Team MAEhem

Nicholas Federizo-Jimenez
Josh Silberstein
Sovannrat Hul
Gokul Varma
Lilia Guerra

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Executive Summary

Team MAEhem learned new technical skills in manufacturing such as 3D printing and laser cutting. Building off of the Introduction to Engineering I, team members developed engineering skills such as computer-aided design, fabrication basics, and soldering. In terms of interpersonal skills, each member gained confidence in speaking to a large crowd, time management, and financing. Lastly, Team MAEhem learned the business paradigm of engineering such as pitching ideas to companies in order to receive funding, gain endorsement, and land partnerships.

Team MAEhem designed a functioning quadcopter with added color recognition and distance recognition. Compared to other designs, MAErolite emphasizes three pillars: stability, durability, and modularity. These three were chosen to make the design process and code simple and minimize the inevitable risks during flight. Maximizing all three of these pillars not only make our quadcopter competitive in today's consumer market and jumpstart the Team MAEhem company.

With the structural design and code complete, Team MAEhem is proud to present its quadcopter called MAErolite. Although time conflicts among issues with fabrication, Team MAEhem collectively motivated the success of one another to overcome these harboring walls. Ultimately, the team handled the adversity and gained new scopes of innovation and creativity when given a problem. With all of the issues in mind, team dynamic proved to achieve Team MAEhem's success.

Problem Definition

Introduction

Team MAEhem's objective is to create a functioning quadcopter that releases a payload through a servomechanism when both the SainSmart HC-SR04 Ranging Mod Distance Sensor (Ultrasonic) reads a certain distance and Pixy2 Camera reads either red or blue color signature. This servomechanism is manifested by an Arduino Uno R3 Microcontroller that establishes the communication between the Pixy2 Camera and Ultrasonic electronic devices. With these in mind, Team MAEhem intends to achieve these specifications in under 30 seconds during the Final Competition of Introduction to Engineering II.

Technical Review

Drones otherwise known as unmanned aerial vehicles prototypes date back to the beginning of the 20th century. For instance, the U.S. in 1918 already had their first UAV called "Kettering Bug" that acted as a projectile bomb (Desjardins). The American military has often pushed drones towards further development for its lower risk of manpower. Through this technological advancements, drones have become more reliable, cheaper, and marketable. The drones have now entered today's commercial market and have given rise to new possibilities in videography and photography.

Although drones have increased mankind's capability, they have also inhibited certain areas. Federal and state regulations are necessary to keep both others safe as well as not obstruct foundations. State legislation began to frequent in 2013 following the proliferation of the quadcopter. Just in 2017, 38 states "considered legislation" while 18 states successfully "passed 24 pieces of legislation" on UAVs (http://www.ncsl.org). Figure 1 develops the reasoning behind why quadcopters need regulations to keep airlines safe. Drones are not just an American legislative issue, but an international one: in the United Kingdom, flying drones must be outside of a "1-kilometer radius from airports or airfield boundaries" (British Broadcasting Corporation). The applications are immense with the new addition of drone technology. Drones enable constructions sights to safely outsource areas of treacherous work. According to Mark C.Tatum and Junshan Liu, drones are able to capture videos and photography of structures. These frames can then be “integrating into building information models” without the previous precautions concerning worker conditions (Tatum).

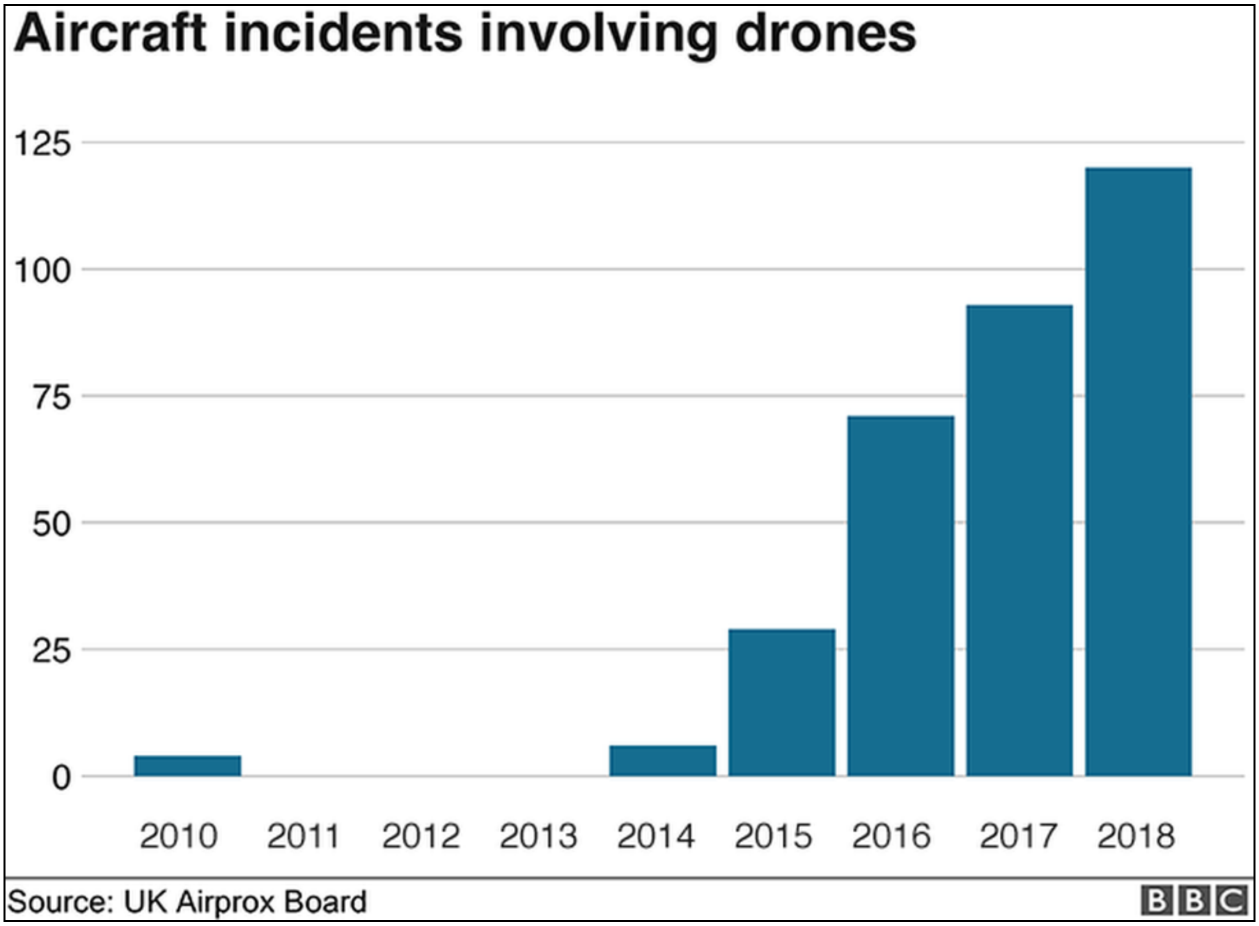


Figure 1: According to the BBC, there has been a substantial increase in issues involving airport incidents due to drones. With the increase in incidents, the federal regulations on drones continue to be administered. Drones and quadcopter alike have multiple application, but further development towards avoiding these type of situations is required.

Design Requirements

Team MAEhem's was given multiple design restraints to the design of MAErolite Quadcopter. The main restriction was the quadcopter's maximum motor-to-motor distance being 14 inches, the quadcopter must be powered through electricity as opposed to internal combustion engines, and each propeller guard must cover 25% of the circumference around its propeller. Furthermore, the design's budget must be within $500 or $550 if 3D printing is used to manufacture.

Design Description

Summary Design

With the goal of a stable quadcopter (Fig. 3) that could easily maneuver through a course, the design incorporated a large frame that would enable for a larger distribution of weight and arms that would allow a motor-to-motor distance of fourteen inches. The landing gear was specifically chosen such that the quadcopter would experience smooth and elastic landings that would not substantially damage the quadcopter. Propeller guards were designed such that they would be able to sustain any damage resulting from horizontal crashes.

Design Details

The frame of the quadcopter consists of two wooden octagonal plates, separated by standoffs; the five and a half inch arms (wood) were attached to the bottom of the top plate, allowing for sufficient space at the top surface for electrical components and storage space in between plates for excess wires.

Regarding the landing gear (Fig. 5), a Z-shape (made of 1/8th inch polycarbonate) was chosen due to its excellent compressibility; partnered with foam squares on the bottom, the landing gear proved to be a well-chosen design due to its elastic landings and, thus, protecting the quadcopter from awkward crashes. Meanwhile, the propeller guards (Fig. 6) were designed as an extruded semicircle with a line of material cutting from the center to the edge.

For the servo mechanism, a simple design was chosen (Fig. 7 and 8); two boxes with dimensions slightly larger than the ball were 3D printed. The boxes consisted of five faces. The servo was then attached to the side of the box, with the servo horn perpendicular to the edge of the box, facing into the plane of the box's open face. Attached to the horn was a long piece of material (with a length equal to that of the box's edge) that would obstruct the ball's fall so long as the servo was in starting position.

In order to maximize space, a sensor tower was 3D printed with sufficient space such that the Arduino microcontroller, PIXY2 camera, and ultrasonic sensor could all be attached. The tower was designed such that the ultrasonic would rest on circular edges on the top, and was just a little over four inches so that the ultrasonic would be out of reach of the propeller's air gusts. The PIXY was also placed on the front of the tower at a height where the rotating propellers wouldn't affect its ability to read signatures. The Arduino was attached to the back side of the tower as this would increase its distance to the sensors and maximize space on the quadcopter.

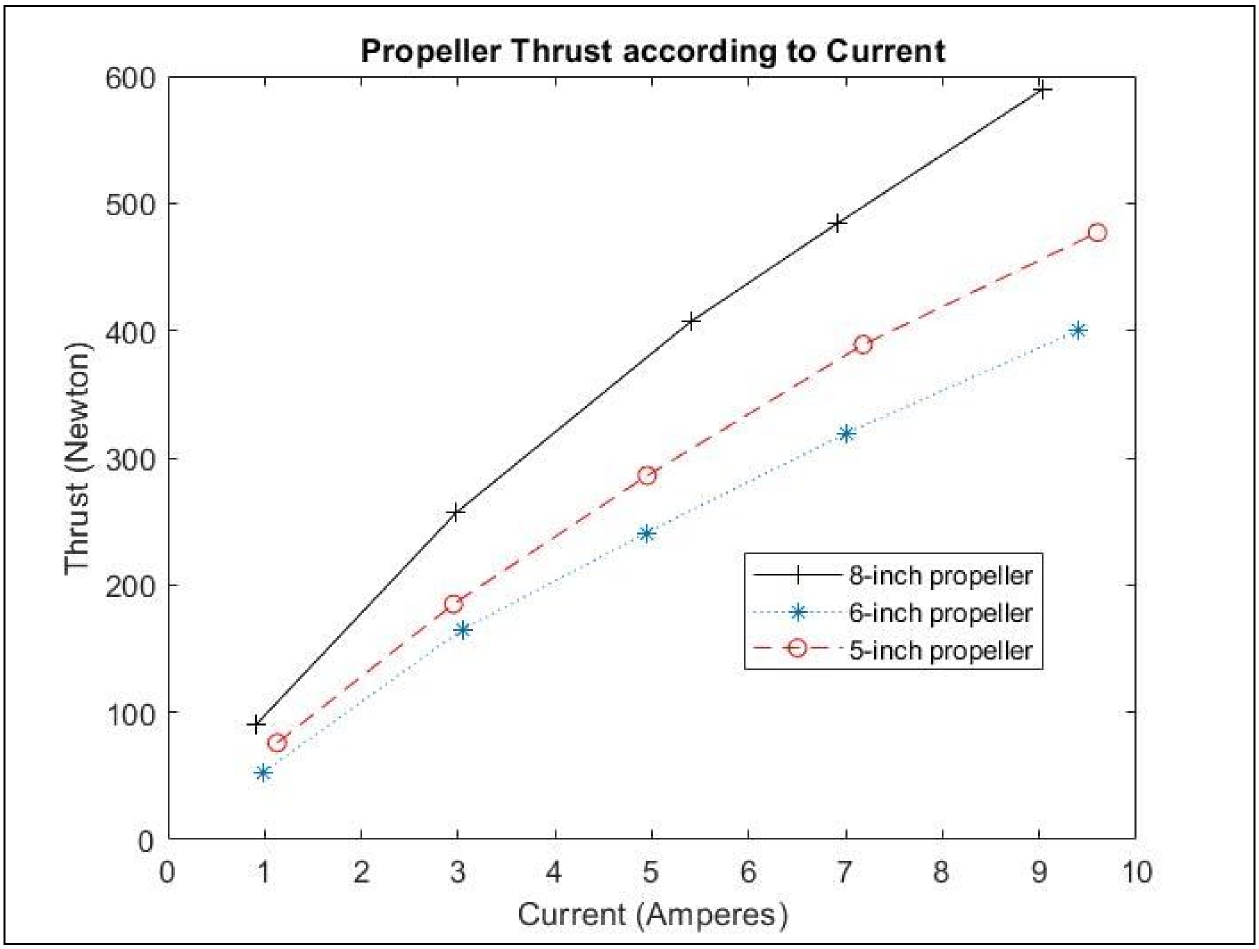


Figure 2: The graph above was sourced empirically October 26, 2018 by the Engineering 7A staff. Team MAEhem chose the widest propeller guards tested in Introduction to Engineer I (ENGR 7A) to accomodate for the increase in weight from the electronics. With the chose, MAErolite had a wide base allowing for optimal flight control.

Wiring Design (*see Fig. 7 in Appendix A)*

In our circuit, the LiPo battery was connected to an octopus cable, which connected ground and voltage to the ESCs, voltage regulator, and Arduino (by soldering bullet connectors). The ESCs were then connected to the respective motors; the ESC connectors on two ESCs were attached to an extension. The red and black cables on the extension were stripped and attached to header pins to connected to the servos to power them; the signal pin stayed intact and was used to connect to the NAZA. Meanwhile, the signal pins on the ultrasonic sensor and servos were connected to Arduino PWM pins, and the PIXY was attached to the ICSP pins on the Arduino. As seen in the diagram, there are connections between NAZA ports and their respective channels on the receiver.

Algorithm Design

For the algorithm for the dropping mechanism, multiple different functions were used for different electrical components; the ultrasonic sensor and PIXY camera both had separate functions to make the program clean and efficient. The algorithm starts with the ultrasonic reading distances by sending a pressure wave and measuring the time interval between when the sensor sends a signal and receives it; the Arduino then computes the distance via a formula. Meanwhile, the PIXY camera reads the signature values that were previously set using the PIXYmon software. Once the readings are received, then the Arduino compares the values to certain constraints that were set: the distance the ultrasonic sensor measures should be between one hundred-twenty and one hundred-fifty centimeters, and the PIXY should recognize a certain color (red or blue). If these constraints are met, then the servo corresponding to the color the PIXY reads will activate, dropping the ball.

Action Item Report

Task Assignment

Before designing and fabricating our quadcopter, our team gave each member an assignment to be in charge of. This way, work would be split up equally and someone would be in charge of the production. Although each member was in charge of an assignment, the team split up the workload so that each member would be able to contribute to the project. It was difficult to work around different schedules since members had jobs or contributed to campus organizations, but the team met regularly on Sundays and in open labs whenever possible.

<u>Week 1</u>: Established Team MAEhem (team name unknown at that time), and decided on team roles and meeting time; learned how to work the Arduino.

<u>Week 2</u>: Came up with the name Team MAEhem; continued to learn how the Arduino works, and started Solidworks designing for quadcopter. The team began making the purchase order form, and discussed the materials that would be necessary to build the quadcopter, and what materials would be preferred.

<u>Week 3</u>: The decision was made on what was going to be 3D printed, laser cut, and what would be manufactured in lab without those techniques. MAEhem continued to work on Solidworks design, and developed the servo mechanism during this time.

<u>Week 4</u>: The Solidworks drawings were finished this week, and the quadcopter manufacturing plan was laid out (what was going to be 3D printed, laser cut, etc.)

<u>Week 5</u>: Preliminary Presentation; prepared for this presentation by practicing and wearing professional clothing! The quadcopter design was also approved.

<u>Week 6</u>: Team MAEhem presented their AIR this week. The team finished 3D printing all the parts that were going to be 3D printed, and also finished manufacturing all the parts on the quadcopter.

<u>Week 7</u>: The quadcopter was completely assembled, and the structure was turned in.

Week 8: The sensor tower was manufactured. The transmitter, motors, and ESCs were all calibrated. There were some issues with the NAZA, however.

Week 9: The NAZA was calibrated after the TAs fixed the problem. The team achieved flight on Monday of this week, and all the parts on the quadcopter were attached; the only things left on the agenda were electrical wiring and editing the Arduino program. In lab, the team worked on fixing the servos to its necessary position.

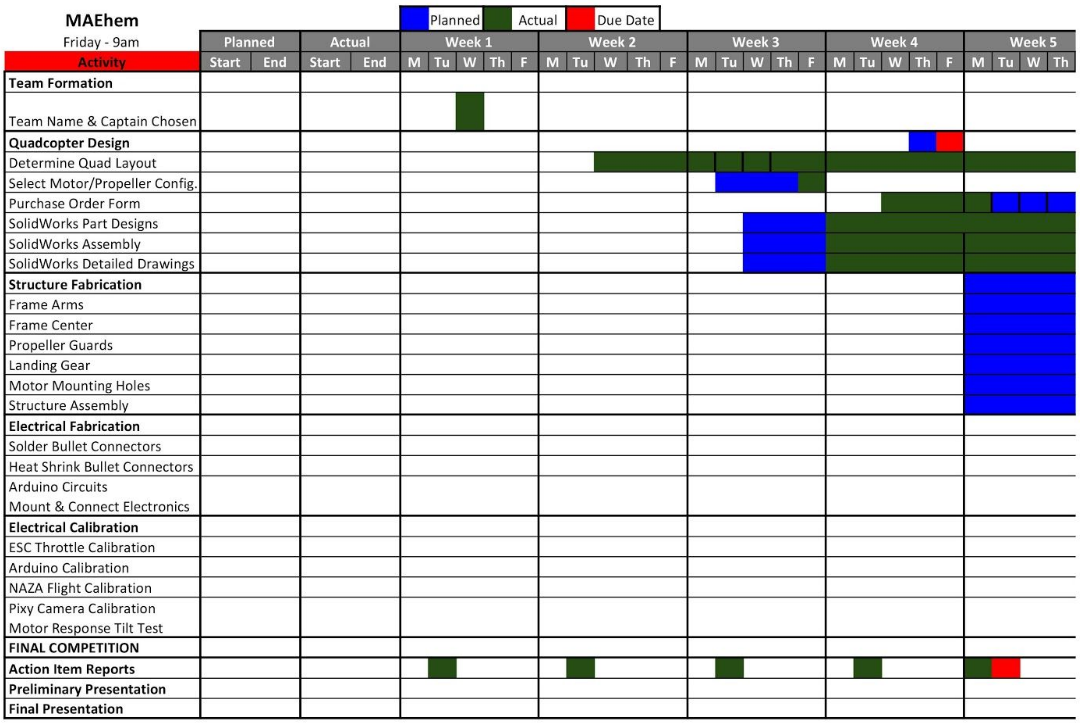
Week 10: Successfully finished the quadcopter by altering the code, connecting Arduino to battery, and flying! The team qualified for the competition after dropping both balls.

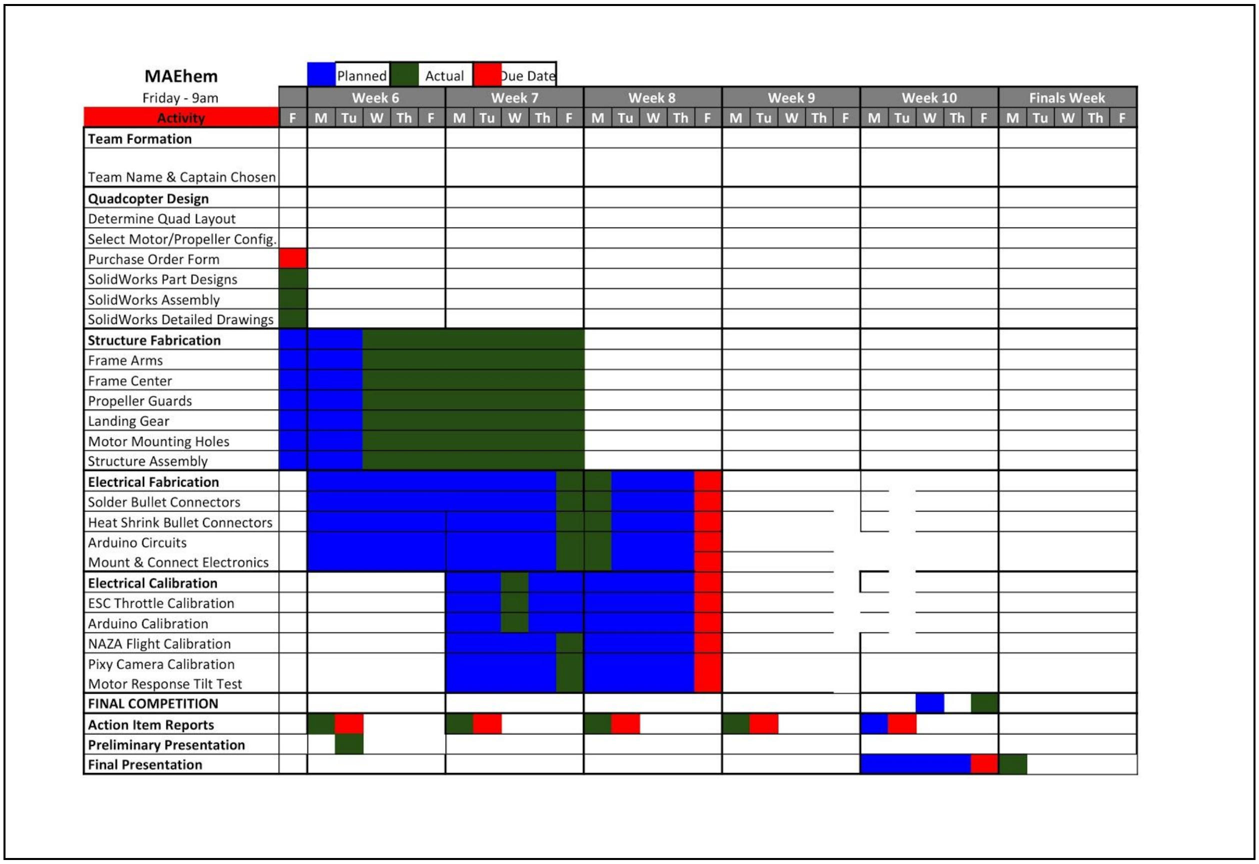
Action Item List

Action Item	Owner	Assigned	Notes
Task #1 Role Designation	Nicholas, Team Captain	01/09/19 - 01/16/19	Lead Manufacturers: ● Josh Silberstein ● Lilia Guerra Lead Design: ● Sovannrat Hul Lead Programmer ● Gokul Varma
Task #2 Solidworks Design	All	01/22/19 - 02/01/19	Arms: ● Nicholas Propeller Guards: ● Gokul Battery Plate: ● Lilia Electronics: ● Josh Landing Gear: ● Sovannrat
Task #3 Purchase Order Form	Josh, Gokul, Sovannrat	02/01/19 - 02/08/19	Includes the price of all raw materials used in the fabrication of our quadcopter and the base

			prices for all of our electronics.
Task #4 Arduino Code Development	Gokul	02/25/19 - 03/15/19	Code developed outside of lab; finished right after fabrication ended
Task #5 Beginning of Fabrication	Josh, Nicholas, Sovannrat, Gokul	02/19/19 - 02/22/19	Prototype Base Plate Landing Gear 4 arms
Task #6 Finished Fabrication	Josh	02/22/19	3D printer to create Arduino Chassis and ball release mechanism
Task #7 Soldering And Wiring	All	02/25/19 - 03/01/19	Soldered wires to header pins for connections from ESC to Servos, battery to Arduino, etc.
Task #8 Electrical Components		03/04/19 - 03/15/19	Calibrating ESC: ● Gokul ● Sovannrat Calibrating NAZA: ● Josh ● Nicholas Arduino, Coding & Wiring: ● Gokul

Gantt Chart


MAEhem
Friday - 9am
Planned
Actual
Due Date
Activity
Planned
Actual
Start
End
Start
End
Week 1
Week 2
Week 3
Week 4
Week 5
M
Tu
W
Th
F
Team Formation
Team Name & Captain Chosen
Quadcopter Design
Determine Quad Layout
Select Motor/Propeller Config.
Purchase Order Form
SolidWorks Part Designs
SolidWorks Assembly
SolidWorks Detailed Drawings
Structure Fabrication
Frame Arms
Frame Center
Propeller Guards
Landing Gear
Motor Mounting Holes
Structure Assembly
Electrical Fabrication
Solder Bullet Connectors
Heat Shrink Bullet Connectors
Arduino Circuits
Mount & Connect Electronics
Electrical Calibration
ESC Throttle Calibration
Arduino Calibration
NAZA Flight Calibration
Pixy Camera Calibration
Motor Response Tilt Test
FINAL COMPETITION
Action Item Reports
Preliminary Presentation
Final Presentation



Evaluation

Calculations

- Arduino - 40 mA per port
- PIXY2- 140 mA
- Servo - 100 mA (2 used)
- Sensor - 15 mA each
- Estimated weight: 1.3 kg or 1300 g
- Thrust per motor = 165g at 6.0 A
- Battery = 3Ah, 20.6 A = estimated total current draw from quadcopter
- **Thrust = (165g*4) * m/s^2 = 660g*m/s^2**
- **Acceleration = (660g*m/s^2)/1300g = 0.51 m/s^2**
- **Predicted hover time = 3Ah / 20.6 A = <u>8.74 min</u>**

Test Plan

In order to test the quadcopter's flight capabilities and sensor measurements, the team decided to first fly the drone without the sensors. The quadcopter would then be fixed (if any problems arose), and then the sensors would all be mounted. Meanwhile, the sensors and servos were being tested to see whether the code should be changed. Once the code was successfully tested, then the quadcopter would be flown with all the parts attached, and the ball-dropping mechanism would be tested in air.

Results and Discussion

The initial flight test had the quadcopter tipping over to one side due to calibration issues; the NAZA was oriented improperly with tape on the bottom, causing it to reorient the quadcopter based on its incorrect orientation. After repositioning the NAZA and recalibrating, the quadcopter flew with grace, leading to the test of the sensors.

Since the code was developed before the sensors and Arduino were wired, the code ran into certain issues right after wiring occurred. The servo motors were not positioning correctly to their starting position; this was resolved by removing the servo horn and repositioning through trial and error until the servo's position correctly related to its value in the code (i.e. 0 represented initial position, 180 represented final position). Later, some issues arose out of the PIXY's recognition of color, which resulted in both servos activating when only one of them should've. This was fixed with a lot of trial and error by resetting the signatures on the PIXY, fixing the ultrasonic readings, and rewriting the PIXY algorithm.

Due to a lack of time, MAEhem was unable to test the quadcopter with all of its parts intact. Thus, the qualifying round was when the quadcopter's abilities were tested. The quadcopter flew magnificently, but the ball-dropping mechanism did not work. During the testing phase afterwards, however, it was discovered that the code worked perfectly and that the sensors were getting the correct readings. Believing this to be an ultrasonic problem, the code was altered to activate the servos at a larger distance. When it came to the last test, the servo mechanism worked for one of the colors, but the other color required the quadcopter to get extremely close to the color. The team believed this to be a problem with the gusts of air from the propellers interfering with the PIXY and ultrasonic sensor, as the code had worked beautifully without flight.

Appendix A: SOLIDWORKS Drawings and Wiring Diagram

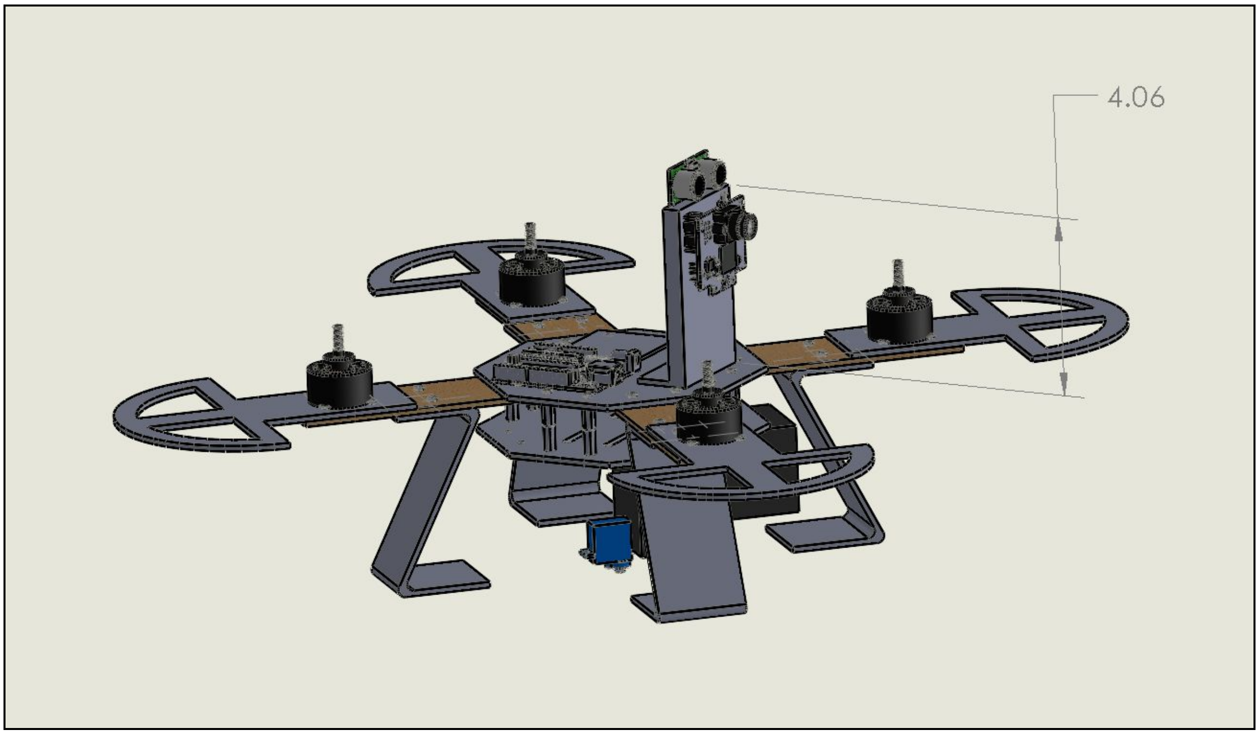


Figure 3: Full-view image of the quadcopter

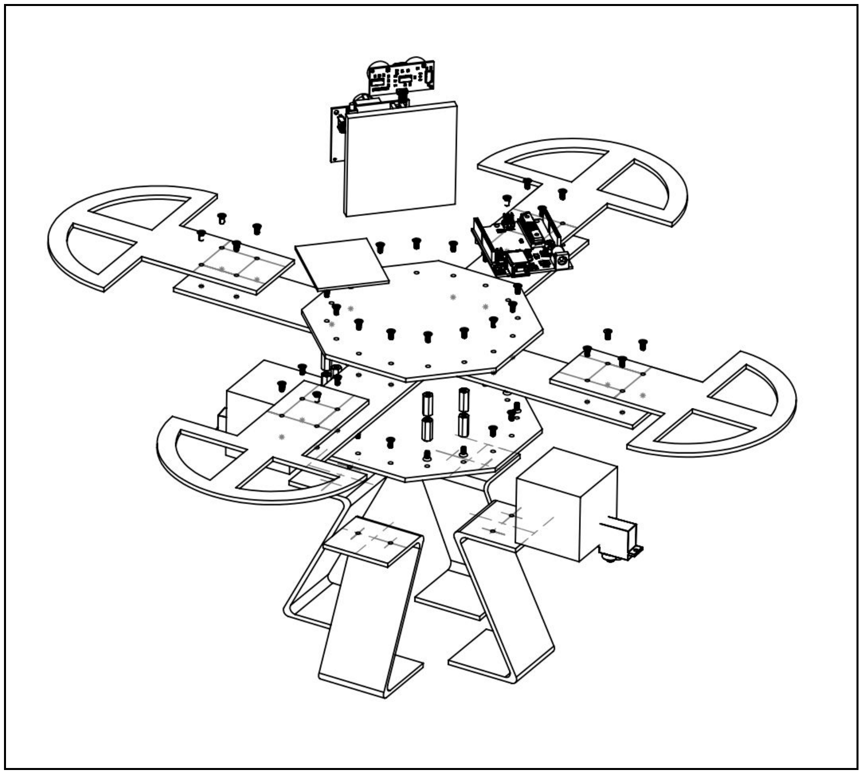


Figure 4: *Isometric Exploded View*

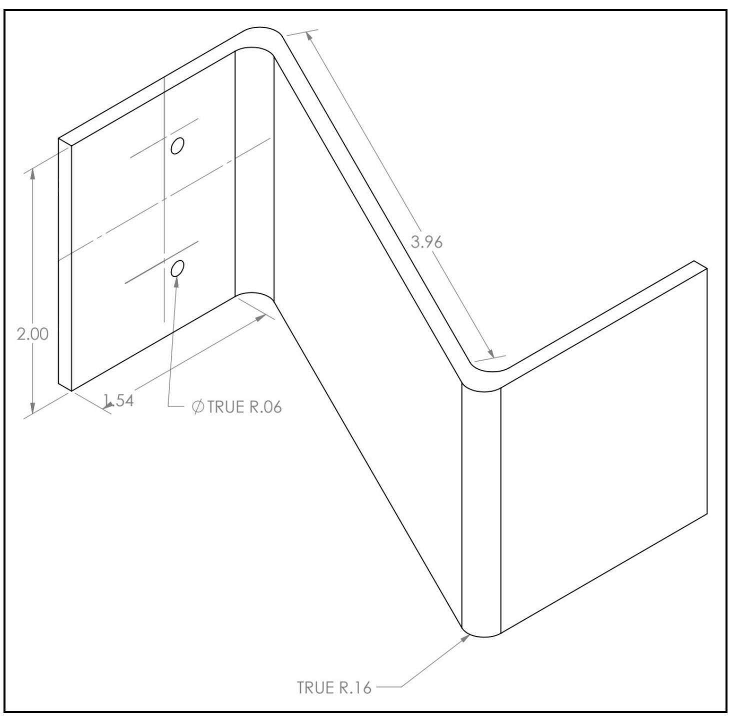


Figure 5: Landing Gear

Figure 6: Propeller Guards

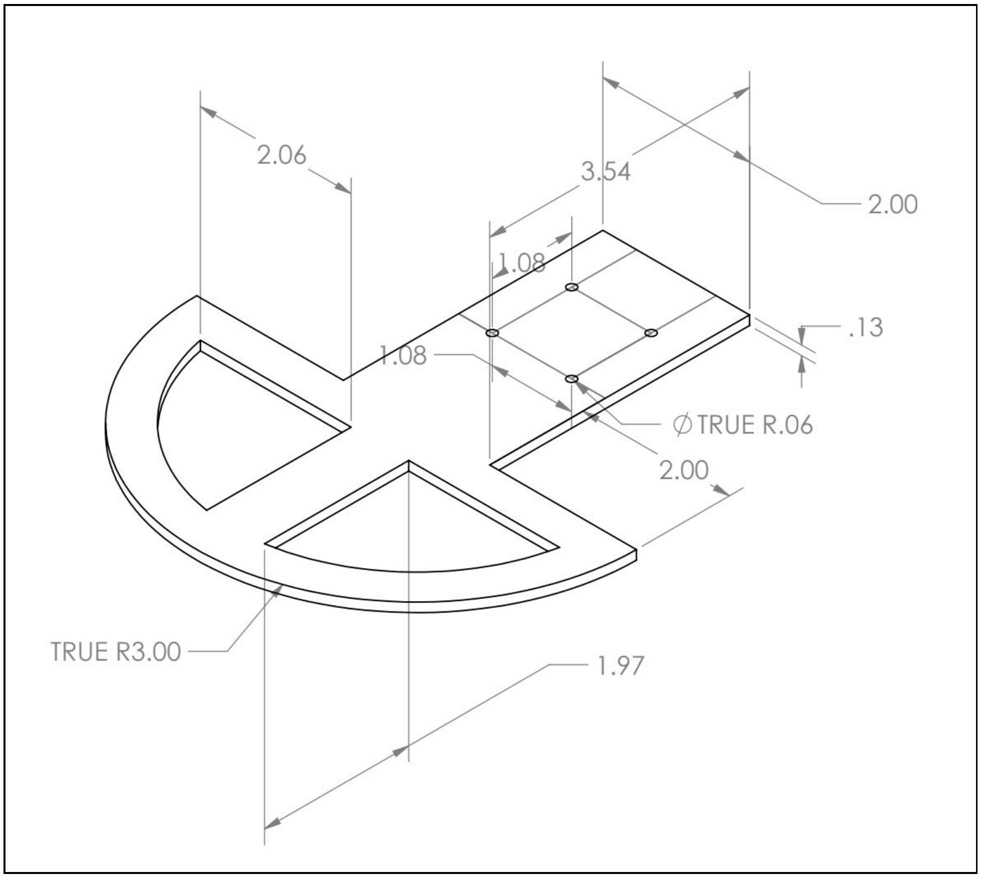


Figure 7: (left) Bottom of Servo Mechanism

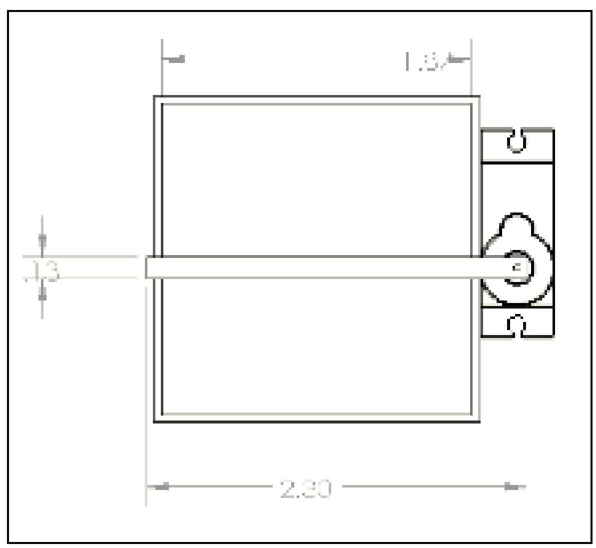
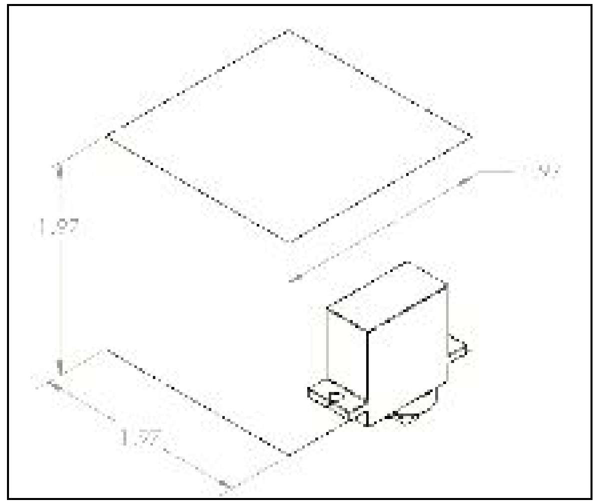


Figure 8: (right) Isometric View of Servo Mechanism



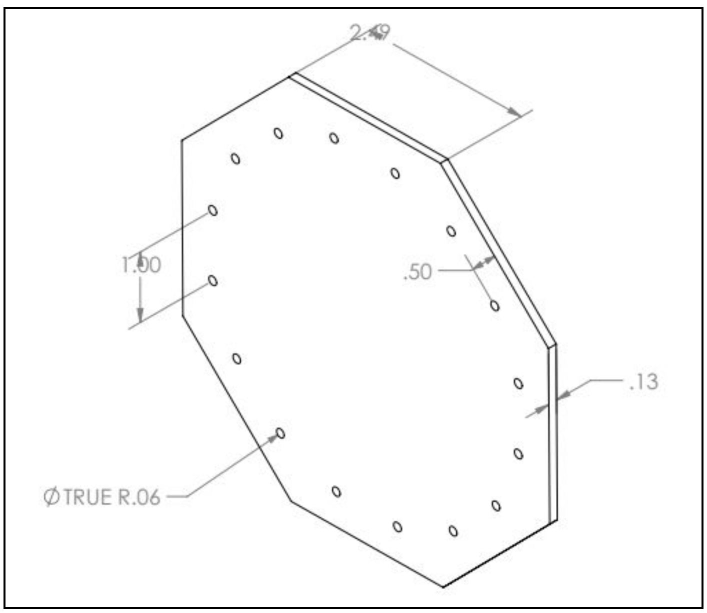


Figure 9: (left) Octagonal Base Plate

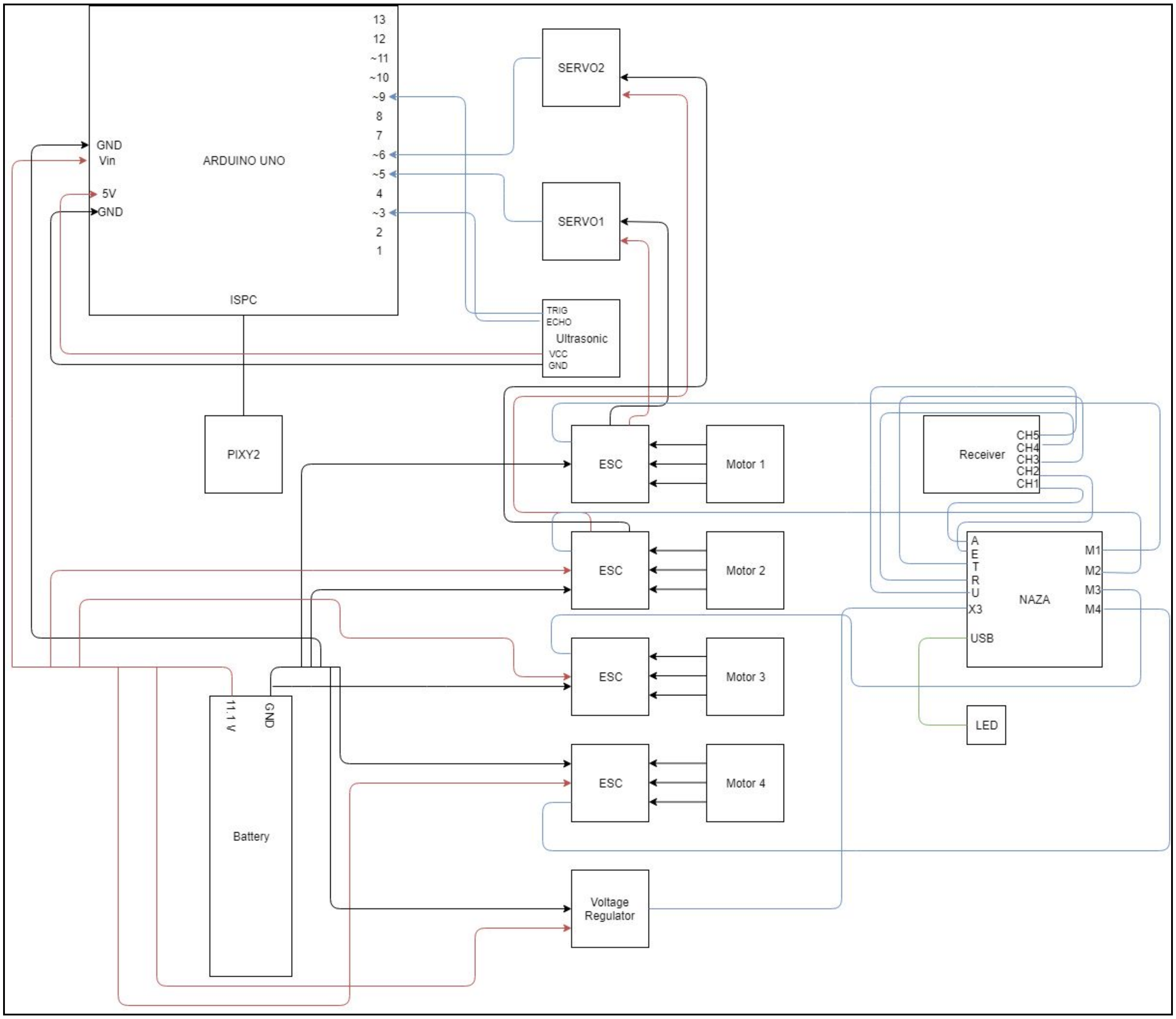


Figure 10: Wiring Diagram

Appendix B: Bill of Materials

Below is the purchase order form for our quadcopter, the total cost was $340.91.

PURCHASE ORDER FORM

The Henry Samueli School of Engineering

Upload your purchase order (PO) for quadcopter parts on Canvas

One PO per team. Parts will be given to you after submitting the PO. The props and motors will be given on a first come first served basis.

Requested By:* Team MAEhem (Team Name) ***Captain:** Nicholas Federizo-Jimenez ***E-Mail:** federizn@uci.edu

Delivery Address:* Engineering Tower (*Building Name (or Abbreviation)) 421 (*Lab Room #) **Date of Request:** 02/03/19

Lab Instructor Name:* Lawrence Kulinsky **Lab Section:*** Wed 2:00 - 3:20

Account Name:* ENGR 7A

Account*	Fund*	Sub	Project	% (If split funding)	Amount	Accounting Review
ENGR 7A	56123	3	7A	100%	$340.91	
				0%	$0.00	

Quantity*	Unit	Company*	Item Description*	Catalog #*	Unit Price*	Estimated Extended Price*
2		Gem Fan Hobby	8" x 4.5" Orange ABS Counter-Rotating Propeller Pair	PSF8045O-A-PK	$3.60	$7.20
1		Sunny Sky	SunnySky X2212-9 KV1400 II Brushless Motor	PSF8045O-A-PK	$16.30	$16.30
4		Hobbywing	Hobbywing Flyfun 30A ESC	HWG-SC-0238	$16.50	$66.00
1		Zippy	ZIPPY Flightmax 3000mAh 3S1P 20C	Z30003S-20	$16.76	$16.76
1		FlySky	FlySky Radio Controller Transmitter and Receiver Kit	B01BZQ15L0	$52.99	$52.99
1		FlySky	Flysky FS FS-R6B 2.4G 6 Channel Receiver	B01FXLZYMY	$13.98	$13.98
1		GetFPV	3.5mm Gold "Bullet" Connectors (12 Pair)	1516	$2.99	$2.99
1		Dovewill	Dovewill XT60 Bullet Plug ESC Power Breakout Cable	B076M4MNRF	$6.41	$6.41
1		Pixy	Pixy2 Smart Vision Sensor	B07D1CLYD2	$59.90	$59.90
1		Arduino	Arduino Uno R3 USB Microcontroller	A000066	$21.99	$21.99
2		SainStore	SainSmart HC-SR04 Ranging Detector Distance Sensor	B004U8TOE6	$5.40	$10.80
2		Adafruit	Micro Servo Motors	169	$5.95	$11.90
2		Pololu	Servo Extension Cable 12" Male - Female	2184	$2.49	$4.98
4		Pololu	Female Header	1031	$0.99	$3.96
4		Pololu	Male Header	965	$0.75	$3.00
16		Fastener Superstore	6 mm OD Hex Standoffs Male-Female M3-0.5 x 15 mm	801467	$0.19	$3.04
16		Fastener Superstore	6 mm OD Hex Standoffs Female-Female M3-0.5 x 15 mm	802211	$0.19	$3.04
2		N/A	1/4" White Coroplast 4'x4'	N/A	$1.94	$3.86
1		N/A	1/16" Polycarbonate 4'x4'	N/A	$3.61	$3.61
1		N/A	Pink Insulation Foam 4'x4'	N/A	$0.89	$0.89

Appendix C: Arduino Autonomous Mapping Code

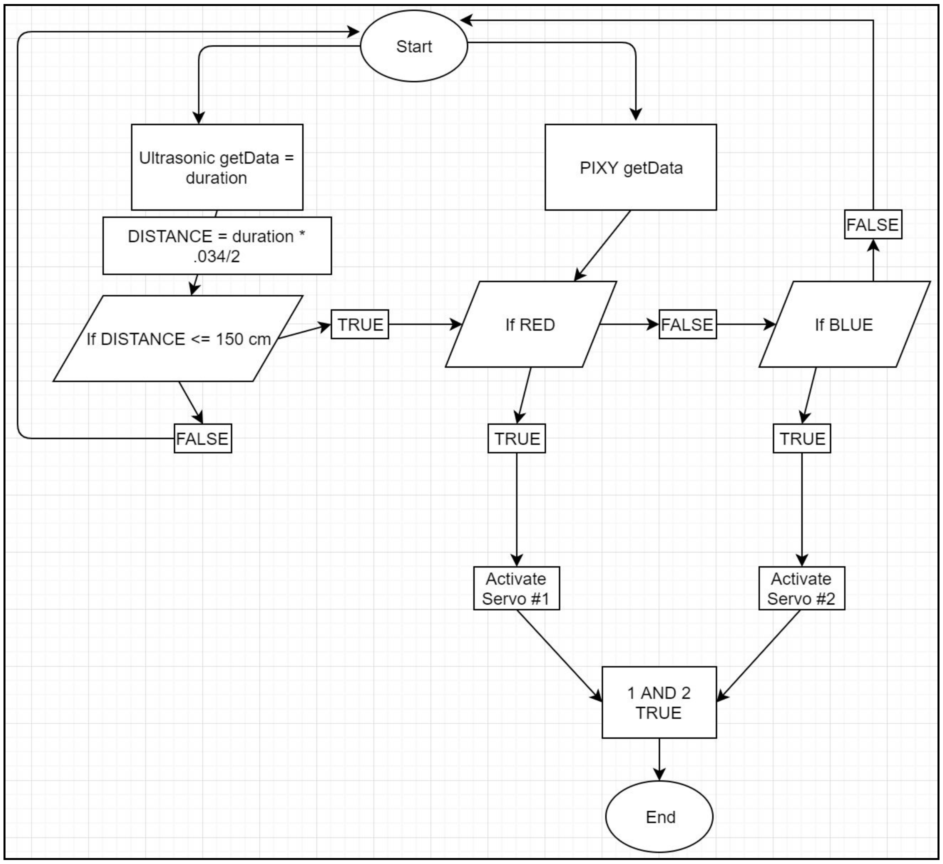


Figure 11: Flowchart for Ball-Dropping Mechanism

```
#include <Servo.h>
#include <Pixy2.h>

Servo myServo1;
Servo myServo2;
Pixy2 pixy;

int pix;

const int trigPin = 9;  //defining pin numbers for ultrasonic sensor
const int echoPin = 3;

long duration;  //defining variables to be used in code
int distance;

void setup() {
  myServo1.attach(5); //attaches Servo 1 to Pin 5
```

```
  mySServo2.attach(6); //attaches Servo 2 to Pin 6

  myServo1.write(120); //starting positions for both servos
  myServo2.write(20);

  pinMode(trigPin, OUTPUT);   //sets pin modes for the Ultrasonic sensor
  pinMode(echoPin, INPUT);

  Serial.begin(9600);
  Serial.print("Starting...\n");
  pixy.init();   //initializes PIXY cam

}

void loop() {
  int dist = ultrasonicReadings();                    //gets data from the ultrasonicReadings function
  int pix = pixyReadings();                           //gets data from the pixyReadings function


  if (dist <=150 and pix == 2){                       //if sensor reads this distance and PIXY gets BLUE
    myServo1.write(180);
    delayMicroseconds(600);                           //servo will be activated

  }
  if (dist <=150 and pix == 1){                       //if sensor reads this distance and PIXY gets RED
    myServo2.write(120);
    delayMicroseconds(600);

    }

}


int ultrasonicReadings(){
  digitalWrite(trigPin, LOW);                         // Clears the trigPin
  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);                        //Sets the trigPin on HIGH state for 10 micro seconds
  duration = pulseIn(echoPin, HIGH);
  //Serial.println("Duration:");
  //Serial.print(duration);
  distance = duration*0.034/2;                        // Calculates the distance
  Serial.println("Distance:");
  Serial.println(distance);

  return distance;
}
```

```
int pixyReadings(){
  int i;
  int x = pixy.ccc.blocks[i].m_signature;
  pixy.ccc.getBlocks();                              //calls the signatures from PIXY
  if (pixy.ccc.numBlocks){
    Serial.print("Detected");
    Serial.println(pixy.ccc.numBlocks);
    Serial.println(pixy.ccc.blocks[i].m_signature);
 return x;
}
}
```

Appendix D: References

Works Cited

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