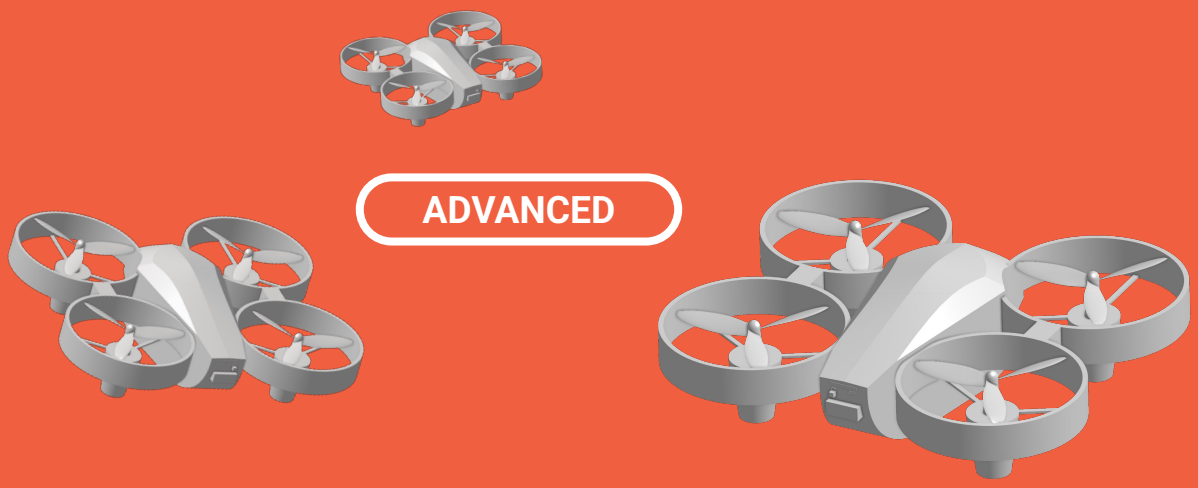
**STAGE ONE EDUCATION**

Hands-on Engineering Workshops

# ROBOTICS WORKSHOP

## ELECTRONICS & CODING



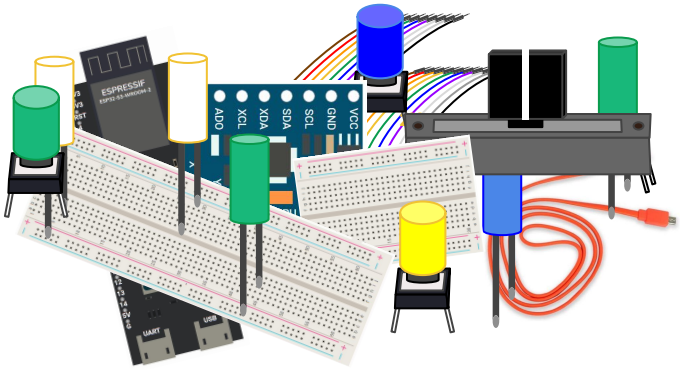
**ADVANCED**

with
**ARDUINO**
**&**
**ESP32**

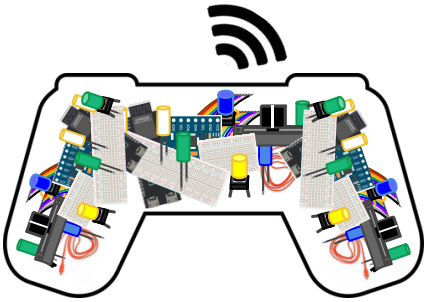
V 1.9

# Background

Get ready to build a controller using simple electrical components!




You'll use this controller to send signals to your drone, allowing you to control its flight both manually and autonomously.



Along the way we will build, program, and optimize our circuit and drones flight.

Build your circuit solely from wiring diagrams

ADVANCED

# Parts that we'll use today

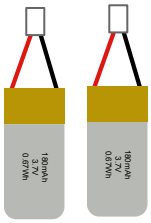
## On your desk

Laptop

Open your laptop and connect to power


Instructions

Safety Glasses

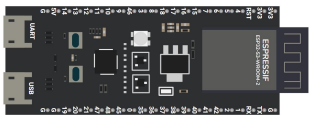


Drone Batteries

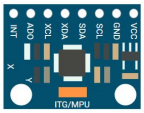
Electronics Box

Check that you have all the parts we will use today

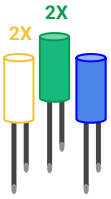
Drone



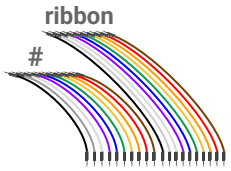
ESP32 Development Board



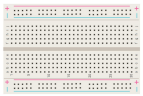

GY-521 Accelerometer



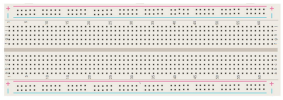

LED's



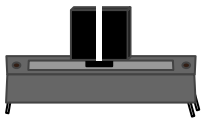

Wires



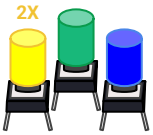
Small Breadboard



Large Breadboard



Slider Variable Resistors




Buttons

Drone Battery Charging Cable

USB to Micro USB

# Start-Up

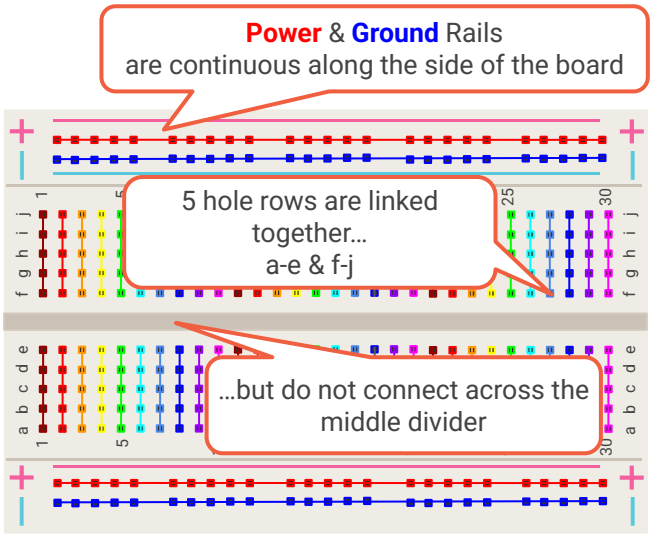
**SAFETY GLASSES REQUIRED**

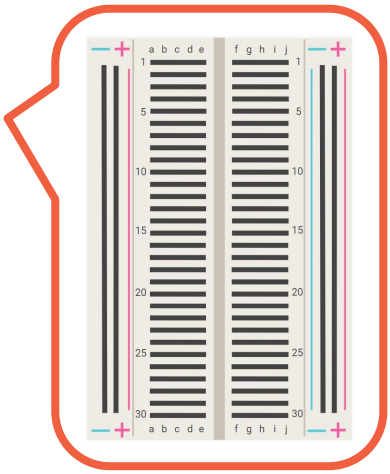
Put on your safety glasses

## BREADBOARDS

**NEVER** twist wires

**ALWAYS** connect wires using the breadboard!



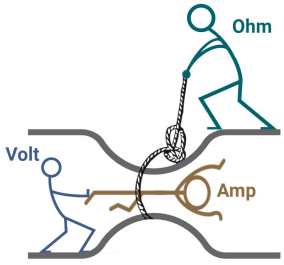
## GOOD TO KNOW

Ohm's Law

**Voltage = Current ✖ Resistance**

**Current (A)**
measure the flow of electrical current in a circuit. It indicates how many electrons are passing a point in the circuit per second. It's measured in amperage (A)

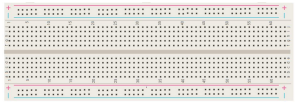
**Voltage (V)**
the electrical potential difference between two points in a circuit. It is measured in volts (V)



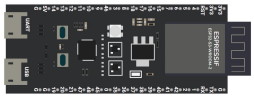

**Resistance (Ω)**
measures how much a component resists the flow of current. It's measured in ohms (Ω)

# Drone Control Board Assembly

## Parts we need



Large Breadboard

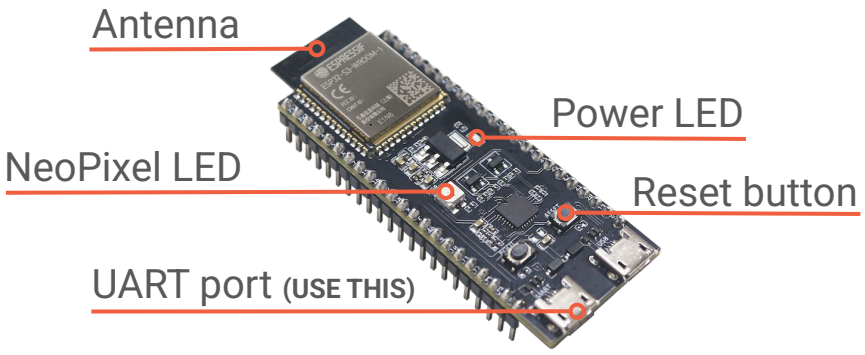


ESP32

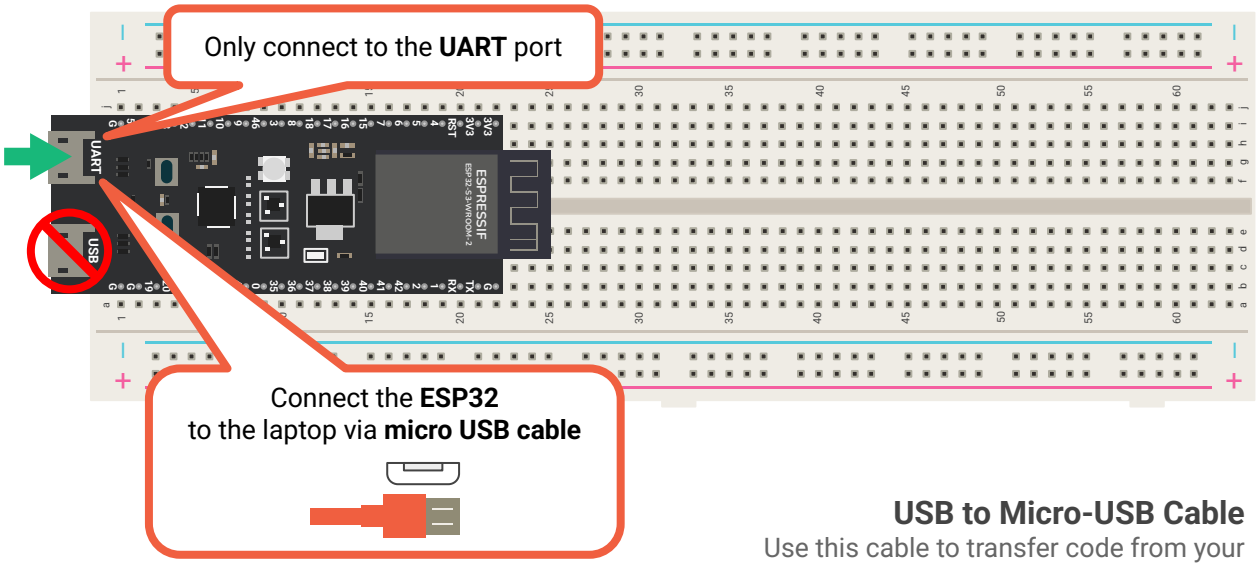
USB to Micro-USB

## ESP32-S3-WROOM Development Module

This component is like a small computer that lets devices communicate.
We'll use it to link to our drone's WiFi and create a controller to pilot the drone!




## The **ESP32** will be installed on the **breadboard**

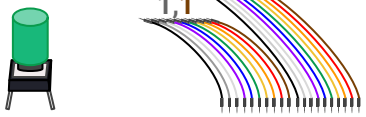



### USB to Micro-USB Cable

Use this cable to transfer code from your laptop to the ESP32. Only connect it when you're ready to upload to protect your circuit.

# Takeoff Button Assembly

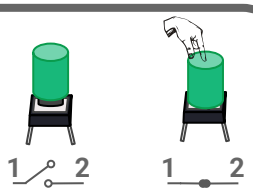
## Parts we need




Green Button  Wire

## Two-Pin Button

- When the button is pressed, pins 1 and 2 connect
- Pressing the button can cause a bouncy connection, sending multiple signals.
- Two-pin buttons are used as on/off switches and triggers in various projects.

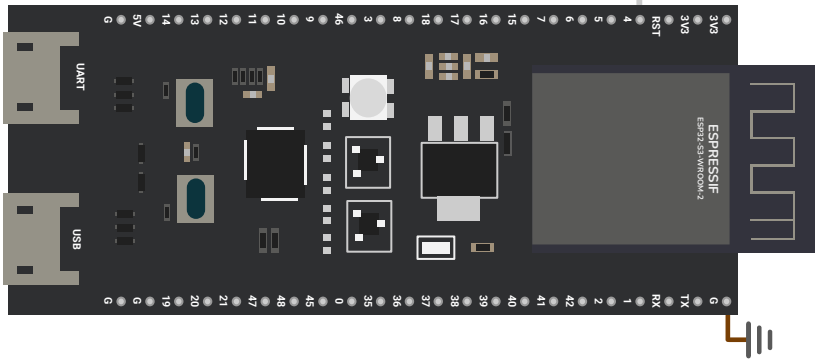



Schematic Symbol

## Wiring Diagram

Let's use a **White** wire to link **pin 4** of the **ESP32** to the **Green** button.

Connect the **ESP32** to ground by using a **Brown** wire to link **pin G** to the **negative rail** (-) on the breadboard.



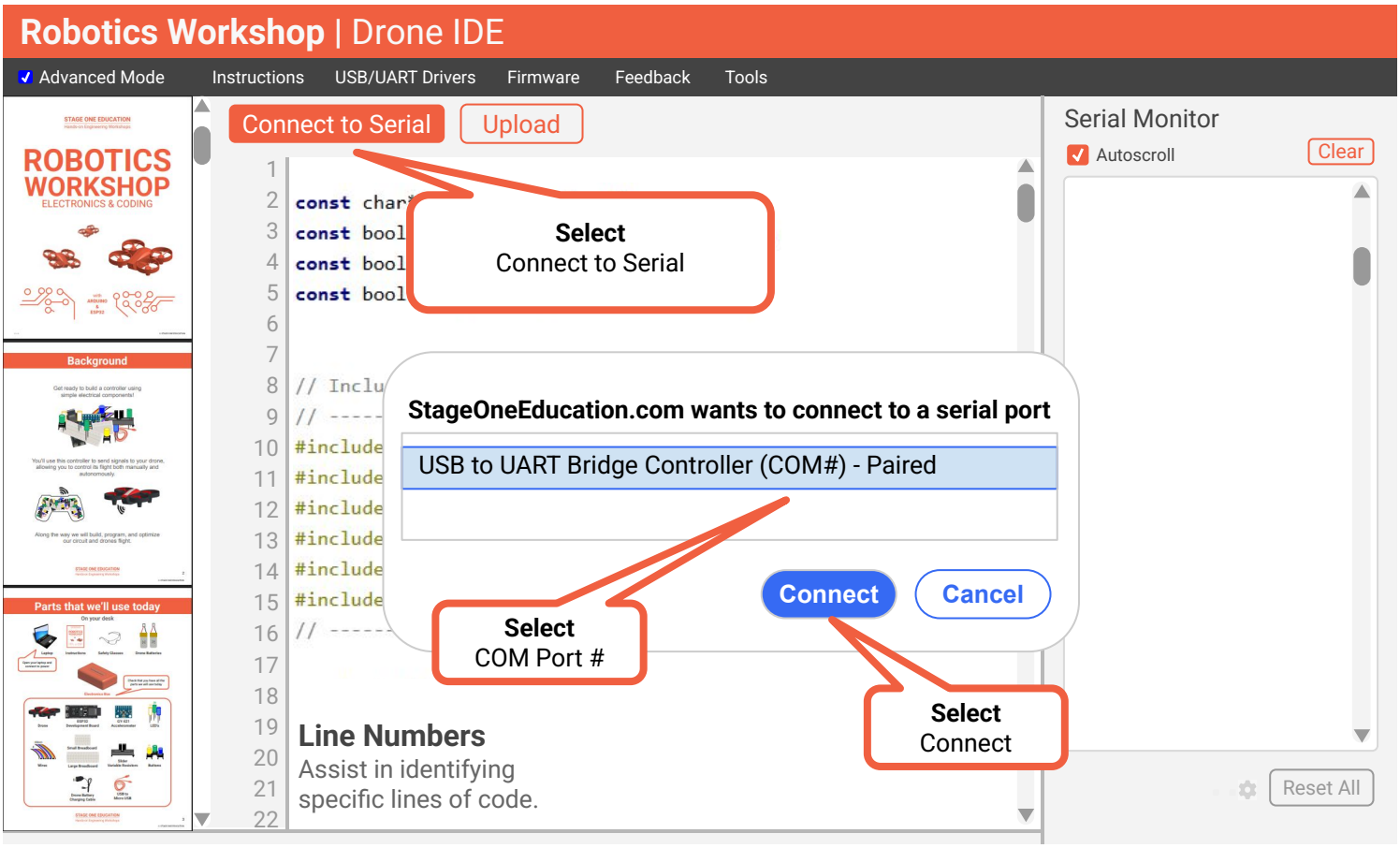

Plug all components directly into the **negative rail** (-) on the breadboard.

## Grounding

- Ensures correct voltage levels by providing a common reference point.
- Reduces noise and interference for accurate readings and stable operation.
- Prevents shocks and protects components by safely redirecting excess electricity.

Schematic Symbol

# Initiating Serial Communication

# Upload

**Robotics Workshop** | Drone IDE

Advanced Mode | Instructions | USB/UART Drivers | Firmware | Feedback | Tools

Connected | Upload

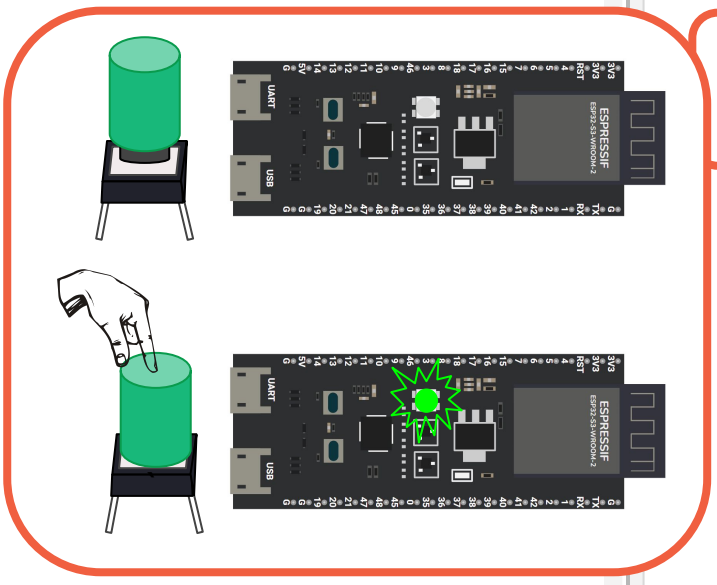
**Select**
Upload to send the software to the ESP32

Serial Monitor

Autoscroll | Clear

```
Green button pressed
Green button released
Green button pressed
Green button released
Green button pressed
Green button released
Green button pressed
Green button released
Green button pressed
Green button released
```

Observe the Serial Monitor when the green button is pressed

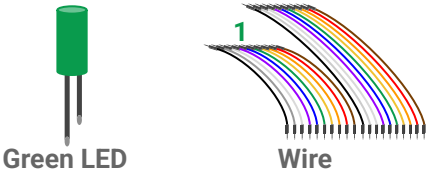


**Serial Monitor**
works like a chat window that lets you see messages between your computer and the ESP32, helping you understand and control what's happening inside your project.

Reset All

# Takeoff LED

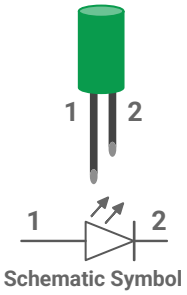
## Parts we need




Green LED  Wire

## Light Emitting Diode - LED

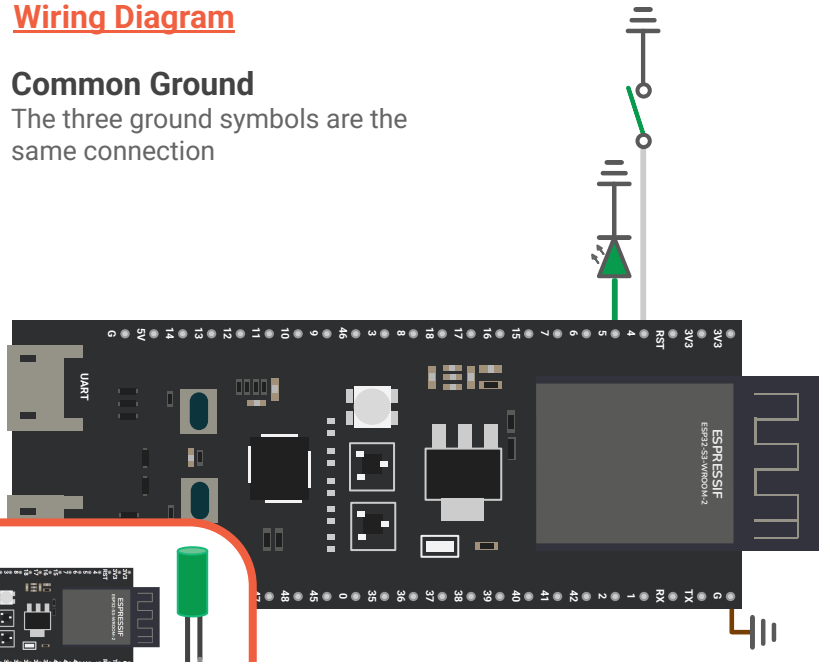
- Long leg = Positive (anode)
- Short leg = Negative (cathode)
- LEDs require different voltages
  - Green, White, Blue: 2.8 - 3.6 volts
  - Red, Yellow: 1.8 - 2.3 volts
- The color of an LED depends on the materials it is made from.
  - EX: Green LEDs use indium gallium nitride (InGaN).




Schematic Symbol

## Wiring Diagram

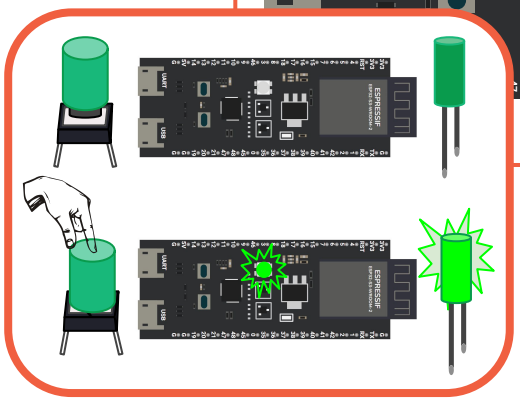
**Common Ground**
The three ground symbols are the same connection




Let's use a **Green** wire to link **pin 5** of the **ESP32** to the **Green** LED.

**LED**

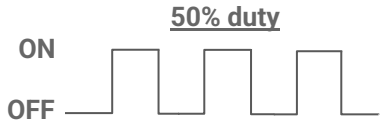
short leg connects to GND



# LED Software Control

## Pulse Width Modulation - PWM

- PWM turns a light on and off so quickly that the flickering is invisible to our eyes
- By adjusting how long the light is on compared to off, PWM controls brightness
- The duty cycle is the percentage of time the signal is on
  - higher means more power, lower means less.




**Robotics Workshop** | Drone IDE

Advanced Mode | Instructions | USB/UART Drivers | Firmware | Feedback | Tools

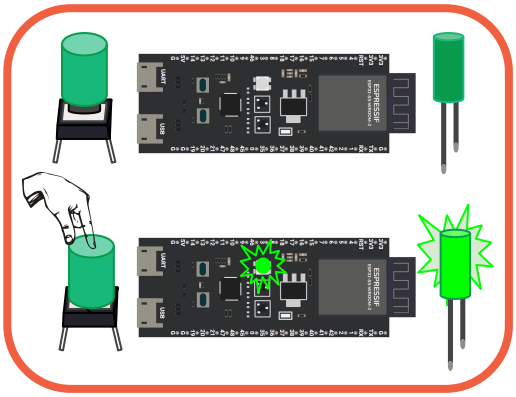
Connected | Upload

```
359 void setLed(int pin_num, bool on_off) {
360   int duty = 0;
361   if (on_off) {
362     duty = 400;
363   }
```

**Change** the LEDs duty cycle
Set the LED to your preferred brightness
Try values: **400** or **4000**

Upload

**Upload the code**
After every software change you will need to reupload



Serial Monitor

Autoscroll | Clear

```
Green button pressed
Green button released
Green button pressed
Green button released
Green button pressed
Green button released
Green button pressed
Green button released
Green button pressed
Green button released
```

Reset All

# Cleared For Takeoff

## Parts we need

Drone

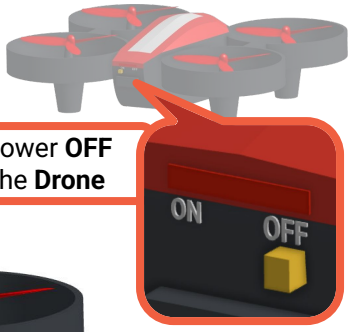
Battery

Safety Glasses

## SAFETY GLASSES REQUIRED

## Installing the Battery

1. Power OFF the drone
2. Open the battery compartment door
3. Insert the battery, silver side first
4. Connect the slotted battery plug
5. Close the battery compartment door





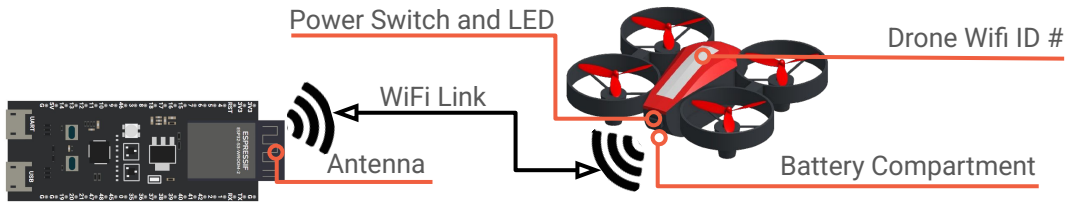
## Airspace

**Stay in your airspace**
Your designated airspace is directly around your table. Keep all test flights within this space.

# Drone Sync

## Wireless Fidelity (WiFi) Drone

- The drone has a WiFi transmitter that creates a local network for the ESP32 to connect to.
- The ESP32 will send signals via WiFi to adjust propeller speeds controlling the drone.
- Powered by a LiPo battery, which offers high energy density in a lightweight package.




**Robotics Workshop** | Drone IDE

Advanced Mode | Instructions | USB/UART Drivers | Firmware | Feedback | Tools

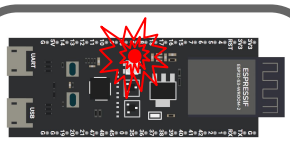
Connected | Upload

```
1
2 const char* quadcopter_id = "";
```

Upload

Type your **Drone ID #** exactly as it appears inside the " "


Power **ON** the **Drone**



**WiFi Not Connected**
Power cycle the drone by turning it OFF and ON

Serial Monitor

Autoscroll | Clear

```
WiFi not connected (turn drone off and back on)
WiFi connected! IP address: 192.168.0.2
No accelerometer.
No throttle.
Pitch | Roll | Yaw | Throttle | Alt (m)
-----------------------------------------
   50 |   50 |  50 |       50 |   -0.03
```

**WiFi Link**
**Serial**.println
(line 904)

**Flight Commands**
**Serial**.println
(line 465)

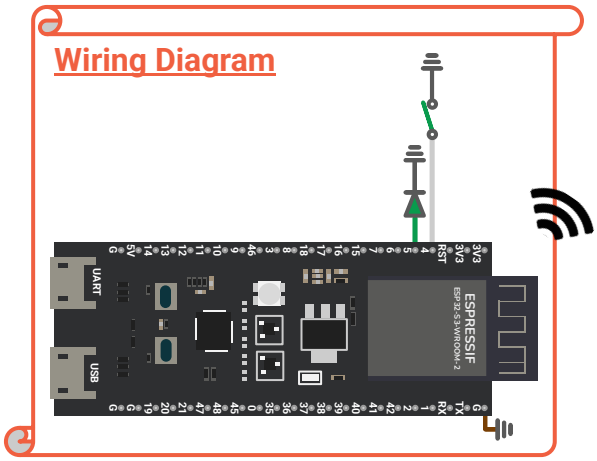
# Takeoff Button Test Flight

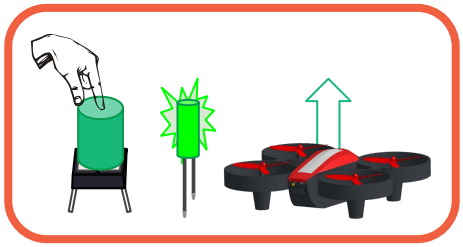
**SAFETY GLASSES REQUIRED**

***Flight Sequence***

Takeoff is a crucial maneuver. Press the green button for a smooth takeoff; the drone will ascend for 1 second.


## Wiring Diagram





Serial Monitor

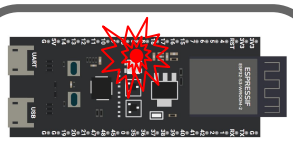
Autoscroll

Clear

```
WiFi connected! IP address: 192.168.0.2
Green button pressed
Green/Take-Off Button Pressed
No accelerometer.
No throttle.
Pitch | Roll | Yaw | Throttle | Alt (m)
-----------------------------------------
   50 |   50 |  50 |       50 |    0.00
```

**Serial**.println (line 612)

Observe the Atl change during flight



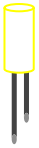
**WiFi Not Connected**

Power cycle the drone by turning it OFF and ON

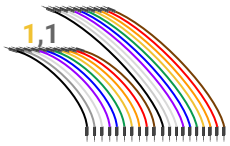
# Stop Button Assembly

## Parts we need

Yellow Button



White LED




Wire

## Stop vs. Landing

To control our soon-to-be autonomous drone, we'll install a stop button that immediately ends the flight. This is different from landing, which is a controlled maneuver we'll program later.

Analyze the #define section of the code to see what **ESP32** pins to connect to the **Yellow_Button_Base** and **White_LED _BASE**

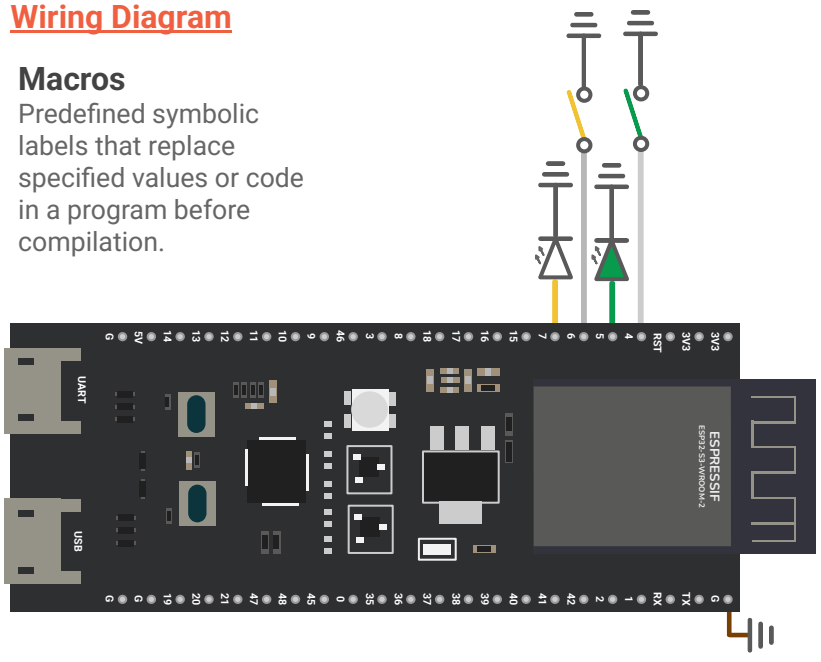
## #define

- lets you give nicknames to numbers, making your code easier to read and change
- It doesn't use extra memory because it replaces the nickname with a number before your code runs

Use a **Yellow** wire to connect the **White** LED to the **ESP32**

### Wiring Diagram

**Macros**
Predefined symbolic labels that replace specified values or code in a program before compilation.



Use a **Gray** wire to connect the **Yellow** button to the **ESP32**

### LED

short leg connects to GND

# Stop Button Assembly

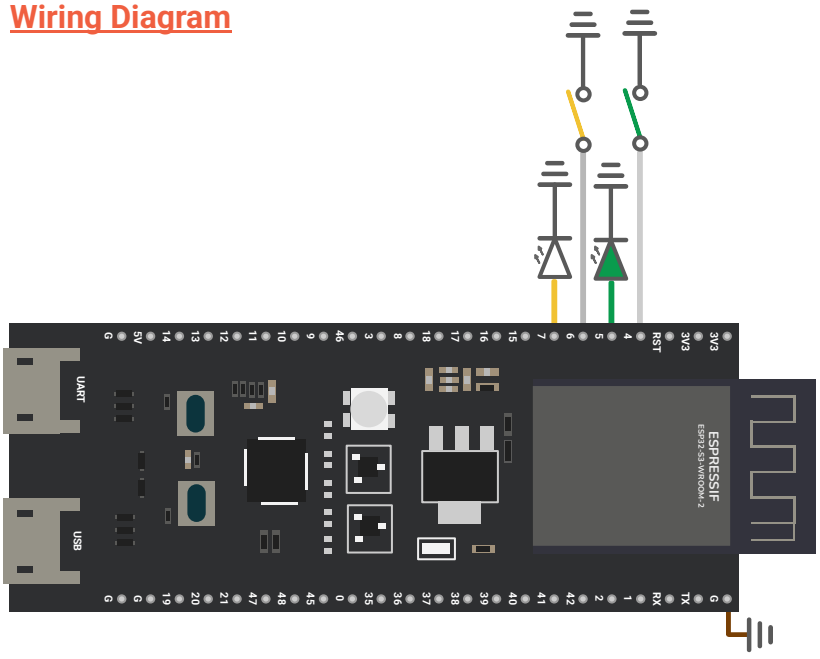
## Flight Mode

We will utilize LEDs to provide visual indicators of our flight controller's state

**Green**
Flight in progress

**White**
Disarmed and in standby

## Wiring Diagram



# Activate STOP

**Robotics Workshop** | Drone IDE

Advanced Mode | Instructions | USB/UART Drivers | Firmware | Feedback | Tools

Connected | Upload

```
1
2 const char* quadcopter_id = "Drone";
3 const bool yellow_button_connected = true;
```

**Change line 3 to true**
This will activate the stop button pins on the ESP32

## Serial.print("Hello, world!");

- Sends data from a microcontroller (e.g., ESP32) to a computer via a serial connection (USB)
- The text between the quotation marks (" ") will be sent and displayed on the serial monitor

## if();

- checks whether a condition is true or false. If the condition is true, the code inside the if block runs.
- If the condition is false, this code is skipped.

```
839 // Sends the actual command to the drone
840 void sendPacket(String packetString) {
841   // Always check for stopped here since this func
842   if ((digitalRead(YELLOW_BUTTON_PIN_BASE) == LOW)
843     Serial.println("Stop/Yellow button pressed");
844     stopPressed();
845   }
```

**Change line 843** Serial.println(

"STOP/YELLOW BUTTON PRESSED"
or
"STOP STOP my drone is crashing! :("
or
"Yellow button pressed! Drone's nap time activated. See you later, aviator!"
);

**Upload the code**

Upload

**//**
In Arduino, // is used to write a comment, which is like a note for humans to read that the computer ignores when running the code.

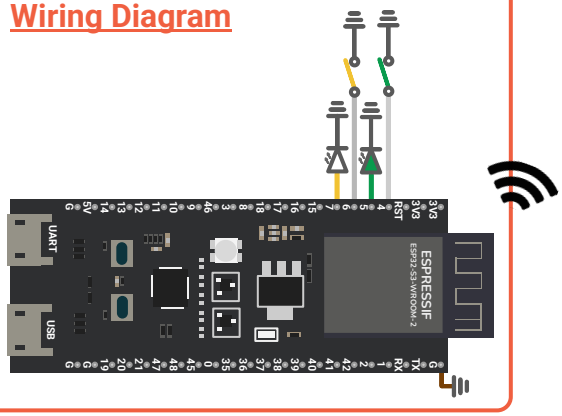
# STOP Button Test Flight

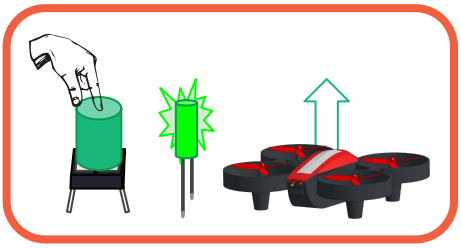
## SAFETY GLASSES REQUIRED

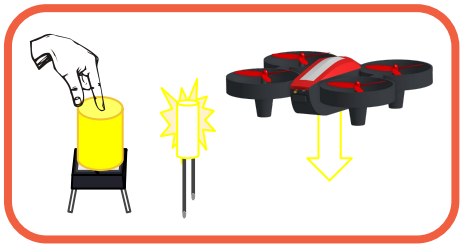
### *Flight Sequence*

Press the green button for a smooth takeoff; the drone will ascend.
Press the yellow button to STOP the flight.


### Wiring Diagram



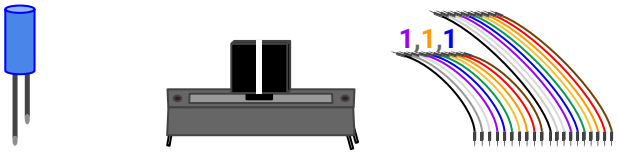





**Not connecting...**
Power cycle the drone by turning it OFF and ON

# Altitude Control Slider

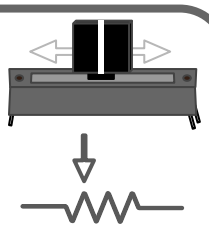
## Parts we need




Blue LED | Slider | Wire

## Variable Resistor - Slider

- Change circuit resistance by moving the slider, controlling electrical flow
- Sliding closer to one end decreases resistance there and increases it at the other end
- Common in volume controls, light dimmers, and sensor inputs, variable resistors are available in linear (straight slider) and rotary (knob) styles

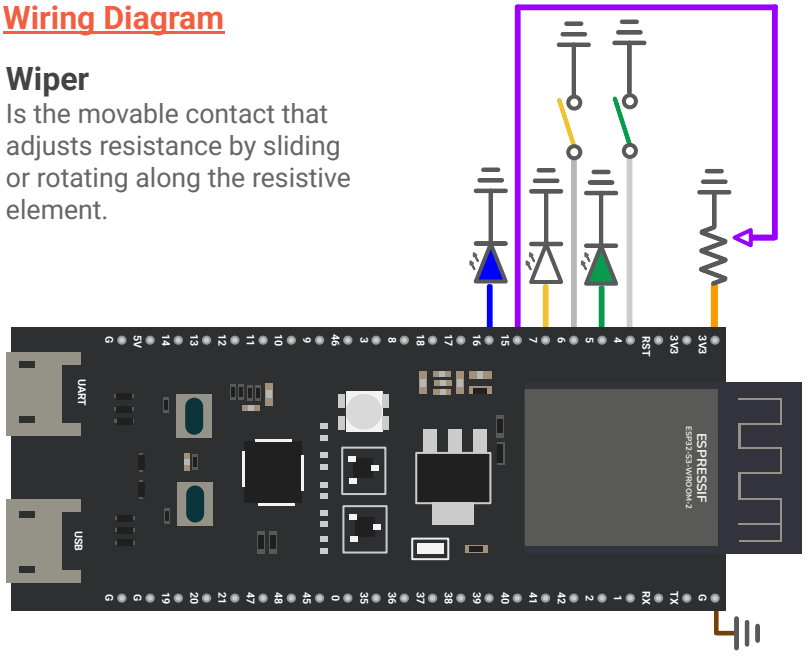


Schematic Symbol

Place the **Slider** at the end of the breadboard opposite of the **ESP32**

### Wiring Diagram

**Wiper**
Is the movable contact that adjusts resistance by sliding or rotating along the resistive element.



Use a **blue** wire to connect **pin 16** to the **blue LED**

Use a **orange** wire to connect **3.3V** to the **slider - left pin**

Use a **purple** wire to connect **pin 15** to the **slider - right pin**

# Activate Altitude Control

**Robotics Workshop** | Drone IDE

Advanced Mode | Instructions | USB/UART Drivers | Firmware | Feedback | Tools

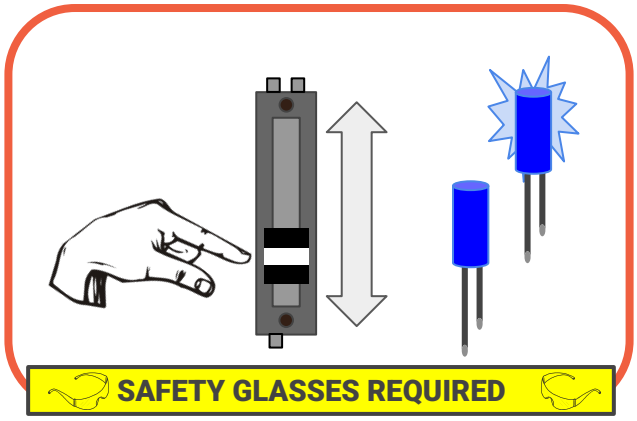
Connected | Upload

```
1
2 const char* quadcopter_id = "Drone";
3 const bool yellow_button_connected = true;
4 const bool slide_connected = true;
```

**Change line 4 to true**
This will activate the slider pins on the ESP32

Upload

**Upload the code**




Serial Monitor

Autoscroll | Clear

```
No accelerometer.
Pitch | Roll | Yaw | Throttle | Alt (m)
----------------------------------------
   50 |   50 |  50 |       19 |    0.00
No accelerometer.
Pitch | Roll | Yaw | Throttle | Alt (m)
----------------------------------------
   50 |   50 |  50 |       32 |    0.42
No accelerometer.
Pitch | Roll | Yaw | Throttle | Alt (m)
----------------------------------------
   50 |   50 |  50 |       81 |    1.32
```

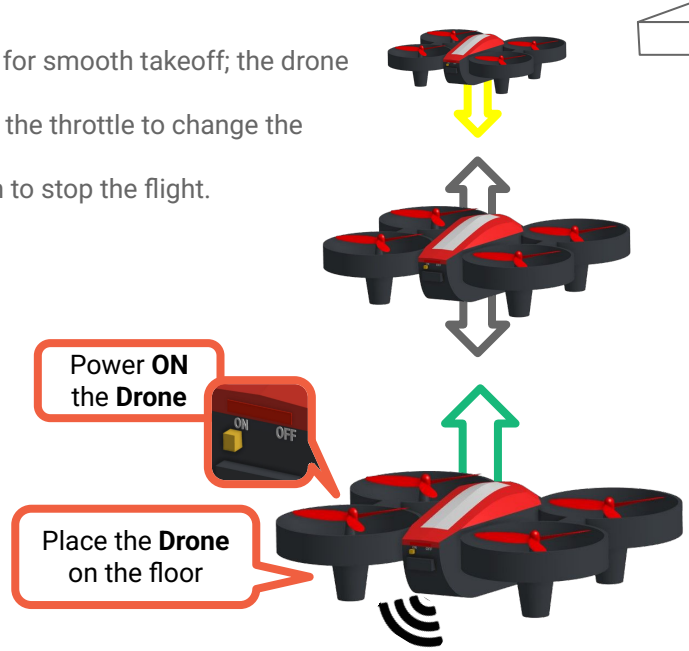
Observe the Throttle and Atl values during flight

# Altitude Control Test Flight

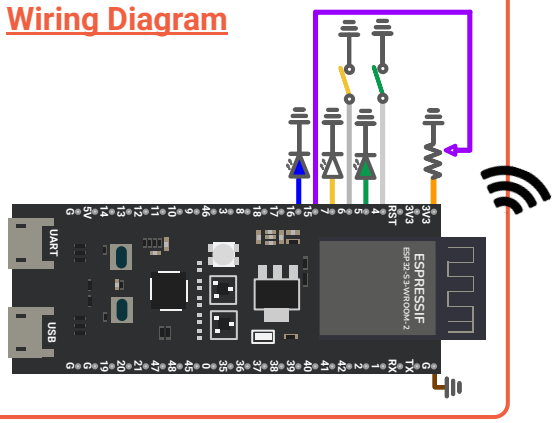
**SAFETY GLASSES REQUIRED**

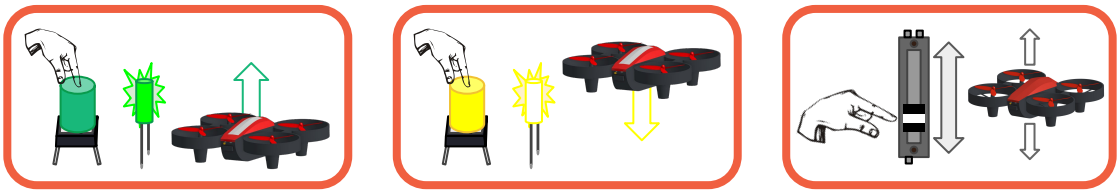
### *Flight Sequence*

Press the green button for smooth takeoff; the drone will ascend.
Use the slider to adjust the throttle to change the drone's altitude.
Press the yellow button to stop the flight.




## Wiring Diagram

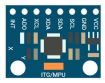


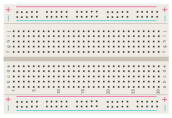



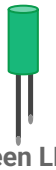
**Not connecting...**
Power cycle the drone by turning it OFF and ON

# Pilot Controller Assembly

## Parts we need

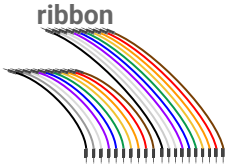

GY-521


Small Breadboard


Green LED


White LED

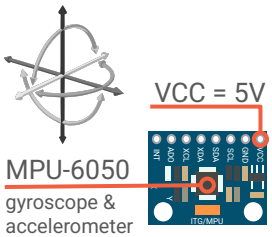

Yellow Button



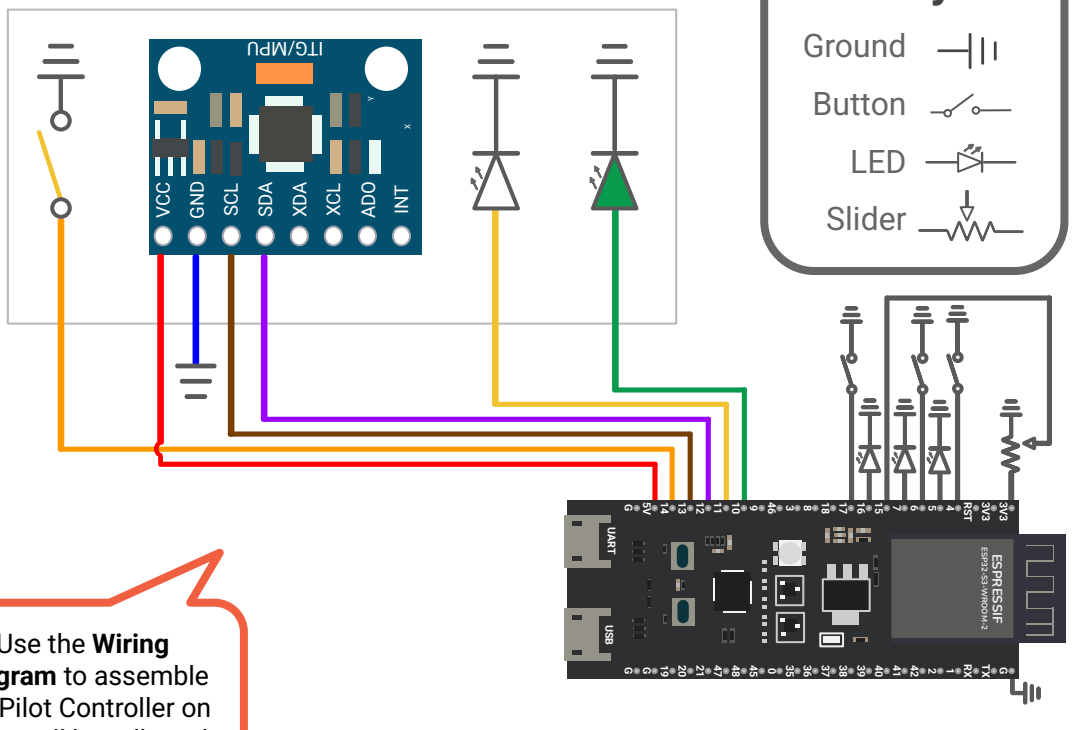
Wire

## GY-521 Module

- Printed Circuit Board (PCB) with an MPU-6050 sensor
- Combines 3-axis gyroscope and accelerometer, measuring angular rates and linear accelerations
- Digital Motion Processor - DMP reduces main processor load
- Used in gaming, virtual reality, and robotics for motion tracking.




### Wiring Diagram

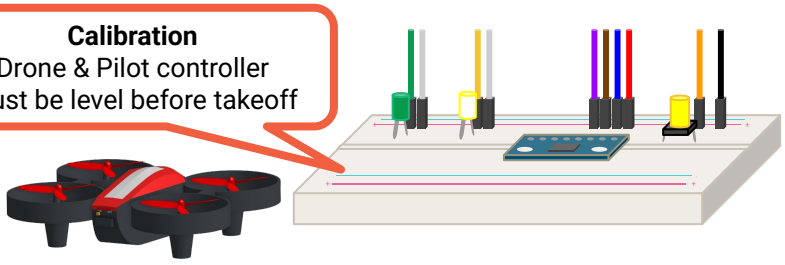



Use the **Wiring Diagram** to assemble the Pilot Controller on the small breadboard

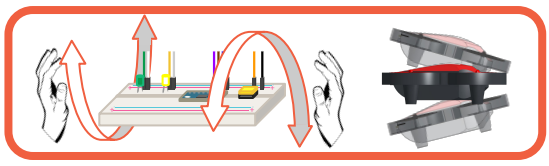
# Pilot Controller

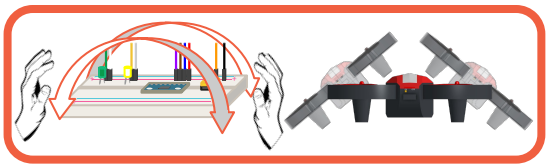
**SAFETY GLASSES REQUIRED**

**Calibration**
Drone & Pilot controller must be level before takeoff



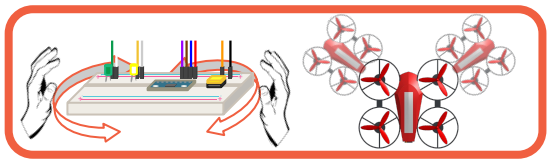
**Pitch**
Tilting up/down moves the drone forward/backward



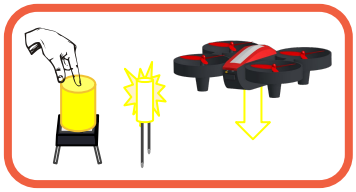


**Roll**
Tilting left/right moves the drone left/right

**Yaw**
Turning left/right changes the drone's direction

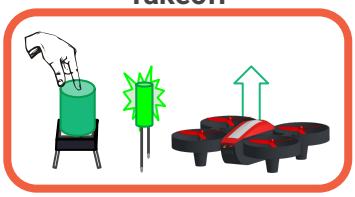


**STOP**
Immediately ends the flight

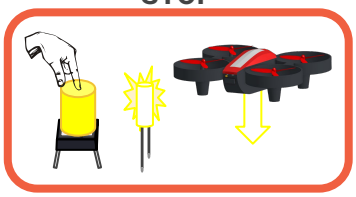


## Ground Controller

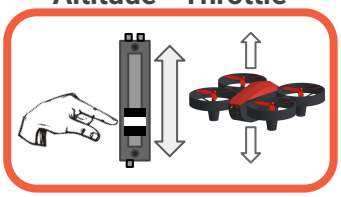
**Takeoff**



**STOP**

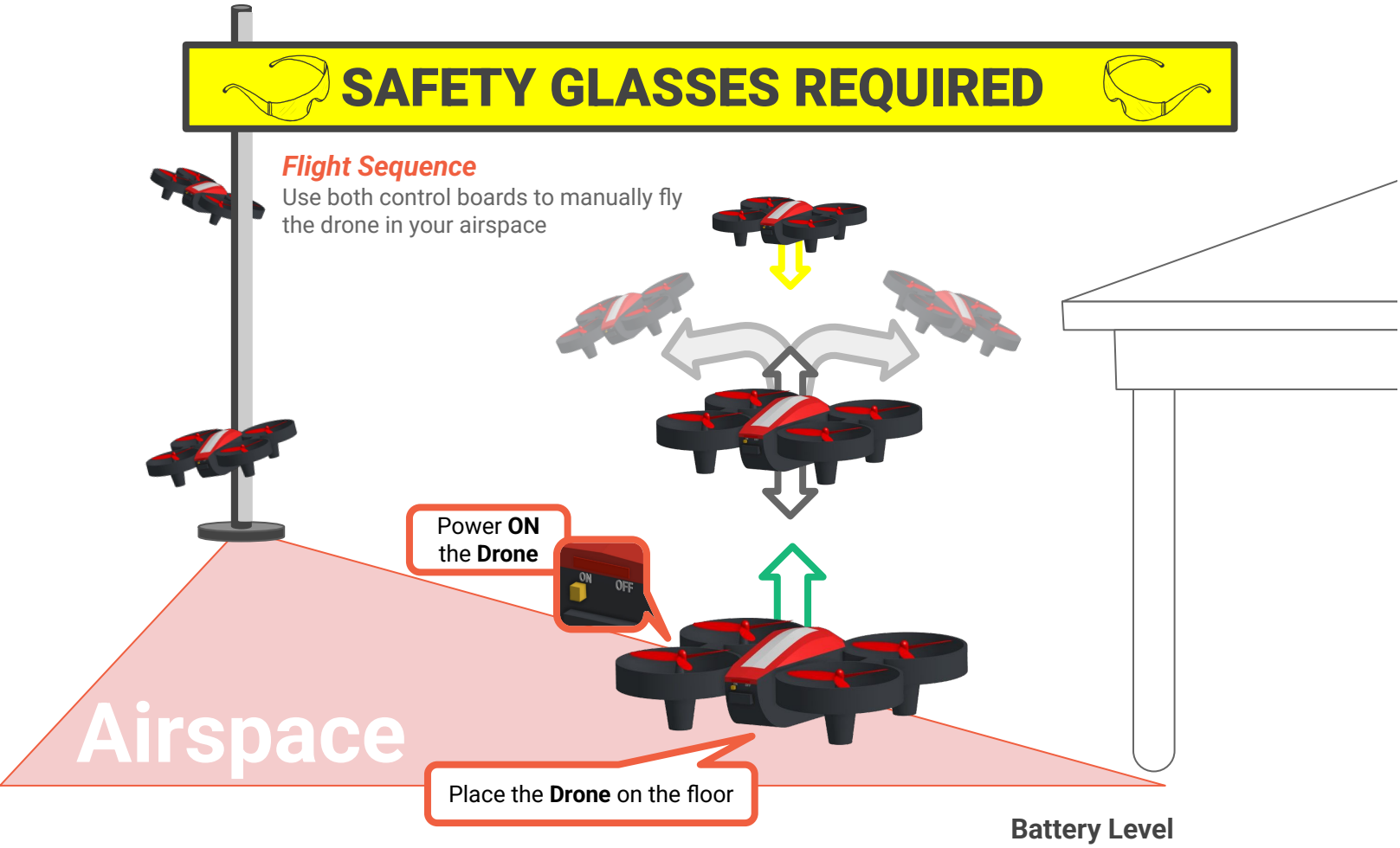


**Altitude - Throttle**



**Teamwork**
Both partners must collaborate for a controlled flight. One person operates the ground controller while the other operates the pilot controller.

# Manual Control Flight




**Battery Level**
Recharge your battery after a few minutes of flight time.

## Challenge

Put your flying skills to the test by controlling your teams drone to fly from your table, fly out a predetermined distance and return to the table.

Serial Monitor

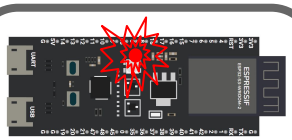
Autoscroll

Clear

```
Green button pressed
Green/Take-Off Button Pressed
Pitch | Roll | Yaw | Throttle | Alt (m)
---------------------------------------
   50 |   50 |  50 |       19 |    0.00
Pitch | Roll | Yaw | Throttle | Alt (m)
---------------------------------------
   34 |   50 |  50 |       70 |    0.48
Pitch | Roll | Yaw | Throttle | Alt (m)
---------------------------------------
   60 |   14 |  50 |       81 |    1.00
Pitch | Roll | Yaw | Throttle | Alt (m)
---------------------------------------
   23 |  100 |  50 |       81 |    0.28
Pitch | Roll | Yaw | Throttle | Alt (m)
```

Observe the values change as you control the drone

We will uses these values to program autonomous flight

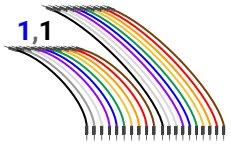


**WiFi Not Connected**
Power cycle the drone by turning it OFF and ON

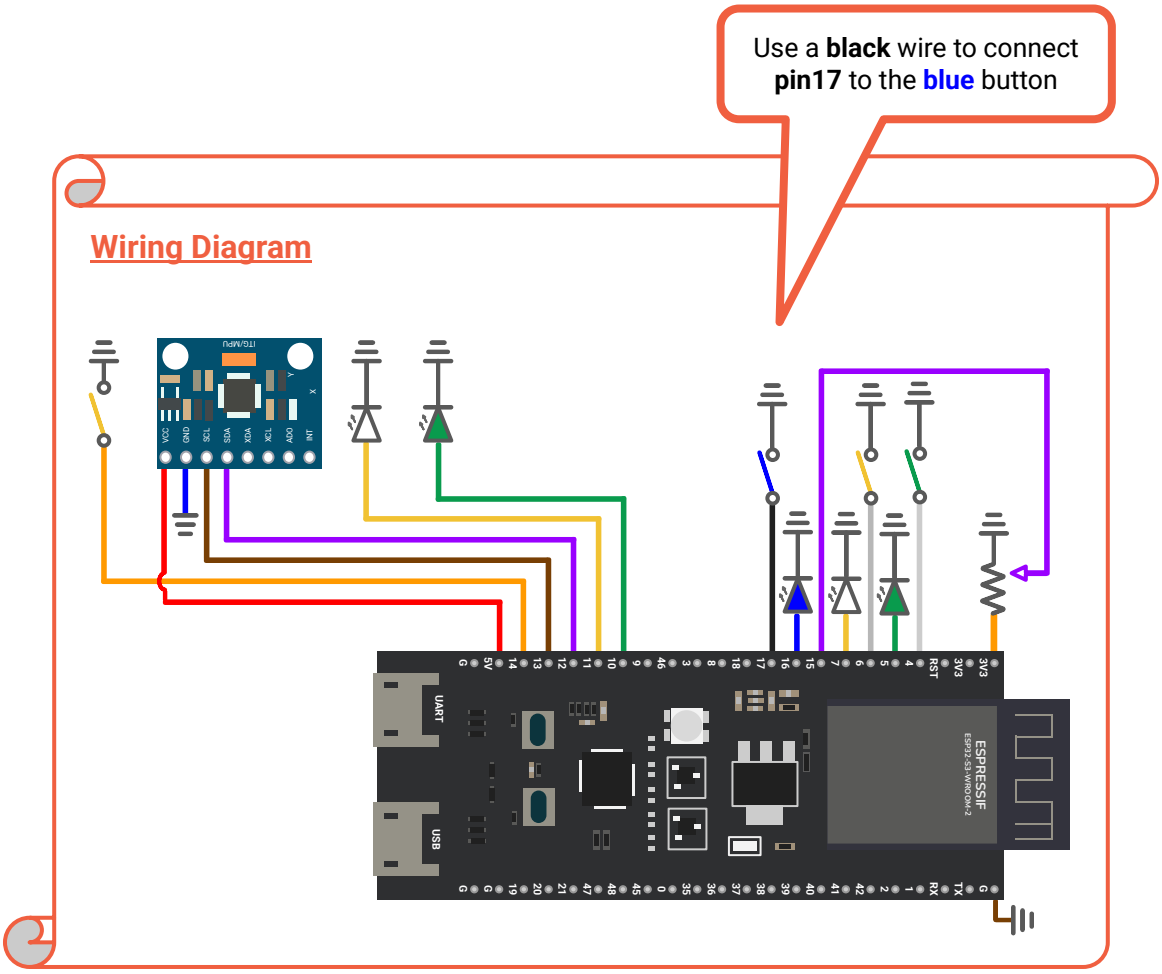
# Autonomous Button Assembly

## Parts we need

Blue Button




Wire



# Activate Autonomous Control

**Robotics Workshop** | Drone IDE

Advanced Mode | Instructions | USB/UART Drivers | Firmware | Feedback | Tools

Connected | Upload

```
1
2 const char* quadcopter_id = "Drone";
3 const bool yellow_button_connected = true;
4 const bool slide_connected = true;
5 const bool blue_button_connected = true;
```

**Change line 5 to true**
This will activate the autonomous button pins

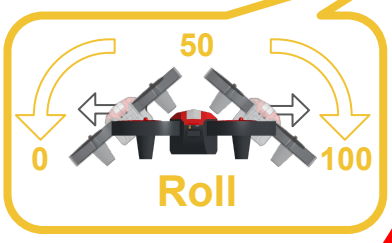
Upload

**Upload the code**

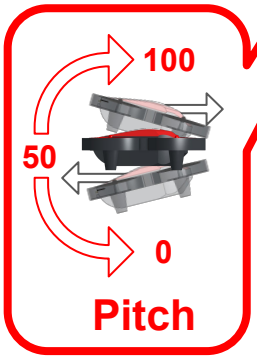
## Autonomous Flight

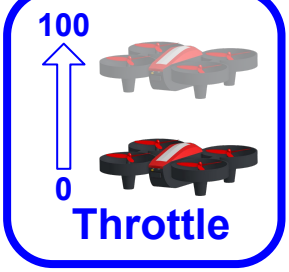
A hold command keeps the drone steady in one position for a set time. This can be a simple hover or a cool descending spiral. We'll use hold commands to create an autonomous flight, combining them to develop a complex flight pattern.

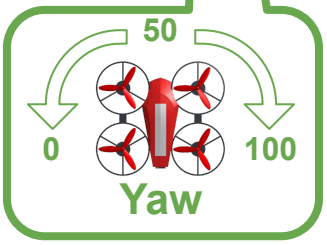
holdCommand(Roll, Pitch, Throttle, Yaw, Time(ms), Color);



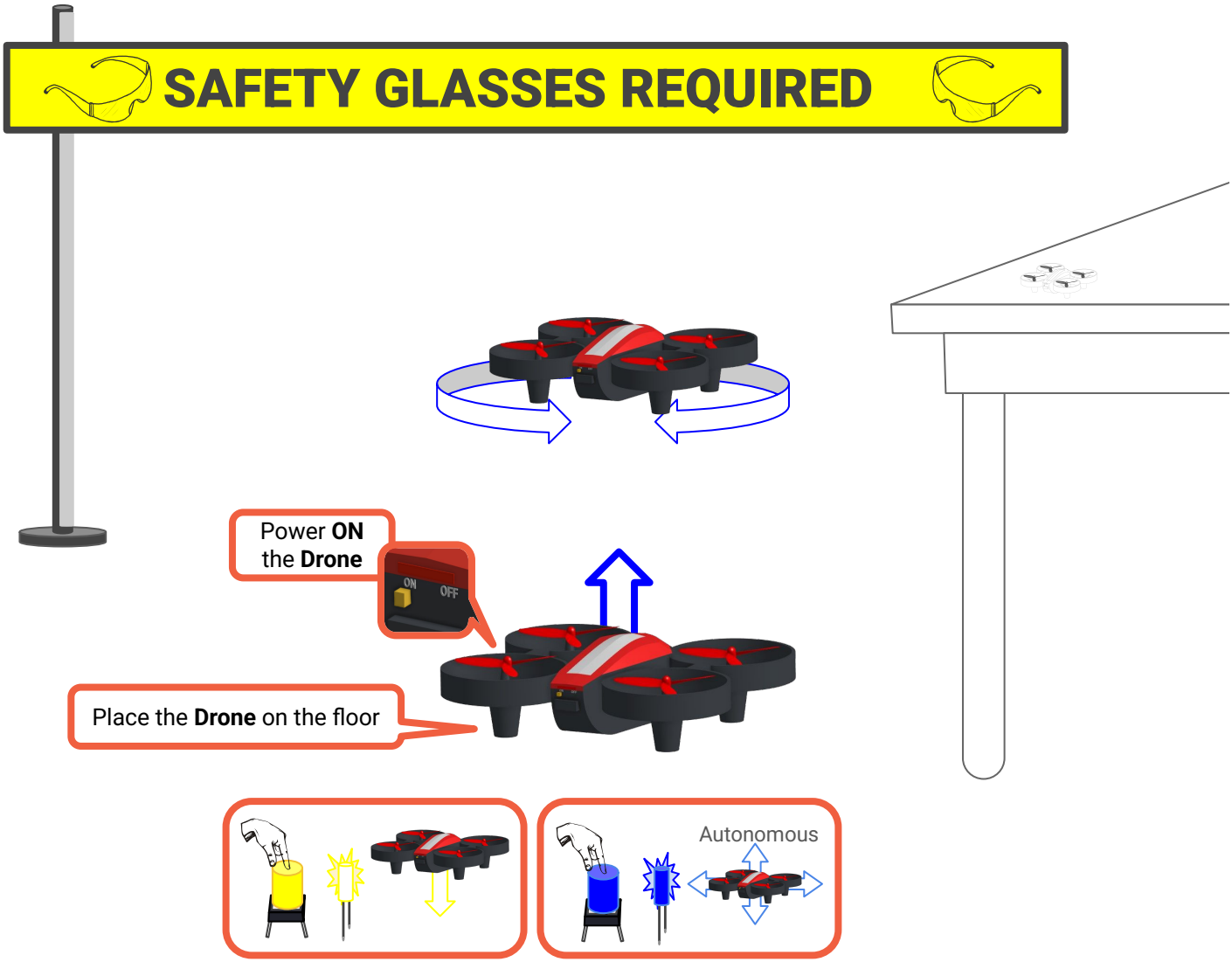

Time command is in milliseconds
1 second = 1000 milliseconds




# Autonomous Control Flight

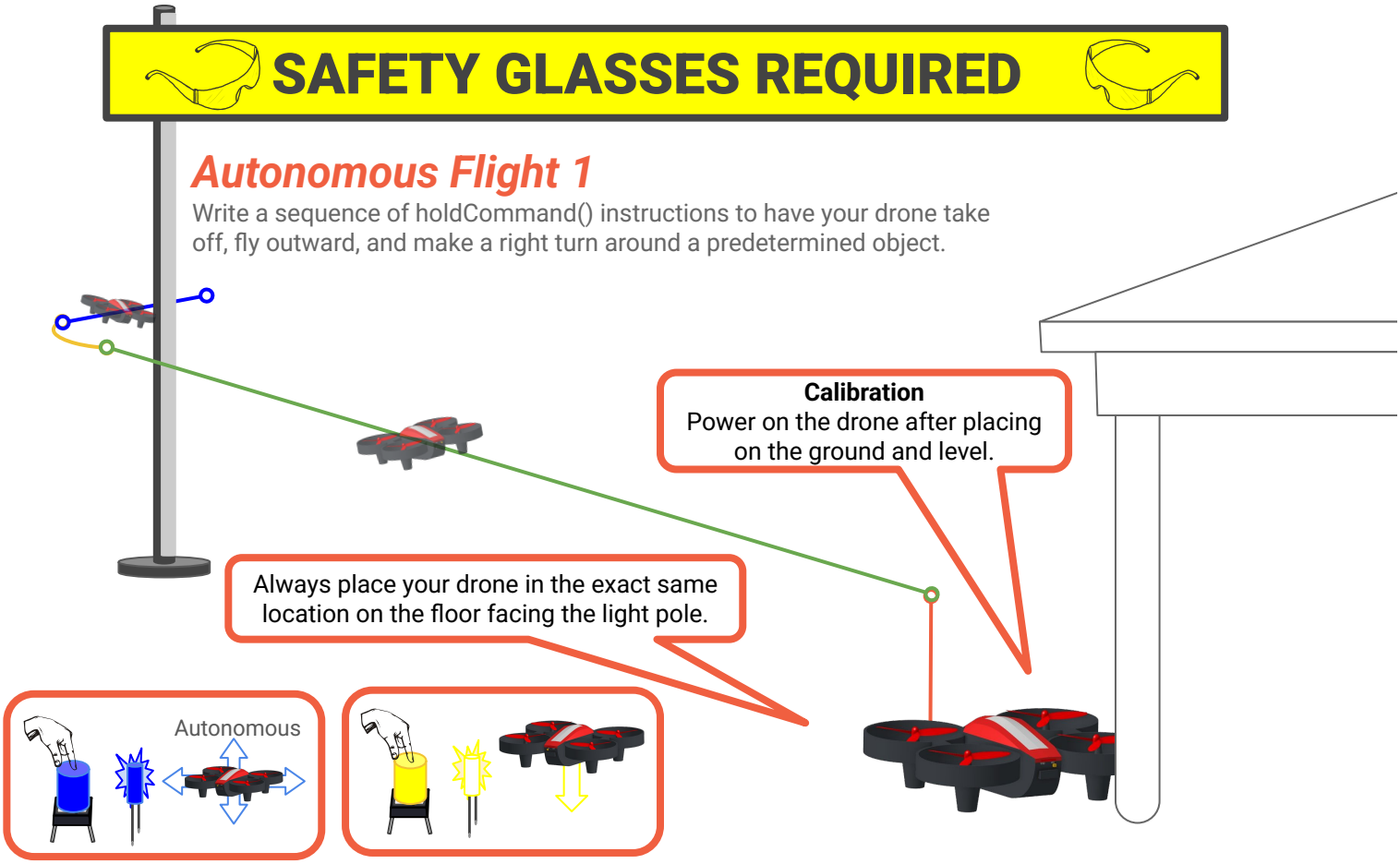



**Autonomous Flight Commands** Upload

```
1
2  // holdCommand(Roll, Pitch, Throttle, Yaw, Time(ms), Color);
3  //
4  // all values (except time) are in range 0 to 100, higher is right/forward/faster
5  //
6  // Colors are:
7  //   white, red, green, blue, yellow, orange, purple
8  //
9  holdCommand(50, 50, 55, 50, 500, 'blue');
10 holdCommand(50, 50, 55, 100, 750, 'purple');
11 holdCommand(50, 50, 55, 0, 750, 'orange');
```

The left and right yaw is due to the change in the 4th value of each holdCommand

# Autonomous Flight 1




## Tuning

- Begin with small adjustments, focusing on the first one or two hold command lines.
- Upload and test each change, expecting to crash many times before achieving a successful flight.
- Embrace the engineering process, which involves learning from each attempt, including inevitable crashes.

**Autonomous Flight Commands**

Upload

**Upload**
After every code change

```
// holdCommand(Roll, Pitch, Throttle, Yaw, Time(ms), Color);
 9 holdCommand(50, 50, 55, 50, 500, 'blue');
10 holdCommand(50, ??, 55, 50, 750, 'purple');
11 holdCommand(50, ??, 55, ??, 750, 'orange');
12 holdCommand(50, ??, 55, 50, 750, 'Red');
```

Line 9: Takeoff

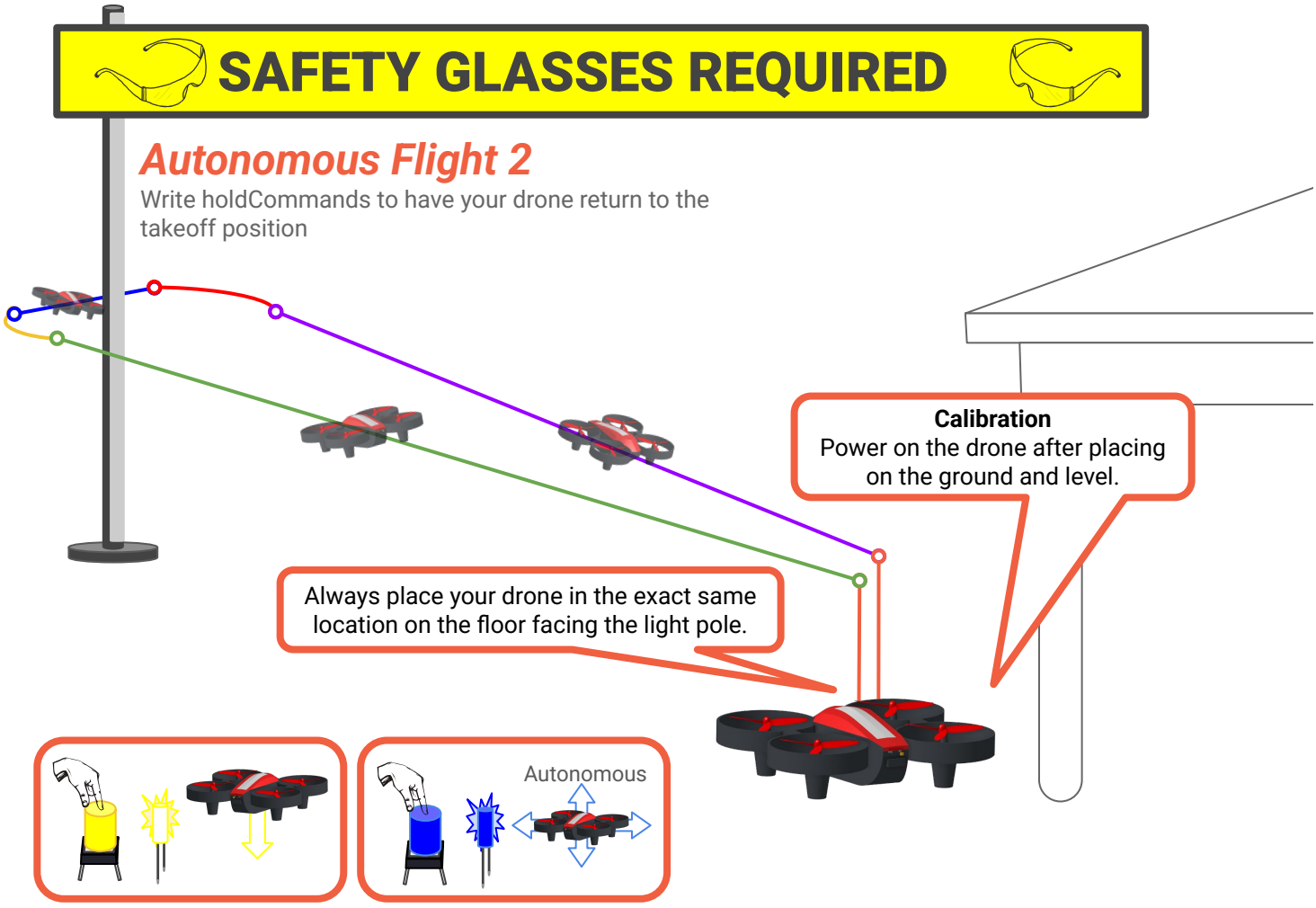
Line 10: Forward

Line 11: Right Turn

Line 12: Forward

**Battery Level**
Recharge your battery to ensure consistent autonomous flights

# Autonomous Flight 2




**Autonomous Flight Commands** Upload

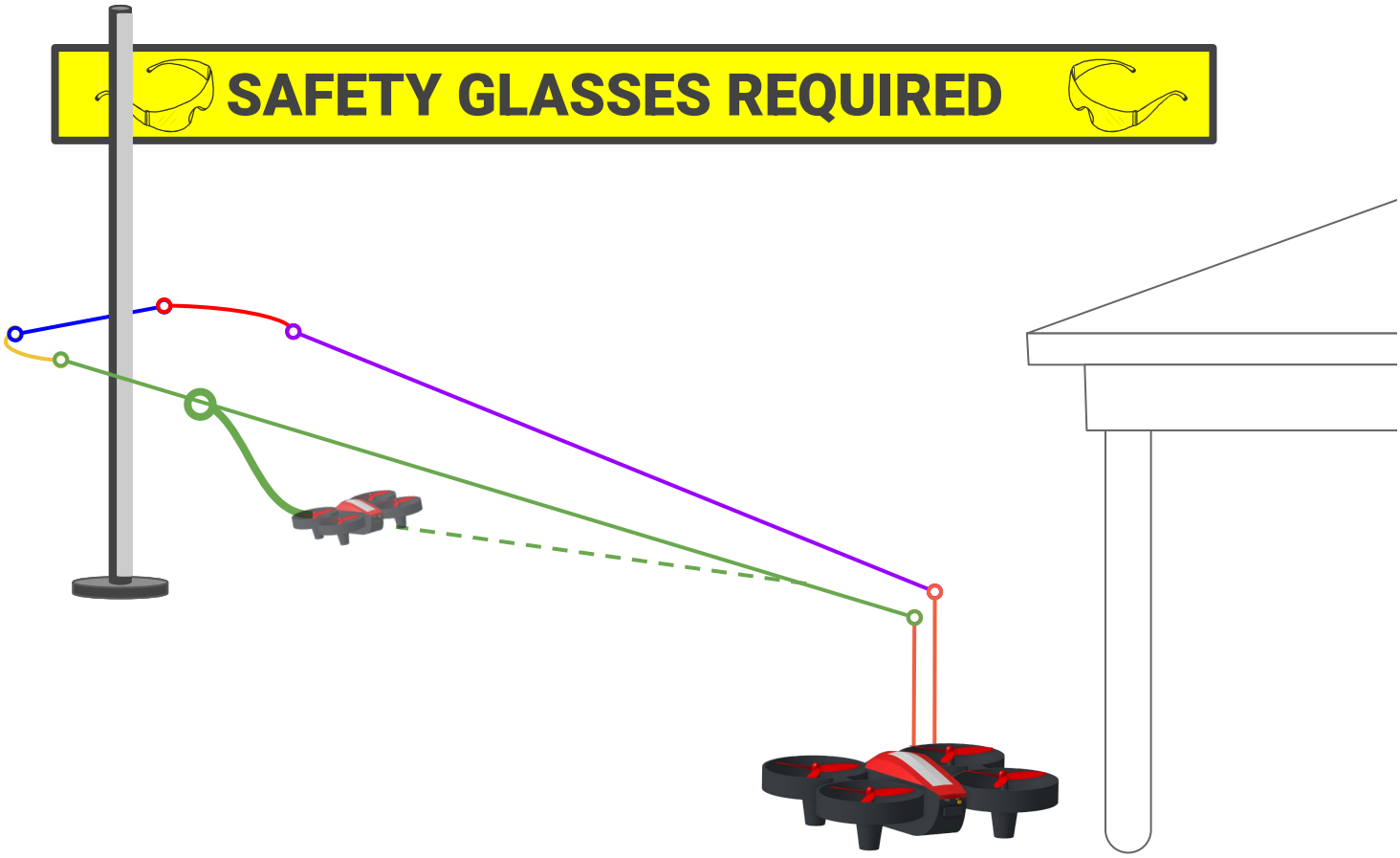
```
// holdCommand(Roll, Pitch, Throttle, Yaw, Time(ms), Color);
```

Modify the values to successfully complete the autonomous flight in your airspace

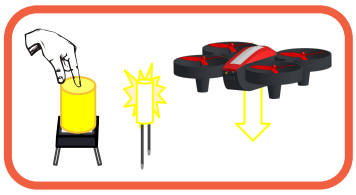
**Upload**
After every code change

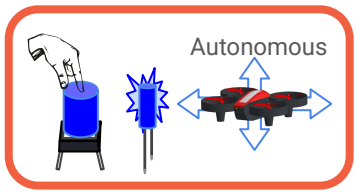
Upload

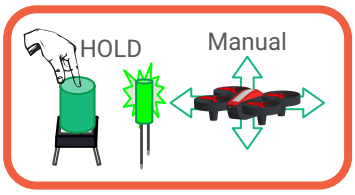
# Pilot Override



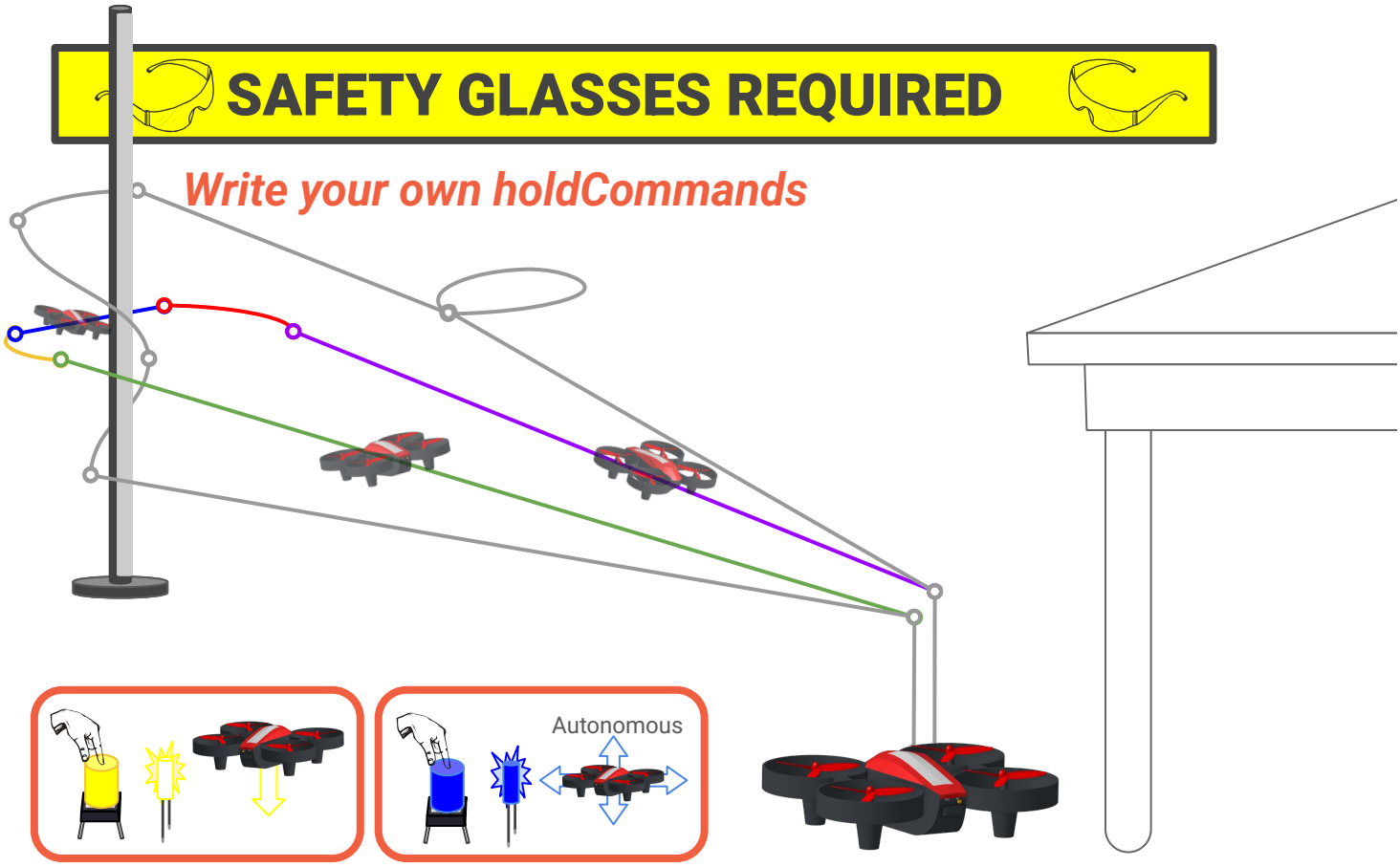

**Pause and Override Autonomous Flight**
Hold down the green button to pause and override the autonomous flight.
Release the green button to resume the autonomous flight.
Be prepared to operate both the pilot and ground controller.





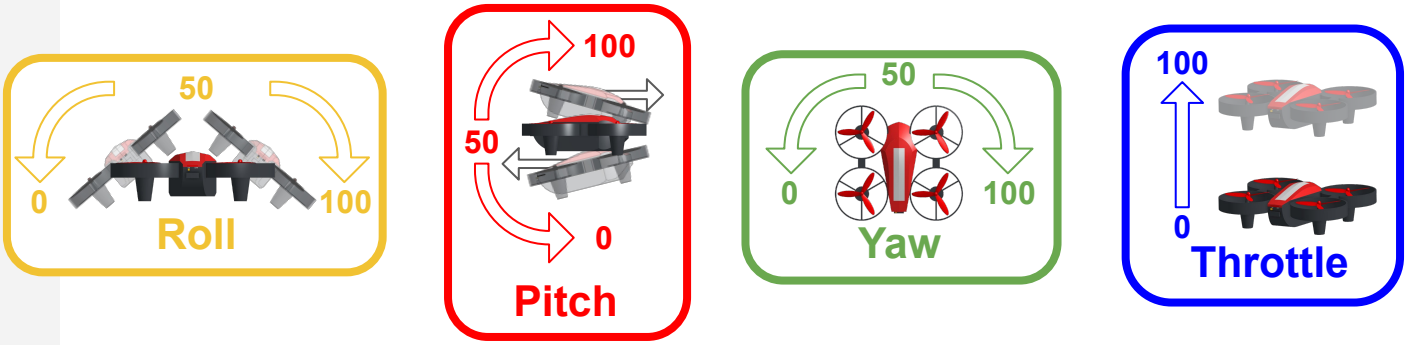
# Custom Mission




**Build your own flight**
You can add and modify your existing hold commands.

Autonomous Flight Commands Upload

holdCommand(Roll, Pitch, Throttle, Yaw, Time, Color);




**Color**

'Red' 'Green' 'Orange' 'Blue' 'Yellow' 'White' 'Purple'

Team Challenge

# Final Approach

**SAFETY GLASSES REQUIRED**


**Program your drone to take off from your group's starting point and land precisely on the designated landing zone.**

- Always launch from the exact same spot, facing the same direction.
- Keep batteries topped-up. Low voltage changes how your drone responds
- Perform many short test flights, making only small adjustments to your hold-commands
- Record settings that work; build up to the full route step-by-step.



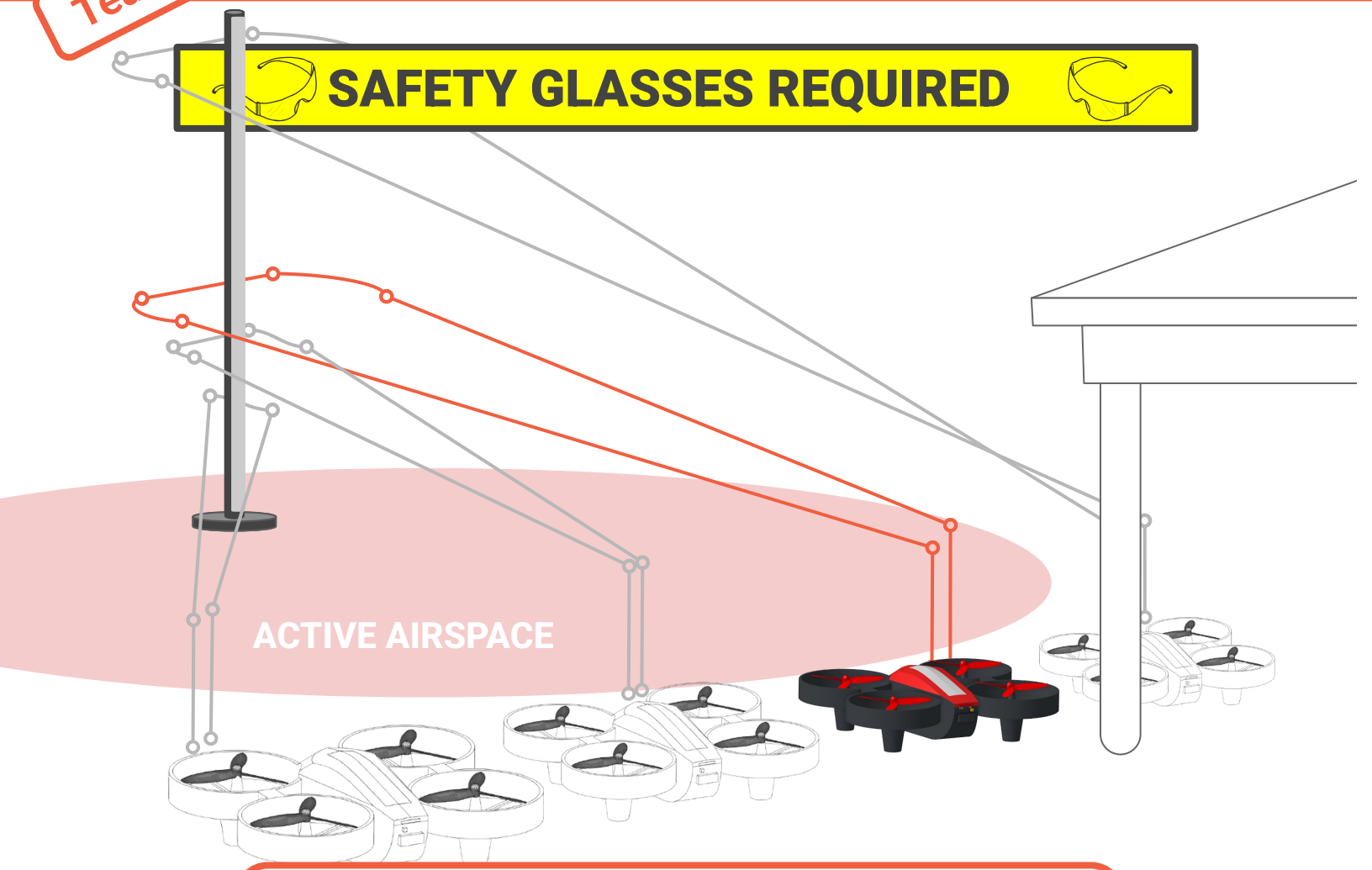




`holdCommand(Roll, Pitch, Throttle, Yaw , Time, Color);`

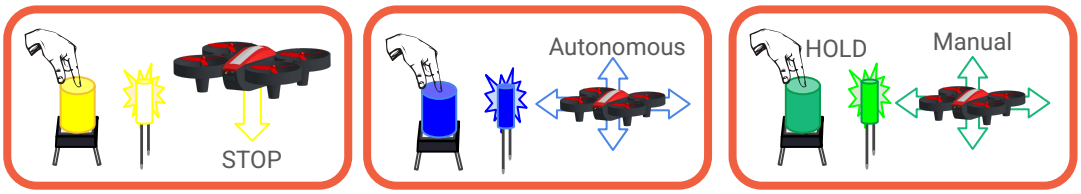
Team Challenge

# Grand Prix




**Program your drone to complete the Out-and-Back course**

- Hold down the green button to pause and override the autonomous flight.
- Release the green button to resume the autonomous flight.
- Be prepared to operate both the pilot and ground controller.




holdCommand(Roll, Pitch, Throttle, Yaw , Time, Color);

# Checklist

## 1 SHUTDOWN

Autonomous Flight Control ……COMPLETE

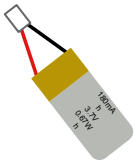
SAFETY GLASSES……..OFF

## 2 COMPUTER

Applications……..CLOSE ALL

Laptop Power……OFF

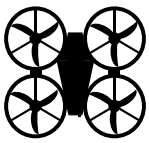
## 3 DRONE



Battery from Drone…….REMOVE

Return Batteries to Instructor….YES

## 4 PARTS



Return All Parts……..NEXT PAGE

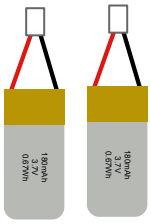
# Parts Cleanup

## On your desk

Laptop


Instructions

Safety Glasses

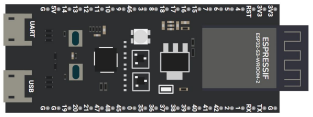


Drone Batteries

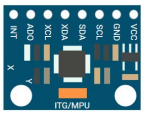
Electronics Box

**Check that all your parts are returned to the Electronic Box**

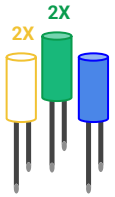
Drone



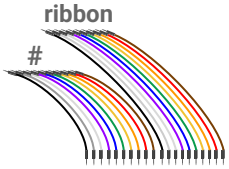
ESP32 Development Board



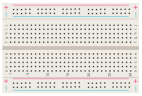
GY-521 Accelerometer



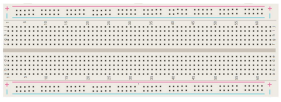

LED's



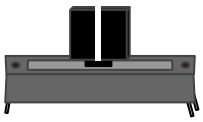

Wires



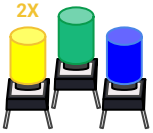
Small Breadboard



Large Breadboard



Slider Variable Resistors




Buttons

Drone Battery Charging Cable

USB to Micro USB

# Feedback Survey

YOU JUST COMPLETED THE

# Robotics Workshop

Workshop Feedback Survey

**feedback.stageoneeducation.com**

## Thank you for your participation