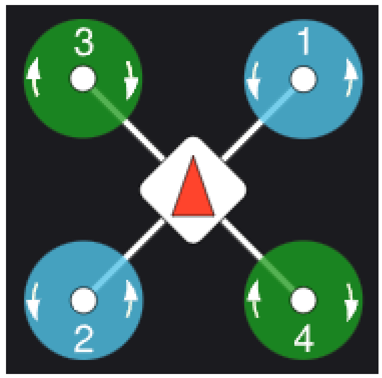
h. Radio Transmitter Programming
i. Toggle on the receiver using the power switch shown in Figure 5.2.
ii. Hold the OK button to open the settings and hit the OK button to select the System Setup
iii. Navigate the menu using the UP and DOWN buttons on the controller
iv. In Model Select, select the Model 1 type and ensure that the that stick configuration is set to Default 2 (Basic Flight)
v. To save any settings, hold the CANCEL button.
vi. Press the CANCEL button to go back
vii. Navigate to Type Select and ensure that the type is airplane or glider (no drone setting so airplane or glider setting works best)
viii. Leave everything else in the System Setup settings on default
ix. Navigate to the Function Setup
x. Navigate to the Assign Switches
xi. Set Flight Mode to SwA and everything else to NONE
xii. Every other setting should be at default
xiii. Check the manual below to see default settings.

i. Motor Mapping
i. To begin motor mapping, first plug in one or both batteries.
ii. Ensure all props are removed for any testing.
iii. The motors should all beep in unison, short-short-pause-long-short. If they do not, see the troubleshooting section for the next steps.

iv. If they do, that means the ESCs are ready for arming. Arm the drone by flipping the SWA switch shown in section 5.2.

v. Once armed, the motors should spin to idle immediately and all in synch. At this point, motor direction needed to be determined and corrected as needed.

vi. Motor direction for a standard quadcopter in PX4 is shown in the below figure.



vii. Based on the above diagram of motor direction, first adjust the connections to the PWM splitter to reflect the motor locations (i.e. Channel 1 is motor 1, Channel 2 motor 2, etc.).

viii. Rerun an ESC calibration.

ix. Retest the motors. If a motor is still spinning in the wrong direction, switch any two of the three wires from the ESC to the motor.

x. Rerun an ESC calibration.

xi. Repeat until all motors are spinning in the correct direction.

2. QGroundControl PX4 Parameters
   - Parameters can be adjusted in the Vehicle Setup menu, on the last tab on the left side of the screen. Listed below is all altered parameters for the drone to operate in a stable flight.

BAT1_A_PER_V	36.36751556	Battery 1 current per volt (A/V)
BAT1_CAPACITY	44000 mAh	Battery 1 capacity
BAT1_I_CHANNEL	-1	Battery 1 Current ADC Channel
BAT1_N_CELLS	6S Battery	Number of cells for battery 1
BAT1_R_INTERNAL	0.0050 Ohm	Explicitly defines the per cell internal resistance for battery 1
BAT1_SOURCE	Power Module	Battery 1 monitoring source
BAT1_V_CHANNEL	-1	Battery 1 Voltage ADC Channel
BAT1_V_CHARGED	4.05 V	Full cell voltage
BAT1_V_DIV	18.10000038	Battery 1 voltage divider (V divider)
BAT1_V_EMPTY	3.60 V	Empty cell voltage
BAT1_V_LOAD_DROP	0.10 V	Voltage drop per cell on full throttle
BAT2_A_PER_V	36.36751556	Battery 2 current per volt (A/V)
BAT2_CAPACITY	-1 mAh	Battery 2 capacity
BAT2_I_CHANNEL	-1	Battery 2 Current ADC Channel
BAT2_N_CELLS	Unknown	Number of cells for battery 2
BAT2_R_INTERNAL	0.0050 Ohm	Explicitly defines the per cell internal resistance for battery 2
BAT2_SOURCE	Disabled	Battery 2 monitoring source
BAT2_V_CHANNEL	-1	Battery 2 Voltage ADC Channel
BAT2_V_CHARGED	4.05 V	Full cell voltage
BAT2_V_DIV	18.10000038	Battery 2 voltage divider (V divider)
BAT2_V_EMPTY	3.60 V	Empty cell voltage
BAT2_V_LOAD_DROP	0.10 V	Voltage drop per cell on full throttle
BAT_AVRG_CURRENT	15 A	Expected battery current in flight
BAT_CRIT_THR	7.00 %	Critical threshold
BAT_EMERGEN_THR	5.00 %	Emergency threshold

CAL_GYRO1_PRIO	Medium (Default)	Gyroscope 1 priority
CAL_GYRO1_XOFF	0.005 rad/s	Gyroscope 1 X-axis offset
CAL_GYRO1_YOFF	-0.024 rad/s	Gyroscope 1 Y-axis offset
CAL_GYRO1_ZOFF	-0.008 rad/s	Gyroscope 1 Z-axis offset
CAL_MAG0_ID	396321	Magnetometer 0 calibration device ID
CAL_MAG0_PRIO	Medium (Default)	Magnetometer 0 priority
CAL_MAG0_XODIAG	-0.038	Magnetometer 0 X-axis off diagonal scale factor
CAL_MAG0_XOFF	0.041 gauss	Magnetometer 0 X-axis offset
CAL_MAG0_XSCALE	0.937	Magnetometer 0 X-axis scaling factor
CAL_MAG0_YODIAG	-0.095	Magnetometer 0 Y-axis off diagonal scale factor
CAL_MAG0_YOFF	-0.027 gauss	Magnetometer 0 Y-axis offset
CAL_MAG0_YSCALE	1.099	Magnetometer 0 Y-axis scaling factor
CAL_MAG0_ZODIAG	0.049	Magnetometer 0 Z-axis off diagonal scale factor
CAL_MAG0_ZOFF	-0.036 gauss	Magnetometer 0 Z-axis offset
CAL_MAG0_ZSCALE	0.983	Magnetometer 0 Z-axis scaling factor
CA_ROTOR0_PX	3.28 ft	Position of rotor 0 along X body axis relative to center of gravity
CA_ROTOR0_PY	3.28 ft	Position of rotor 0 along Y body axis relative to center of gravity
CA_ROTOR1_PX	-3.28 ft	Position of rotor 1 along X body axis relative to center of gravity
CA_ROTOR1_PY	-3.28 ft	Position of rotor 1 along Y body axis relative to center of gravity
CA_ROTOR2_KM	-0.050	Moment coefficient of rotor 2
CA_ROTOR2_PX	3.28 ft	Position of rotor 2 along X body axis relative to center of gravity
CA_ROTOR2_PY	-3.28 ft	Position of rotor 2 along Y body axis relative to center of gravity
CA_ROTOR3_KM	-0.050	Moment coefficient of rotor 3
CA_ROTOR3_PX	-3.28 ft	Position of rotor 3 along X body axis relative to center of gravity

CA_ROTOR3_PX	-3.28 ft	Position of rotor 3 along X body axis relative to center of gravity
CA_ROTOR3_PY	3.28 ft	Position of rotor 3 along Y body axis relative to center of gravity
CA_ROTOR_COUNT	4	Total number of rotors
COM_FLIGHT_UUID	808	Next flight UUID
COM_FLTMODE1	Manual	Mode slot 1
COM_FLTMODE2	Altitude	Mode slot 2
COM_FLTMODE4	Manual	Mode slot 4
EKF2_MULTI_IMU	3	Multi-EKF IMUs
FD_ACT_EN	Disabled	Enable Actuator Failure check
FD_ACT_MOT_THR	35.00 %	Motor Failure Throttle Threshold
FD_ACT_MOT_TOUT	300 ms	Motor Failure Time Threshold
FD_ESCS_EN	Disabled	Enable checks on ESCs that report their arming state
GPS_UBX_DYNMODEL	airborne with <1g accele	u-blox GPS dynamic platform model
IMU_GYRO_FFT_EN	Enabled	IMU gyro FFT enable
IMU_GYRO_RATEMAX	800 Hz	Gyro control data maximum publication rate (inner loop rate)
LND_FLIGHT_T_HI	1	Total flight time in microseconds
LND_FLIGHT_T_LO	1191669310	Total flight time in microseconds
MAN_ARM_GESTURE	Disabled	Enable arm/disarm stick gesture
MAV_TYPE	Quadrotor	MAVLink airframe type
MC_AT_EN	Enabled	Multicopter autotune module enable
NAV_ACC_RAD	6.6 ft	Acceptance Radius
PWM_MAIN_FUNC5	Motor 1	MAIN 5 Output Function
PWM_MAIN_FUNC6	Motor 2	MAIN 6 Output Function
PWM_MAIN_FUNC7	Motor 3	MAIN 7 Output Function

PWM_MAIN_FUNC8	Motor 4	MAIN 8 Output Function
PWM_MAIN_MAX5	1900	MAIN 5 Maximum Value
PWM_MAIN_MAX6	1900	MAIN 6 Maximum Value
PWM_MAIN_MAX7	1900	MAIN 7 Maximum Value
PWM_MAIN_MAX8	1900	MAIN 8 Maximum Value
PWM_MAIN_MIN5	1100	MAIN 5 Minimum Value
PWM_MAIN_MIN6	1100	MAIN 6 Minimum Value
PWM_MAIN_MIN7	1100	MAIN 7 Minimum Value
PWM_MAIN_MIN8	1100	MAIN 8 Minimum Value
RC1_MAX	2001.000 us	RC channel 1 maximum
RC1_MIN	1001.000 us	RC channel 1 minimum
RC1_TRIM	1503.000 us	RC channel 1 trim
RC2_TRIM	1503.000 us	RC channel 2 trim
RC3_MAX	1995.000 us	RC channel 3 maximum
RC3_MIN	1003.000 us	RC channel 3 minimum
RC3_TRIM	1003.000 us	RC channel 3 trim
RC4_MAX	1998.000 us	RC channel 4 maximum
RC4_TRIM	1501.000 us	RC channel 4 trim
RC5_MAX	2001.000 us	RC channel 5 maximum
RC_CHAN_CNT	8	RC channel count
RC_MAP_ARM_SW	Channel 5	Arm switch channel
RC_MAP_FLTMODE	Channel 1	Single channel flight mode selection
RC_MAP_PITCH	Channel 2	Pitch control channel mapping
RC_MAP_ROLL	Channel 1	Roll control channel mapping
RC_MAP_THROTTLE	Channel 3	Throttle control channel mapping

RC_MAP_YAW	Channel 4	Yaw control channel mapping
RTL_DESCEND_ALT	32.8 ft	Return mode loiter altitude
RTL_RETURN_ALT	50.0 ft	Return mode return altitude
SENS_IMU_MODE	Disabled	Sensors hub IMU mode
SYS_AUTOSTART	4001	Auto-start script index
UAVCAN_ENABLE	Sensors Automatic Confi	UAVCAN mode

3.4.4 Payload System

a. Install 3D-printed **MagSwitch Actuator Wheels** onto MagSwitches, then install 4-pronged servo end affecter onto actuator wheel
b. Install MagSwitches/**actuator wheels** into the payload subassembly frame (**Drone_Payload_Bracket_1**), make sure magnets are bolted in before proceeding.
c. Attach servo to secondary payload frame bracket (**Drone_Payload_Bracket_2**); ensure that servos are bolted to the secondary bracket before proceeding
d. Install secondary payload frame bracket on top of MagSwitches/**actuator wheels**; ensure that the servo gear is properly inserted into servo arm attached to **actuator wheels**. Also ensure that after this, the secondary bracket (**Drone_Payload_Bracket_2**) is bolted to the primary payload frame piece, using M4 socket-head bolts.
e. Install 3D-printed payload bay to the underside of frame. Ensure sub-assembly is properly fastened to the bottom frame plate of the drone
f. Connect actuation servos to Channels 3 and 4 of the HotRC receiver. These are associated with static on/off buttons on the HotRC controller.

3.4.5 Final Checks

g. Verify motor order and directions in QGroundControl.
h. Complete ESC and radio calibration.
i. Confirm arm symmetry and secure wiring connections.

4. Disassembly Instructions

- Disconnect batteries and store them in LiPo-safe bag/container.
- Follow reverse of assembly steps.
- Detach and store payload separately.
- Label all connectors and parts for easy reassembly.

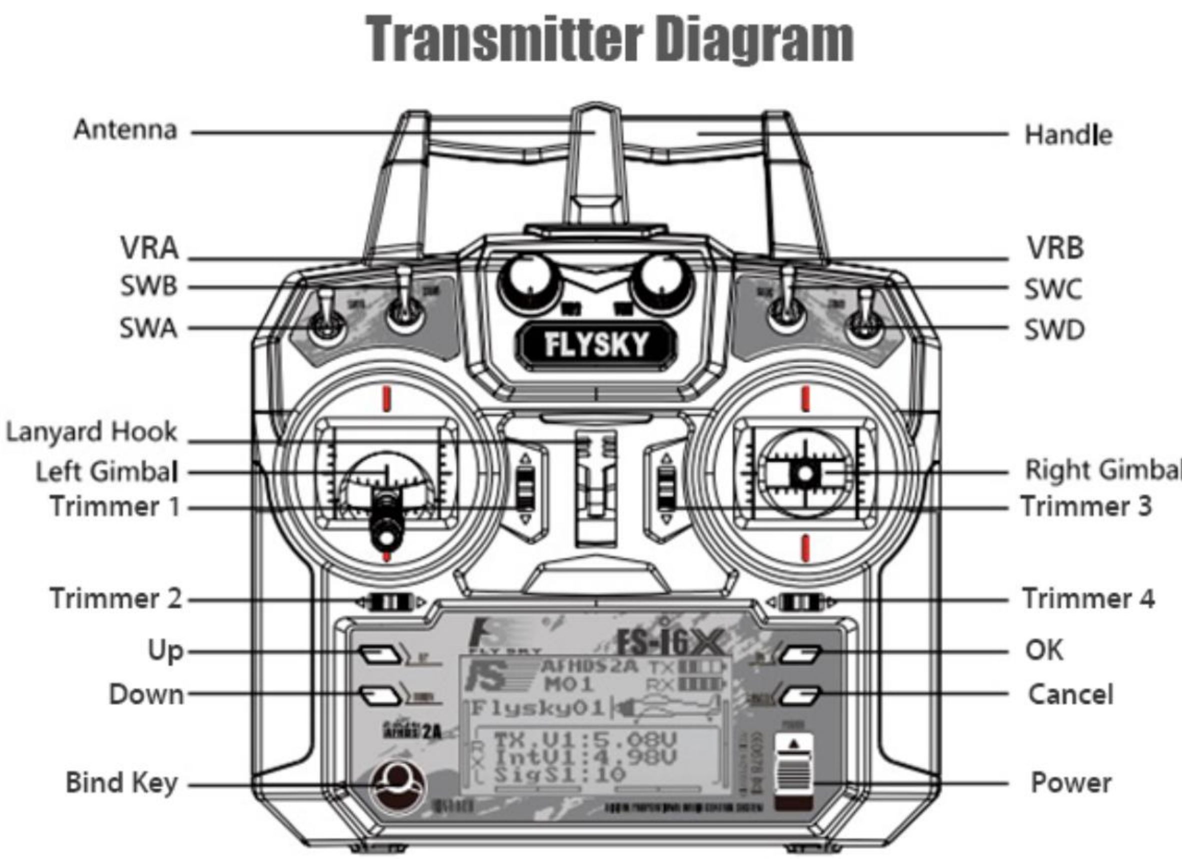
5. Operation

5.1 Pre-Flight Checklist

- Fully charged batteries (check voltage > 24V per pack)

- IMU calibration confirmed
- Props tightened and balanced
- ESCs and receiver functioning
- Payload mounted securely (if starting with payload)
- Payloads orientated correctly at pickup locations
- Radio connection verified
- Low Altitude Authorization and Notification Capability (LAANC) filed and approved with FAA through B4UFly system and maximum altitude for mission area identified

5.2 FLYSKY FS-i6X Remote Diagram



5.3 Arming and Flight Procedure

1. Power drone by plugging in both batteries.

2. Ensure all switches are in the up position, throttle (Left Gimbal) in down position, pitch/roll (Right Gimbal) in neutral position on transmitter.
3. Turn on transmitter (FS-i6 or compatible, this manual uses the above FS-i6X).
4. Arm the drone using the designated switch (SWA).
5. Increase throttle smoothly but swiftly to 100% for takeoff.

5.4 Payload Delivery

- Power on the subsystem by plugging in the small battery and turning on the separate joystick controller.
- To activate the servos, press each button that was assigned to each individual servo, at close to the same time to disengage the MagSwitches.
- Ensure that the payload landing site is clear and safe before release.
- To pick up payloads, press those same buttons again to engage the MagSwitches.
- When picking up payloads, ensure that the drone does not touch the ground per flight behavior restrictions.
- Please note that the MagSwitches sit low enough to where the drone legs will not touch the ground when physically contacting the payload.

5.5 Post-Flight

1. Disarm via transmitter (SWA up)
2. Ensure propellers have stopped spinning before approaching
3. Unplug batteries and place in LiPo-safe container/bag
4. Remove propellers
5. Download logs from Pixhawk through direct computer plug in and QGC for flight data

6. Maintenance Instructions

- **Daily Use**
    - Check motor mounts, props, payload subassembly bracket, and arms for cracks/deformation
    - Ensure proper servo and magnet operation by operating this separate system regularly
    - Clean servos, motors and frame with compressed air
    - Visually inspect batteries for swelling, punctures, or corrosion before use

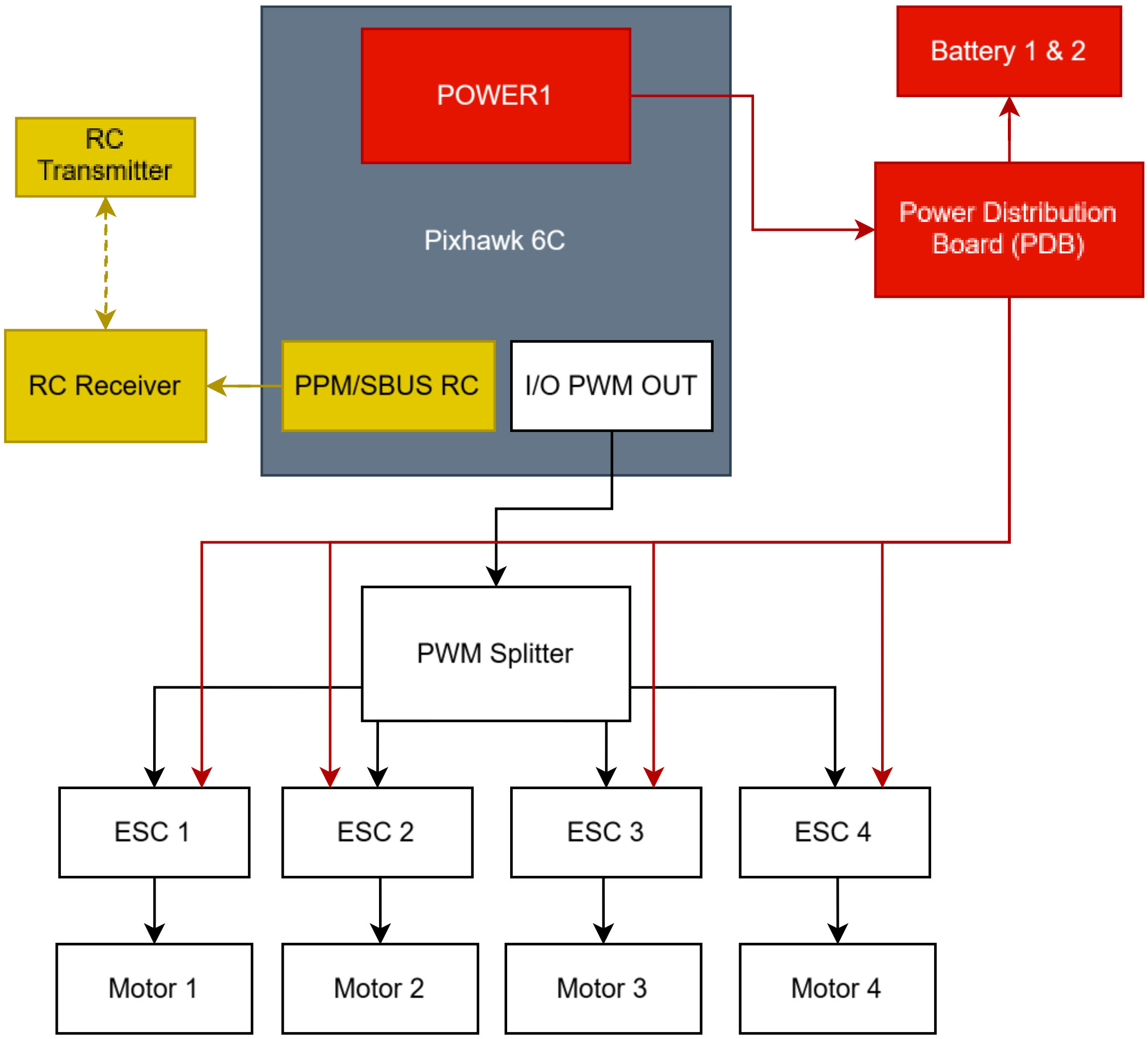
    - Check for and apply any firmware updates for flight controller, transmitter, or onboard sensors
- **Every 5 Flights**
    - Verify solder joints and ESC heat
    - Run sensor calibrations
- **Monthly**
    - Inspect battery health with cell checker
    - Perform range check for transmitter/receiver
    - Ensure all screws are secure, especially the arm and motor mounts.
- **Storage**
    - Store LiPo batteries at 3.8V per cell in a fire-resistant LiPo bag or metal container.
    - Keep drone components in a dust-free, temperature- and humidity-stable environment. Avoid direct sunlight or freezing conditions.

7. Troubleshooting

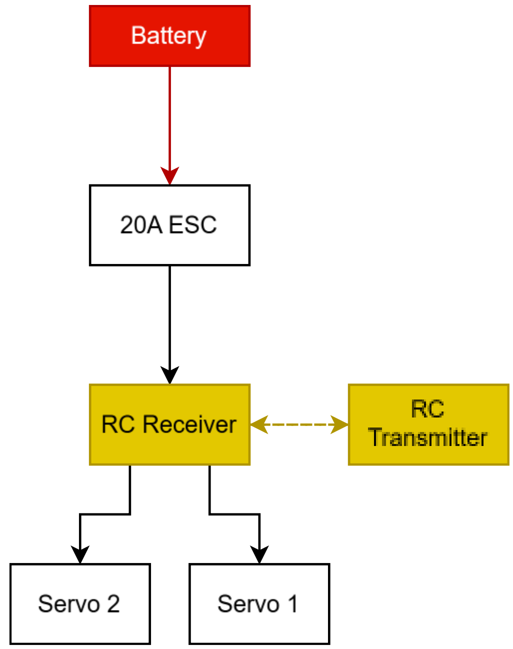
Problem	Cause	Solution
Drone won't arm	Failsafe triggered or calibration missing	Calibrate compass/accelerometer, check RC
ESC beeping repeatedly	Throttle not at zero, no signal	Rebind transmitter, check PWM wiring
One motor spins wrong direction	Wiring order reversed	Swap two motor wires, rerun ESC calibration
Drone vibrates heavily	Unbalanced propeller or loose arm	Replace prop, check motor/arm alignment
Battery drains too fast	Overloaded payload or damaged cells	Reduce weight, test each battery
Drone lifts off the ground slightly then returns to ground (Hopping)	Battery Voltage Sag over the limit.	Change Bat_Crit_Thr and Bat_Low_Thr in QGroundControl to higher amounts (14% & 7%) OR Purchase higher quality batteries

8. Appendix

- Wiring Diagram (Drone)



- Wiring Diagram (Payload)



- CAD Model Exploded View: drone_assembly_v3.step
- Motor/ESC Spec Sheets:
  - XING 4214 2-8S X CLASS FPV Motor
  - file:///C:\Users\jgmal\Downloads\150%20ESC%20Instructions.pdf
- Links to Firmware & Calibration Tools:
  - https://www.iflight-rc.com/
  - QGC Download & Documentation: https://docs.qgroundcontrol.com/master/en/qgc-user-guide/getting_started/download_and_install.html
  - PX4 Documentation: https://docs.px4.io/main/en/
- RC Controller/Transmitter Manual:
  - Power Off - Fly Sky FS-i6X Instruction Manual | ManualsLib

- Bill of Materials

Purchased Item	Primary Vendor	Manufacturer	Lead Time	Qty	Unit Cost	Total Cost	Part Status
DRONE ONLY					Total Cost:	$2,276.37	
22Ah 6S LiPo Battery	Aliexpress	Tattu	2 weeks	2	$ 240.00	$ 480.00	Installed
Flight Controller (Pixhawk 6C)	HolyBro	HolyBro	7-10 business days	1	$ 231.46	$ 231.46	Installed
10pcs 150mm DuPont extension wires	Aliexpress	Any	2 weeks	1	$ 5.29	$ 5.29	Installed
Pixhawk Wiring Kit	HolyBro	HolyBro	7-10 business days	1	$ 35.00	$ 35.00	Installed
6-pin Molex PicoBlade to 6-pin JST-GH wire	3DR	3DR	7-10 business days	1	$ 8.76	$ 8.76	Installed
XING 4214 660KV Motor	iFlight	iFlight	2 weeks	4	$ 62.75	$ 251.00	Installed
6-channel RC receiver	Any	Any	7-10 business days	1	$ 35.00	$ 35.00	Installed
Power Distribution Module (Sky-Drones SmartAP PDB)	Sky-Drones	Sky-Drones	7-10 business days	1	$ 90.00	$ 90.00	Installed
Electronic Speed Controller (150A)	Amazon	Flycolor	7-10 business days	4	$ 119.00	$ 476.00	Installed
RC Controller (must be compatible w/ receiver)	Any	Any	7-10 business days	1	$ 50.00	$ 50.00	Installed
Wiring kit (12AWG, 60ft)	Amazon	NAOEVO	3 business days	1	$ 25.00	$ 25.00	In use
LiPo Battery Charging Kit	Amazon	SmartCharger	3 business days	1	$ 52.00	$ 52.00	In use
4pk)	Amazon	ZSJ	2 weeks	2	$ 25.00	$ 50.00	Installed
3D Printing Filament (ABS)	Amazon	Any	3 business days	2	$ 20.00	$ 40.00	In use
3D Printing Filament (PLA)	Amazon	Any	3 business days	1	$ 24.00	$ 24.00	In use
3D Printing Filament (TPU 95A)	Amazon	Any	3 business days	1	$ 26.19	$ 26.19	In use
XT90 Connectors (10pk)	Amazon	Amass	3 business days	1	$ 14.17	$ 14.17	Installed
Propellers (16", tri-blade)	HQProp	HQProp	7-10 business days	4	$ 35.68	$ 142.72	Installed
Extreme Fasteners	Home Depot	Scotch	0 days	2	$ 13.03	$ 26.06	Installed
M6 locking nut	Home Depot	Any	0 days	8	$ 0.68	$ 5.44	Installed
Birch markerboard (4ft x 4ft x 1/4in)	Home Depot	Any	0 days	2	$ 15.98	$ 31.96	Installed
Fiberglass cloth (8 sq ft)	Home Depot	Any	0 days	4	$ 8.28	$ 33.12	Installed
Fiberglass resin (1gal)	Home Depot	Any	0 days	1	$ 59.98	$ 59.98	In use
Socket cap screw M6x100mm 4pk	Home Depot	Any	0 days	5	$ 3.25	$ 16.25	Installed
Socket cap screw M4x20mm 4pk	Home Depot	Any	0 days	2	$ 3.25	$ 6.50	Installed
Socket cap screw M4x60mm 3pk	Home Depot	Any	0 days	2	$ 3.25	$ 6.50	Installed
Socket cap screw M3x50mm 4pk	Home Depot	Any	0 days	4	$ 3.25	$ 13.00	Installed
Socket cap screw M3x10mm 3pk	Home Depot	Any	0 days	1	$ 2.25	$ 2.25	Installed
Socket cap screw 1/4x7 in	Home Depot	Any	0 days	1	$ 1.99	$ 1.99	Installed
M6 Nut 4pk	Home Depot	Any	0 days	5	$ 1.25	$ 6.25	Installed
M4 Nut 4pk	Home Depot	Any	0 days	4	$ 1.25	$ 5.00	Installed
M3 Nut 4pk	Home Depot	Any	0 days	5	$ 1.25	$ 6.25	Installed
1/4 Nut	Home Depot	Any	0 days	1	$ 0.75	$ 0.75	Installed
12 -10 AWG 0.25 in. Tab Male Fully-Insulated Disconnect (10pk)	Home Depot	Any	0 days	2	$ 4.62	$ 9.24	Installed
12 -10 AWG 0.25 in. Tab Male Fully-Insulated Disconnect (10pk)	Home Depot	Any	0 days	2	$ 4.62	$ 9.24	Installed
REGULAR PAYLOADS					Total Cost:	$ 443.11	
GoPro Hero 4K	GoPro	GoPro	7-10 business days	1	$ 220.00	$ 220.00	Installed
MG995 Servo Motor 4pk	Amazon	Any	7-10 business days	1	$ 16.99	$ 16.99	Installed
Magswitch MagJig Magnet	Amazon	Magswitch	3 business days	2	$ 26.73	$ 53.46	Installed
3D Printing Filament (PLA)	Amazon	Any	3 business days	2	$ 19.64	$ 39.28	In use
3D Printing Filament (PETG)	Amazon	Any	3 business days	1	$ 19.64	$ 19.64	Installed
5lb dumbell	Amazon	Any	3 business days	1	$ 18.95	$ 18.95	Installed
2-4S 20A Brushless ESC	Aliexpress	Surpass Hobby	2 weeks	1	$ 25.10	$ 25.10	Installed
RC controller/receiver	Aliexpress	HotRC	2 weeks	1	$ 20.44	$ 20.44	Installed
1050mAh LiPo battery	Amazon	Tattu	3 business days	1	$ 29.25	$ 29.25	Installed
TOTAL OVERALL COST:						$2,719.48	

Manufactured Item	Vendor	Manufacturing Method	Lead Time	Qty	Unit Cost	Total Cost	Part Status
DRONE ONLY					Total Cost:	$ -	
Outer Arm Mount (TPU)	In-House	3D FDM Printing	4 hours	8	$ -	$ -	Installed
Motor Mount (TPU & ABS)	In-House	3D FDM Printing	2 hours	4	$ -	$ -	Installed
Drone Legs (TPU)	In-House	3D FDM Printing	4 hours	4	$ -	$ -	Installed
Body Plates (Fiberglass on birch)	In-House	Jigsaw cutting, layups	10 hours	2	$ -	$ -	Installed
Battery Holder	In-House	3D FDM Printing	4 hours	1	$ -	$ -	Installed
REGULAR PAYLOADS					Total Cost:	$ -	
Magswitch Turning knob (PLA)	In-House	3D FDM Printing	1 hour	2	$ -	$ -	Installed
Magswitch/servo Attachment Plate (PETG)	In-House	3D FDM Printing	16 hours	1	$ -	$ -	Installed
GoPro Payload (PETG)	In-House	3D FDM Printing	8 hours	1	$ -	$ -	Installed
Weight Payload (PLA)	In-House	3D FDM Printing	22 hours	1	$ -	$ -	Installed
Payload Magnetic Plates	In-House	Saw and Drill	3 hours	2	$ -	$ -	Installed
TOTAL OVERALL COST:						$ -	