DORIS

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Project Description

Statement:

- We will Develop a Utility Drone with Variable Payload Capacity

Description/Objective:

- Design a unique drone frame
- Engage and deploy different payloads, while remaining airborne
  - camera for potential surveying
  - One payload weighing 30% of total weight
  - MC-01F30 Cruise Missile (deployable)
- Drone must be able to return to user and deliver/retrieve a payload to/from a desired location/target

Sponsor/Client:

- Mechanical Engineering Department at Northern Arizona University
- Contact: Professor David Willy

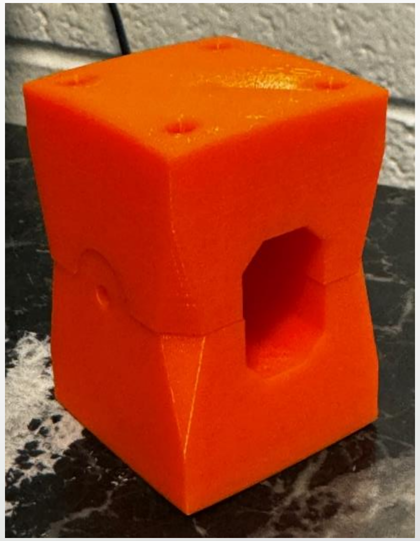
Importance:

- Satisfies a need for a more affordable and easier to manufacture, payload capable drone
- Drone could be used to deliver and receive any kind of package (first aid & emergency supplies)
- Necessity for remote piloted drones that are durable, easy to fly, and can return to the user while performing tasks

Project Description: Updates

Prototyping:

- CAD Modeling
    - Frame brackets
    - Motor brackets
- Real-world modeling
- Manufacturing
    - Frame brackets
    - Cruise missile parts
- Material Selection
    - Frame material selection
    - Bracket material selection (TPU)



Design Requirements - QFD

System QFD

Project:	**DORIS Drone**
Date:	11/6/2024

Engineering Requirements (3 Highest on scale)

	Thrust : weight > 3:1	Compact Design under 3'x3'x3'	Complete Course < 10 min	Payload > 30% of weight	Time of flight > 10 min	Total Cost under $3,000
Thrust : weight > 3:1						
Compact Design under 3'x3'x3'						
Complete Course < 10 min	3					
Payload > 30% of weight	1		1			
Time of flight > 10 min	3		1	1		
Total Cost under $3,000		3			1	
Meets FAA requirements (weight < 55 lbs)	3	3		1	3	3

Technical Requirements (5 highest)

Customer Needs	Customer Weights: 1-5	Thrust : weight > 3:1	Compact Design under 3'x3'x3'	Complete Course < 10 min	Payload > 30% of weight	Time of flight > 10 min	Total Cost under $3,000	Meets FAA requirements (weight < 55 lbs)
High mobility	4	5	5	5	1	2	1	
Small	1	4	5	3		5	5	5
Complete Boeing Recon Mission	5	5	3	2	4	2		
Payload Capacity	5	5	1	2	5	1	2	
Battery Capacity for small mission	4	3	2	4	4	5	1	1
Cost Efficiency	3	1	2	3		2	5	4
Thrust Efficiency	4	5	3	5	4	5	2	
FAA Registered	5		3					5
Technical Requirement Units			3x3x3 Feet	minutes	% weight	minutes	USD	pounds
Technical Requirement Targets		3:1	< 3x3x3	< 10	> 30	> 10	>3000	< 55
Absolute Technical Importance		28	24	24	18	22	16	15
Relative Technical Importance		1	3	3	5	4	6	7

Design Requirements – CRs/ERs

Customer Requirements

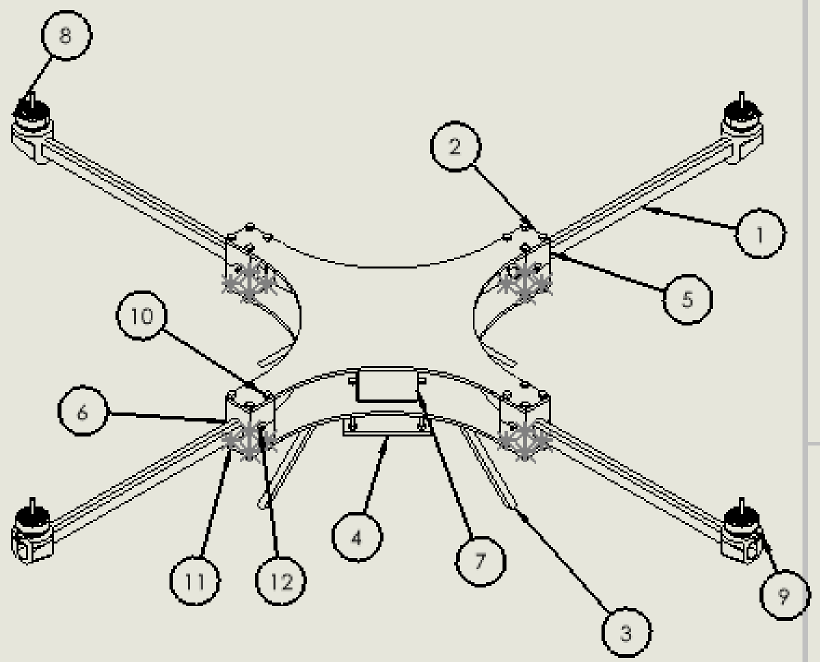
- High mobility
- Small
- Complete Boeing Recon Mission
- Payload Capacity
- Battery Capacity
- Cost Efficiency
- Thrust Efficiency
- FAA Registered

Engineering Requirements

- Thrust to weight ratio of at least 3:1
- Design under 36” x 36” x 36"
- Complete Course < 10 minutes
- Payload > 30% of drone weight
- Time of flight > 10 minutes
- Total Cost under $3000
- Meets FAA requirements (weight < 55 lbs, flown under 400 ft AGL)

Design Description – CAD

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Drone_Arms	Arms	4
2	Drone_Base_V2	Top frame plate	1
3	Drone_Bottom_Base	Bottom Frame plate	1
4	Drone_Payload_Base	Payload Attachment plate	1
5	ArmMount_Top	Top Spacer/ Arm Mount	4
6	ArmMount_bottom	Bottom Spacer/ Arm Mount	4
7	TATTU 22000 mAh TAA22K6S30ASX	Battery	1
8	XING 4214 2-8S X CLASS FPV Motor	Motors	4
9	MotorMount	Motor Mount to arms	4
10	hex bolt_ai	Hex Bolts for frame	20
11	HNUT 0.2500-28-D-N	Hex Nuts for frame	28
12	hex screw_ai	Hex Screws for Arm Mounts	8
13	MSHXNUT 0.164-32-S-N	Hex Nuts for Arm Mounts	8



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NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

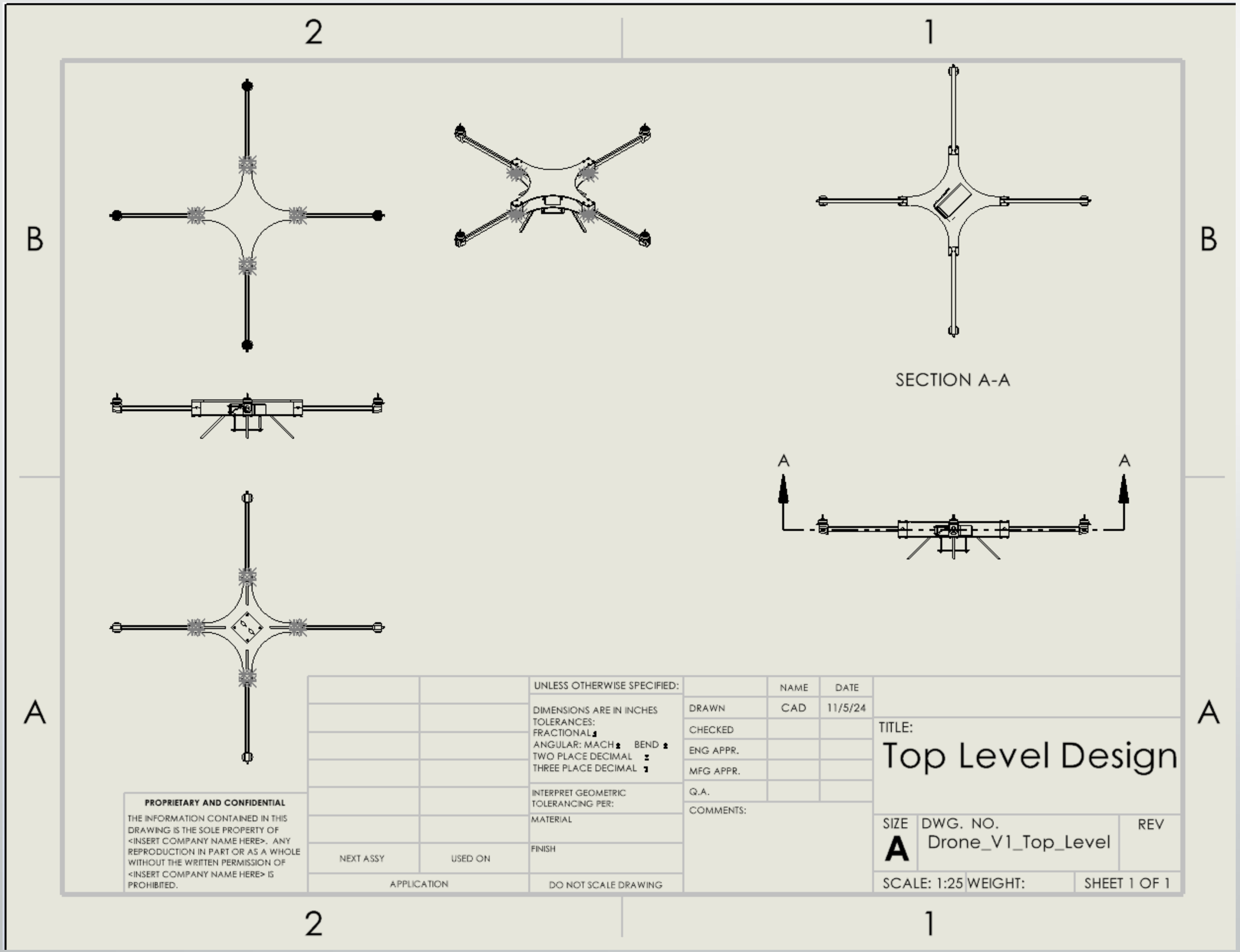
	NAME	DATE
DRAWN	CAD	11/5/24
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:
Top Level Design With Parts Shown

SIZE A | DWG. NO. Drone_V1_Bubbles | REV

SCALE: 1:8 | WEIGHT: | SHEET 1 OF 1

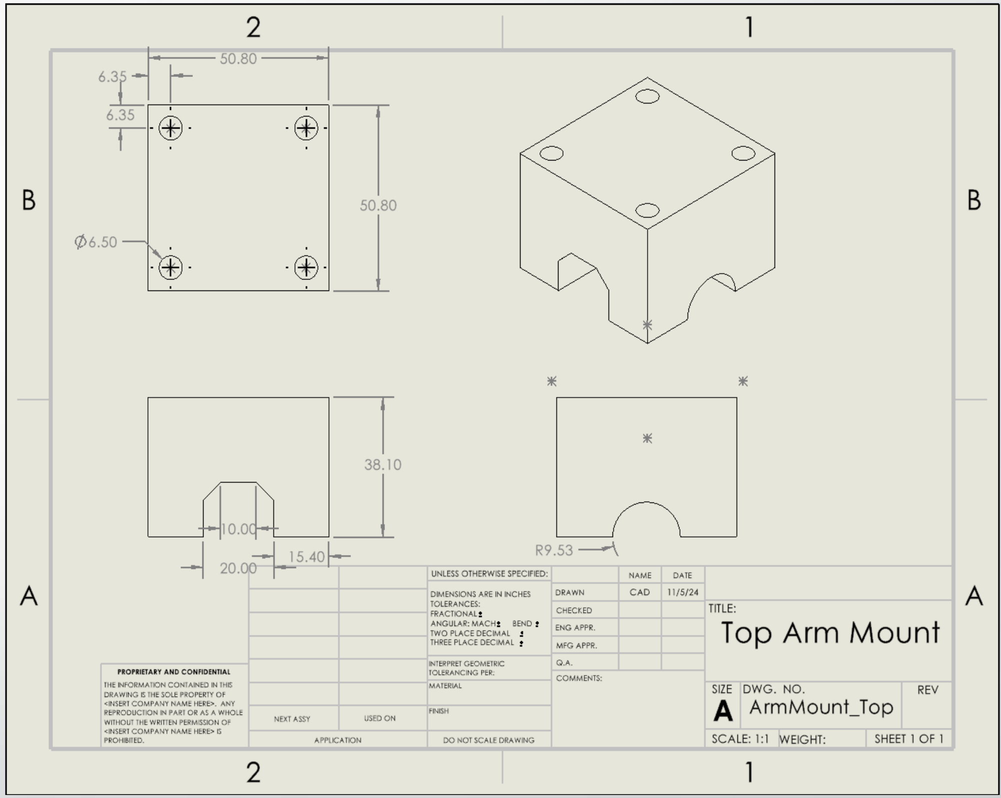
Design Description – CAD Top Level Design

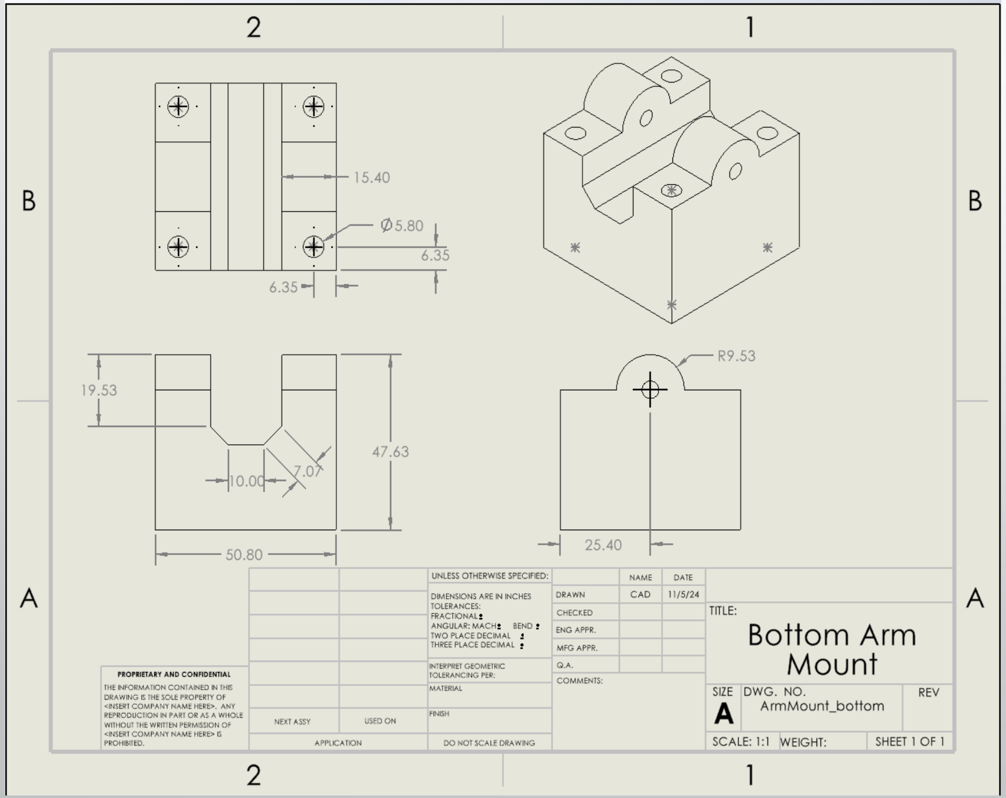


Design Description – Arm to Frame Mount

Functions:

- Holds arms in place
- Acts as a separator for the frame plates
- Bolts in them hold the mounts and frames together

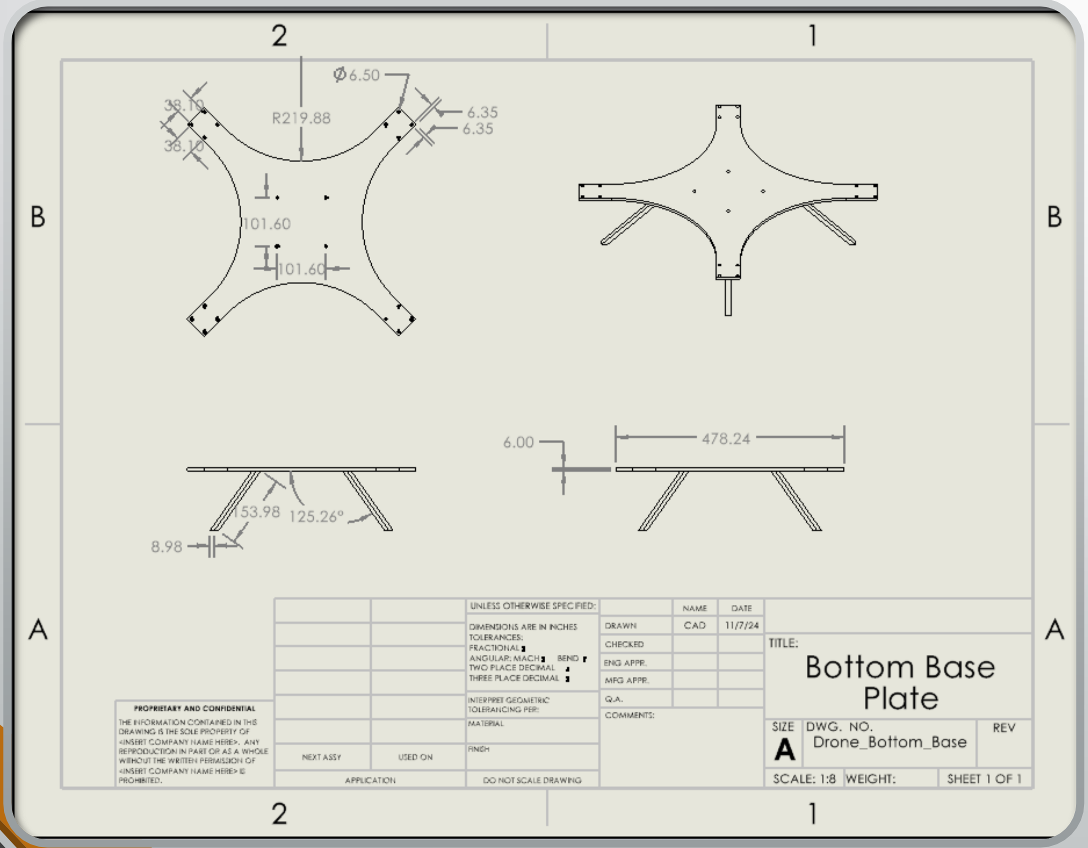


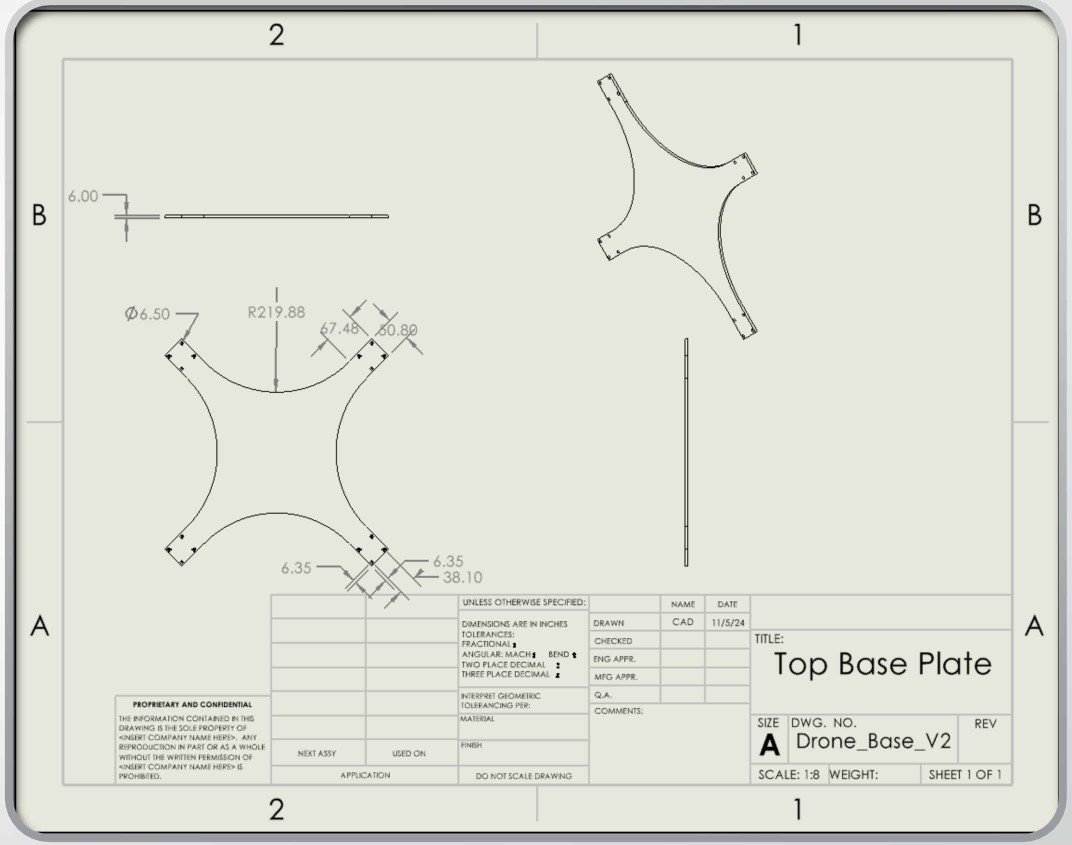


Design Description – Frame

Functions:

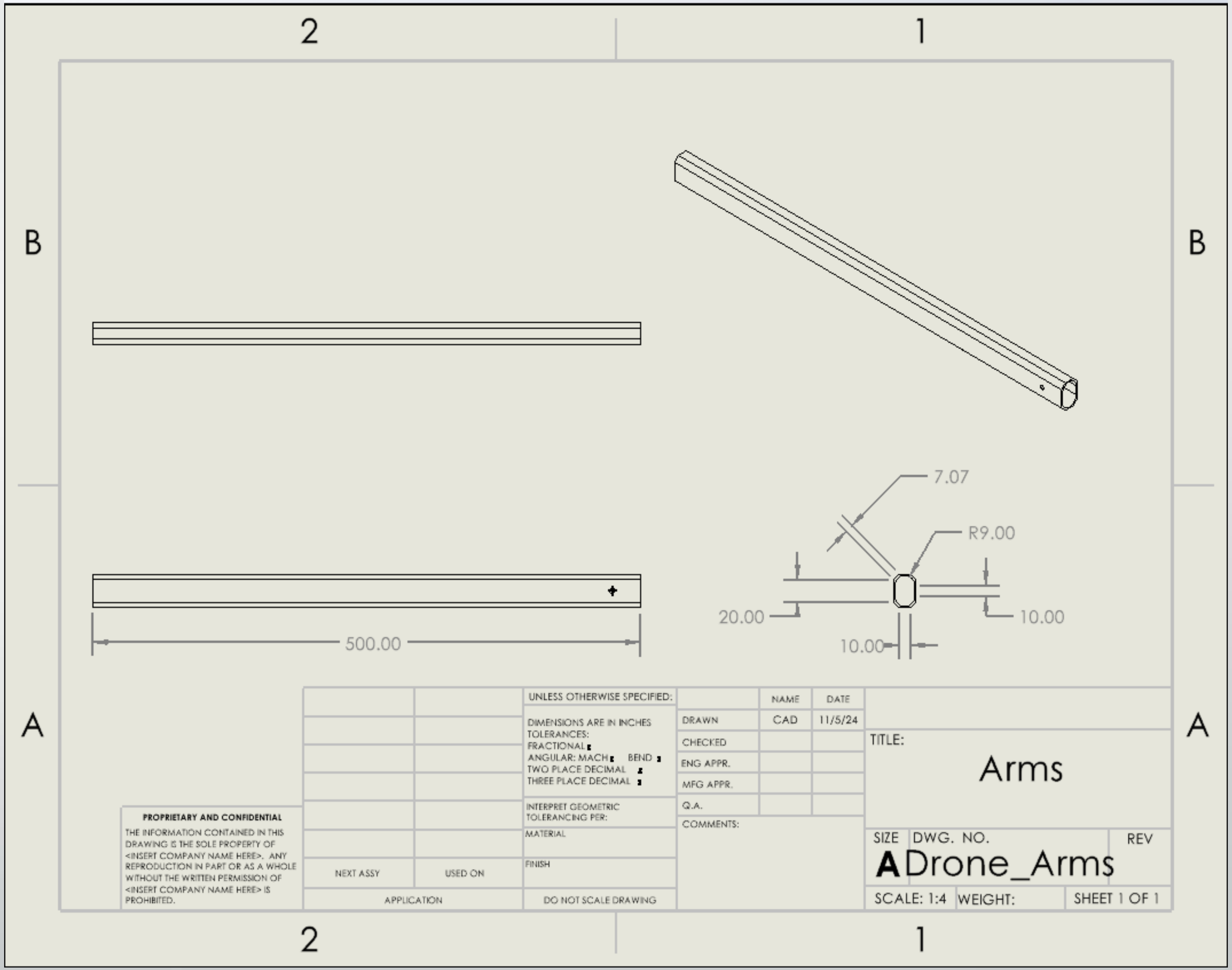
- Main body parts for the drone
- Houses electronic components between the plates
- Bottom plate includes landing gear for the drone





Design Description – Arms

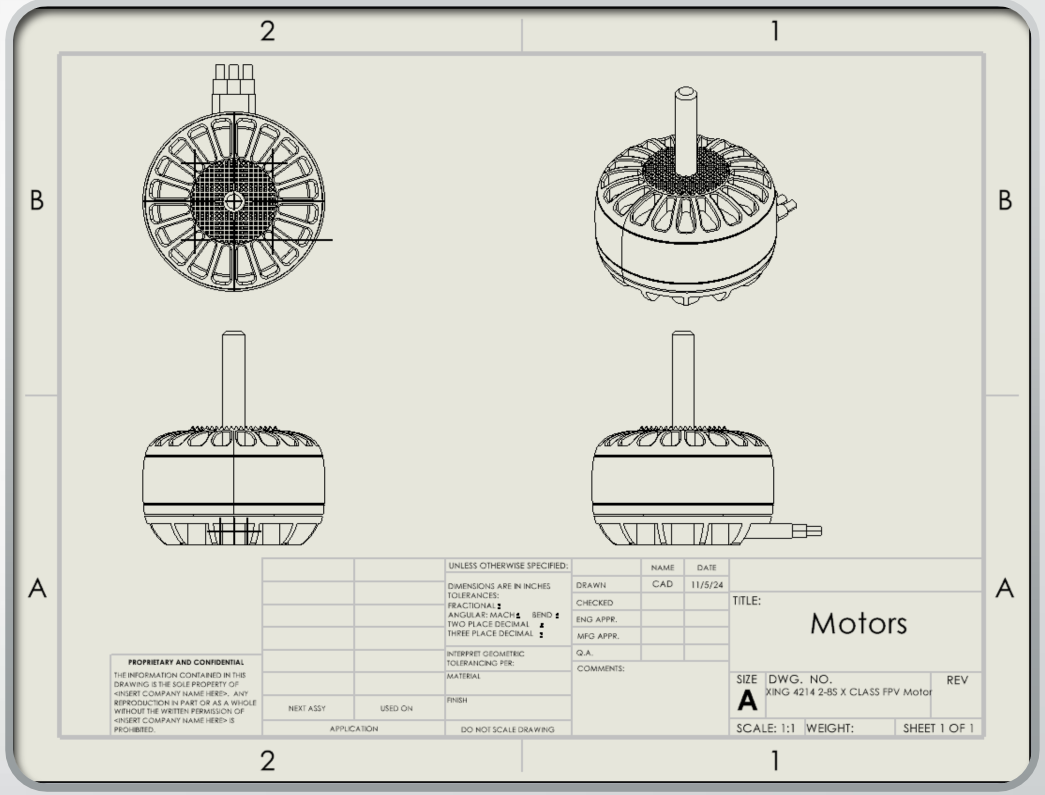
Functions:
- Ensures motors are evenly spaced and supported
- Provides structure for flight
- Open tube design to allow wires to be fed through

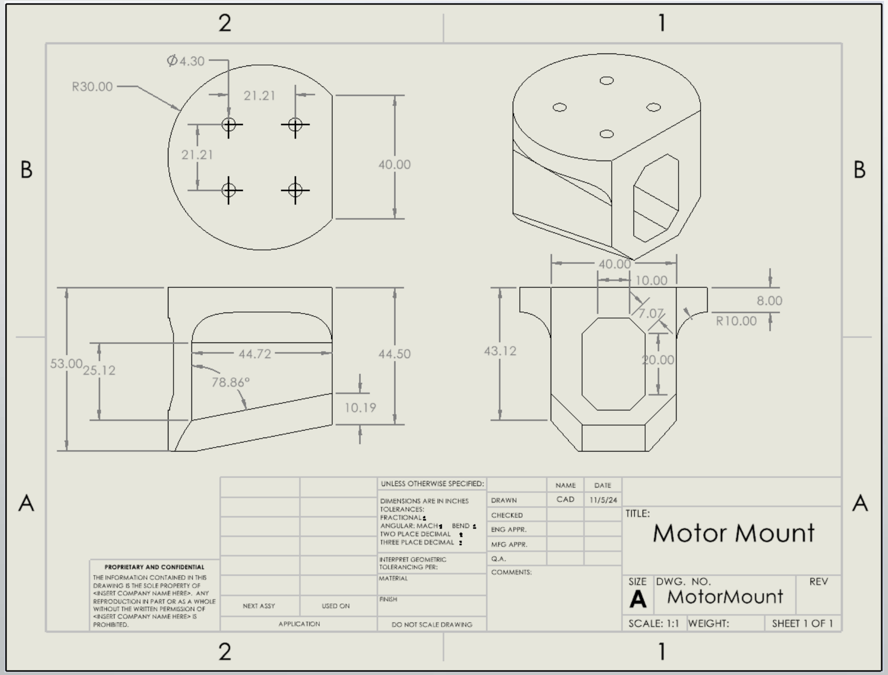


Design Description – Motors and Motor Mounts

Functions:
- Motor mounts secure the motors to the arms
- Motors drive propellers that give flight

Motor Type:
- Xing 4214 2-8s X Class FPV Motor

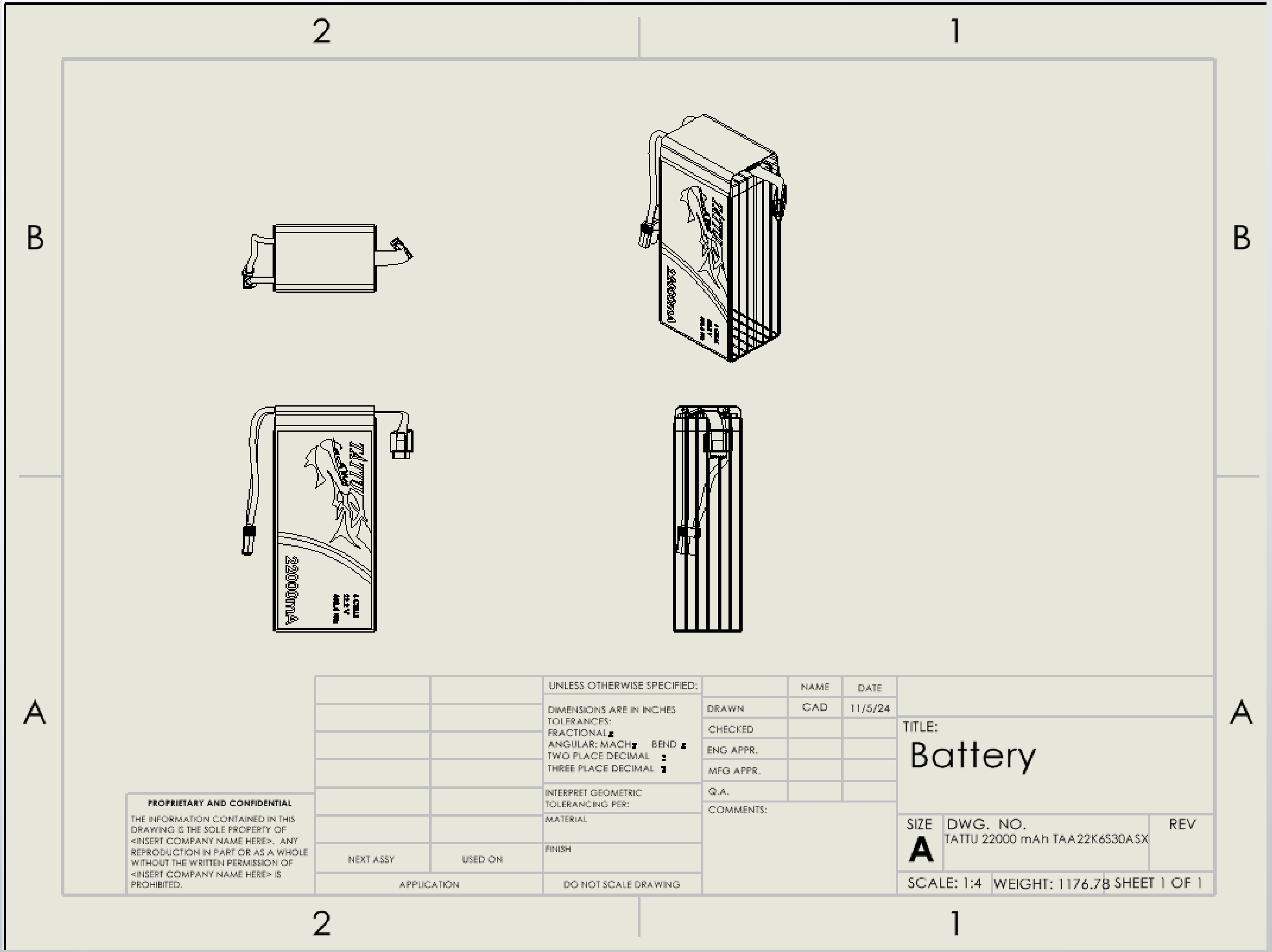




Design Description – Battery

Functions:
- Supplies power to drone

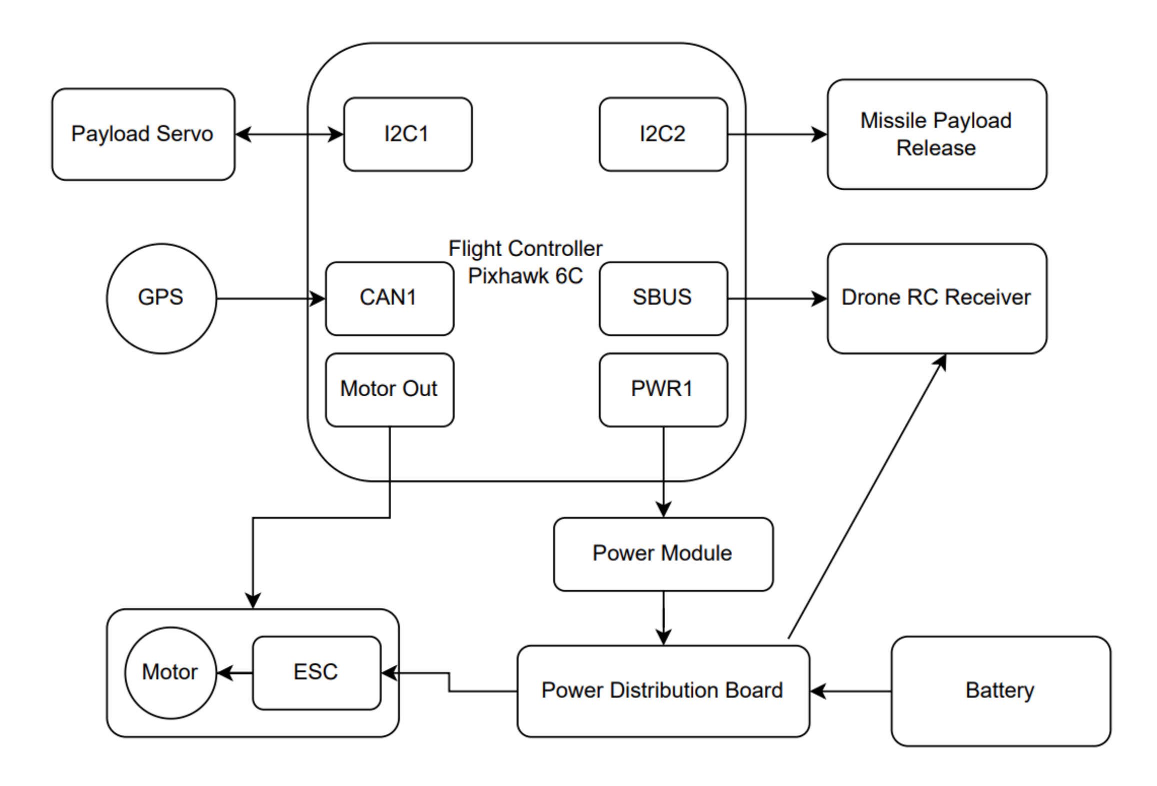
Battery Type:
- Tattu 6S 22000 mAh TAA22K6S30ASX Battery



Design Description – Electrical Network

Functions:

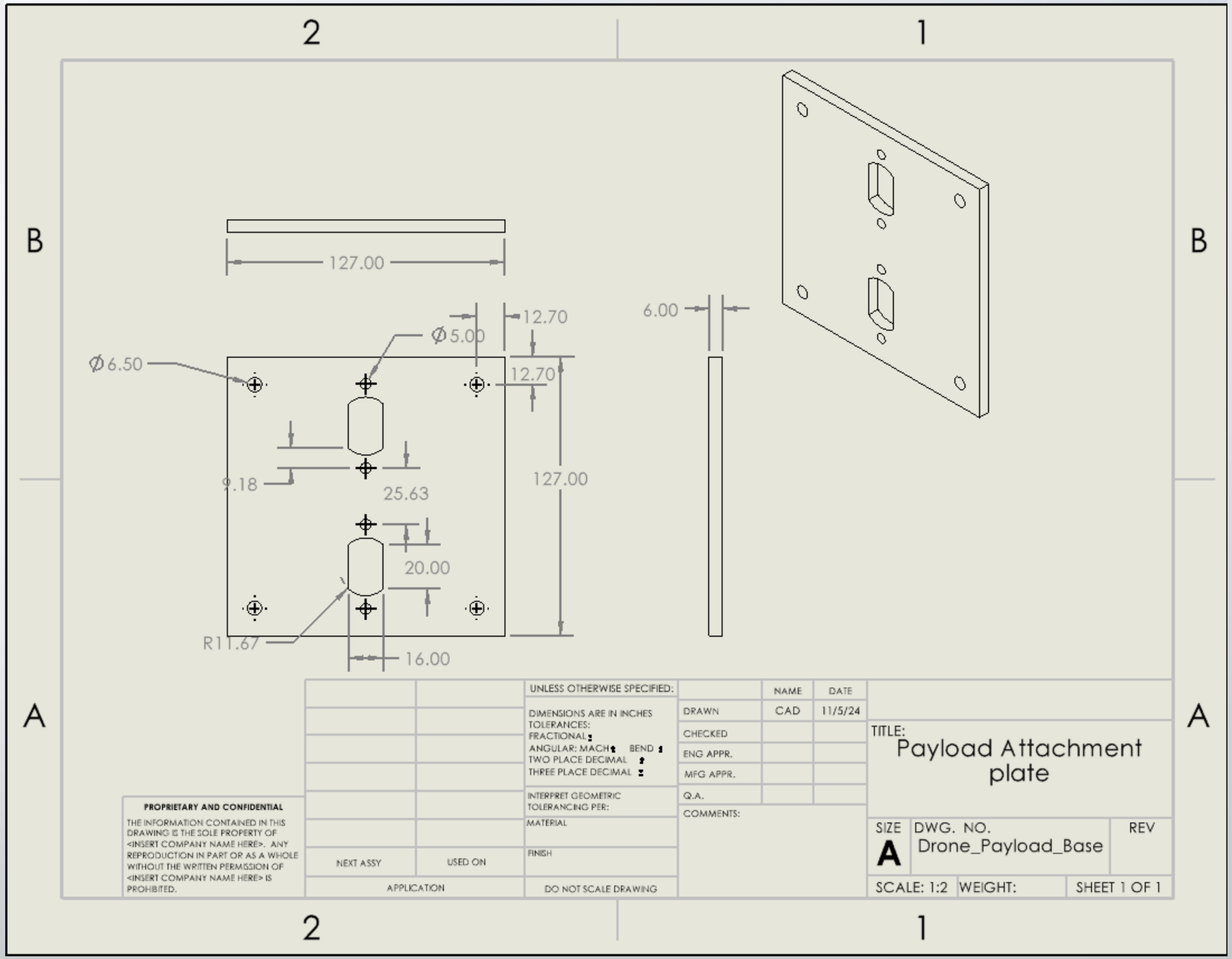
- Provide communication between pilot and flight controller
- Provide signal from flight controller to ESCs to respond to user inputs and environmental conditions
- Flight controller provides "brain" to drone – removes workload from pilot
- ESCs delivers PWM signal to DC brushless motors and controls speed
- PDB/Power Module distributes power to ESCs/payload systems



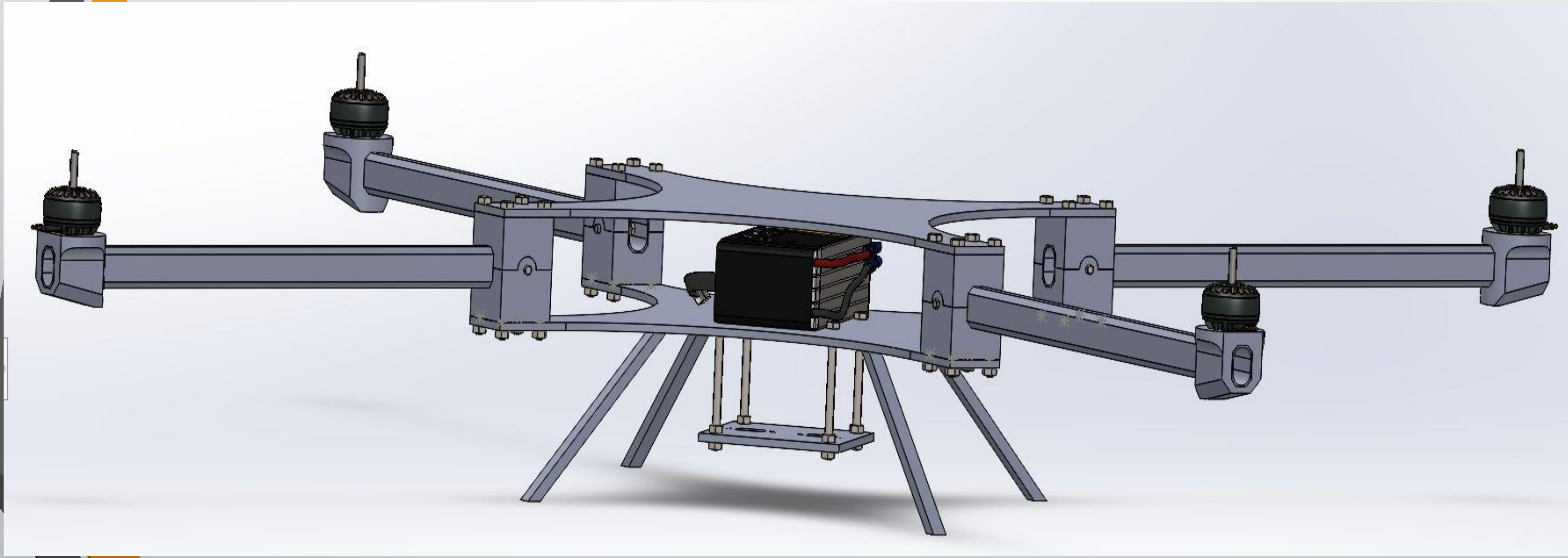
Design Description – Regular Payload System

Functions:

- Bracket designed to capture 2 MagSwitch magnets and servo motor mounting
- Stand-offs will mount bracket to the drone frame (lower bracket) and servo to bracket
- Actuator wheel designed to attach to servo to actuate magnet (will be investigated)
- Magnets will attach to metal plate on a payload (will be decided on at a later date)
- Torque needed to actuate magnet is still be investigated



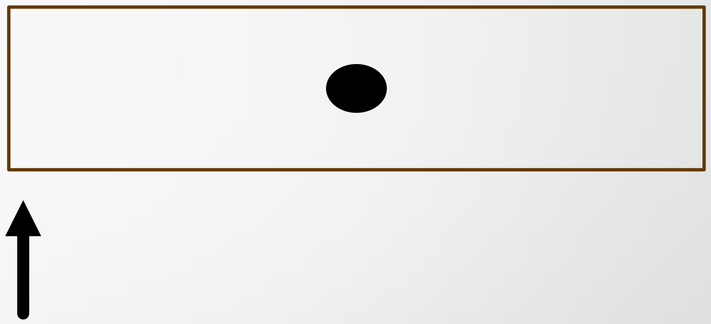
Design Description – Final CAD Design



Engineering Calculations – Magnet Analysis

1 Magnet vs. 2 Magnet System:
Pull off- Force reduction by applied Torque (only one magnet in center):

- Max Hold Force(F_H) = 60 lbs = 267 N
- Pull-off Force(F_P) = Max Hold Force; under ideal conditions
- $F_H = F_P = \frac{B^2 A}{2\mu_0}$;
- $L = 6in; r = 3in = 0.0762\ m$
- $Torque\ (\tau) = rFsin\theta \quad and \quad F_{shear} = \frac{\tau}{r}$;
- Effective Pull-off force reduction: $F_{effective} = \sqrt{F_P^2 - F_{shear}^2}$
- Assuming a drag/wind force applied perpendicularly to payload:
- $\tau = (0.0762)(1.84N)\sin(90) = ; r(magnet) = 0.0113m;\ F_{shear} = \frac{1.84}{0.0113m} = 163\ N$
  - $F_{effective} = \sqrt{(267N)^2 - (163N)^2} = 212\ N,\ \ 21\%\ perecent\ reduction$
  - 2 magnet system would greatly reduce this (assuming the payload is fixed in place by the 2 magnets
  - Torque would be approximately zero, making force reduction essentially zero



Design Validation – Electrical FMEA

Part	Potential Failure Mode	Potential Failure Effects	Mechanisms of Failure	Likelihood of Occurrence	Recommended Action
Flight Controller	Software Failure	Loss of control	Incorrect programming, firmware bug	Low	Ensure programming accurate before flight
Regular Payload Release	Servo Failure	Unreleasable/ Early released payload	Servo not strong enough, not receiving enough power	Moderate	Test all servos before flight, use factor of safety during selection
RC Communication (Missile and Drone)	Loss of signal	Loss of manual control	Loose connections, malfunctioning part	Low	Ensure all connections secure before flight, test on ground
Battery	Reduced Voltage	Reduced power	Aging, improper charging	Moderate	Ensure storage charge when not in use

Design Validation – Regular Payload FMEA

Part	Potential Failure Mode	Potential Failure Effects	Mechanisms of Failure	Likelihood of Occurrence	Recommended Action
Mounting bracket	Cracking/ breaking	Loss of stability and alignment	Stress concentration, fatigue cracks, impact	medium	Use strong material, ensure sufficient load capacity
Actuator wheel	Misalignment	Poor fitment & vibration	Uneven torque, part wear	medium	Ensure secure install, frequently check alignment
Stand-offs	Material fatigue & loosening	Loss of control of magnet, potential payload drop	Vibration, material fatigue	medium	Use strong material, verify secure install
Switched magnet (x2)	Misalignment & loss of force	Vibration loosening & exposure to high heat	Demagnetization & mechanical shock	low	Ensure magnet is fully engages, protect from heat & impact
Servo motors (x2)	Over heating, electrical failure	Reduced performance, loss of control	Excessive current draw, high load, over-voltage, short-circuit	medium	Ensure proper wiring, monitor cooling

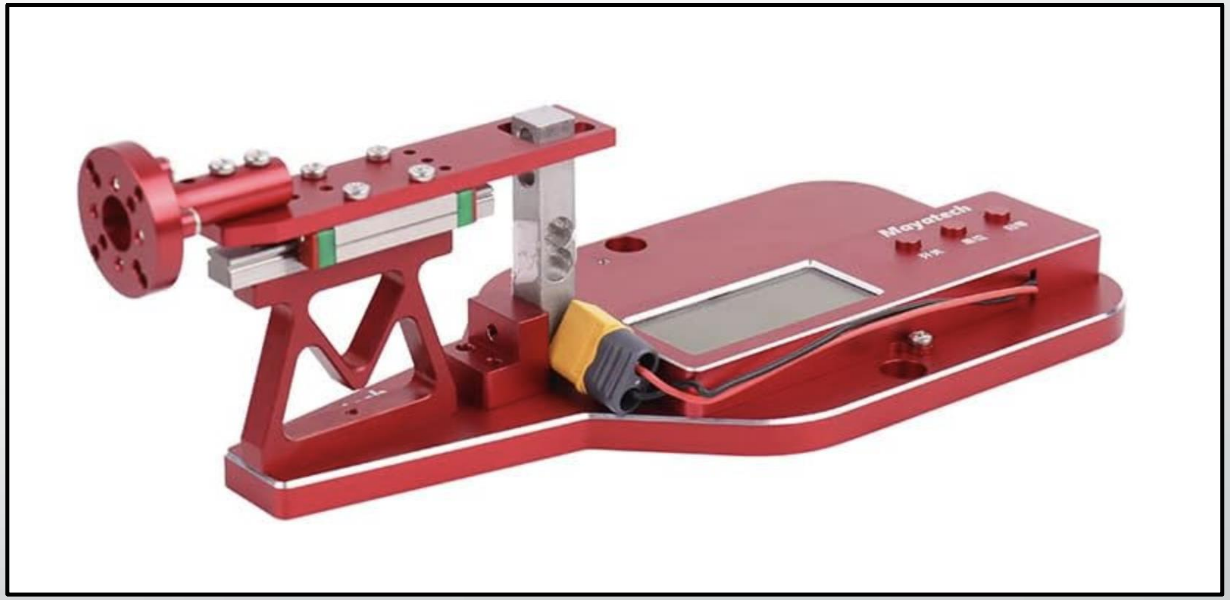
Design Validation – Arm Bracket to Motor Mount FMEA

Part	Potential Failure Mode	Potential Failure Effects	Mechanisms of Failure	Likelihood of Occurrence	Recommended Action
Frame Arm Mount	Twisting/Deformation of TPU mount	Unstable Flight	Part (TPU) infill density to low.	Not likely, TPU density is at 35%	Increase infill density.
Octagonal Carbon Fiber Arm	Carbon fiber critical failure.	Highly unstable flight/ inoperable drone	Cracked carbon fiber arm	Likely after testing.	Purchase extra carbon fiber tubes
Motor Mount	Twisting/Deformation of TPU mount	Misaligned motors causing unstable flight	Part (TPU) infill density to low.	Unlikely, infill density will be rigid enough to counteract	Increase infill desnity

Design Validation – Thrust Load Analysis: Dynamometer

Constructing a dynamometer to measure the different efficiencies of different sized propellers under load.

Materials
- 10 kg Load Cell
- Mini Linear Rail
- 13 x 8 x 3 Blade Propeller
- 14 x 7 x 3 Blade Propeller
- 16 x 8 x 3 Blade Propeller
- 3-D printed Test Stand Frame
- Arduino



Experiment
- Test different propeller sizes and pitches to optimize drone thrust.

Design Validation – Testing Procedures

Engineering Requirement	Testing Procedure	Resources Needed
Thrust to weight ratio of at least 3:1	Attach motor to DIY dynamometer and measure different thrust forces from different propellers. Then divide the found thrust by weight.	Dynamometer
Design under 36"x36"x36"	Measure the length/width from tip of propellor on one corner to tip of propellor on adjacent corner	Tape measure
Complete Course < 10 minutes	Use cones to lay out a course for the drone to pickup/drop the payload, take photo of team, and launch cruise missile at a target	Stopwatch, cones, large sheet for target, open field (South Fields)
Payload > 30% of drone weight	Measure the drone weight and the payload weight then perform a simple calculation	Scale
Time of flight > 10 minutes	Hover the drone at a fixed position in the air until low battery warning goes off	Stopwatch, open field to test (South Fields)
Total Cost under $3000	Track purchases on a budget sheet	Excel spreadsheet
Meets FAA requirements (weight < 55 lbs, flown under 400 ft in elevation)	Measure the drone weight using a scale; monitor the altitude in-flight	Scale, equipment to measure AGL in-flight

Schedule: ON TIME

Tasks	Week 11 (Nov 4 - Nov 10)	Week 12 (Nov 11 - Nov 17)	Week 13 (Nov 18 - Nov24)	Week 14 (Nov 25 - Dec 1)	Week 15 (Dec 2 - Dec 8)
Presentation 3					
P3 (Project Description)					
P3 (QFD)					
P3 (CAD)					
P3 (CAD Drawings)					
P3 (Electric Flow Chart)					
P3 (Engineering Calculations)					
P3 (Design Validation)					
P3 (Schedual)					
P3 (Budget)					
P3 (Conclucion)					
Presentation 3 - feedback to other teams					
Peer Eval 3					
Timecard Wk11					
1st Prototype Demo					
DAC meeting extra credit					
Timecard Wk 12					
Staff Meeting #9 (Wk13)					
HW04 - Individual Analysis					
Timecard Wk13					
Report #2					
Staff Meeting #10 (Wk14)					
Timecard Wk14					
Final CAD and Final BOM					
[Insert Sub Tasks for Final CAD and Final BOM here]					
2nd Prototype Demo					
[Insert Sub Tasks for 2nd Prototype Demo here]					
2nd Proto Demo - feedback to other teams					
E-fest Extra Credit					
Project Management for 486C					
Website Check #2					
(FINAL) Peer Eval 4					
Course Eval Extra Credit/Close					
Timecard Wk15					

Budget

Budget:	$ 3,717.70	Amount of 10%:	$ 717.70
Expense:	$ 1,361.92	Left in CEIAS:	$ 1,880.75
Remaining:	$ 2,355.78	Left in donations:	$ 475.03

Date	Vendor	Item	Quantity	Tracking Number	Cost	Status	Notes
10/17/24	Amazon	Octagonal carbon fiber tubing	1	LZ084689834CN	$ 108.09	Shipped	Capstone PO#2
		ApisQueen 120A ESC w/ BEC	4		$ 213.91	Delivered	
		SunLu TPU Filament Orange	1		$ 26.19	Delivered	
		XT90 Connectors (10pr)	1		$ 13.94	Delivered	
		12 Gauge wire kit	1		$ 27.08	Delivered	
	HQProp	Propellers	4		$ 130.12	Payment not complete	
10/22/24	AliExpress	HotRC controller/receiver for missile	1		$ -	Delivered	Michael Paid, GoFundMe funds ($20.44)
11/4/24	Target	Gorilla glue for missile	1		$ -	Delivered	Michael Paid, GoFundMe funds ($6.54)

Questions?

Thank you!