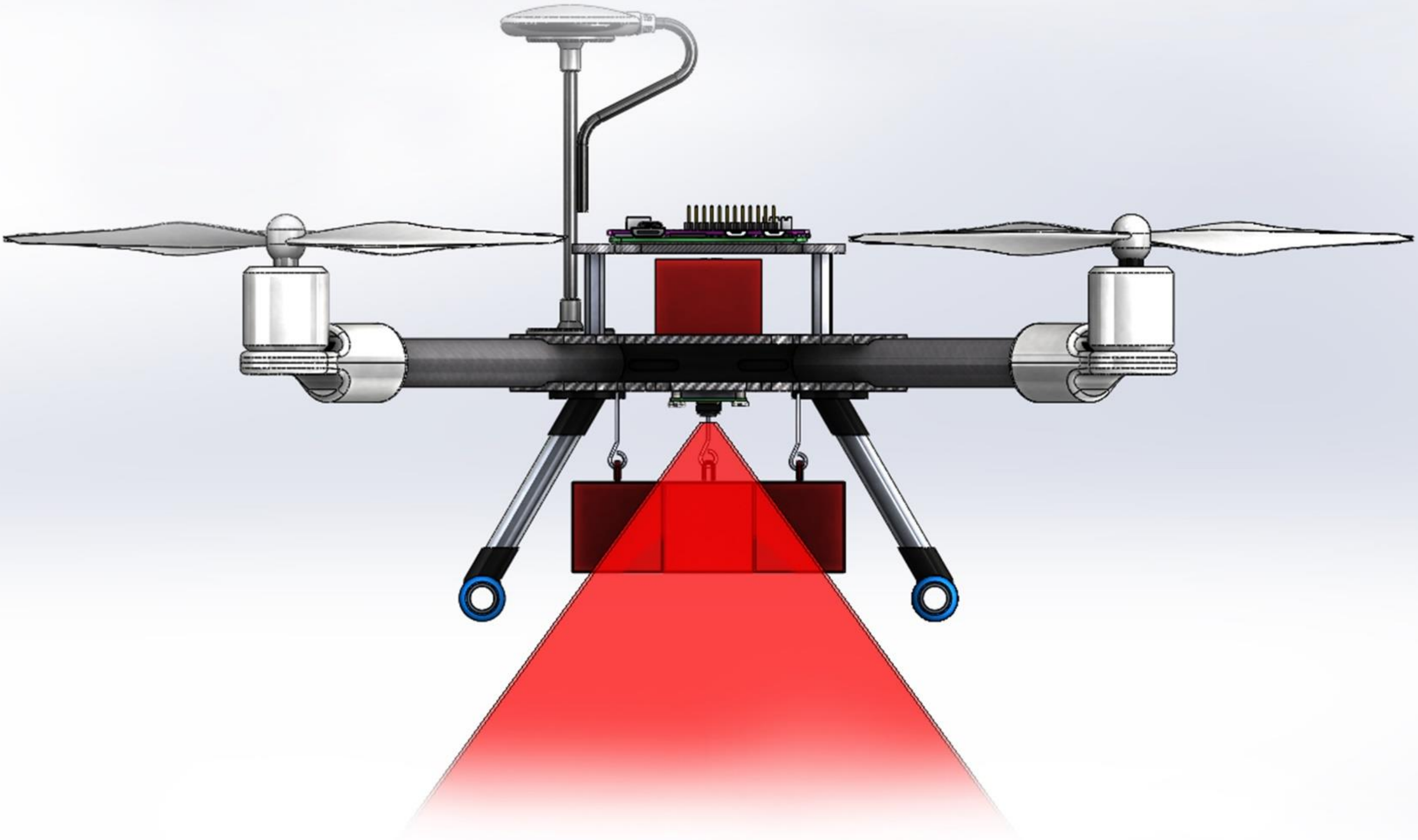
PIKS



DETAILED DESIGN REPORT

Team Number and Name: T214 || PIKS
Vechile Name : 407S
University : Yildiz Technical University (YTU)
Academic Advisor : Asst. Prof. Revna Acar Vural, Ph.D

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1.EXECUTIVE SUMMARY

This report summarizes the conceptual design of the Piks team's 407S Unmanned Aerial Vehicle (UAV) for the TUBITAK UAV competition 2017. The Team aims to produce an UAV that is going to complete missions provided by the competition organizers in fastest way and maximize the team score. There are two missions in the competition – image processing and airdrop. Teams must finish the first mission successfully in order to proceed to the second mission.

1.1 DESIGN PROCESS

The general objective for the 407S is gaining good results. This would be achieved through analysis of the competition rules. We all agreed to go with multicopter type UAV. At the beginning we considered several different configurations such as tricopter, quadcopter, octocopter and coaxial rotor. However, because of the great capabilities of quadcopter and team's interest in this vehicle, we concluded in classic quadrotor type UAV for the competition. The design was then further analyzed to reflect important mission variables. This included stability, weight, reliability, fail safe, autonomous flight, airdrop, image processing and manufacturability. This is the phenomenal theme for today's transportation companies. In preliminary phase the team rethought this once again to confirm mission success. And we all agreed that wire-cut mechanism is the best way to go. The mechanism is based on melting a rope of roughly 1mm diameter by heating a ressitance wire up. Previously, in conceptual design phase the team decided upon servo triggered shift-rod mechanism but this mechanism requires extra weight and area which is very limited factors for our UAV. We target to keep as simple – light, reliable etc. - as possible.

1.2.1 KEY MISSION REQUIREMENTS

TUBITAK UAV Competition 2017 missions are categorized as primary and secondary. Teams have to perform primary mission first in order to proceed to the secondary mission.

- Primary mission aims to test autonomous flight and image processing capability of the UAV by recognizing colors of cells of 4x4 matrix. The cells can take 3 different colors. The UAV must specify the colors of matrix elements and save them in its memory during autonomous flight.
- Secondary mission aims to test the capability of payload release with proper sequence. in addition to the primary mission. First, the UAV must save color sequence in the matrix, then it must release the cubes every 5 second according to color sequences in the matrix.
- Besides these, The UAV must fly autonomously but it can take off manually by the pilot.

1.2.2 DESIGN FEATURES

For performing these missions, **quadcopter** type UAV was chosen because of its hover capability, high stability and smaller area requirement for testing. Electronics of quadcopter consists of Ardu Pilot Mega 2.8 flight computer as autopilot, Neo_m8n Ublox GPS receiver, XBee S2C module as radio receiver, Raspberry Pi zero as image processing computer and Pi camera v1.3 camera module.

- The crucial point for primary mission is recognizing the matrix colors quickly and then save them. Raspberry Pi will process images captured by Pi camera. Pi camera will take clear images that is suitable to detect cell colors easily. And then Raspberry Pi will apply detection algorithm.

For drop mechanism, we preferred wire cut mechanism over servo mechanism. A mosfet, resistance wire and tiny rope is necessary for this. The heating process will be kept 2 second. This is enough for melting the tiny rope. After melting the wire gravity will do rest of job. A parachute will deploy after rope cut. A spill hole will be included in parachute to increase stability.

The chosen quadcopter is X configuration. To be lightweight quadcopter frame will be made from carbon

1.3 PERFORMANCE CAPABILITIES OF THE SYSTEM

fiber. Carbon fiber frame ensures complete system rigidity and operativeness during mission execution. Drone’s flight timing is enough for competition missions. That power is provided from LiPo battery. Flight controller stability and camera angle is satisfied for image processing mission. Our flight controller also has a feature which is called waypoint. As competition is based on autonomous flight, we need to choose a flight controller that includes all features. Our flight controller provides all features.

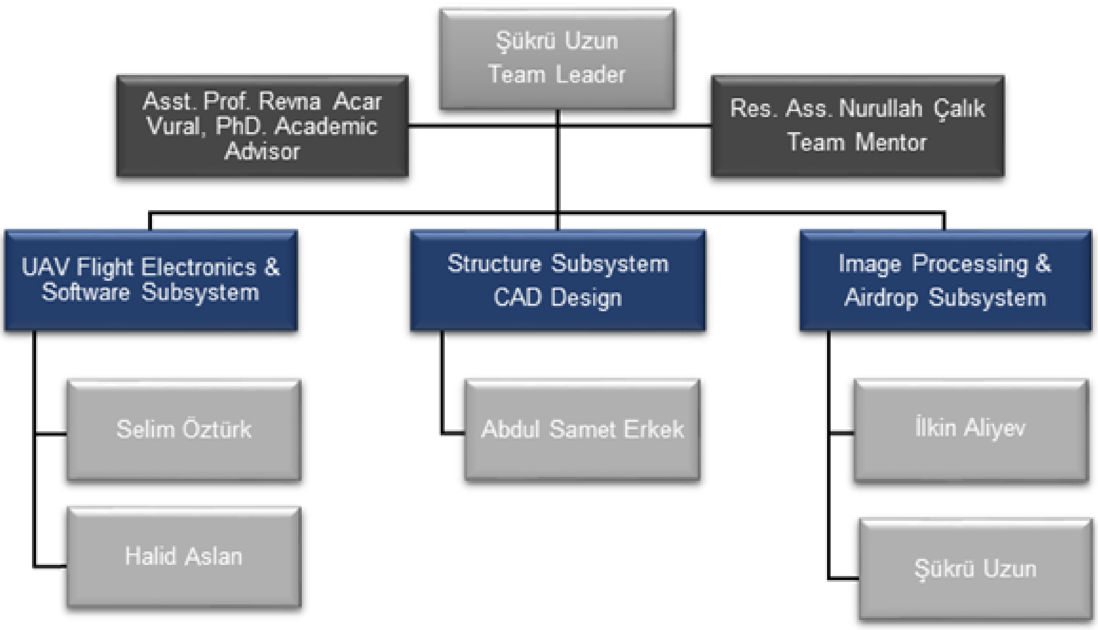
2. MANAGEMENT SUMMARY

The Piks team consists of 5 multidisciplinary undergraduate students, which has their own knowledge of their field. All members are juniors, 4 of Electrical &Electronics Faculty and 1 of Mechanical Engineering Faculty.

2.1 TEAM ORGANIZATION

The UAV system was separated into 3 subsystems

1) Structure subsystem design
2) UAV flight electronics & software subsystem design
3) Image processing & Airdrop subsystem design.



2.2 MILESTONE CHART

Some of Piks team members have their separate ongoing projects, thus going with Schedule acting according to program is a crucial point in terms of project robustness.

	February			March			April			May			June			July		
	1	15	28	1	15	30	1	15	30	1	15	30	1	15	30	1	7	14
DESIGN OF DRONE																		
Conceptual Design																		
Preliminary Design																		
Final Design																		
MANIFACTURING																		
Prototype Construction																		
Payload Mechanism																		
Final Construction																		
TESTING																		
Optimizations & Upgrading																		
Structure Test																		
Material and Rigidity Test																		
Drop Mechanism Test																		
Flying Test																		
IMAGE PROCESSİNG																		
Read Raw Data																		
Get Image on the Screen																		
RGB Detecting																		
DROP MECHANİSM																		
Design Drop System																		
Preparing Loads																		
COMPONENT SELECT.																		
Motors→ESCs→Battery Selection of Flight Cont.																		
ELECTRONICAL SYS.																		
Design of Radio Control																		
PID Tuning and Autonomous Flight Sw.																		
DEADLINES																		
			R							R & V								F

- Lighter color indicates planned
- Darked colors indicates actual

Model 1	Model 2	Final Model	Payload Mechanism

3. CONCEPTUAL DESIGN

Conceptual design phase aims to research and review possible and feasible solutions for provided rules. Trade studies have significant impact on the design process. The team carefully analyzed scoring formula and found that it is initially important to take off quickly so the drone must be lightest possible, then recognizing many of the cells of the matrix as possible and finally the drone must drop correct colored loads according to pattern sequence.

Total score = 30 (report) + 30 (mission 1) + 40 (mission 2)

3.1 MISSION REQUIREMENTS

No	Requirement	Rationale
1	High speed	Low weight Good aerodynamic characteristic Suitable motor selection
2	Image Processing	Stable in the air Good camera view Long flying time
3	Payload Capacity	Drone must handle extra weights Good motor selection Should have take-drop mechanism
4	Autonomous Flying	Should have GPS.
5	Stability	Good aerodynamic characteristic Correct component selection Correct Frame Structure
6	Fail-Safe Mode	Fail safe mode should be added

The **general objective** of the competition is to design an UAV system which is capable of performing autonomous flight, image processing and airdrop mechanism. In general, feasibility of drone components such as motor, ESC, LiPo battery and flight controller maximizes the team's score. Besides feasibility planning right mission for cell recognition and dropping right colored loads increases the total score. An overview of mission requirements is presented below.

3.2 TRANSLATION INTO DESIGN REQUIREMENTS

To fulfill the key system requirements, we plan to design our UAV with below features.

- UAV's was decided to be quadcopter as it performs very stable flight with minimum propellers and fast flight.
- The frame of the quadrotor/quadcopter was planned to be carbon fiber as it will ensure vehicle lightness as well as its strong and rigid characteristics.
- The brain of autonomous flying system was planned to be Naze32. But we decided to use APM

2.8 flight controller, because it is more accurate in terms of stability and mission capability.

- For image processing, we have two options Raspberry Pi with PiCam and STM32F4 ARM cortex m4 based low cost and extra fast microcontroller with OV7670 camera.
- We chose second one which is STM32F4 because we have a base experience with this MCU and we want to expand our knowledge. Its specifications are highly enough for image processing and drop mechanism.
- For airdrop mechanism shift-rod triggered by servo was chosen among all because of its reliability and suitability to our vehicle.

No	Requirement	Rationale	Reflections in Design
1	High speed	Low weight Good aerodynamic characteristic Suitable motor selection	Carbon fiber plates and tubes Good air flow through the system Flexible motor holder design
2	Fail-Safe Mode	Competition challenge	APM 2.8 will be planned to switch to fail safe
3	Image Processing	Stable in the air Good camera view Long flying time	Simulated design Designing modifiable camera angle Suitable LiPo selections
4	Payload Capacity	Drone must handle extra weights Good motor selection Should have take-drop mechanism	Thrust must have extra room for payloads Optimized motor selection Suitable design for mechanism
5	Autonomous Flying	Flight Electronic will be equipped with GPS sensor. Autonomous flight most probably will be realized utilizing GPS coordinates	GPS located on the top of the design because of carbon fiber's distortion capability
6	Stability	Good aerodynamic characteristic Correct component selection Correct Frame Structure	Optimized aerodynamic characteristic Most suitable parts should be detected Low weight frame

3.3 CONFIGURATIONS CONSIDERED

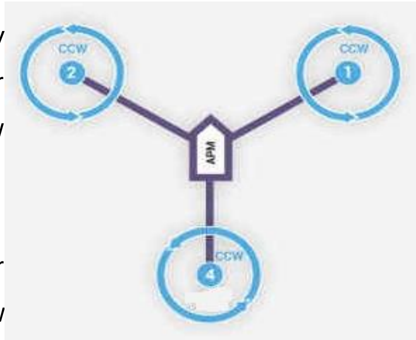
There are two main categories in UAVs as like in our competition that are fixed wing and rotary wing. As comparison between these two configuration rotary wings can hover and stay stable in air at a constant location. The system can protect its location and this brings certain advantages for taking image of a location. Fixed wings cannot stay at a point, they must coil up the location. Taking image from rotary wing is easier than fixed wing. On the other hand, rotary wings have advantages in agility. Since suitability for missions and our teammates' interest, we chose a rotary wing configuration.

Also, there is rotary wing configurations variety. Main property of these configurations is frame shape and rotor number. The configurations listed below.

Criteria	Tricopter	Quadcopter	Y6	Hexacopter	Octocopter	X8
Motor	3	4	6	6	8	8
Frame variations	Y , T	X, +	Y	Hexa X, Hexa Y	Octo X, Octo Y	X
Cost	Lowest	Low	Normal	More expensive	Expensive	Expensive
Camera view	Good	Good	Good	Good	Good	Good
Stability	Low	Good	Good	Better	Best	Very good
Agility	Low	Good	Better	Good	Good	Good
Payload capacity	Low	Good	Better	Higher	Best	Higher
Manufacturability	Hardest	Easy	Hard	Normal	Normal	Hard
Mechanical simplicity	Low	High	Low	Normal	Normal	Low

1. Tricopters

Tricopters has 3 motors that are usually 120 degrees apart and generally in Y configuration. Two propellers at the front sides and other propeller at the rear center. Rear motor has a servo mechanism to enable yaw motion of the system.

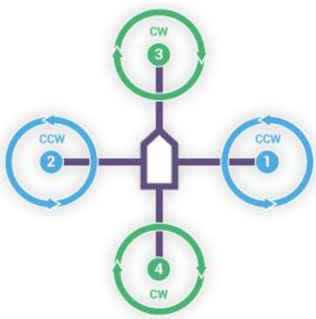


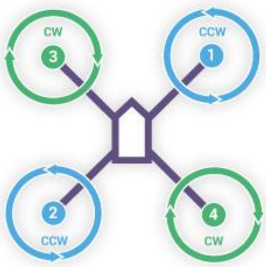
This configuration is the cheapest configuration because of motor number, but it has lowest stability. Also, it is hard to build a yaw mechanism in this configuration. So it is not suitable for our team.

2. Quadcopters

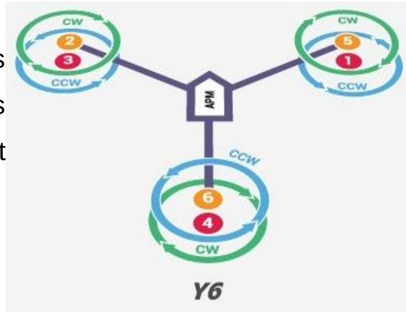
The most popular multirotor configuration is quadcopter thanks to its cost performance character. Quadcopters are fully symmetrical frame which gives simplicity to analyze the characteristics of the system. It has good stability and agility. Mainly there are two main structures of the frame; X, +. X4 configuration gives better view for the camera as design can keep the propellers out of the screen.

We chose X4 (QUAD X) configuration due to its low cost and good property characteristics as in the table that we gave earlier pages.





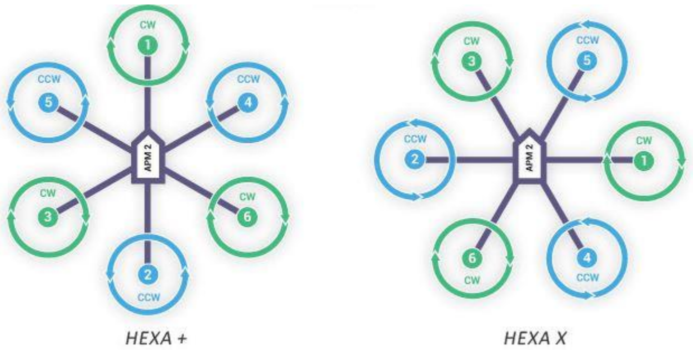
3. Y6



Y6 configuration is similar to tricopter but difference is that, Y6 has two motor coaxial per arm. It has similar character with hexacopters in many ways, such as payload capacity. However, it is less efficient due to the coaxial motor arrangement.

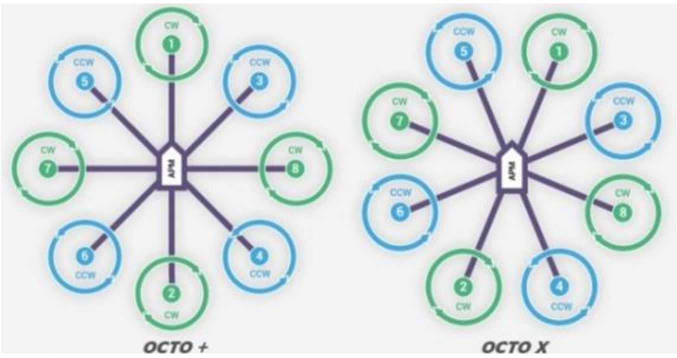
4. Hexacopter

Hexacopters have six motors that are mounted on six arms symmetrically. Mainly there are two configurations as quadcopters which are Hexa X and Hexa +. They are very similar to quadcopter, but it provides more lifting capability thanks to extra two motors. The disadvantage of this configuration is being large in size and they have more expensive cost.



5. Octocopter

Octocopters are basically doubled quadcopters. They have eight motors on the eight arms. The advantage of this configuration is even more payload capacity than hexacopters. They are very stable in the air even if one of the motors, propellers or ESCs fail, they can still be able to land safely. But these features make octocopters most expensive in rotary wing UAVs.



6. X8

X8s have similar properties as octocopters. The difference is that, X8 has eight motors at four arms that are mounted coaxial. It has a more compact body than octocopters but the disadvantage of the high cost still continues.

As our team aimed in mission requirements, we should choose lightest and cost effective frame material. Here our comparison of frame weights.

3.4 COMPONENT WEIGHTING AND SELECTION PROCESS

FRAME MATERIAL

PART NAME	Weight	Material	Note
Drop Mechanism Base	40 g	3D Printed - PLA	%50 – 4 – 4 – 3 – 0,3
Landing Gear Part	7 g X 4	3D Printed - PLA	%50 – 4 – 4 – 3 – 0,3
Motor Holder	25 g X 4	3D Printed - PLA	%50 – 4 – 4 – 3 – 0,3
Plate 1	150 g	Aluminum	2mm Aluminum Plate
Plate 1	106 g	G10	1,9mm G10 Plate
Plate 1	88 g	Carbon Fiber	2mm Carbon Fiber Plate
Plate 2	150 g	Aluminum	2mm Aluminum Plate
Plate 2	106 g	G10	1,9mm G10 Plate
Plate 2	88 g	Carbon Fiber	2mm Carbon Fiber Plate
Plate 3	60 g	Aluminum	2mm Aluminum Plate
Plate 3	43 g	G10	1,9mm G10 Plate
Plate 3	35 g	Carbon Fiber	2mm Carbon Fiber Plate
Camera Holder	20 g	Aluminum or 3D	
Arm Tubes	30 g X 4	Aluminum	Aluminum Profile
Arm Tubes	17 g X 4	Carbon Fiber	Carbon Fiber Tube
Fasteners	25 g		Bolts, nuts
U Profiles	20 g X 2	Aluminum	
Landing Gear	80 g	Not specified	
TOTAL	**333 + 480 = 813 g**		**With Aluminums**
TOTAL	**333 + 375 = 708 g**		**With G10 Plate + Aluminum Profile**
TOTAL	**333 + 323 = 656 g**		**With G10 Plate + Carbon Fiber Profile**
TOTAL	**333 + 279 = 612 g**		**With Carbon Fibers (SELECTED)**

FRAME COST TABLE		
MATERIALS	**DIMENSIONS**	**COST**
2mm Carbon Fiber Plate	400x500 (mm)	350 TL + Manufacturing Cost(?)
16-13mm Carbon Fiber Tube	1m	135 TL + Manufacturing Cost (?)
3D Printed Parts	-	50 TL
Fasteners	-	15 TL
Aluminum U Profile	1m	10 TL
TOTAL		**560 TL+ Manufacturing Cost(?)**

MICROCONTROLLER

Features	Products	
	STM32F429ZI	Raspberry Pi Zero (Selected)
Cost	90 TL	70 TL
Weight	68 gr	42 gr
Difficulty	Hard	Normal
Peripherals Supports(Related to image processing)	UART, SPI, I2C, DCMI, FSMC, DMA	UART, SPI, I2C, CSI
Memory Size	2 MB	1 GB
Clock Frequency	180MHz	1GHz
Size	115mm x 65mm x 14mm	65mm × 30mm × 5mm
Power Consumption	44 mA (145.2 mW)	65 mA (325 mW)

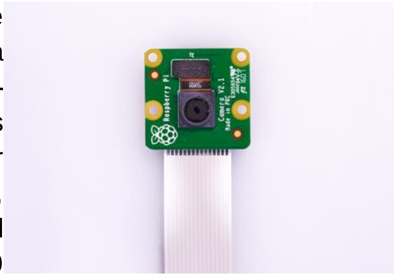
Raspberry Pi Zero is a powerful microcontroller. In our situation Raspberry Pi Zero is used for image processing and drop mechanism. Executing GPIO for drop mechanism is little bit easier than image processing and needs less cpu power in that process. We need to get a microcontroller which process the image got from the camera. Our camera has 480x640 pixels that makes nearly 4 kilobytes each image. This is not big data but microcontroller's clock frequency, cpu power, CSI and like those options must be required. Microcontroller is communicated with camera via SPI and I2C interfaces (depends on user choice) so that SPI and I2C interfaces should be fast to not get any delay. Raspberry Pi Zero's power consumption is 65 mA typical and has 1.7V to 3.6V application supply voltage that makes 2.88 W, in any case this situation is fair for power consumption. Also there is a 1 GB Flash Memory for transferring the image data if needed.

- 512MB RAM
- 1GHz, Single-core CPU
- Mini-HDMI port
- Micro-USB OTG port
- Micro-USB power
- HAT-compatible 40-pin header
- Composite video and reset headers
- CSI camera connector (v1.3 only)

CAMERA MODULE

Features	Products		
	OV7670	Pi Camera V1.3 (Selected)	Logitech Webcam C100
Cost	26 TL	140 TL	48 TL
Weight	13 gr	3 gr	77 gr
Difficulty	Hard	Normal	Easy
Maximum Resolution	640x480	3280 x 2464	640x480
Frame Per Second(FPS)	30	30	30
Power Consumption	0.02 mA	0.014 mA	0.12 mA
Output Format (RGB)	✓	✓	✓
Connection Type	SPI, I2C	CSI (Camera Serial Interface)	Corded USB

The Pi Camera is a low voltage CMOS image sensor that provides the full functionality of a single-chip VGA camera and image processor in a small footprint package. The Pi Camera provides full-frame, sub-sampled or windowed 8-bit images in a wide range of formats. This product has an image array capable of operating at up to 30 frames per second (fps) in VGA with complete user control over image quality, formatting and output data transfer. It's capable of 3280 x 2464-pixel static images, and also supports 1080p30, 720p60 and 640x480p90 video.



It attaches to Pi by way of one of the small sockets on the board upper surface and uses the dedicated CSI interface, designed especially for interfacing to cameras.

- Fixed focus lens on-board
- 8-megapixel native resolution sensor-capable of 3280 x 2464-pixel static images
- Supports 1080p30, 720p60 and 640x480p90 video
- Size 25mm x 23mm x 9mm
- Weight just over 3g
- Connects to the Raspberry Pi board via a short ribbon cable (supplied)

MOTORS

Features	Products		
	Emax XA2212 1400Kv	**Emax GT2215/09**	**SkyRC X2830 (Selected)**
Cost	60 TL	120 TL	60 TL
Weight	50 gr	70 gr	65 gr
Stator Dimension	22 mm x 12 mm	22mm x 15mm	28 mm x 27.5 mm
Shaft diameter	3 mm	4 mm	3 mm
Maximum Current	21A	26A	28A
Li-xx Battery (cell)	2-3	2-3	2-4
Power	205W	280W	350W
Maximum Thrust	940 gr	1250 gr	1300 gr
RPM / V	1400	1180	950

Better Material

- CNC Machined T6 Billet Aluminum Heatsink Can for Impressive and Durable Appearance
- High Quality Bearings for Less Resistance
- High Purity Copper Windings for Maximizes Conductivity

Better Construction

- Leaf-shaped Front Cap for Better Heat Dissipation
- Silicon Cable for Easy Cut and Neat Wiring

Better Craft

- Balance Correction Before Leaving Factory for Best Balance While Running

ESCs

Features	Products		
	Hobby wing Skywalker 20A	Emax SimonK-30A (Selected)	Hobby wing Skywalker 30A
Cost	57 TL	60 TL	61 TL
Weight	19 gr	28 gr	37 gr
Dimension LxWxH	42 x 25 x 8 mm	52 x 26 x 7 mm	63 x 25 x 8 mm
Continuous Current	20A	30A	30A
Burst Current (10sn)	25A	40A	40A
Li-xx Battery (cell)	2-3	2-3	2-3
BEC Mode	Linear	Linear	Linear
BEC Output	2A/5V	2A/5V	2A/5V
Programmable	Yes	Yes	Yes

Features:

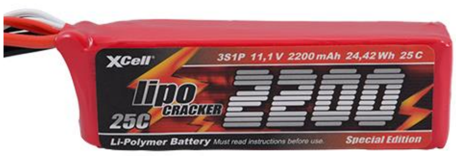
- Based on SimonK firmware, further optimized to the perfect drive performance.
- Low-voltage protection, over-heat protection and throttle signal loss protection.
- Separate power supply for MCU and BEC, enhancing the ESC's ability of eliminating magnetic interference.
- Parameters of the ESC can be set via program card or transmitter.
- Throttle range can be set to be compatible with different receivers.
- Max speed: 210,000 rpm for 2-pole, 70,000 rpm for 6-pole, 35,000 rpm for 12-pole. receivers

PROPELLERS

In order to get the desired efficiency from the motors, we will use the self-tightening 9443 sized propellers.

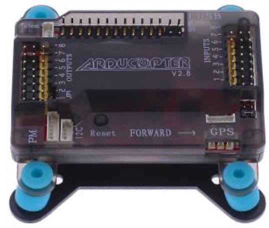
BATTERY

We selected a 3S 2200mah 25C LiPo battery. This battery can provide 55A continuous current. Maximum 40A current required for our quadcopter. This battery provides 6 minutes flying time. This time is sufficient for missions.



FLIGHT CONTROLLER

Features	Products		
	Naze32	Pixhawk	APM 2.8 (Selected)
Cost	83 TL	436 TL	195 TL
Weight	6 gr	38.4 gr	34.8 gr
Difficulty	Normal	Normal	Normal
Autopilot Support	✓	✓	✓
Microchip and Clock Frequency	STM32F3/F4 32-bit, 72 MHz	STM32F427 32-bit, 168 MHz	ATmega2560, 16 MHz
Usage area	Monitorizing ground (for image processing)	Autonomous	Autonomous and stabilization
Power Consumption	0.02 mA	0.014 Ma	0.12 mA
Size	36mm x 36mm	81.5mm x 50mm x 15.5mm	15cm x 12cm x 10cm
Supported Sensors	Accelerometer, Barometer, GPS	Accelerometer, Barometer, GPS	Accelerometer, Barometer, GPS



Ardupilot Mega (APM) is a professional quality IMU autopilot that is based on the Arduino Mega platform. This autopilot can control fixed-wing aircraft, multi-rotor helicopters, as well as traditional helicopters. It is a full autopilot capable for autonomous stabilization, way-point based navigation and two-way telemetry with XBee wireless modules. Supporting 8 RC channels with 4 serial ports. The APM 2.8 a 32bit microcontroller and is capable of flying octos with ease. We have noticed that with the mount stabilization enabled it gets to max CPU, especially when you enable stab in 3 axes. There's work being done to make all the code optimized to run the current feature set on APM 2.8. It's a good stable platform

- Arduino Compatible!
- Can be ordered with top entry pins for attaching connectors vertically, or as side entry pins to slide your connectors in to either end horizontally
- Includes 3-axis gyro, accelerometer and magnetometer, along with a high-performance barometer
- Onboard 4 Megabyte Data flash chip for automatic data logging
- Optional off-board GPS, uBlox LEA-6M module with Compass.
- One of the first open source autopilot systems to use Invensense's 6 DoF Accelerometer/Gyro MPU-6000.
- Barometric pressure sensor upgraded to MS5611-01BA03, from Measurement Specialties.
- Atmel's ATMEGA2560 and ATMEGA32U-2 chips for processing and usb functions respectively.

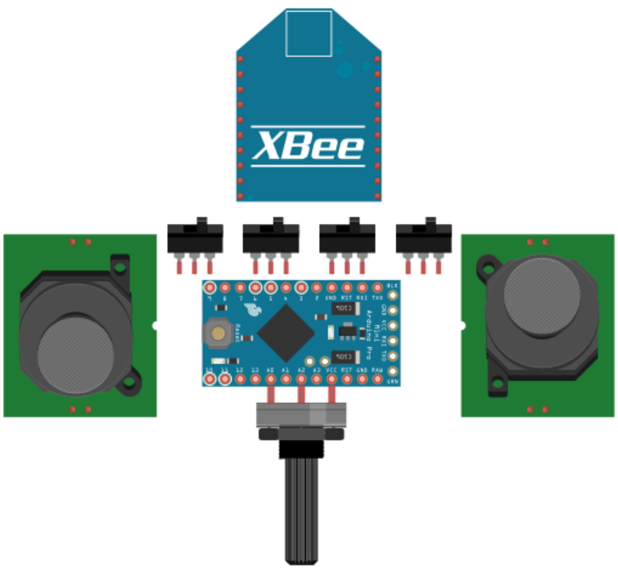
GPS SENSOR

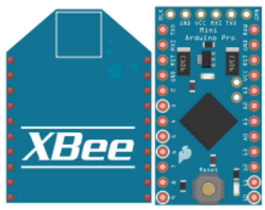
Features	Products	
	Neo-6m (Selected)	Adafruit Ultimate GPS V3
Cost	50 TL	146 TL
Weight	12gr	8.5 gr
Difficulty	Normal	Normal
Range	-161 dBm sensitivity	-165 dBm sensitivity
Accuracy	5Hz,50 Channels (Fair)	10 Hz updates, 66 channel (Good)
Size	16.0 x 12.2 x 2.4 mm	25.5mm x 35mm x 6.5mm
Power Consumption	67 mA	20 mA

The NEO-6 module series is a family of stand-alone GPS receivers featuring the high performance u-blox 6 positioning engine. These flexible and cost effective receivers offer numerous connectivity options in a miniature 16 x 12.2 x 2.4 mm package. Their compact architecture and power and memory options make NEO-6 modules ideal for battery operated mobile devices with very strict cost and space constraints. The 50-channel u-blox 6 positioning engine boasts a Time-To-First-Fix (TTFF) of under 1 second. The dedicated acquisition engine, with 2 million correlators, is capable of massive parallel time/frequency space searches, enabling it to find satellites instantly. Innovative design and technology suppresses jamming sources and mitigates multipath effects, giving NEO-6 GPS receivers excellent navigation performance even in the most challenging environments.

REMOTE CONTROLLER

Remote controller will build with XBee Pro S2C modules. The modules can communication maximum 3200m outdoor range. Handheld control will include toggle switches, joystick button and potentiometer. The data will be processed by Arduino pro. XBee will be transmit to quadcopter. Then Other XBee will receive data that will convert to ppm or pwm signals by Arduino pro.

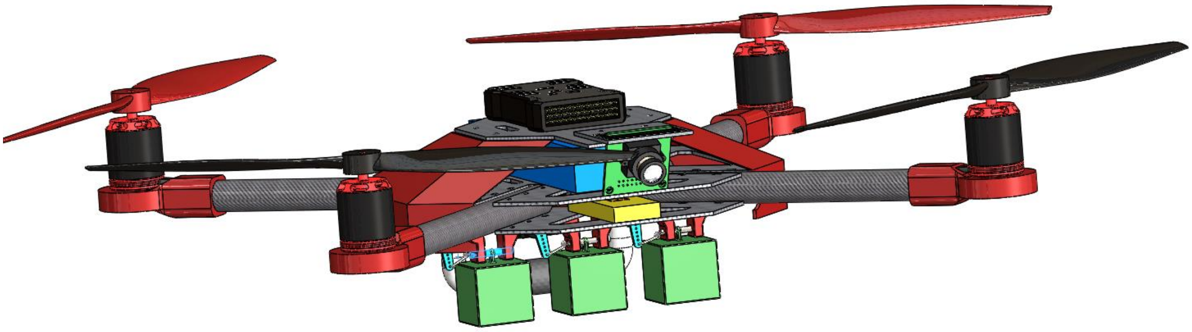




3.5 FINAL CONCEPTUAL DESIGN CONFIGURATION

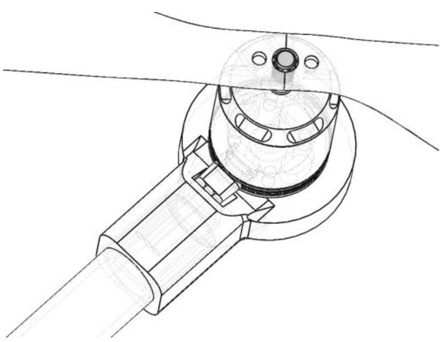
1) Universal Design

Drone structure includes three main plates and four circular tubes. Design is compatible with every kind of components. Every LiPo, motor, ESC, FC or other components can be used in this design. Many components are researched and designed universal.

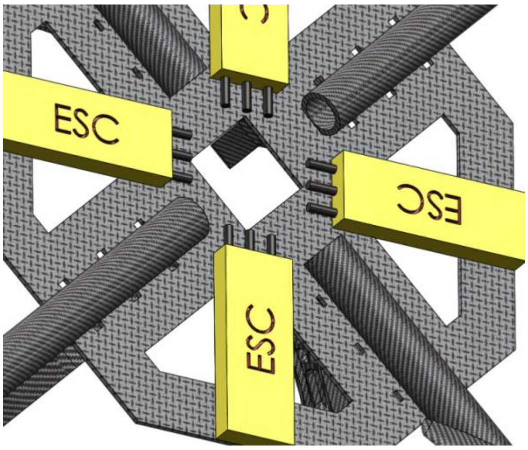


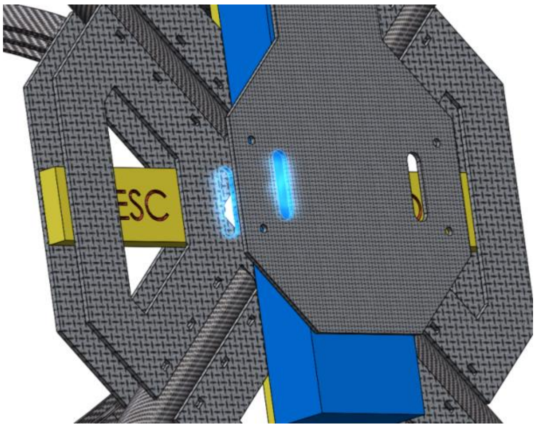
2) Good Planned Multiple Floors

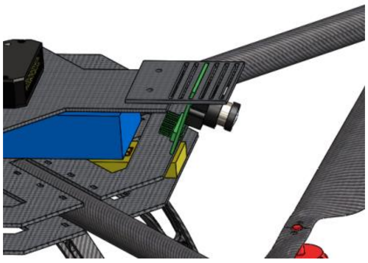
Three main plates hold all electronics. Air is canalized to ESC's floor (bottom plate) to cooling. Motor cables are coming to this floor and connecting to the ESCs. The center plate holds LiPo, thus all power connections are made here. Top plate holds FC, GPS in order to avoid distortion capability of carbon fiber.



First floor is the motors and ESC's floor and it includes their connections. Motors cables are moved in the tube. Connections are at the center. Plate's places where ESC's center is mounted is empty. The reason is cooling. Frame has openness at the front and air enters and circulation is completed through ESCs.







3) Modifiable Camera Mounting

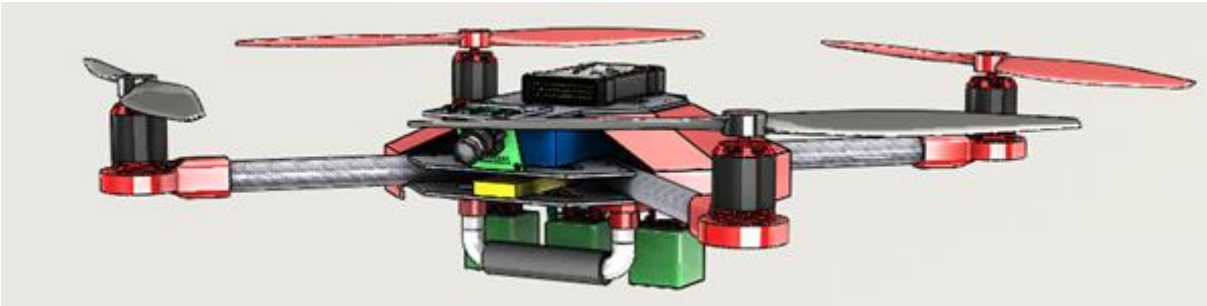
The angle of the camera can be easily changeable. It gives certain flexibility to take a good view from the camera.

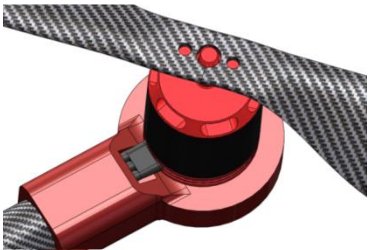
4) Low Inertia

All heavy components are in the middle in order to reduce the inertia in each axis. The heaviest part "LiPo" is at the geometric center of the design.

5) Natural Air Flow – Cooling

Air flow is turned to advantage to cooling electronics and air flow provides better aerodynamic characteristic.

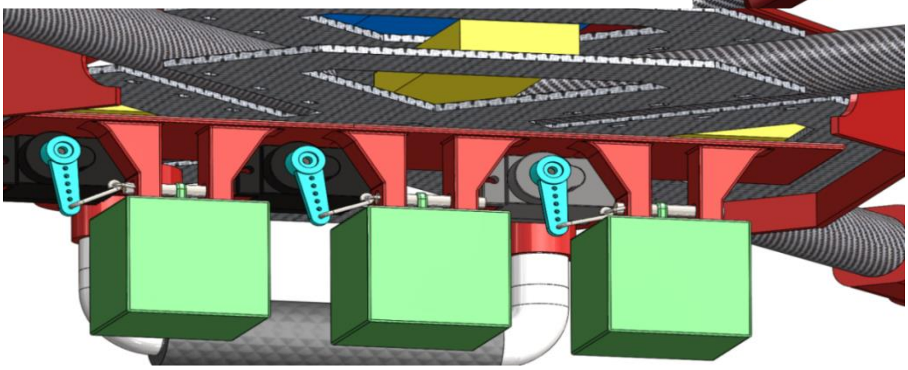




6) Changeable Motor Mounts

In order to have modifiable design motor holders are easily changeable and suitable for every kind of motor.

7) Airdrop Mechanism



4.PRELIMINARY DESIGN

Preliminary design phase provides a more comprehensive summary. The aim of this phase is to further narrow the design space. Piks team investigated materials, design sizing and autopilot computer once again. The team also investigated image processing methods, airdrop mechanism once more.

4.1 DESCRIBE DESIGN/ANALYSIS METHODOLOGY

Initially, as presented in conceptual design report, universal design was chosen, but after report was sent, team focused deeper to obtain most optimum design in which will accomplish both missions successfully with lightest weight and minimum time. Just because all of the design parameters are variable, this was the most reliable way to go. So, after that point, all design parameters should be handled again and they should be optimized.

The design has to be able to;

- Provide fastest, most reliable and autonomous flight
  - Must have minimum weight
  - Should be stable
  - Capable of programming for autonomous route
- Be capable of image processing
  - Detect the 4x4 RGB matrix truly
  - Detect the 4x4 RGB matrix as fast as possible
- Provide payload carry and drop the weights

After detecting the design requirements, the team followed an approach that divides design process into 3 major phases;

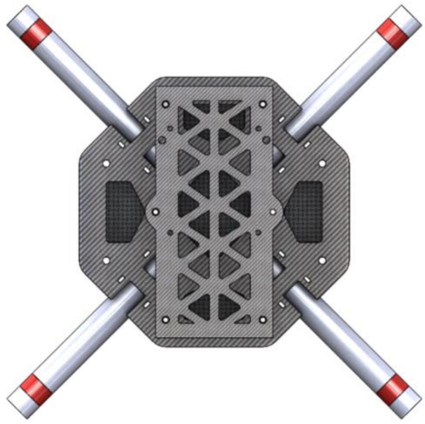
- Mission Requirement and Analysis & Conceptual Design
- Preliminary Design & System Integration and Tests
- Final Design & System Integration and Tests

In the first part of our route, conceptual design, mission requirements, analyzed the datas from rationales was handled again to look deeper. By using inferences from these, preliminary design was developed. Design phase involved subsystem integration, laboratory tests and field tests was done.

4.2 DESIGN AND SIZING TRADES

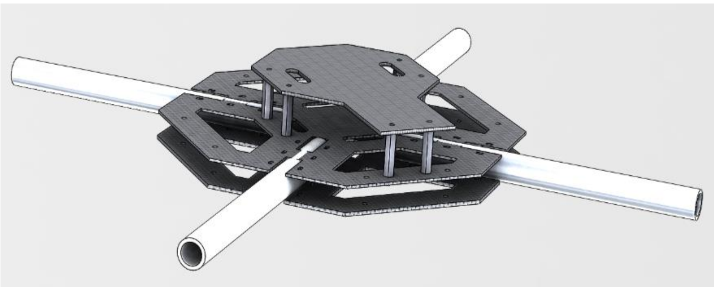
The PIKS team adopted universal design concept at the first stage for being flexible for all requirements and components. Preliminary design optimized by using detected design parameters and components that team was chosen. Preliminary design cost should be low as possible as it can be. In order to produce at low cost, common materials was used and tested. For example, frame material was chosen as carbon fiber, but team used Plexiglas in preliminary design for reduce the cost. But in this case, we payed attention to design to make suitable for both two materials by making small changes. After testing preliminary design team has decided to final design highlights. Preliminary design has same structure concept as in the conceptual design. Design get more compact and as mentioned above, some parts was designed for low cost common materials.

1) Frame

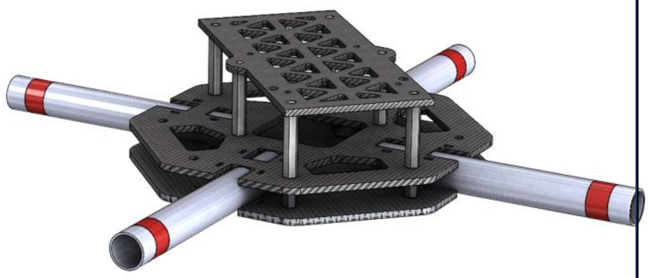


Frame was planned as 3 floor in conceptual design. Same concept continues in preliminary design. Frame material selected as Plexiglas and laser cutting as manufacturing method. Motor arms was planned as carbon fiber in conceptual design. This design uses aluminum profiles for low cost.

Design will be using carbon fiber frame and tubes in final model. This configuration is designed as suitable for both carbon fibers and Plexiglas. Only difference is thicknesses and middle emptying configurations. The differences between conceptual design and planned changes in preliminary model is described as;



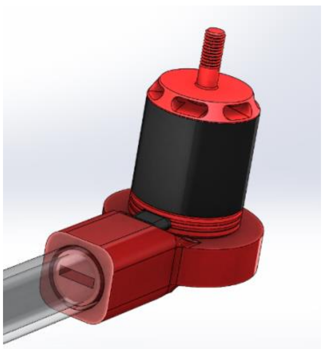
Conceptual Design



Preliminary Design

CHANGES IN	Conceptual Design	Preliminary Design
Frame	Frame was designed universal for all components such as LiPo, flight controller… etc.	More compact and small form is generated Thickness increased for manufacturing from Plexiglas
Motor Arms	Carbon tubes was long for large propellers.	Motor arms was shortened and material thought as aluminum tube.

2) Motor Holders



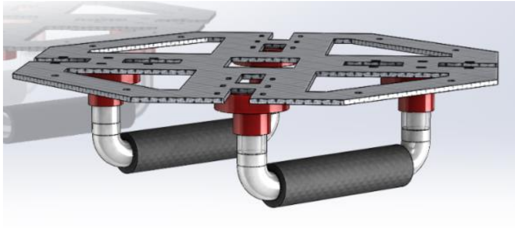
Motor holders are 3D printed ABS parts as planned in conceptual design. In order to more light design, thickness and connection type changed. Strength test was made until optimum thickness was founded.

Preliminary and final design motor holders are same.

Conceptual Design

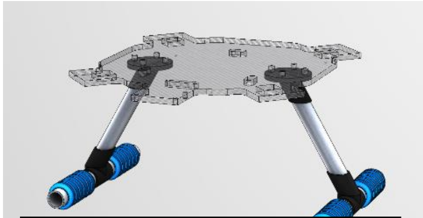
Preliminary & Final Design

3) Landing Gear



Conceptual Design

Landing gear was heavy and it was thought as plastic. Different designs made by different materials of landing gears was tested in same conditions. Plastic was heavy to obtain same strength with respect to aluminum. Carbon fiber wasn't chosen because of its fragile characteristic under shock loads. As a result, aluminum based landing gear was designed.



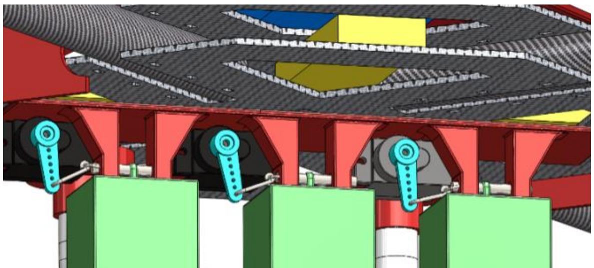
Preliminary and Final Design

Landing gear was not changed after preliminary design.

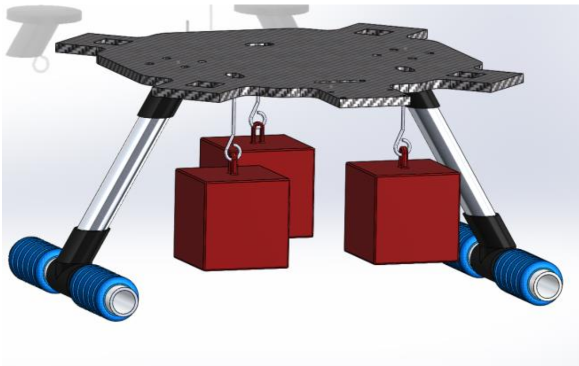
4) Payload Mechanism

Payload mechanism in conceptual design was created from 3D printed base and 3 servos for 3 payloads. Weight calculation for drop mechanism including servos was 115 grams. Total weight's 18,8% was originating from this mechanism. Team investigated light solutions for payload drop and concluded with resistance wire. A plastic based rope is used to connect payload. Plastic rope is connected to base via resistance wire. When drop situation wanted, controller gives current to resistance wire to heat it up and it cuts the plastic wire to drop the payload. It has only wire's and rope's weight which gives excellent amount of weight saving.

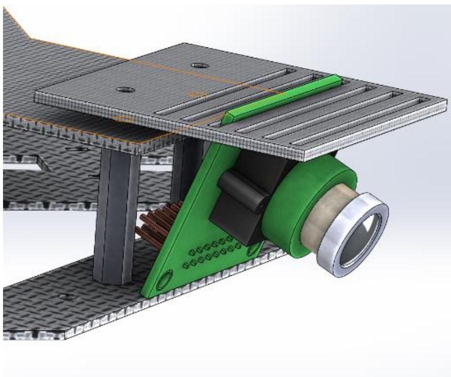
Payload mechanism was not changed in preliminary and final designs as landing gear.



Conceptual Design

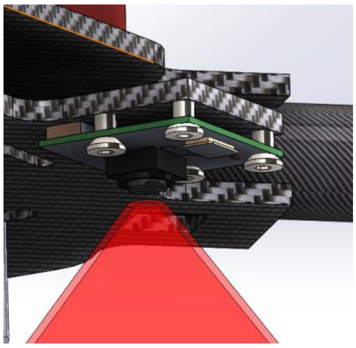


5) Camera Holder



Conceptual Design

Tests was made for taking images from air and angled camera was not that much useful because of perspective. Team has concluded horizontal positioned camera. In order to reduce the weight, gimbal was not used.



Preliminary and Final Design

4.3 MISSION MODEL

UAV must perform two missions. First mission verifies autonomous flight and image processing capabilities of the UAV system whereas second one verifies payload releasing capabilities in addition. The drone will fly in optimum altitude for two reasons. First mission requires minimum altitude to capture very clear pictures whereas second mission requires enough high altitude for parachute deployment after payload releasing. Description of each mission modelling is explained below

- **Image Processing (Mission 1)**
  Image processing code is running in Raspberry Pi Zero microcomputer. Pi camera v1.3 - The latest camera of Raspberry pi – was utilized for its better capturing characteristics. The software is written in python language and developed in Linux OS terminal. OpenCV library is used for edge detection and color recognition.
  Images are taken right after drone comes over the matrix platform. Once drone arrives the preplanned point the autopilot of drone, pixhawk, informs the Raspberry pi by using pixhawk's MAVLink protocol then Raspberry pi initializes its regular operations.
- Operations are described below;
  - ✓ Take picture of 4x4 matrix and save in a folder.
  - ✓ İmport the saved picture to be analyzed.
  - ✓ Detect the edge of overall matrix and then detect edges of each cell.
  - ✓ Recognize color of each cell by applying RGB filter.
  - ✓ Create a .txt file and write the proper matrix there. (each color is assigned to a dedicated number. I.e.: R- 1. G – 2, B - 3)

Operations are carried 3 times. Expected duration for image processing operation is approximately 3 - 4 seconds. For each step, colors of matrix cell are changed randomly, and every iteration remains stationary for 10 seconds and also time interval between iterations is 5 second.

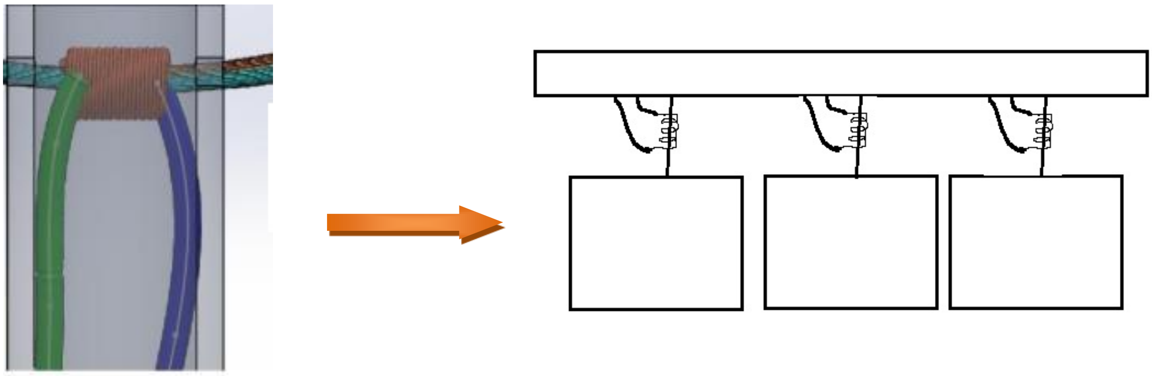
Drone must stay over the matrix pattern totally 45 second, then it must return to home. This means that there are only two waypoints. The whole flight will be autonomous including take – off and landing.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
#import image

frame = cv2.imread('test_image.png')

a = np.random.randint(3, size=(4, 4))
ax = np.random.randint(500, size=(4, 4))
ay = np.random.randint(500, size=(16))

lower_color_g = np.array([0,220,0])
upper_color_g = np.array([255,255,255])

lower_color_b = np.array([220,0,0])
upper_color_b = np.array([255,255,255])

lower_color_r = np.array([0,0,220])
upper_color_r = np.array([255,255,255])

mask = cv2.inRange(frame, lower_color_r, upper_color_r)
res_r = cv2.bitwise_and(frame, frame, mask = mask)

mask = cv2.inRange(frame, lower_color_g, upper_color_g)
res_g = cv2.bitwise_and(frame, frame, mask = mask)

mask = cv2.inRange(frame, lower_color_b, upper_color_b)
res_b = cv2.bitwise_and(frame, frame, mask = mask)

kernel = np.ones((5,5), np.uint8)
```

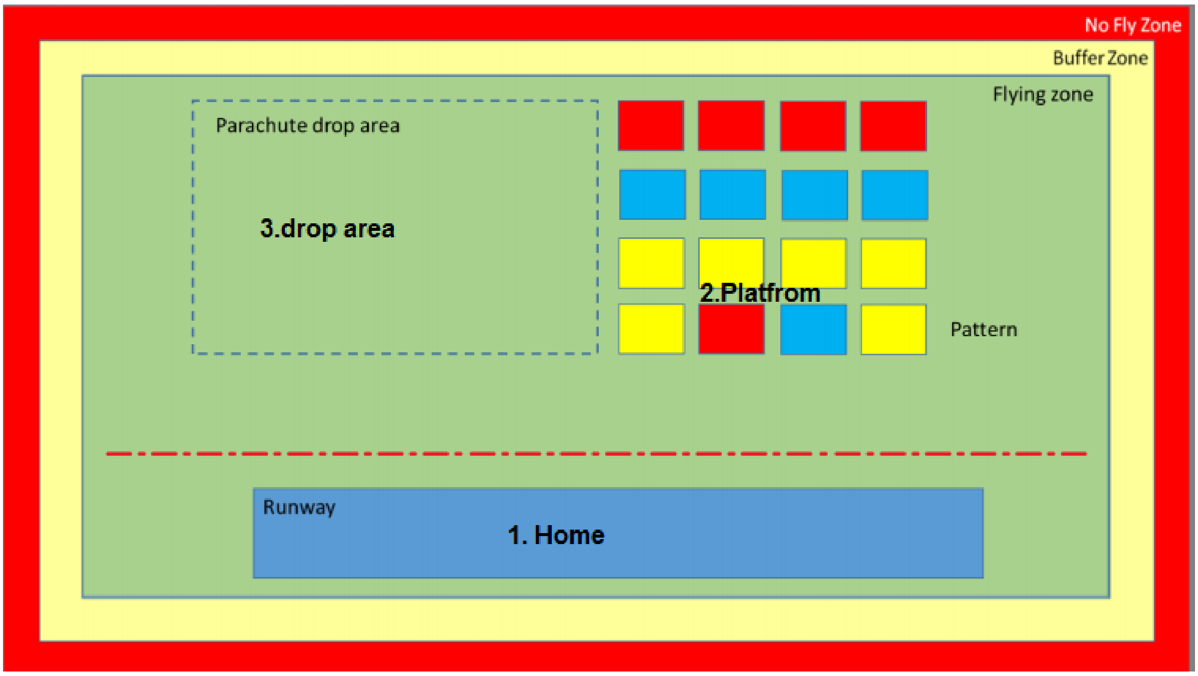
Drop Mechanism (Mission 2)

Load release/drop mechanism is controlled by Raspberry Pi Zero. The camera previously described is used for photographing. The mechanism is based on melting a nylon rope that is connecting payloads to the drone. Colored payloads (Red, Green, Blue) will be attached to drone. And the resistance wire will be wrapped around rope 3 times to ensure it will melt the rope rapidly. Parachute will include a spill hole to allow continuous airflow and so stabilize descent of payloads.

The wire cut mechanism was tested. The nylon rope cut in 5 seconds.



In this mission there are three waypoint compared to first mission. First one is home second is platform and final one is drop area. The drone will first take off autonomously up to 15 meter then it will fly toward the platform and stay over the platform. The crucial point is to confirm it is over the platform either way. The mavlink protocol will be used for this task. Right after confirming that drone is in right place the image processing will initialize and drone will detect the color sequence on the matrix platform. Once sequence detected, drone will fly toward third waypoint where will drop the loads. The drone will drop the loads according to the color sequence with 5 seconds interval. On-board computer will handle all of operations.



4.3 ESTIMATES OF AIRCRAFT LIFT, DRAG AND STABILITY CHARACTERISTICS

The performance analysis is feedback of designing the aircraft. In order to achieve the mission requirements in most optimum way; many tests, calculations and design process had been carried on. Our aim was design and manufacture the quadcopter as light as possible and also stable as much as we need. In that case, our final design parameters are given as below.

Ampere(A)	Power Consumption(W)	Thrust Value(gr)
2	23.7	233
3	36.2	320
4	48.5	390
5	58.5	460
6	71	540
7	82.5	590
8	96.1	660
9	107.2	700

DJI 9443 (Selected)

Ampere(A)	Power Consumption(W)	Thrust Value(gr)
2	24.6	210
3	38.4	300
4	48.7	370
5	59.6	440
6	72	500
7	84.2	580
8	97	630
9	107.7	670

DJI 9450

Ampere(A)	Power Consumption(W)	Thrust Value(gr)
2	25	210
3	36.2	280
4	49.7	350
5	56	400
6	72	460
7	82.5	510
8	96	570
10	116	650

1045

Ampere(A)	Power Consumption(W)	Thrust Value(gr)
2	25	170
3	36	230
4	47	290
5	56	340
6	72	390
7	82.5	450
8	96.1	530
10	114	610

8045

4.4 ESTIMATES OF AIRCRAFT MISSION PERFORMANCE

The main reason for choosing the Raspberry Pi Zero was its enough processing power for missions. Besides this, it will accomplish both missions quickly. With APM controller the drone will take off and navigate waypoints autonomously. With marlin protocol the APM inform the Raspberry Pi to start out mission operations. With wire cut mechanism the drone will drop the loads.

Drone has 27 km/h speed in standard condition. Patterns are approximately 100 meters far away from landing area. If calculations are made, we should able to get patterns in 14 seconds. However, we assume that there may be unexpected conditions so we give 5 seconds tolerated value. Patterns are changed in 5 seconds and this will happen 3 times. The tolerated timing value is 60 seconds. In second mission arriving time to drop area will be 10 seconds or little bit more. Dropping time has to be at least 15 seconds so we give 40 seconds to complete that submission.

5 DETAIL DESIGN

5.1 DIMENSIONAL PARAMETERS OF FINAL DESIGN

Mission 1	Timing(s)
Reaching patterns	20
Taking pictures from ground	60
Coming back	20

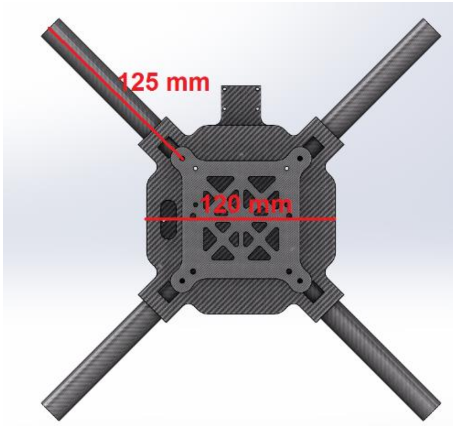
Mission 2	Timing(s)
Reaching patterns	20
Taking pictures from ground	60
Reaching dropping area and dropping loads	40
Coming back	30

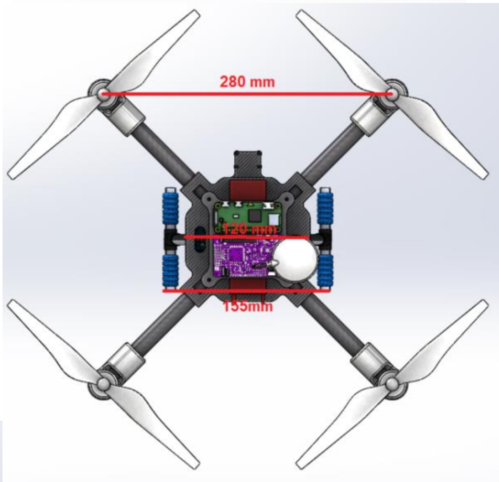
Frame has octagonal structure with 120mm length as shown in figures. It is the minimum length to carry the electronics and space for motor arm connections.

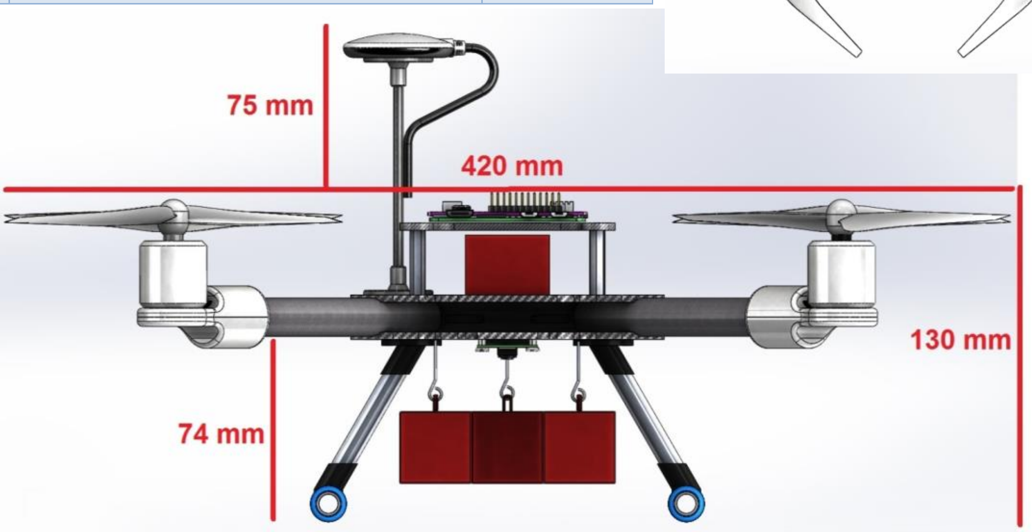
Motor arms has 125mm total length.

Overall system dimensions shown in the both figures and tables to be more readable.

		Dimension
Heights	Maximum Height	210 mm
	Height (Except GPS)	130 mm
	Height of Landing Gear	75 mm
	Height of Payloads from Ground	15 mm
Widths	Maximum Width	420 mm
	Width (Except Propellers)	280 mm
	Frame Width	120 mm
	Landing Gear Width	155 mm
Lengths	Length of Motor Arms	125 mm
	Maximum Motor to Motor Length	395 mm
	Propeller Diameter	240 mm







5.2 STRUCTURAL CHARACTERISTICS OF FINAL DESIGN

The structural frame of the vehicle was designed keeping in mind active loads applied during flight. The loads are as follow;

- **Thrust load** which applied by propulsion system - The system must survive shock. Torque is transferred adequately to the all parts of drone.
- **Ground loads** which applied during landing - the system must survive when during landing since landing impact and weight of drone plays major role

5.3 SUBSYSTEM INTEGRATION & SYSTEM ARCHITECTURE

Piks team’s initial target was to manufacture an UAV system as original as possible. Thus the team investigated several different ways in the conceptual design phase. We first attempted to design our own special dedicated flight controller which will be capable of fully autonomous flight and robust stabilization supported by GPS + GNSS system. However, considering multiple projects, the team members are currently enrolled we unable to enter this marathon. But we still did not give up this initial idea that we should design and produce such special aerial vehicle for fulfilling the rules in very best way.

To sum up, the team achieved to design at least some subsystems originally which means it absolutely belongs to the Piks team. Team spent so much time on this. Because it is not only important to gain the best score and get a significant ranking in the competition, either way we will get the considerable score in the competition but the actual factor which satisfy team desires is to obtain an original and robust system. Finally, the team achieved to design below subsystems originally. We are currently working on the subsystems production. And also we aim to work on our own flight controller for the following years. With government support we deeply believe we will achieve this.

- **Radio Control Subsystem;**

  Remote controller was specially designed by Team Piks. It’s architecture is based on XBee communication module and Arduino pro mini. The detailed architecture of the UAV is described in the following sections. The system relies on potentiometers turning which gives ADC value to Arduino. On the opposite side there is another Arduino and Bee, likewise. The XBee at ground station sending ASCII encoded data to opposite XBee in the UAV. The XBee at the vehicle receives the incoming data and forwards to Arduino. The Arduino converts the ASCII value to PPM/PWM signal which is recognized by APM autopilot control board. The entire system was embedded into a classical RC and it is tested. After test we saw that it is functioning just like the traditional remote controller (AT9).

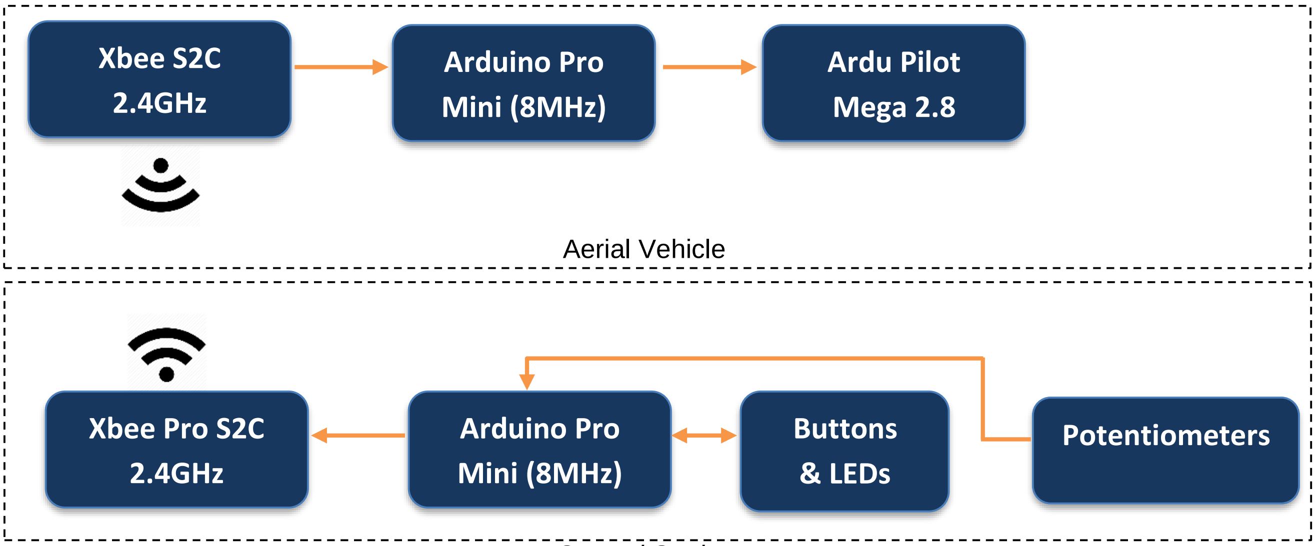
  For fail safe, Arduino was programmed to detect that state. İn case of any communication loss, the system will shift to the required state (descent with half throttle) – security. Battery state indicator and power off button is also included on the RC. Besides those, a special dedicated toggle button is included as autonomous flight initiator.

  At the beginning there were several troubles in the system, especially delays momentary outliers and we fixed those troubles by making minor changes in the code – removed some bugs. Used XBee model is S2C. At the ground station the XBee Pro S2C is used with 2dbi duct antenna whereas XBee S2C is used in the aerial vehicle without any external antenna (its own wire antenna). The communication frequency is 2.4GHz. We present block diagram and pictures of achieved system.

XBbee at ground

Xbee at the vehicle

The block diagram of Radio Controller

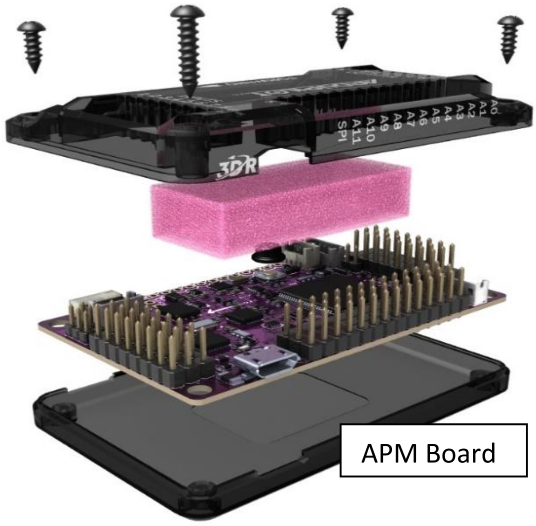


- **Autopilot Subsystem;**

  in order to execute autonomous flight, the drone is equipped with autopilot control board. The board is preferred as **Ardu Pilot Mega** as it has required features.

  The features;

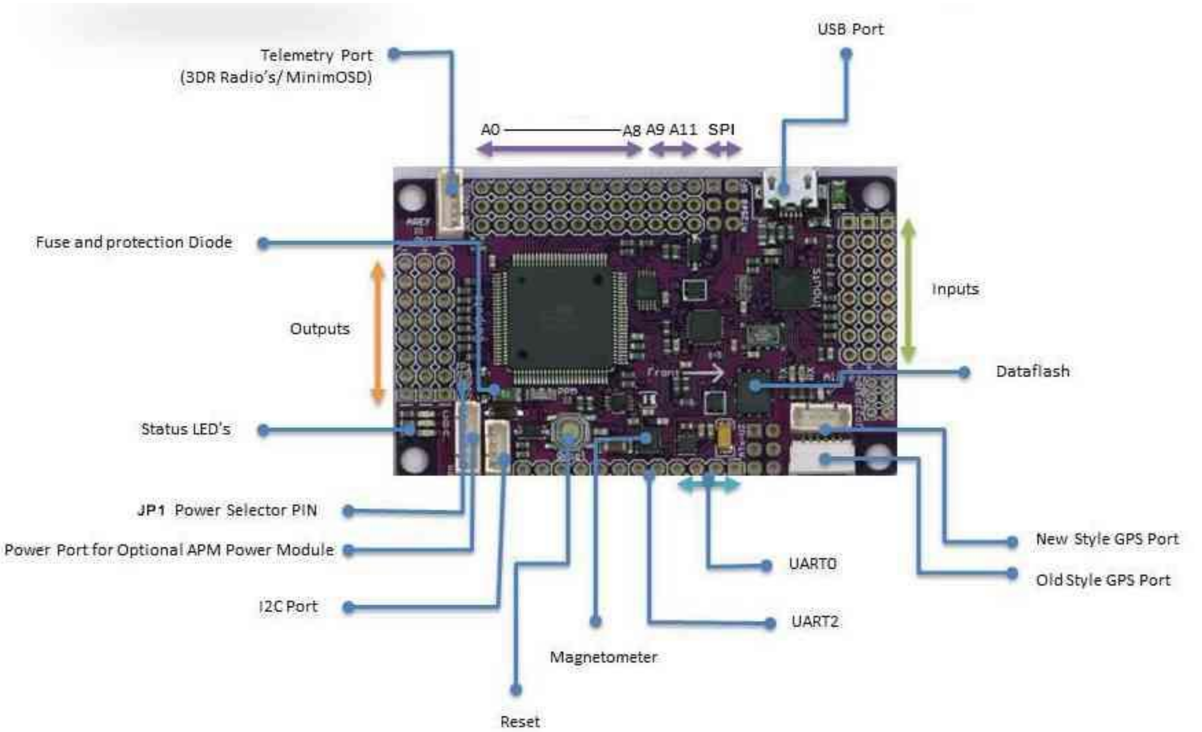
  - ✓ Easy to use and reliable hardware and
  - ✓ software.
  - ✓ Fully autonomous autopilot – capable of self-take-off, navigation and landing
  - ✓ Very nice interface for mission planning
  - ✓ Possibility to modify source code.
  - ✓ Small size which is important factor throughout design.
  - ✓ Relatively cost effective.



APM Board

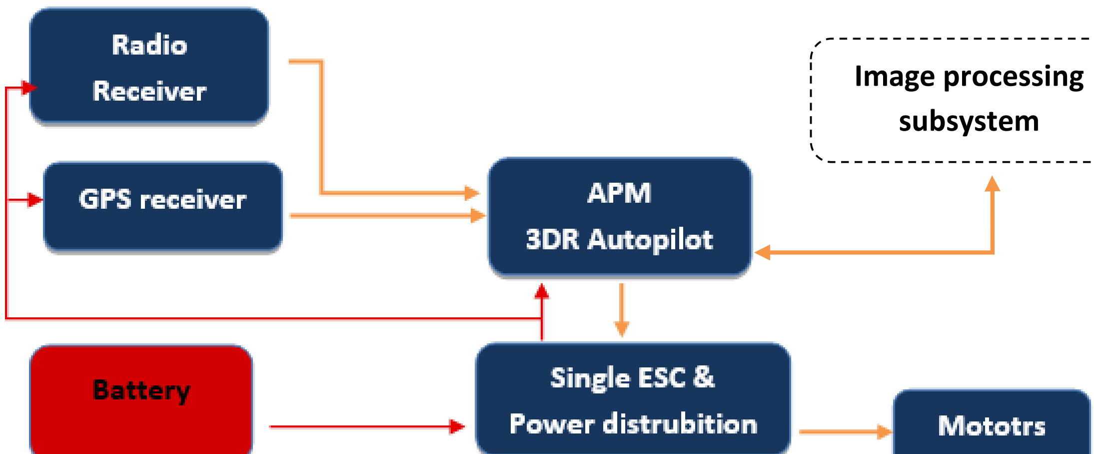
As discussed in preliminary design section of report, we initially considered naze32 control board. The board was extremely cost effective, very small and available in turkey. However, after several tests we saw the weakness of the board. The board was not very stable in autonomous especially in GPS hold mode – reliability problem. Finally, we realized that those boards re aimed for racing vehicle they support autonomous flight but not as useful as desired. There are multiple choices for naze32 mission planning software but even the most common one – iNav – was not so satisfying in terms of mission planning.

After giving up the naze32 we researched most reliable and cheap boards. And open source feature was still remaining. We concluded with APM and Pixhawk control board. Since Pixhawk is not easily accessible and also APM and Pixhawk are supported by the same software the only difference was in the hardware. We cannot ignore the robustness of Pixhawk hardware APM last version was the closest choice for us. The APM has on-board İMU sensor which includes 9 dof

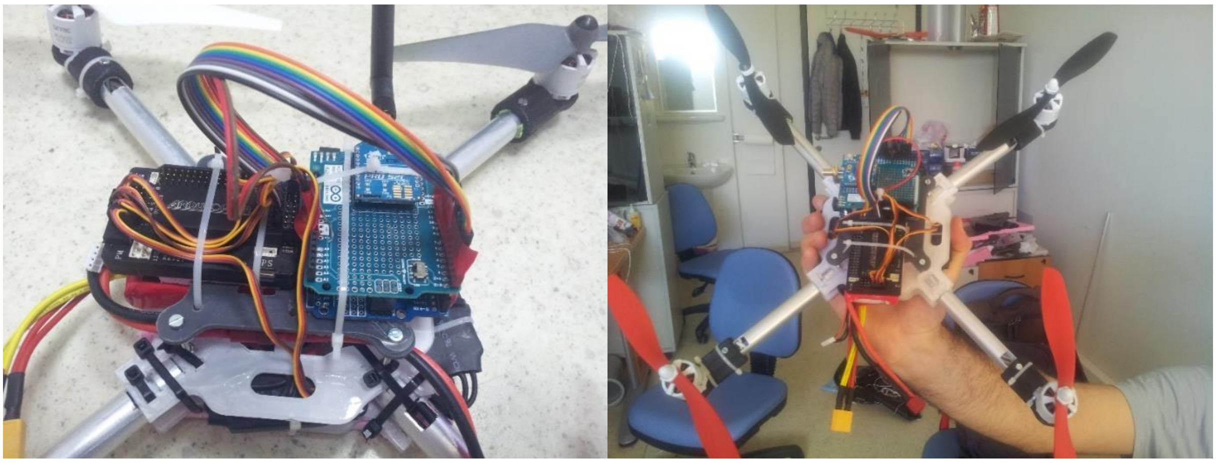


APM Board (without case)

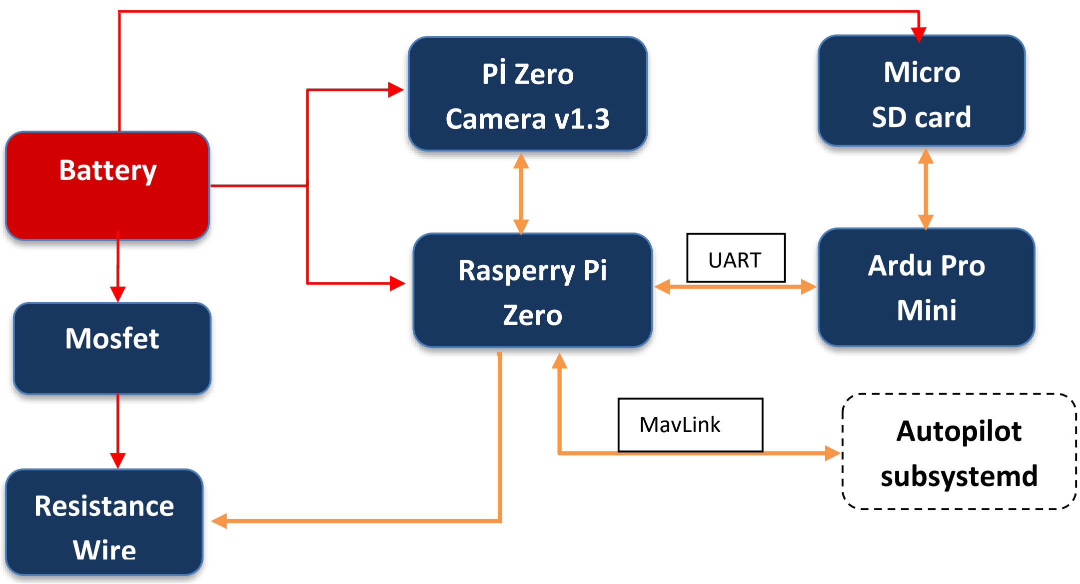
The board is easily found in Turkey (bought from robotistan) and has simple setup. Our another reason for choosing this board was its capability to communicate with the payload system. The communication is operated over MAVlink protocol of ardupilot. We present autopilot architecture of 407S aerial vehicle.



Autopilot System of 407S

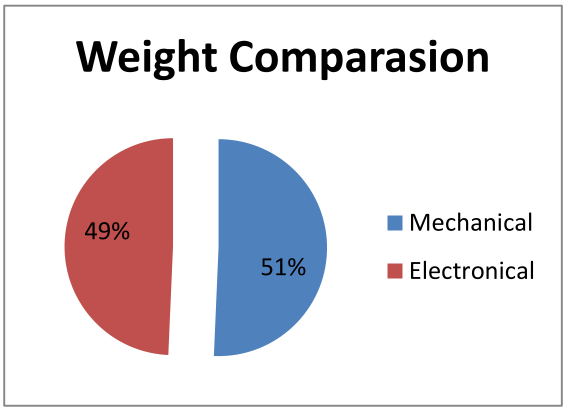


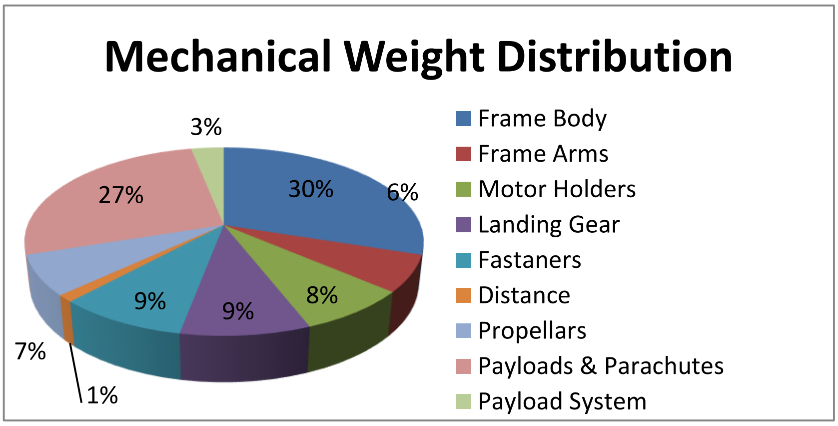
- **Payload;**
  The UAV was purposed to execute specific tasks – image processing and airdrop mechanism. We present the block diagram of our payload subsystem.

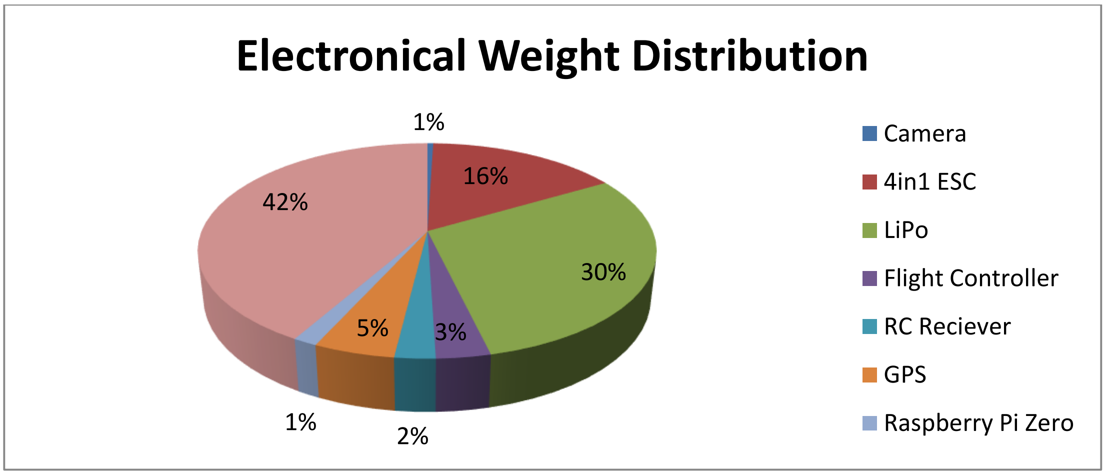


5.4 WEIGHTS AND BALANCE OF FINAL DESIGN

	Materials, Components	Pcs	Total Weight (g)	Notes
Mechanical Systems	Frame Body	1	201	3 mm Carbon Plate
	Frame Arms	4	42	16mm Carbon Tube
	Motor Holders	4	52	3D Printed ABS Plastic
	Landing Gear	2	60	10mm Aluminum Tube + 3D Printed ABS Plastic
	Fasteners	60	50	Different diameters and lengths
	Distance	4	8	
	Propeller	4	46	DJI 9443
	Payloads &Parachutes	3	180	
	Payload System	3	21	
	TOTAL MECHANICAL	**-**	**660**	
Electronic Systems	Camera	1	3	RasPi Camera
	4in1 ESC	1	100	Emax
	LiPo	1	185	
	Flight Controller	1	20 (?)	Ardupilot
	RC Receiver	1	15 (?)	XBee + ProMini + PCB
	GPS	1	? 30	
	Raspberry Pi Zero	1	9	
	Motors	4	260	
	TOTAL ELECTRONIC		**642**	
	TOTAL		**1302**	







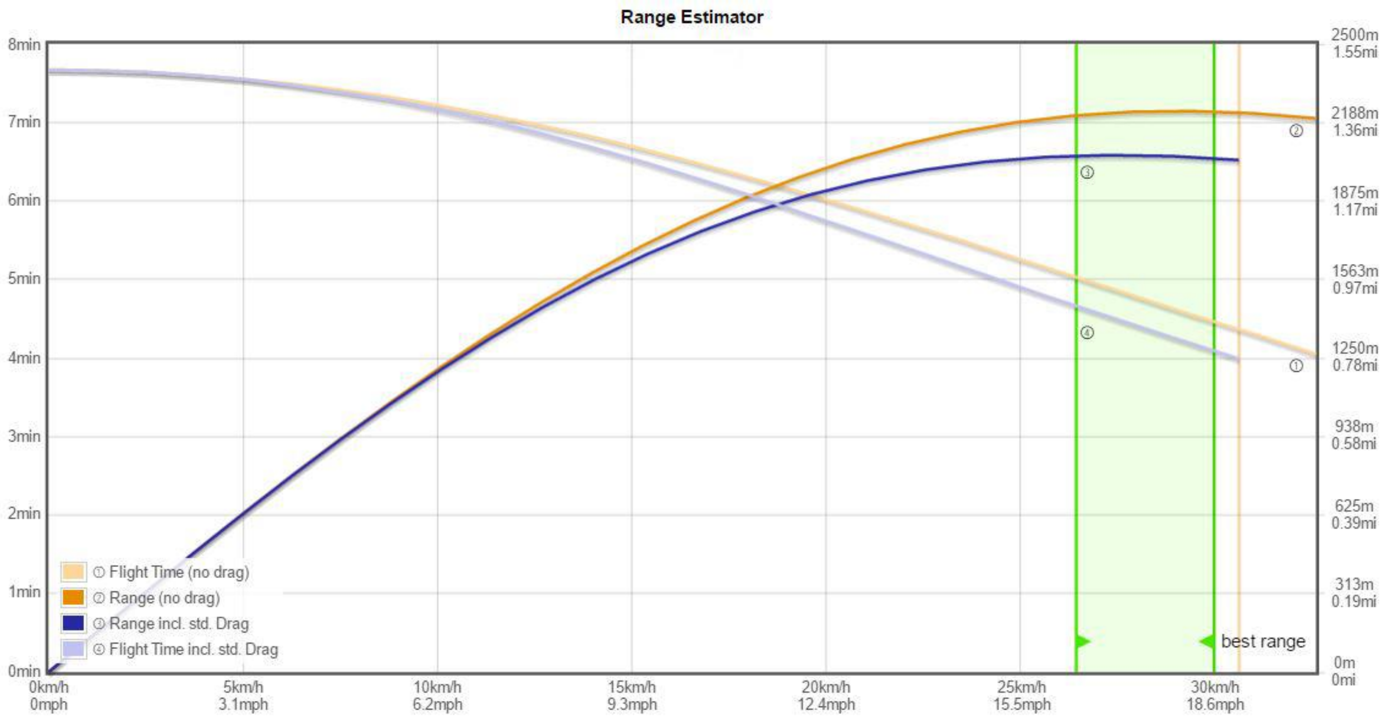
5.5 FLIGHT PERFORMANCE OF FINAL DESIGN

The performance of drone and mission expectations was compered until results satisfies the team. Our expected and final design parameter comparison is also given as a table. Calculations was made under 30 °C temperature and 1000hPa pressure. 2200 mAh LiPo's only 1870 mAh capacity was used to calculate flight time.

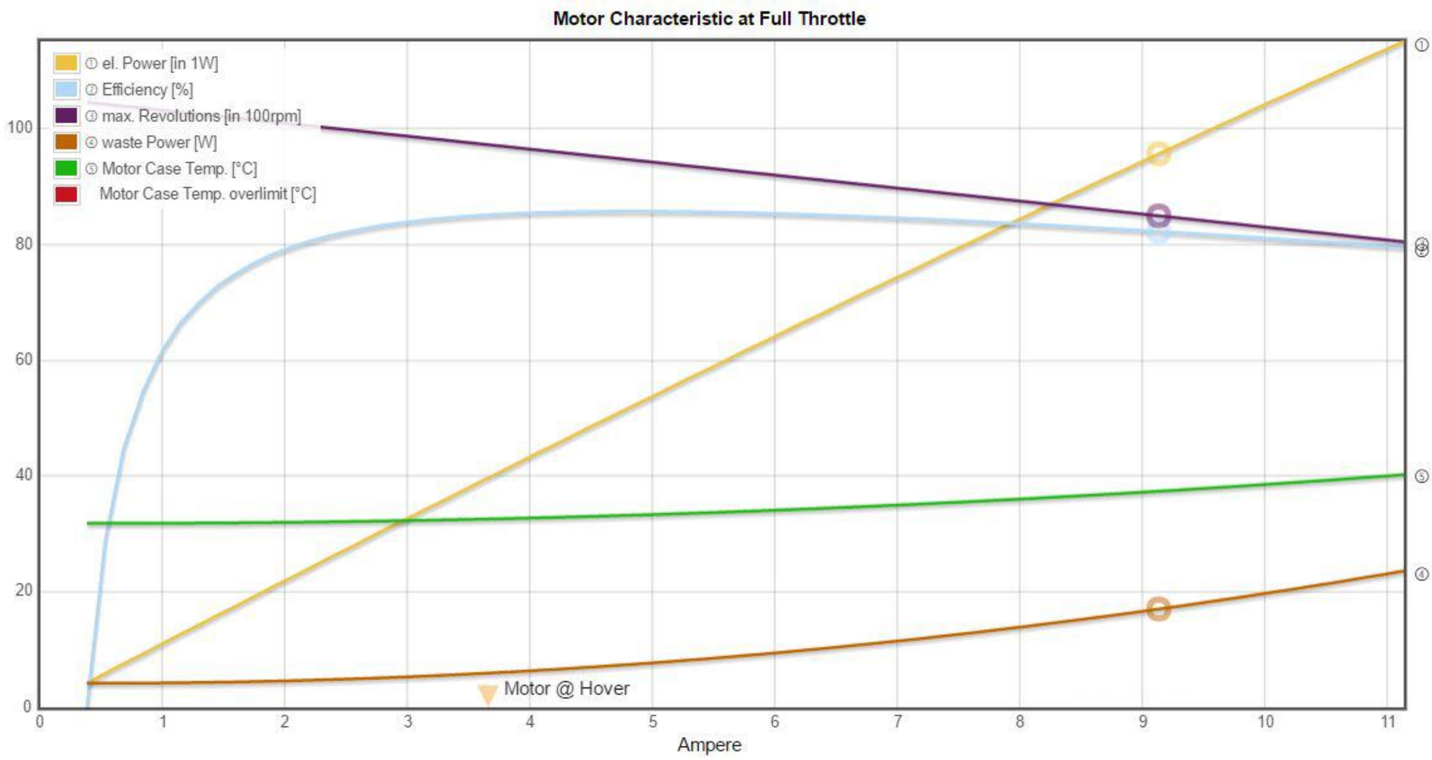
Calculated performance parameters are given as a table at the right side. Comparisons between expected and final results are given below. Also the graphs about finding best speed – travel distance – flight time and motor characteristic under different conditions.

Performance Parameters	
Load to battery (C)	16,86
Hover flight time	7,7 min
Electrical power	97,1 W
Estimated temperature	38 °C
Thrust – weight ratio	1,8
Specific thrust	7,6 g/W
Payload capacity	750 g
Maximum tilt	50°
Maximum speed	34 km/h
Speed of climbing	18 km/h

	Parameter	Expected;	Final Result
Flight Times	Minimum flight time	3 min	3 min
	Mixed flight time	5 min	5.8 min
	Hover flight time	7 min	7.7 min
Efficiencies	Overall efficiency at Maximum Load	78 %	77,2 %
	Efficiency at Hover	78 %	79,7 %
Thrusts	Thrust – weight ratio	1,75	1,8
	Specific thrust	7,5 g/w	7,66 g/W
Speeds	Maximum speed		34 km/h
	Speed of climbing		18 km/h
	Best efficient speed		27,5 m/s



This above graph shows the preferable speed for efficiency is 26-29 km/h. Team planning to use 27,5 km/h speed during missions. Preferred speed gives expected mission time as mentioned in related chapters.



This graph shows the response of the parameters with increasing motor current values. By simply looking at the graph, we could see the minor changes of the motor case temperature. It doesn't exceed the critical temperatures. Between 4-9 amps the power wasted changes normally, but it increases more while it exceeds 9 amps. Electrical power increases linearly with the motor current. When it comes to the efficiency, it is almost steady between 2-9 amps. As for rpm, we could choose the efficient point as 9 amps for motor current and we could use this average data in calculating the time of flight.

5.6 AIRCRAFT COST

FRAME COST TABLE		
MATERIALS	**DIMENSIONS**	**COST**
3mm Carbon Fiber Plate	151 x 170,5 (mm) First Floor 151 x 151 (mm) Second Floor 113 x 110 (mm) Third Floor	500 TL + Manufacturing Cost(?)
16-13mm Carbon Fiber Tube	1m	65 TL
3D Printed Parts	-	50 TL
Fasteners	-	15 TL
Aluminum Profile	3m	15 TL
TOTAL	**-**	**645 TL+ Manufacturing Cost(?)**

ELECTRICAL COST TABLE		
PART	**QUANTITY**	**COST**
APM Flight Controller	**1**	**COST**
ESCs	4	

Motors	4	65 TL
Power distribution board	1	50 TL
Pi Zero Camera v1.3	1	15 TL
Receiver (Arduino Pro mini + XBee)	1	15 TL
TOTAL	**-**	

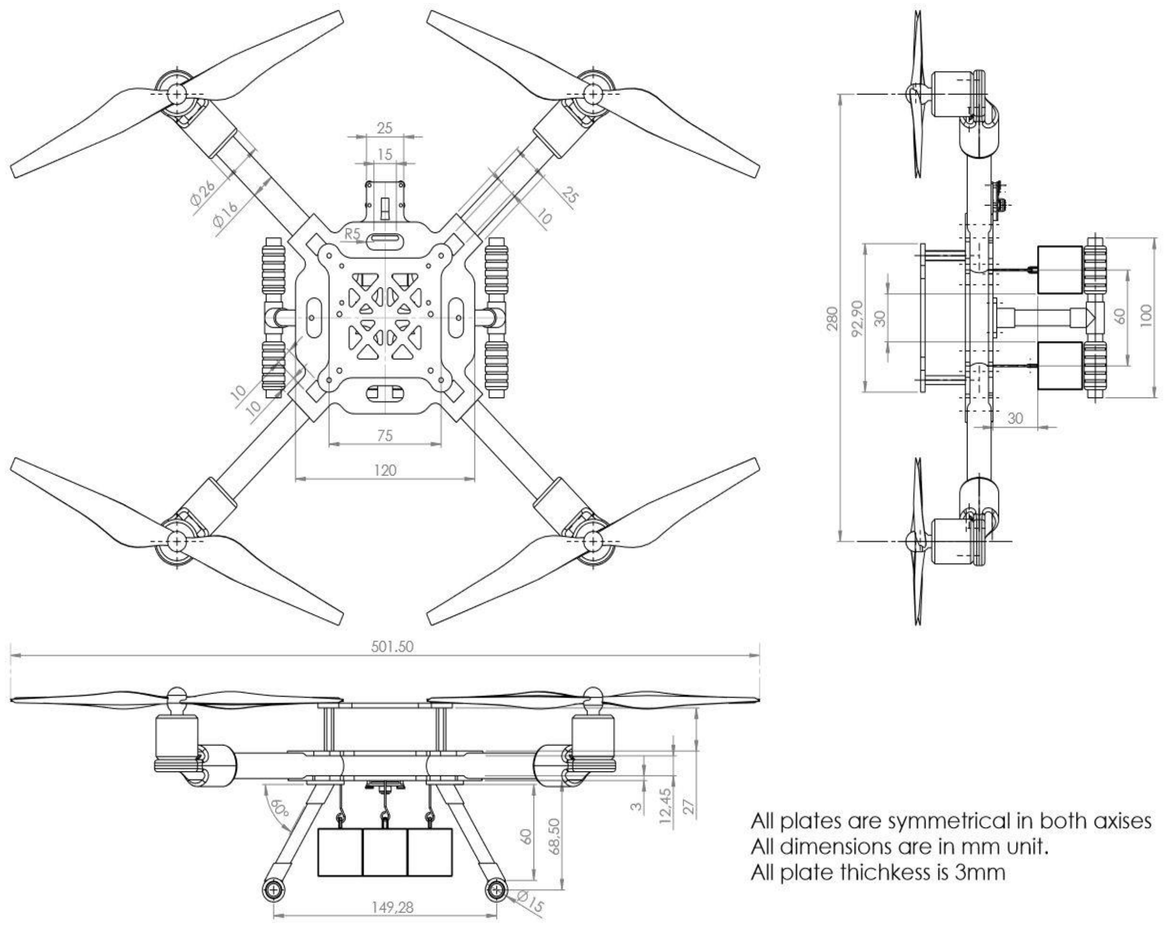
5.7 MISSION PERFORMANCE OF FINAL DESIGN

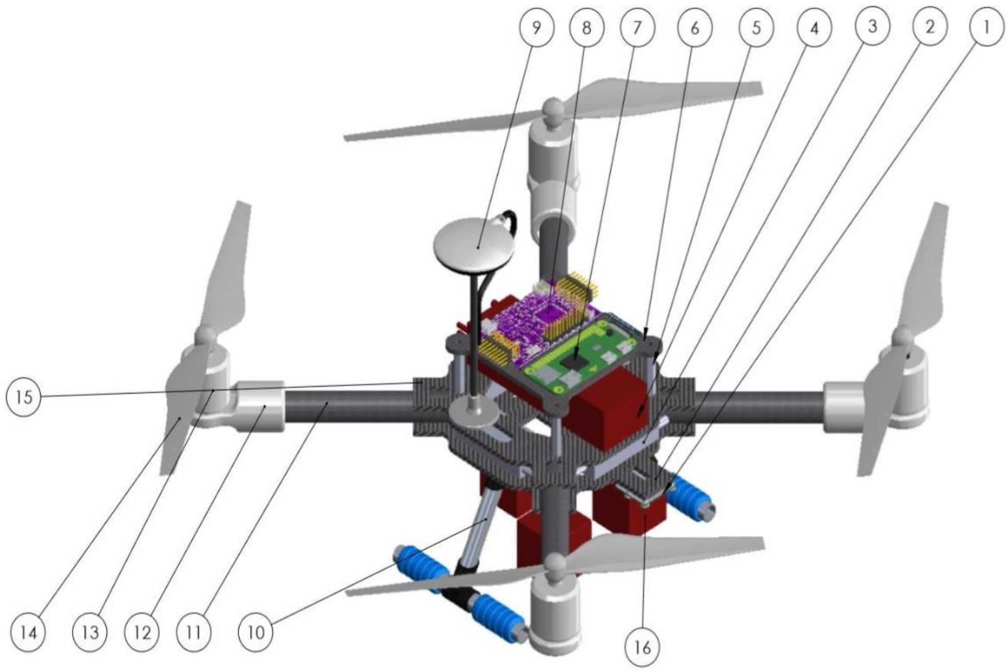
The drone is expected to take off within 10 seconds with maximum 18km/h take-off and fly onto the platform within 5 seconds. In order to eliminate the effect of aerodynamic shadow, an airframe in special cooling structure was designed. This will lead to smooth flight of the drone.

- **Mission 1**
  The ideal duration for image processing operation is 45 seconds. The drone will hover over the platform for 45 seconds. APM will be planned in mission planner to wait over the platform for 45 second and then it will return to home. Tos um up, total mission 1 duration is approximately 2 minutes with safe tolerances.
- **Mission 2**
  Similarly, 5 seconds are sufficient for recognizing the color sequence on the platform. The drone will drop loads every 5 second, this corresponds to approximately 1 minutes.

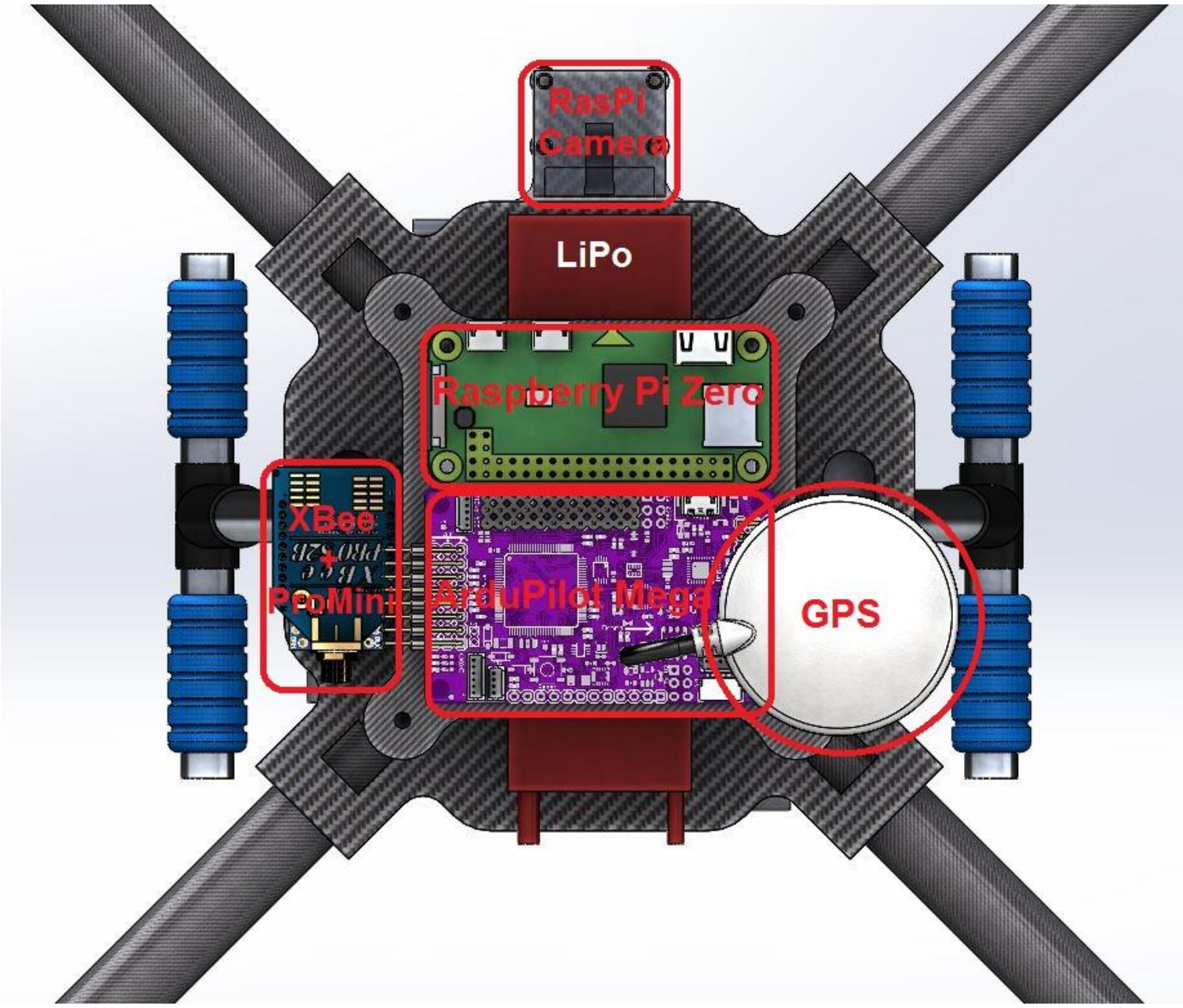
The battery is chosen by checking these values.

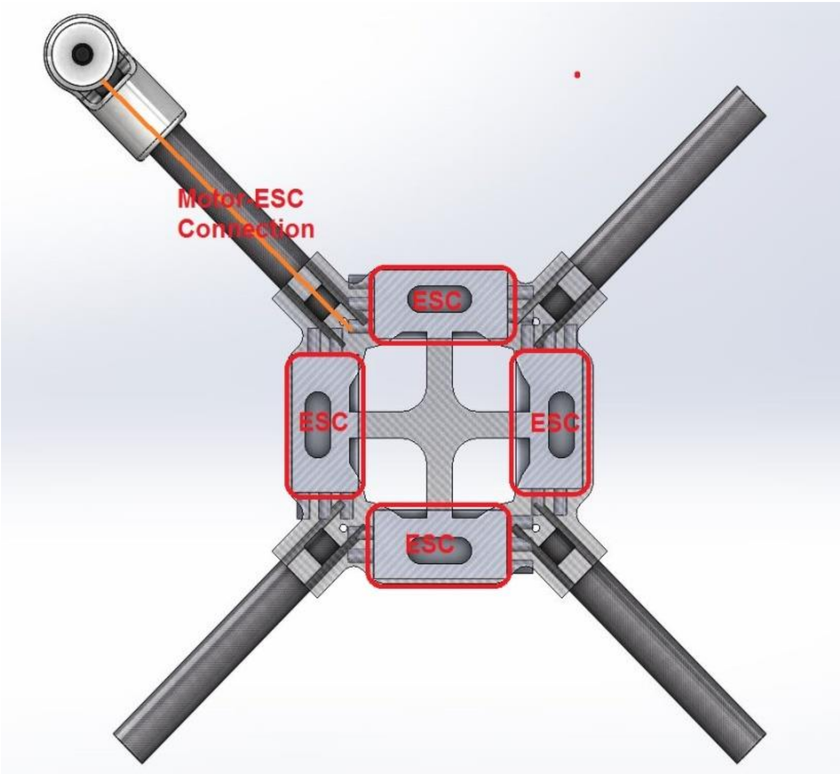
5.8 DRAWINGS

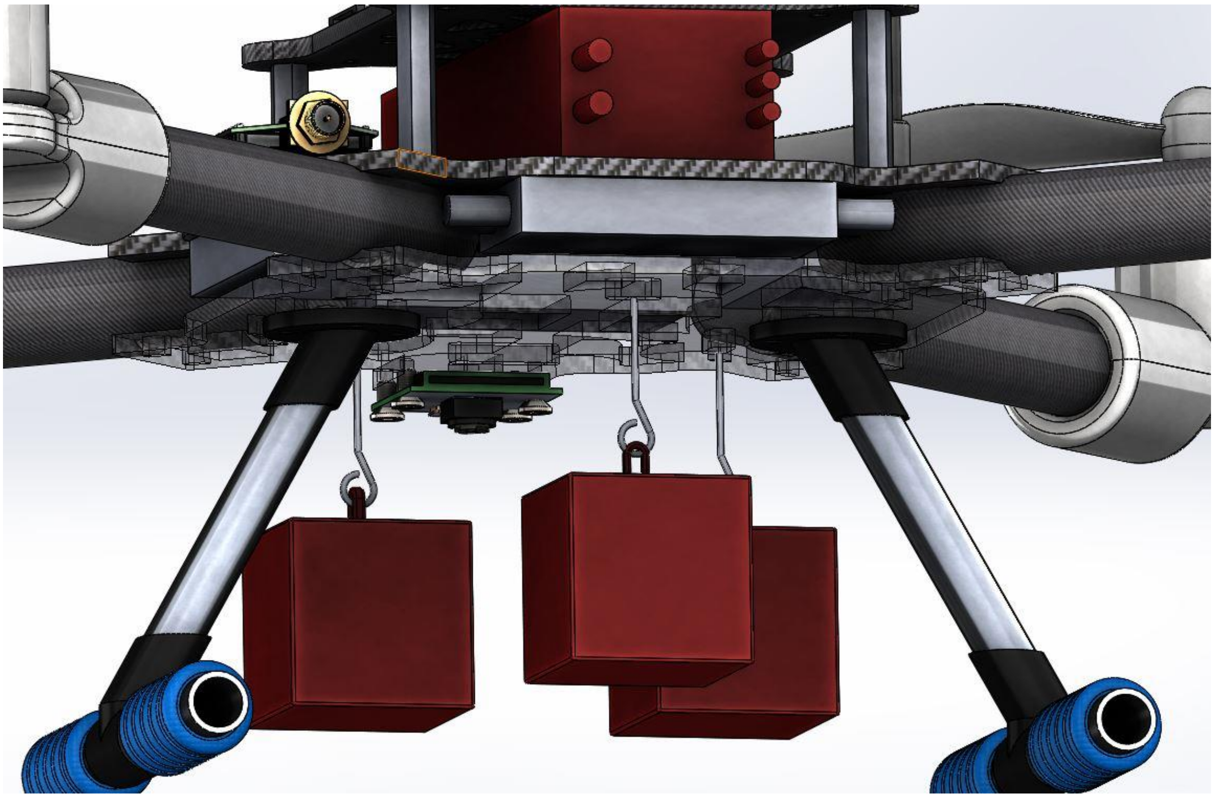




Nu	Item Name
1	RasPi_Camera
2	First Plate
3	Emax SimonK
4	LiPo 2200mAh
5	Distance
6	Third Plate
7	RaspberryPiZeroW
8	ArduPilot
9	GPS
10	Landing Gear
11	Motor Arm
12	Motor Holder
13	SKYRC Brushless Motor
14	Propellar
15	Second Plate
16	Payloads
28	Emax SimonK ESC


RasPi
Camera
LiPo
Raspberry Pi Zero
XBee
+
ProMini
ArduPilot Mega
GPS


Motor-ESC
Connection
ESC
ESC
ESC
ESC



Simplicity in mechanisms ensures mission success. That is why, after conceptual design report sent we rethought second mission and investigated a better way for accomplishing this task in very reliable way.

6. MANUFACTURING PLAN AND PROCESSES

- **Plan**
  The aerial vehicle was planned to be manufactured using carbon fiber reinforced epoxy at the beginning. But prototyping was planned using cheap materials to allow us better optimized system. After build process, testing & risk mitigation process was added to plan.
- **Process**
  The overall system was designed using solidworks program and analyzed using ANSYS program. Later it was prototyped using Plexiglas, aluminum profiles and ABS. Foam sheets were used as spacer and shock absorber.

6.1 SELECTED MANUFACTURING COMPONENTS

For the main frame of the vehicle, we decided to use Plexiglas material. Motor mounting parts are produced in 3-D printer. We used aluminum pipes as motor holding arms. We modeled the parts in the Solidworks program and tested by mounting them all. Throughout the test, we had some parts broken. So, we re-modeled them and enhanced the broken parts. Eventually, we decided our final design for the frame.

As Remote Controller we choose to make our own. We bought a broken RC controller and removed broken electronic circuits in it. Next we embedded our electronic circuits which have XBee and Arduino. After a few tests we could spin our motors. For the remote control system, we used analog buttons to send and receive information. We used XBee communication modules in order to communicate receiver and transmitter. We tested joystick buttons with an Arduino software whether they function properly. In the end, we could control the flight controller board with our 8-channel remote controller.

The fundamental purpose of the flight control system is to fly the vehicle safely and hold the vehicle stable throughout the flight. As a result of experiments which are conducted on the vehicle and flight controller, we concluded that the naze32 board is not a stable board for our primary missions. So we changed it to ardupilot APM 2.8 board which is capable of both flight stability and mission planning.

6.2 INVESTIGATED MANUFACTURING PROCESS, SELECTION PROCESS, RESULTS

One of the major component of the vehicle is flight control system. At first, we decided to use Naze32 flight controller board for its simplicity. Yet, during the testing procedure we realized that the board is not as accurate as we expect in terms of flight stability. Also, we need a flight controller that has accurate waypoint feature and stable GPS hold for image processing. As a result of research for the flight controller, we found Ardupilot Mega - APM 2.8- board which is known stable and accurate in terms of gps and imu sensors. Also, Ardupilot flight control software provides us with the mission planning capability. It handles both autonomous stabilization and GPS navigation and allows fully scripted waypoint missions and camera control. It supports 8 RC channels, has four serial ports and features an all-in design.

As for remote control system we worked with a testing procedure to control the receiver and transmitter compatibility. We used an Arduino software to communicate receiver and transmitter. We tried to control the motor with our remote controller as we move away from the vehicle. We have succeeded in controlling the vehicle away from an adequate distance. Theoretically, XBee Pro-S2C communication modules have 3 km range. In practice, we reached to 500 meters range and this is enough for our primary missions.

For microcontroller selection which we use it for image processing was STM32F4. After several tests and searching on internet we realize that making image processing with STM32F4 is little bit challenge and there is no standard library about image processing. If we still want to do it with STM32F4 we need to create our own library and unfortunately this process takes long time. For this reason, we changed our decision to Raspberry Pi 3. It has couple of library both python and C++ languages. That makes our job easy.

For image processing missions we needed a specific camera and also should have compatibility with Raspberry Pi 3. Camera has to be fast and have different resolutions. It also should be as small as possible. In the light of these we chose OV7670 but this camera module has no compatibility with Raspberry Pi 3 so that we chose Raspberry Pi’s own camera, it is called Pi Camera V1.3. It is a camera which easy to supply. Its communication with Raspberry Pi 3 is not so tough. Pi Camera converts raw datas into JPEG or PNG picture format itself, it is a good feature for us because Raspberry Pi 3 does not slog on to write datas into SD card.

6.3 MANUFACTURING PLAN

İnitially, we considered several different materials such as aliminium, plastic and composite. Finally, we decided upon carbon fiber. We cannot mold carbon fiber because we do not have laboratory facility to mold it. So we will buy G10 plates. Carbon fiber profiles also will be CNC cut and motor holders will be 3d printed from ABS as their shape are more complex.

7. TESTING PLAN

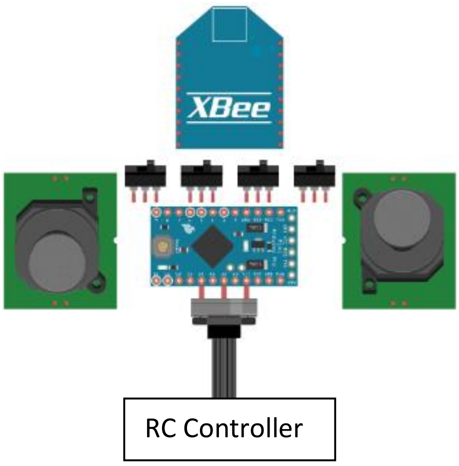
Flight Testing
Continuous testing leads to system refinement. Firstly, we should test manual flight characteristic of drone. In manual flight, we test also **remote control** and **PID control** - We test wither drone keeps its stability despite windy weather at the same time we test how many max km range we can get for RC. We test remote command robustness. The manual test procedure is described below
• Calibrate RC • Take off and look the drone stability • Turn the joysticks on the RC right, left forward and back to see RC robustness. • Go to far away to test the maximum range of RC – here also we see fail safe property (when signal is lost the drone must switch to fail safe mode in 2 seconds).

Mission Testing
We test mission 1 by generating very same matrix platform. Testing ensures mission robustness and gives us more clues for optimization.
• Generate 4x4 matrix which consists of RGB color. • Take picture and process the image • Create .txt file and save in SD card. (Image processing algorithm do the job) • Calculate total mission duration. • Release the loads every 5 second. We ensure wire cut mechanism functionality and load's parachute deployment.

7.1 TEST OBJECTIVES AND SCHEDULE

7.1.1 Manual Flight

Manuel flight test is the first step of testing process. In that section we need to make sure RC controller is stabile which we make. We have two joysticks for RC controller and two XBees for communication. Range of velocity must be very sensitive. PID system must be very accurate so that we should test the system in every condition. There might be windy air, this is unwanted condition for monetarizing ground. We need to get clear image from ground to process it. Hence PID system has critical importance. It has to be tested and configurated well.



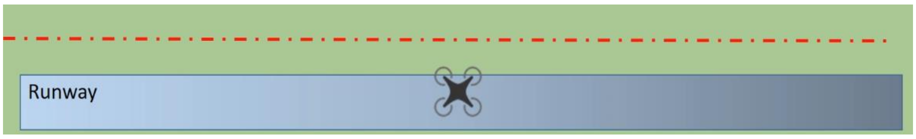
7.1.2 Autonomous Flight

For autonomous flight we need to make more test. In competition autonomous flight is very crucial. It ıs required for both missions and also it is related with image processing in some way. We have three sub-mission for this task and we are gonna do them in order. Firstly, we better make the auto takeoff and landing test because it is first movement of the flight. It is little bit easier than other sub-missions. We just need to take off drone without any accident.

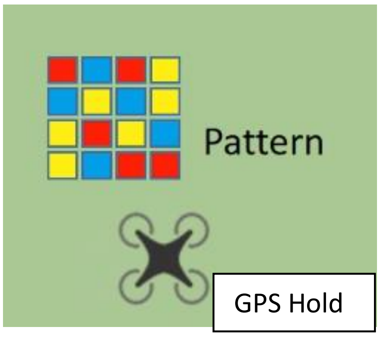
We have another sub-mission which is waypoint navigation and this is very important for competition. We need that part to be very accurate. This property effects image processing directly. If drone can not stand right position for image processing, we fail. Another importance is about dropping loads. Drone will go to drop area where we determine before competition and drone must reach exact point that we show, this feature is provided with our tests.

Waypoint positioning

The last sub-mission in this task is GPS hold and GPS home features. This is quite important for image processing. As long as drone is stable, taken pictures will be more clear. In order to make drone stable GPS hold has to be tested many times. Teams should test this feature to get best image from ground. If drone can not stand the position which we specify, we will not able to get full patterns. In this task we have another test which is GPS home. GPS home is needed for landing. Unless we land restricted area, whole things we made fail. This is important for finishing missions.



GPS Home



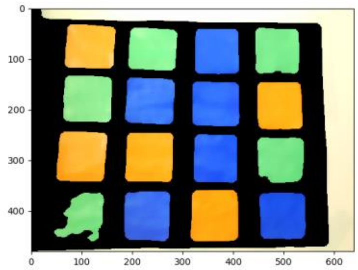
GPS Hold

7.1.3 Fail-safe Mode

This task is required for safety. According to competition rules we need to pass that test. If we fail, we will not able to fly our drone so we might disqualify at the beginning. That task seems easy to make but we have no chance to do something wrong because we are talking about human's lifes.

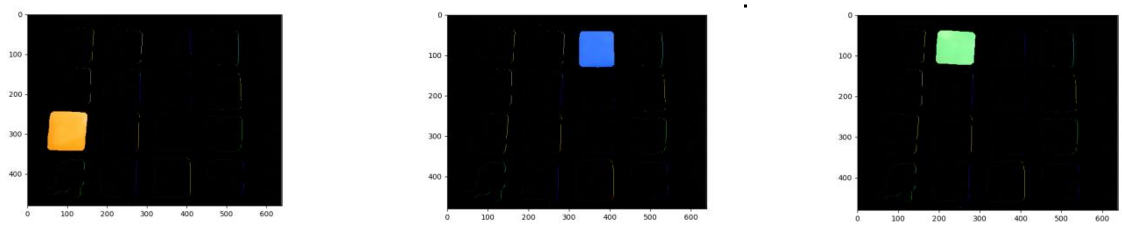
7.1.4 Image Processing

This section is so important with autonomous flight because these tasks are needed for both mission and also competition based on these two tasks. We have several sub-mission about it. In this section sub-missions have their own sub-missions. First of all, we need to get our drone to right position and then detect patterns. In order to do that this section should be tested with waypoint part. Object detection part should make drone's position certain because waypoint feature may not find exact point where patterns stand.



Object detection

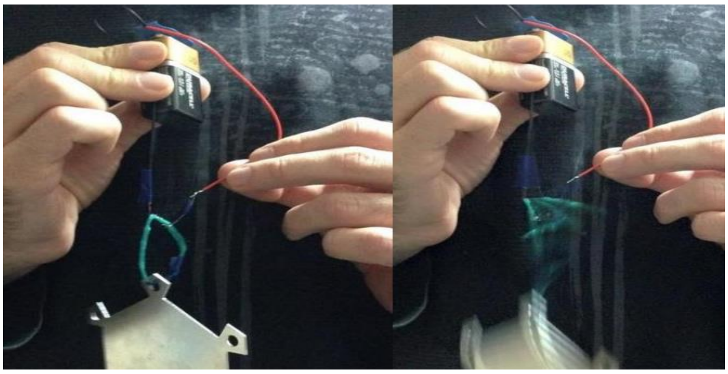
Our microcontroller detects patterns via threshold methods and then we detect each color respectively. Detected patterns are controlled with threshold values. We test every pattern's color, that makes 16 patters, and then write it down to SD card. We need to test image processing in every air condition. Object detection part is effected less by air but color detection part is so changeable because of sun brightness. Threshold values is changeable due to air so that we should make sure that in every condition we get true colors. After all these sub-missions completed, we need to save color numbers into SD card. This sub-mission is also made both missions



Color detection

7.1.5 Drop Mechanism

In this section we will be dropping one load for beginning. Firstly, we better test parachute without drone. We release the load from optimum high. When we make this sub-mission correct, we test it with drone. We make this part with resistance rope. We assign just one GPIO output from Raspberry Pi 3. When we detect colors, Raspberry Pi Zero look at just first row and control each element in that row. If three of elements are same color, we give 5V to assigned pinout. After we accomplish this sub-mission we should drop three of them relatively. After first load dropping, we should determine a timer which adjust second and third load's dropping time. According to competition rules there has to be at least 5 seconds between load's dropping. To make it correct we should adjust drone's speed as well, we can not exceed.



Drop Mechanism

7.1.6 Schedule

Mission Task	**Mission Sub-Task**	**Date**							
		01.05	*08.05*	*15.08*	*22.05*	*29.05*	*05.06*	*12.06*	*19.06*
Manuel Flight	RC Controller Test								
	PID Test								
Autonomous Flight	Waypoint Navigation								
	Auto Takeoff and Landing								
	GPS Hold, GPS Home								

Fail-safe Mode	Fail-safe Mode Test								
Image Processing	Object Detection								
	Color Detection								
	Writing on SD Card								
Drop Mechanism	Release Timing								
	Release Mechanism								
	Parachute								

7.2 TEST AND FLIGHT CHECK LISTS

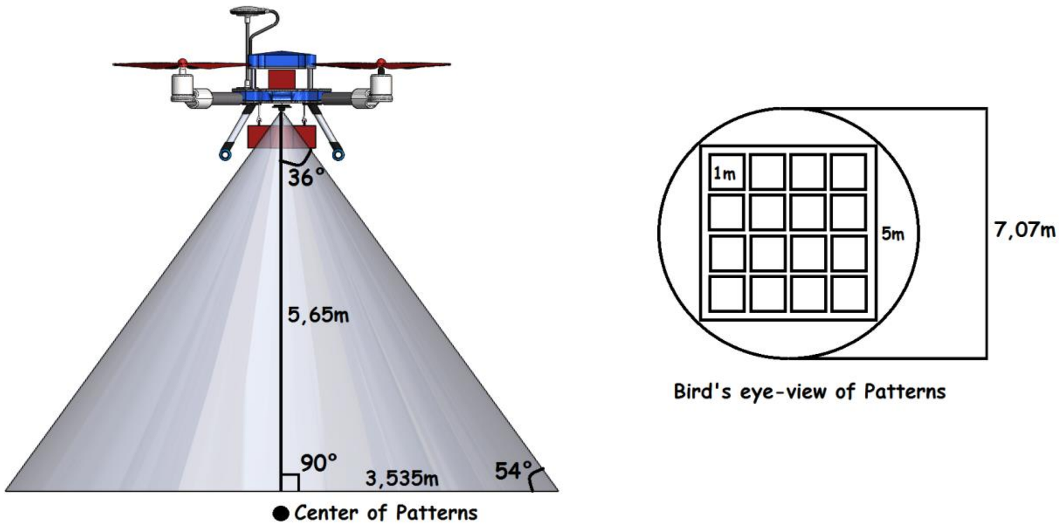
Mission Task	Mission Sub-Task	Status
Manuel Flight	RC Controller Test	Accomplished
	PID Test	Accomplished
Autonomous Flight	Waypoint Navigation	
	Auto Takeoff and Landing	
	GPS Hold, GPS Home	
Fail-safe Mode	Fail-safe Mode Test	Accomplished
Image Processing	Object Detection	Accomplished
	Color Detection	Accomplished
	Writing on SD Card	
Drop Mechanism	Release Timing	
	Release Mechanism	
	Parachute Deployment	
	Parachute decrease descent rate	

8. PERFORMANCE RESULTS

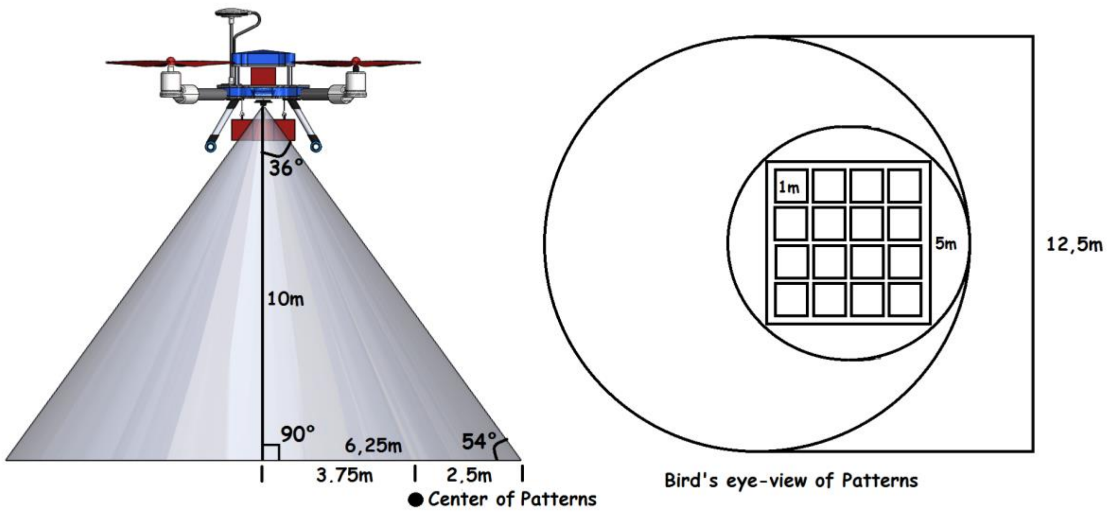
Our main purpose about performance is to make our drone light and small so that we have tried lots of components to get maximum efficiency from our drone. We compact our drone as much as possible. We minimize all components and drone frame as well. As a result of these drone will be able to fly fast. We have tried to make a drone just like competition wants.

8.1 DESCRIBE THE DEMONSTRATED PERFORMANCE OF KEY SUBSYSTEM

Our microcontroller that we use for image processing is Raspberry Pi Zero. It has 1 GHz clock frequency, 32-bit operation system and 512 MB ram. These numerical datas are enough for processing any image. Camera module has 640x480 resolution, this image size does not force our Raspberry Pi Zero's processor. Raw data's size is 38,4 kilobytes. However, our camera module converts the raw data into compressed data format like JPEG or PNG and that makes image's size processable. Our camera's view angle is 72 degrees. It is little bit less than other camera modules but we can handle with right calculations. We need to approach to patterns carefully. Our distance should be at least 5 meters. We assume that patters' length 5 meters, half of it 2.5 meters. That makes our rectangle's diagonal 7.07 approximately. As a result of that our high should be at least 5.65 meters.



If we can not approach center of patterns for worst situation, we should be 3.75 meters far away from center of patterns (assumed 10 meters for height). We need to fly-past to get clear images.



We have 2200 mAh for LiPo battery. It lets our drone to fly about 5-6 minutes on air. It is a fair battery for missions. Our missions take no longer than 5-6 minutes. 2200 mAh LiPo battery is more compact than other batteries which have high ampere per hour.

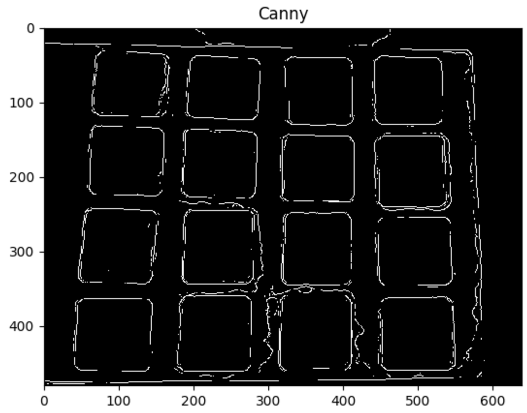
We use four ESC for brushless motors. Thanks to that we keep our place and reduce weight. This ESC is also more economical than using just one ESC as power consumption. Our ESCs gives 9A in optimum condition for each motors. However, when we use single ESC, it gives 12A in optimum condition for each. Another disadvantage using single ESC is that if one of ESCs is broken during testing we can change it with the worked one. However, if we use single ESC and if it is broken, it might challenge to supply another ESC. It is also bad for costing.

As RC controller we use XBee which has 2.4 MHz frequency. That makes 1.5-2 kilometers approximately. We just use RC controller during tests.

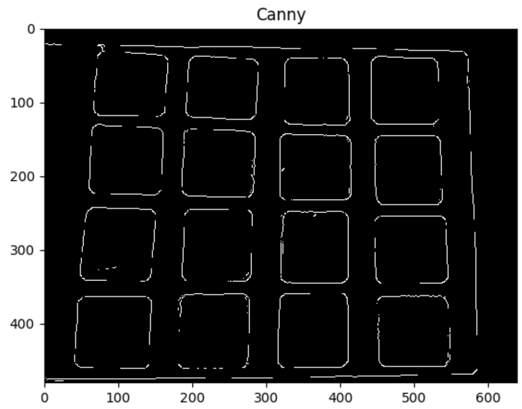
8.2 COMPARE TO PREDCTIONS AND EXPLAIN ANY DIFFERENCES AND IMPROVEMENTS MADE

At the beginning we decided to use Raspberry Pi 3 but that microcontroller has bigger size than Raspberry Pi Zero so we changed our decision to Raspberry Pi Zero. We need to make frame minimal size and reduce weight.

In the software part we assumed that edge detection method is enough for image processing. However, there is lots of contras differences on the ground. We may detect more than 16 shapes, that is not suit for us. We have tried to combine both methods which are edge detection and threshold method. We had to pass image into some filters to get clear image.



Edge Detection Method



Filtered Edge Detection

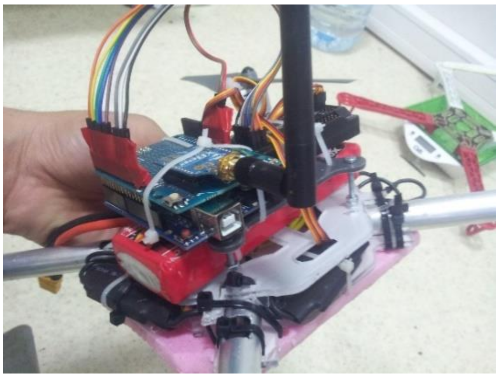
These two pictures are not results we want. Filtered image is not full covered for each pattern as it is seen. As a result of it we tried to pass threshold method. It is much better than edge detection. In competition we can get RGB color values, that makes our job easy because threshold method is required these color values.

8.3 DESCRIBE THE DEMONSTRATED PERFORMANCE OF YOUR COMPLETE AIRCRAFT SOLUTION

Our initial design was heavier than current one because of servo mechanism for load drop and Raspepirry Pi 3 for image processing. We changed servo drop mechanism with wire cut and Rasperry Pi 3 with Pi Zero. Finally our drone become smaller and lighter.

As result of tests made, we also notşced that our drone is flying very stable but there are drifting by the wind effects. During one of test the frame was completely broken since pilot unexperience. After this failure we set up fail safe mode and in the next test we also observed fail safe mode reliability. We used propeller protector to prevent damage to propeller during crash. We used foam at the buttom of drone to prevent damage to frame.

UAV before first test



UAV Flight Electronic

Special motor holder designed by team

9. REFERENCES

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