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EML4551-2

Team 307: Emergency Management Drone

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Abstract

Drones are very important to utilize in dangerous situations or inaccessible terrain. Our sponsor, the Florida State Emergency Management and Homeland Security (EMHS), contacted us to create a drone that uses a computer to find targets in emergency situations. This project is a continuation of a previous senior design project. The past design did not meet the customer's needs for flight time or flight range. The customer wants longer flight time and range to have a more effective search and rescue option. To increase the flight time, we are using batteries with more energy and a more effective power system. We are also using a better communication system in order to get the desired range. We are designing the drone to be more like an airplane instead of a helicopter so that the drone can travel through the air more efficiently. Due to these factors, we find that the drone can now cover a larger area than the last design. The original design of the drone was built to have a flight time of around 10 minutes along with a low range. With the fixed wing design and new communication systems, the drone will achieve a flight time of about 70 minutes and a range of about 10 km.

Disclaimer

Acknowledgement

Team 307 would like to give a special thanks to our sponsor, David Merrick, for providing the opportunity for us to be a part of this project as well as being an active supporter of the project's progression. We would also like to express our gratitude to our advisor, Rodney Roberts, for providing constant advice and support. Team 307 would like to also thank Dr. Harvey, who provided advice and knowledge about the communication systems. Lastly, we would like to thank our design instructor, Jerris Hooker, for always providing technical advice as well as aiding us through each step of the project.

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Notation

PLA	Polylactic acid
PVC	Polyvinyl chloride
FPV	First person view
NACA	National Advisory Committee for Aeronautics

Chapter One: EML 4551C

1.1 Project Scope

The current iteration of the client's drone, while functional, is not practically useful and needs to be improved to be effective. In particular, the range, flight time, and camera stabilization are of vital importance. Moreover, the client has also requested a number of improvements to the user interface, including autonomous flight. The design must be made with reliability and longevity as primary characteristics. If successful, this drone design could be used not only in emergency situations, but also for general wide-area searching.

The primary users of this design will be the Department of Emergency Management and Homeland Security (EMHS), but could also be used by various organizations including the FBI for kidnapping cases, conservation groups for counting animals, and penitentiaries to aid in the capture of prisoner escapes. The final product of this design will also be able to aid in environmental disaster surveys and reliefs. The city of Tallahassee could be a tentative stakeholder for this project. Several departments such as the police and the fire department would benefit from having an Emergency Management Drone at hand for situational purposes.

1.2 Customer Needs

After speaking with the customer, it became relevant that the current version of the drone design is not up to par for the needed performance. As requested by the customer, the main focus of adjustments to the drone will be flight time, flight range, and camera stabilization. The budget has been set at 1,500$ but is flexible.

1.2.1 Interview Questions

1. How many times was the current drone design flown?
   a. One time
2. What are the complications with the current drone design?
   a. Camera vibrations
   b. Range is abysmal
   c. Flight time is too short, around 10 minutes
   d. Poor user interface
   e. Flight is not autonomous
3. Is reliability or speed a higher priority?
   a. Range and efficiency are of much higher priority than speed
   b. Possibility of switching from video footage to still images since speed is not a concern
4. How often are the photos taken?

a. Live video footage is currently used
5. Is there a set budget for this project?
    a. The budget is sitting around a few thousand dollars

1.2.2 specifications determined from the sponsor interview.

- Video footage is not a necessity; as long as the user is able to access what has been detected by the image processing unit and receive coordinates, they can then determine whether ground resources are needed.
- The flight time can be improved in a variety of ways.
    - Heavy optimization of both the power consumption and the multi-rotor's mass could increase the flight time.
        - If the mass is reduced enough, the drone could be downgraded from 6 rotors to 4 rotors which would reduce both power consumption and mass.
    - The overall design could be changed to a fixed wing design which is inherently more power efficient.
        - A fixed wing design can introduce problems related to launching and recovery of the drone.
    - The flight range can be improved by using more powerful transmitters, or by introducing a lower frequency band.
        - Stronger transmitters will increase power consumption, but using a lower frequency band reduces the data transfer rate.

1.3 Functional Decomposition

The main function of the emergency management drone is to conduct successful and efficient search and rescue missions. There are several sub functions that make this possible. The drone design was split up into six sub functions that are analyzed in Figure 1.

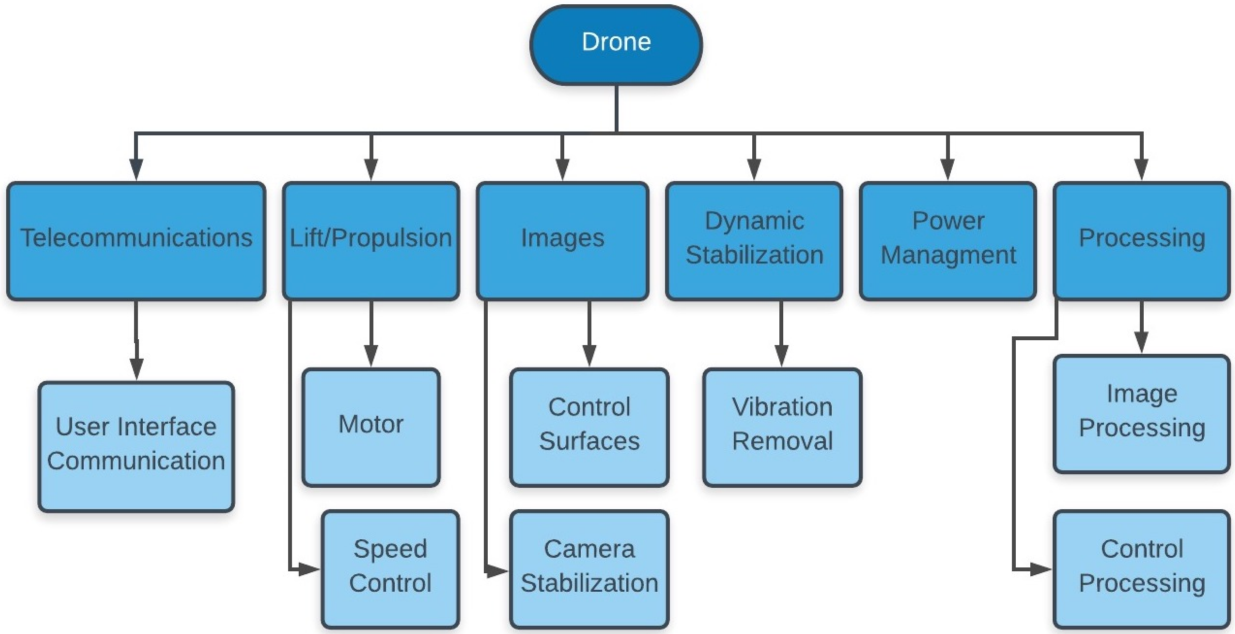


Figure 1. Functional decomposition diagram

Telecommunications is an integral part of the drone; the drone must be able to communicate with a source on the ground to control and receive the images transmitted from the drone. Lift and propulsion are other vital aspects of the drone design and will allow the device to overcome drag forces in order to be remain airborne after take-off. Subcategories of lift and propulsion include power from a motor and speed control. A motor is needed to convert electrical energy to mechanical in order to provide the drone with power, whereas speed control will regulate the movement of the device once in flight. Along with lift and propulsion, power management is needed to route power from batteries to the computer and motor(s) and also regulate the power efficiently.

Stabilizing the camera is needed to provide the user with quality images for object detection, and control surfaces prove to be a very important function in the stabilization of the drone as a whole. Dynamic stabilization is essential for the drone to stay controllable at all times, even in unidealistic conditions. Eliminating vibrations will help with both the image processing and the flight controls of the drone. Lastly, the processing will be done by the computer in the drone which will process the images and control the drone as it moves.

1.4 Target Summary

Target 1 quantifies how far can the drone be reliably operated from the pilot. An increased range from the previous iteration of the drone was specified by the customer as an essential need for this project. The customer argued that being able to fly the drone a longer distance away from the drone operator was essential to the search and rescue efforts that his team conducted. The marginal value for the range of the drone was chosen to be 1 kilometer, while an ideal value would be 2 kilometers. These values were chosen so that the customer and his team can take advantage of the enhanced visibility that a bird's eye view provides. The flight range will be improved by overhauling the communications system by removing the 2.4GHz communication and using a more reliable standard. The flight range will be tested in a large open field, provided that there are no bystanders and line of sight will always be maintained on the drone. The weight (5 being most important) of target 1 has been rated at 5 because the customer noted that this was an essential upgrade that they required.

Target 2 quantifies the time the drone is able to remain airborne. Increasing the flight time was specified by the customer as a high valued need, and vital function to the drone's practicality. The customer has clarified that ideal flight time would be 20 minutes or greater. In the past, the drone has had a flight time of an average of 10 minutes. The plan to increase the flight time is to redesign the structure of the previously designed 6 rotor drone to cut down on power consumption and in return, increase flight time. The new structure of the drone would be the one of a fixed wing UAV, the use of this design would decrease the power consumption which would greatly increase the flight time. The importance of target 2 has been rated at a 5 because it was directly communicated from the customer as a top priority.

Target 3 quantifies how clear the images are once they've been transmitted from the drone to the ground. There are many concerns with taking photos/videos on a moving platform, however the main concern is the vibration. If the platform is vibrating too much, then the images taken from the camera will not be clear enough for the image processing program to reliably operate. Therefore, camera stabilization is essential. The marginal value for camera stabilization was chosen to be 80% of the vibrations to be reduced, while the ideal value was chosen to be 100% of the vibrations to be reduced. Camera stabilization will be tested by flying the drone erratically and taking video. The footage will be reviewed to determine the clarity of the images captured. We plan to improve camera stabilization by using rubber mounts where the gimbal mounts to the drone. Using a more reliable gimbal will also help reduce the vibrations produced on the drone. The weight of Target 3 has been rated at 4 because camera stabilization is essential to the success of the image processing program, but it is not essential to the drone's operation.

Target 4 correlates cruise speed to the need of longer flight time to ensure that the drone last as long as its required. The marginal value was chosen to be 30 km/h which is a little bit faster than what it actually needs to be. An optimal cruise speed has been chosen at 25 km/h which will be the perfect speed for the drone to capture a point of importance for the search and rescue team. This target will be verified in a large open field using measurements capacities available in FlytOS to make sure that the cruise speed needed is archived. The importance of this target is 1 because speed is not a priority as long as the drone is able to successfully detect objects in an efficient matter.

Target 5 quantifies the necessary power for the drone to work properly and last as long as its required. A reduction in the power consumption of the drone will be essential to increase the flight time as required by the sponsor. Being able to regulate the power consumption to an optimal level will increase the control on the amount of thrust produced by the motor. The marginal value for the power consumption was chosen to be 150W. This amount of power gives the drone the ability of working for at least 30 minutes at the desired capacity. The ideal value for the power consumption would be 125W, with this capacity we think that the drone would be able to fulfill all of the requirements while also using less power compared to the previous iteration of the drone. This target will be verified by running the drone for 30 minutes and testing the drone afterwards to assess the power consumption. This target is rated at 5 because lowering the power consumption of the drone is essential for its correct functionality as described by the needs of this project.

Target 6 identifies the options for autonomous flight. Having a predetermined autonomous flight path ensures a wide section is covered without there being a need for a person to pilot the drone. There is an open source code for autonomous flight that will be used to implement this feature into the drone. The marginal value chosen for this target was 50% autonomous, while the ideal value for autonomous flight is 80%. The weight of this target has been rated at 4 because autonomous flight is important in making sure the best search path is covered but is not mandatory in making the drone achieve its goal.

Target 7 compares the flight time of the vehicle to the total vehicle mass. By reducing the mass of the entire drone, the drone will be able to fly for a longer time as the heavier the vehicle is, the more power will be needed to counteract its weight. The marginal value for the mass of the drone is 2.5 kg, with the ideal value being less than 2 kg. It will be easy to determine the mass of the drone, through the use of some sort of scale. This metric is rated as a 3 in importance, as decreasing the drone's mass will be helpful in reducing the power demands but is not essential to the drone's operation.

Target 8 compares the flight time of the vehicle to the payload mass of the vehicle. Reducing the mass of the payload will in turn reduce the amount of power needed to fly using the same logic as in Target 7. The marginal value for the payload mass is 1.5 kg, with 1 kg being the ideal payload mass. As with Target 7, the mass of the payload can be easily measured with the same previously mentioned scale. This metric is also rated as a 3 for the same reasons as with Target 7.

1.5 Concept Generation

The following section includes a table, represented as Table 1, of all of the components of the design with corresponding options and an explanation for the dominant concepts generated from the table. The design was split up into two main vehicles, a multirotor drone and a fixed wing vehicle. A total of 16 feasible concepts are discussed below.

Table 1
Concept Generation Table

Components	Options					
Vehicle Type	Multi-Rotor	Fixed Wing				
# of Motors	1	2	3	4	6	8
Motor Configuration	Quad Rotor "+"	Quad Rotor "X"	Y-6 Rotor	X-8	Nose	Wings	Nose and Wings
Frame Material	Carbon Fiber	Foam	PLA Filament	Epoxy Fiberglass	Aluminum	PVC	
# of Battery Packs	1	2					
Type of battery	1s	2s	3s	4s	5s	6s	
Power Management	Linear Voltage Regulator	Buck Boost Converter	Buck Converter	Fly Buck Boost			
Camera	Thermographic	Gopro	Webcam	FPV			
Processor	NVIDIA TX1	NVIDIA TK1	Odroid XU4	Raspberry Pi 1	Raspberry Pi 2	Raspberry Pi 3	

Communications	Directional Wifi	4g	3g	Directional Antennas				
Airfoil	NACA 0012	NACA 1408	20-32C Airfoil	NACA 63(2)-615				
Fuselage	Blunt Body	Bluff Body	Narrow Body	Flying Wing				
Landing	Parachute	Belly Land	Landing Gear					

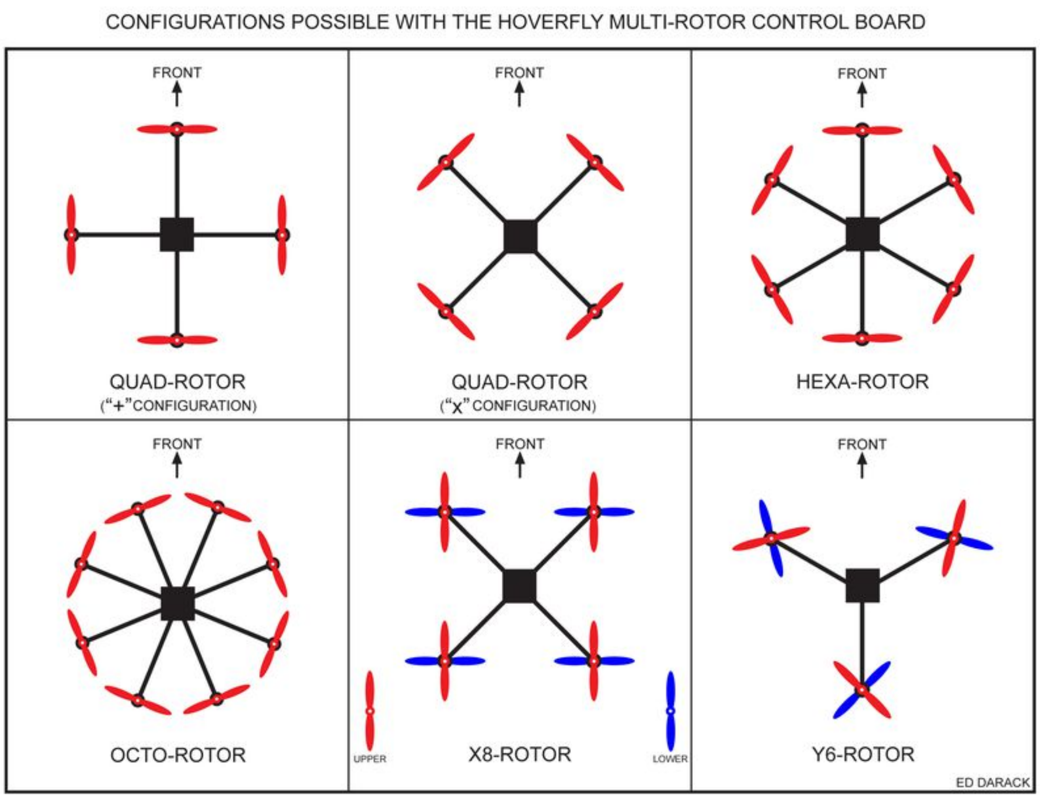


Figure 2. Configurations of motors for a multirotor drone [1]

Concept 1.

The idea behind this design is to minimize the budget while keeping a standard frame configuration for a multirotor drone. This design would be a quad rotor with a "X" configuration, shown in Figure 2. By using PLA filament for the frame material, the price would decrease while still providing the drone with the needed frame support. Although PLA filament is brittle, a multirotor drone has the ability to hover land which will minimize impact force to the drone. This design would have one standard three cell battery to minimize weight and use a buck boost converter to conserve power. A Raspberry Pi 3 processor was chosen to keep the budget down and lower power consumption from the previously used NVIDIA TX1 processor.

Concept 2.

This design was made to keep the features from the previous drone, 'Saurus'. The goal of this design is to optimize the weight such that only four motors will be needed, and redesigning the power management for efficiency. Since this processor is very powerful, the autonomy of the drone could be improved significantly by adding features such as investigation of points of interest (such as reducing altitude to get a better image). Since a new frame would be required, carbon fiber was chosen due to its durability which will remain intact in various weather conditions.

Concept 3.

This design was made with maximum multirotor range in mind. By optimizing the weight of the drone to only require four motors and by using a less power-hungry processor as well as better power management, the flight time of the drone would be significantly increased. In conjunction with using 4G communication, the drone would have significantly higher effective range.

Concept 4.

The main idea behind this design was to take advantage of the "Y" configuration, shown in Figure 2, to optimize power consumption and range of the drone. The frame material of this drone would be plastic to lower the weight of the drone accordingly. The communication system would be directional antennas which will give the drone longer range as desired by the customer. This design will use a three-cell battery in combination with a buck boost converter for power management. As for the camera, a Thermographic camera would be the main choice in combination with an NVIDIA TX1 for processing.

Concept 5.

This design was made with optimization in mind. It uses four motors in a quad-rotor "+" configuration, shown in Figure 2. The frame material for this design would be carbon fiber which was the one used in the "Saurus" drone. Similar to concept four, the communication system would use directional antennas which offer a much larger range compared to Wi-Fi or 4G. For the power management, a three-cell battery will be used in combination with a buck boost converter. The camera would be a webcam which was used in the previous group drone design, and the main microprocessor choice for this design would be the NVIDIA TX1.

Concept 6.

This design was made to optimize the drone's power usage. Three motors will be utilized in a "Y-6" configuration shown in Figure 2. The frame material will be foam to keep the weight of the drone light and the structure easy to repair. For power management, the drone will use a three-cell battery as well as a buck boost converter. A GoPro will be implemented to minimize power consumption, while still being able to take clear and usable pictures. The communication system will use a 4G network. This will allow the drone to fly at at decent range without consuming a substantial amount of power. Finally, the processor chosen was the Raspberry Pi 3. This processor is light and not as power hungry as others, making it ideal for this design.

Concept 7.

In this design, four motors will be used in a "+" configuration. The use of an FPV camera will be implemented to provide live feed to the viewers. This will result in the system consuming more power. Two 3 cell batteries will be implemented to accommodate for this additional use of power. The drone will use foam for its frame material in order to keep it light. This will also help the power consumption aspect of this design. Directional antennas will be used for the communication system of the drone. This will increase the range capability of the drone. Finally, the processor chosen for this design is the NVIDIA TX1. This processor will be able to handle the power required for the FPV camera.

Concept 8.

Concept 8 is a hexacopter with dual battery packs. The camera on this design would be FPV camera which would broadcast live feed to a source on the ground. Live feed imagery would require more power and therefore two battery packs would be used in this design. Using six motors opposed to four would allow the drone to carry more weight, which would be the extra battery pack in this case. Carbon fiber was chosen for this design to allow more weight to be taken up by the batteries which will enhance the flight time and range of the vehicle.

Concept 9.

This design was made with ease of launch and landing in mind. A fixed wing vehicle design was chosen using a NACA 1408 airfoil to provide very high lift and to have a very low landing speed. Using EPA foam will make the drone durable and light, and will be very easy to repair for minor scuffs and belly damage. The fly buck boost converter was chosen to increase power management so that only one battery needs to be used. The camera was chosen to be light, have very high frames per second, and to have a high field of view such that individual images can be stabilized to be very clear for the image processing. The 4G communication should be sufficient for ground communication since a maximum of one picture per second is expected to be sent. The processor was chosen to have maximum processor utilization for power spent for stabilization, image processing, and flight control.

Concept 10.

This design was made with speed in mind. The 20-32C Airfoil was chosen to maximize lift during the initial climb and provide a good lift versus drag characteristic. This drone would have a flying wing fuselage with aluminum as the frame material so that it can survive the high drag. Three motors would be used to maximize the flight speed and the aerodynamic control while at high speeds. A fly buck boost converter was chosen to maximize flight time by using power efficiently. The image processing system would be designed to be a basic Raspberry Pi 3, and the communications scheme (3G) would be designed to send very few images in order to minimize power consumption.

Concept 11.

This design was also made with ease of launch and landing in mind. Again, the airfoil was chosen as a 20-32C airfoil to have very high lift and to have a very low stall speed, making it very easy to fly and land. Using a foam body will make the drone be very durable in the event of a crash. Similar to concept 10, the power management system was chosen to be very efficient so that only one three cell battery would need to be used. The camera used for this concept will be a small FPV camera because a lot of weight will be taken by the NVIDIA TX1 processor that will be used for this design. This design also incorporates the use of a parachute system which the operator can use to stall the aircraft, and then deploy the parachute so that there the required landing distance is reduced significantly. Essentially, the aircraft is oriented towards safe landings, and very pilot friendly. This concept uses directional antennas as its form of communication.

Concept 12.

This design concept is very similar to Concept 11 in most aspects besides the camera system. This concept will have a FPV camera to opposed to a webcam. The increase in weight from the upgraded camera means that the Raspberry Pi 3 microcontroller will be used instead of the NVIDIA TX1 to reduce weight. This concept also differs from Concept 11 in its form of communication. This concept will be using 4G for its main mode of communication.

Concept 13.

This design introduces a new management system that focuses on high voltage and longer flight time. It uses two battery packs instead of one and has a fly buck converter for power management. This fixed wing drone is oriented towards flight time and flight performance. This design has similarities to concept 12. The main differences between the two concepts lie on the method used for power management.

Concept 14.

This design is a combination of concepts 9 and 13. It keep the main features of 9 which were the flying wing design with the low landing speed, and it incorporates the longer flight time from concept 13. It also adds the NVIDIA TX1 to handle live video processing. This design uses the airfoil NACA 1408 for very high lift and very low landing speed. The frame will be made out of foam and the main landing method would be stalling combined with crashing. This drone will use a nose motor configuration combined with a power management which will use two battery packs and a fly buck converter for efficient power management. The main camera for this drone would be a GoPro and the communication system would be 4G.

Concept 15.

This design uses concept 10's ideas but incorporates more batteries and less power consuming features. The airfoil of this material is NACA 0012. The frame material used for this design is aluminum. Furthermore, this design uses two six cell battery packs. This design also focuses on incorporating flying techniques that save power, as well as using a weaker processor, Raspberry Pi 2, as well as a weaker 3G communication system.

Concept 16.

This design was made to use the cheapest materials possible in order to minimize cost to the consumer in the case of commercial viability, while being easy to fly for novices. The airfoil was chosen for its decent lift and drag characteristics, but also for its low airfoil moments. Using a bluff body made out of epoxy fiberglass makes it durable, while the parachute makes escaping poor piloting very simple. The power consumption should be relatively low as it uses an older processor, Raspberry Pi 2, with a relatively low-quality webcam and an older communication scheme.

Exclusions

A few concepts were excluded due to practicality issues, a few explanations are listed below.

Raspberry Pi 1 was not used due to its extremely slow processing speed. The processor should be able to handle both timed imagery, at the least, and real time GPS tracking. It should also be able to use Saurus' image processing system, which can be decently processing heavy. The NVIDIA TK1 wasn't used because of the lack of power it has relative to the NVIDIA TX1. Each of the concepts were striving for either reliability of live video through the TX1 or saving power through the Raspberry Pi series.

Other amounts of cell batteries were not used because the power efficiency will come from the drone design and the power electronics in the drone. The cell of the battery is not the focus, so the 3-cell battery was used due to its cost and accessibility. The exception is in the concept 15 which places sole emphasis on flight time, in this case a six-cell battery provides longer flight time. For the power management, the linear voltage converter was excluded because this device does not offer the necessary efficiency to extend the flying time of the drone to the required time. The efficiency of the linear voltage converter is about 30-40%, while standard power converters have around 85-90% efficiency

The other fuselage options besides flying wing and bluff body were not used because these options don't offer the stability necessary for the drone to work properly as a search and rescue device.

1.6 Concept Selection

This section breaks down the selection process in which the final concept was chosen. Table A highlights the concept selection criteria taken from the engineering requirements on the House of Quality shown in appendix D. The metrics are ranked by importance based off customer requirements and product capability and were taken into account for the selection of the final design. The following section is split up into concept selection criteria, evaluation of concepts with aid of the Pugh matrix, elimination of concepts, and lastly the selection of a final concept. The elimination of concepts is explained in depth below.

Table 2

Concept Selection Criteria

Metric	Rank	Type	Optimal	Range	Description
Camera Stabilization	5	Value	Low	<= 30 Hz	Max jitter
Power Consumption	3	Value	Low	<= 100W	Max power consumed from the drone
Aerodynamics	1	Quality	High	>= 1.0 at 10° <= 0.08 at 5° >= 5°	Shape of frame
Weight	4	Value	Low	<= 2 kg	Max weight
Payload Capacity	5	Value	Low	<= kg	How much weight the drone will be able to carry
Image Processing	7	Value	High	>= 1 fps	Processing frame rate
Communications	2	Value	High	>= 2km	Communication Range

Table 3 represents a Pugh chart used for the selection of which vehicle type will be used for the drone. The options were the original "Saurus" hexacopter, two quadcopters with different frame configurations ("X" and "+" configurations), and two fixed wing designs (flying wing and bluff body configurations). Since the Saurus hexacopter was the original design, this was chosen as the datum for the Pugh chart.

Table 3

Vehicle Type Pugh Chart

	Concepts

Criteria	Weight (0-5)	"Saurus" hexacopter (datum)	Quadcopter "X" Configuration	Quadcopter '+' configuration	Flying Wing	Bluff Body
Range	5	200m	0	0	+	+
Power Consumption	5	300 W	+	+	+	+
Mass	5	3.6kg	+	+	+	+
Cruise Speed	3	10 m/s	-	-	+	+
Score			7	7	18	18
Continue?			No	No	Yes	Yes

Deciding on the vehicle type to be used drone is essential to the success of the vehicle. As stated above, during the concept generation phase of our project, five different vehicle type configurations were discussed. Using the Pugh chart analysis, it was found that both of the quadcopter designs were better than the datum in two areas, and worse than the datum in two other areas. The flying wing and bluff body configurations were both better than the datum in all of the areas. Since the selection was narrowed down to two options, it was decided to compare the two options outright and refrain from creating another Pugh chart. The flying wing configuration was selected because the flying wing is much more aerodynamically stable, has a higher glide ratio compared to a similarly sized bluff body. It is also easier to repair in the event of a botched landing.

Figure 3 Skywalker black X8 flying wing drone [2]

Table 4 represents a Pugh chart used for the selection of the motor configuration for a flying wing drone. The datum concept is a single motor mounted on the nose of the drone and three other concepts were compared to it. The three additional configurations included a rear motor, duel wing mounted motors and duel wing motors with an additional nose mounted motor.

Table 4

Motor Configuration Pugh Chart

			Concepts			
Criteria	Weight (0-5)	Nose (datum)	Wings	Nose and Wings	One Rear	Two Rear
Aerodynamics	5		-	-	0	+
Yaw Control	5		+	+	0	+
Cruise Speed	1		+	+	0	-
Power Consumption	5		-	-	0	-
Ease of Construction	3		-	-	0	-
Durability	3		-	-	+	+
Cost	3		-	-	0	-
Score			-13	-13	3	2
Continue?			No	No	Yes	Yes

The results above yield that using wing motors would not be a feasible design for the requirements of this project. The elimination of the wing motors leaves the option for a rear or nose mounted motor. Due to the variance in durability of the two configurations, a rear mounted motor was chosen for this design. The reasoning for choosing a rear mounted motor over a nose motor is because a nose mounted motor is more susceptible to damage in the event of a crash. The decision for whether to use one or two rear motors will come down to how difficult controlling the yaw of the drone will be in flight. If substantial control becomes necessary, then two motors will be needed.

Airfoil shape is an important mechanical property of an aircraft. The airfoil shape strongly affects the lift, drag, moment, and stall characteristics which will affect the aerodynamics of the vehicle as a whole. To capture the importance of the airfoil shape in the vehicle, Pugh charts were created to compare the various airfoil shapes. Previously, in the concept generation section, 4 airfoil shapes were introduced; NACA 0012, NACA 1408, NACA 63(2)-615, and Dillner 20-32C

Airfoil. Figures 4,5,6 and 7 show visual representations of each airfoil shape discussed. The following Pugh charts compare the characteristic of the airfoils in the process of selecting the most practical shape for this design. The criteria on the Pugh chart was selected due to their effects on the aerodynamics of the vehicle.

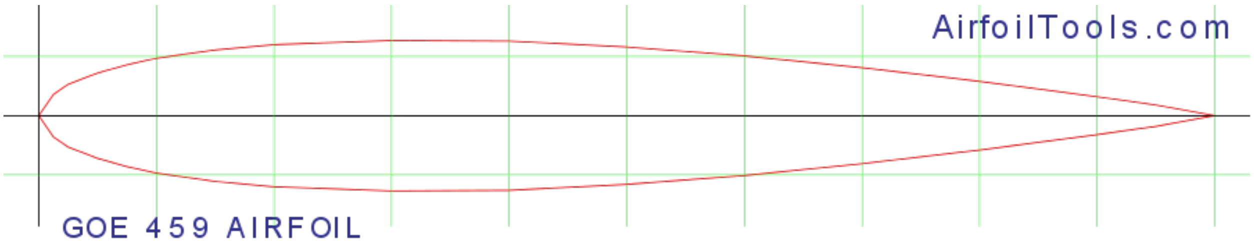


Figure 4 NACA 0012 airfoil [3]

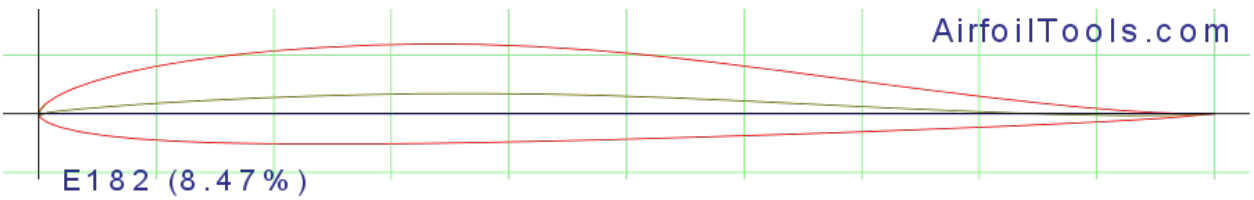


Figure 5 NACA 1408 airfoil [3]

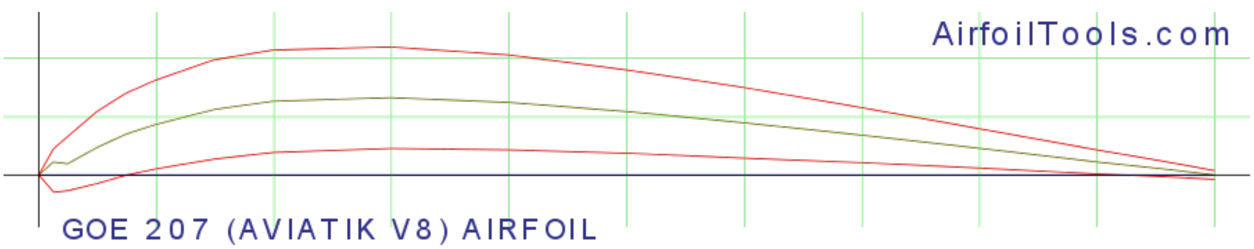


Figure 6 20-32C airfoil [3]

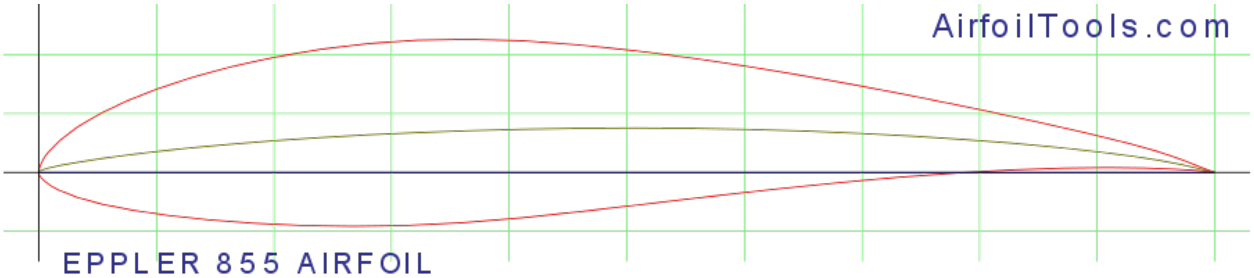


Figure 7 NACA 63(2)-615 airfoil [3]

Table 5
Airfoil Shape Pugh Chart 1

			Concepts		
Criteria	Weight (0-5)	NACA 0012 (datum)	NACA 1408	20-32C Airfoil	NACA 63(2)-615
Lift	5		0	0	+
Drag	5		0	-	-
Moment	2		+	+	+
Stall Characteristics	4		0	+	-
Mass	1		+	+	-
Score			3	2	-3
Continue?		Yes	Yes	Yes	No

Since the NACA 0012 airfoil is the simplest airfoil, being mathematically similar to a flat plate, it was chosen as the datum for the chart. After comparing the airfoils in Table 5, the NACA 63(2)-615 airfoil was eliminated due to its poor stall characteristics and very high mass, which more than cancel out its good lift characteristics. Both the NACA 1408 and 20-32C airfoil are more mass efficient than the NACA 0012 airfoil while producing the same lift and having better moments. These three airfoils are compared once more in a second Pugh chart in Table 6 below.

Table 6
Airfoil Shape Pugh Chart 2

Concepts

Criteria	Weight (0-5)	20-32C Airfoil (datum)	NACA 0012	NACA 1408
Lift	5		-	-
Drag	5		+	+
Moment	2		-	-
Stall Characteristics	4		-	0
Mass	1		-	0
Score			-7	-2
Continue?		Yes	No	No

For the second Pugh chart, 20-32C airfoil was set as the datum because in the previous Pugh chart, this airfoil differed the most to the NACA 0012 airfoil. In summary, the NACA 0012 airfoil was better than the datum in 1 area, while it was worse than the datum in 4 areas. The NACA 1408 airfoil was better than the datum in 1 area, and worse than the datum in 2 areas. Since both of these airfoils were worse than the airfoil in more areas than they were better, it was decided that the 20-32C airfoil is the best airfoil choice for the vehicle.

The previous created, "Saurus", used a carbon fiber frame. Saurus, being a multirotor drone, has different aerodynamic capabilities compared to that of a flying wing drone and therefore more materials were examined for the use of this design. Carbon fiber was used as the datum reference in Table 7 due to its decently low density, and high strength. Environmental durability was chosen as a criteria due to the excessive amount of flight time this vehicle will be exposed to in high temperatures. Ease of construction was chosen to show the manufacturability of each material, as the shape of wings will need to be molded to the previously selected airfoil. The results of the Pugh matrix are discussed below.

Table 7
Material Selection Pugh Chart

			Concepts				
Criteria	Weight (0-5)	Carbon Fiber (datum)	Foam	Epoxy Fiberglass	PLA Filament	Aluminum	PVC
Density	5		+	0	+	-	+
Impact	4		-	-	-	-	-

Strength							
Environmental Durability	2		-	0	-	-	-
Ease of Construction	3		+	0	+	-	0
Ease of Repair	4		+	0	+	+	-
Cost	3		+	+	+	+	+
Score			9	-1	9	-7	-2
Continue?		Yes	Yes	No	Yes	No	No

With the results from the Table 7, the Pugh chart for material selection, carbon fiber, foam and PLA filament were further examined. Although carbon fiber has high impact strength and durability, the cost of the material outweighs the benefits of strength. The high strength of carbon fiber would be excessive for the requirements of this design. Eliminating carbon fiber from the choices of materials leaves foam and PLA filament, a material used in 3-D printing. Both materials scored equally on the Pugh chart when compared to carbon fiber, but there are significant benefits to using foam opposed to PLA filament. Foam is extremely easy to repair, especially in the field. Damage to a drone made of PLA filament would require maintenance in a shop which takes time and would cause a delay in a search and rescue mission, whereas foam could be repaired on site. Also, PLA filament does not handle high temperatures well and faces the risk deformation when exposed to high temperatures. With the aid of the Pugh chart and further examination of the materials, foam was chosen as the most functional material for the design.

In the concept generation phase several microprocessors were considered to handle the image processing for the new drone including Raspberry Pi 2, Raspberry Pi 3 model B, Raspberry Pi 3 model B+, NVIDIA TX1 and NVIDIA TK1. The previous drone used an NVIDIA TX1 as the main processor. This computer was used to handle all of the image processing while also communicating with the flying hardware when needed. The NVIDIA TX1 was used as the datum reference in Table 8 due to its low power consumption, medium weight, and high processing ability. Power requirement was chosen as a criterion because of its importance due to the power management on the drone. Power consumption was chosen as a criterion because of the necessity of reducing this factor due to the requirement of longer flight time for the drone. Size and mass are also two very important criteria to look at because of the limited space available in the drone for the components and the limitations on the weight of the drone. The last criterion consists of the processing power and memory available on the board. This criterion is vital because it relates directly to the ability of the processor to manage the image processing needed for the drone.

Table 8

Processor Pugh Chart 1

			Concepts			
Criteria	Weight (0-5)	NVIDIA TX1 (datum)	NVIDIA TK1	Raspberry Pi 3 B	Raspberry Pi 3 B+	Raspberry Pi 2 model B
Power Requirement	3	5.5-19.6V, 4A max	0	+	+	+
Max Power Consumption	5	10W	0	+	+	+
Size	2	85.60 mm × 53.98 mm	+	+	+	+
Mass	2	144 g	0	+	+	+
CPU and Memory	5	1.73GHz and 4GB LPDDR4	-	-	-	-
Score			-4	7	7	7
Continue?		Yes	No	Yes	Yes	No

From the first iteration of the Pugh method, various different processors were viable being the processor of the drone. These were the NVIDIA TX1, the Raspberry Pi 3 B+, and Raspberry Pi 3 B. The concepts excluded in the first iteration of the Pugh chart represented processors that could work, but when compared to the others they lacked essential capabilities to compete. These exclusions were based primarily from power consumption and processing speed. The second iteration of the Pugh chart was executed using the Raspberry Pi 3 B+ as the datum because of its score from the previous chart and its different characteristics when compared to the NVIDIA TX1.

Table 9

Processor Pugh Chart 2

			Concepts	
Criteria	Weight (0-5)	Raspberry Pi 3 B+ (datum)	NVIDIA TX1	Raspberry Pi 3 B
Power Requirement	3	5V and 2A	-	+
Max Power Consumption	5	5.6 W	-	0
Size	2	82mm x 56mm x 19.5mm	-	0
Mass	2	50g	-	0

CPU and Memory	5	1.4GHz and 1GB LPDDR2	+	-
Score			-7	-2
Continue?		Yes	No	Yes

With the results from Table 9, the Raspberry Pi 3 B+, the Raspberry Pi 3 B, and the NVIDIA TX1 were further examined. In the case of the NVIDIA TX1, the only criteria that proved better when comparing it to the datum was the CPU and memory. Although this criterion is very important, the high-power requirement and max power consumption outweighs the benefits of having very good CPU and memory. After excluding the TX1 board, the only two options left which were the Raspberry Pi boards. In this case, the previous iteration of the Raspberry Pi 3 B+ board has slightly better max power consumption and power requirements, but fails at everything else. In the end, the Raspberry Pi 3 B+ was chosen as the main processor because of its great performance coupled with great power qualities and perfect size and weight.

The selected camera for the drone needs to have certain elements to attain the highest detection accuracy for the image processing. This camera needs to provide consistent and reliable images using a 720p resolution because of the data rate and power consumption requirements. The previous drone used the Logitech C920 HD PRO as the main camera. This component was successfully used and tested for the image processing in the previous drone. For this reason, the Logitech C920 HD PRO was used as the datum for Table 10. Weight and size were chosen as criteria because of the weight requirement for the drone and the limited space for components available in the drone. The next criterion chosen was HD recording; This criterion is very important because the drone needs a camera that is able to record and transmit video at 720p. The last criterion for Pugh chart was chosen to be still photo resolution. This criterion is vital because the camera needs to able to produce reliable images for the image processing.

Table 10
Camera Selection Pugh Chart

			Concepts		
Criteria	Weight (0-5)	Logitech C920 HD PRO (datum)	GoPro Hero 7 Silver	Polaroid Cube +	Kodak Pixpro S360
Weight	3	162g	+	+	+
Size	1	94 mm x 24 mm x 29 mm	+	+	+
HD Recording	4	720p/30fps	+	-	-

Still Photo Resolutions	5	15MP	-	-	+
Score			3	-5	5
Continue?		Yes	Yes	No	Yes

With the results from Table 10, there are three main concepts that were further examined for the selection of the camera. In the case of the GoPro Hero 7, the camera offers good weight, size, and HD recording. Although the GoPro Hero 7 has high still photo resolution, the concept falls short when compared to the datum. The next camera considered for the drone was the Kodak Pixpro. This concept excels in three out the four criteria considered but when compared to the datum it falls short on the HD Recording which is a vital part of the design. The last option for the camera would be the one used in the previous drone, the Logitech C920 HD PRO. This camera falls short in the weight and size criteria, but excels in the still photo resolution and HD recording. Using this camera for the new design also means that the cost of the camera can be neglected because this component will be taken from the previous drone. With the aid of the Pugh chart and further examination of the selected cameras, the Logitech C920 HD PRO was chosen as the most practical camera for the design.

The power management needs to be simple to design and implement, due to the time constraints of the project. The fly buck boost topology was put as the datum because its design was simply a chip and a few other components. The output power available for each topology differs, and each one does a different function. The input voltage range is slightly important, because the batteries that will be used will change in voltage. Most topologies account for this though, so it is only slightly important. The power output is very important, since not all topologies can yield the required current at a low voltage. The required current is high due to the motors and the processor requiring high currents. The accessibility is important, since control chips are designed for specific applications in mind, and will not always bend to the design parameters.

Table 11

Power Management Pugh Chart

			Concepts		
Criteria	Weight (0-5)	Fly Buck Boost (datum)	Fly Buck	Buck Boost	Buck
Input Voltage Range	2		0	-	-
Simplicity	4		-	0	0

Power Output	5		0	-	+
Accessibility	3		0	+	+
Score			-4	-4	6
Continue?		No	No	No	Yes

Upon researching synchronous buck boost and buck converters, the buck boost and buck topologies became significantly better for the design of the power management. The fly buck converter is very similar to the fly buck boost, but since it becomes more complex with additional outputs, it is worse than the datum. The buck boost converter is very accessible, but is not rated well for low voltage high current situations. The synchronous buck converter not only appeals to the design parameters, but the chips for it plentiful and flexible. All options fall short compared to the synchronous buck converter, so the buck topology was chosen.

From the concept generation phase, several communication modules were considered for the design. These were the XBEE Pro 900 HP, the TI CC1312R, the XBEE Pro SX and the XBEE SX RF. The communication modules need to provide reliable data transfer with a very long range and low power consumption. The XBEE Pro 900 HP was picked as the datum for the communication Pugh chart because it was tested previously, and it had a good performance. Bandwidth was picked as a criterion because having a reliable bandwidth is related for data transfer. Output power is another very important part of a communication module because it is one of the parameters that sets the range of the communication system. The next criterion chosen was data rate, this criterion is also involved in the signal strength calculations. Sensitivity is the most important criterion for the system. The sensitivity is directly correlated to the range, so the range criteria was replaced with receiver sensitivity. The last criterion was chosen to be features which are the extra characteristics that each module has to offer, such as being programmable or configurable.

Table 12
Communications Pugh Chart

			Concepts		
Criteria	Weight (0-5)	XBEE Pro 900 HP (datum)	TI CC1312R	XBEE Pro SX	XBEE SX RF Modem
Bandwidth	1		0	+	-
Output Power	3		+	+	-

Data Rate	4		0	-	+
Sensitivity	5		+	+	-
Features	2		+	-	+
Score			10	3	-3
Continue?		No	Yes	No	No

With the results from Table 12, there is only one option that fulfills the requirements of the communication module for the design. The TI CC1312R was the final concept selected because it had the best score when compared to the other XBEE communication modules and the datum. The TI CC1312R excels in being programmable and configurable, which it will allow various modes and data ranges. The TI transceiver also has the best sensitivity, which significantly increases the range! The transceiver has average data rate, but everything else about it exceeds the other communication systems, making it the chosen system.

In summary, based on all of the Pugh charts and the comparisons that were conducted, it was decided to create a fixed wing drone that has a flying wing for its body type, and foam for the material. The 20-32C airfoil shape will be implemented for the wings and the motor will be mounted in the back, in a pusher configuration. For the communications, the TI CC1312R MCU was chosen as the main communication module. It will be paired with a high gain Yagi antenna at the ground station, and an omnidirectional antenna on the drone itself. The processor will be Raspberry Pi B+ and will handle all of our processing needs, including the flight controller. All of this will be powered by one 3s battery. The buck converter topology was the one decided on at the end because it was the most optimizable, as well as it is simple to implement and buy. The selections for each component of the design are organized in Table 11 below.

Table 13
Final Selection Table

Component	Selection
Vehicle Choice	Flying Wing
Motor Configuration	Rear
Airfoil	20-32C
Material	Foam
Power Management Systems	Buck Topology

Communications	TI CC1312R MCU
Processor	Raspberry Pi 3 B+
Battery Type/Number of Batteries	1 3s Battery
Camera	Logitech C920 HD PRO

1.7 Spring Project Plan

The following milestones represent a timeline of the tasks that need to be completed in spring. Major tasks include prototype assembly, design testing, alterations, presentations, and engineering design day, where the final project will be presented. The final project must be completed in April to prepare for the final presentation. Included along with the milestones is a Gantt chart, Figure 8, that puts all the tasks for spring onto a visual representation.

Milestone 1: Beginning of the Spring semester
- Set up a team meeting to discuss the next steps for the project
- Document the new available times for each of the team members
- Contact Mr. Merrick to check if the parts ordered have arrived, or when they will arrive
    - Update BOM regarding status of parts

Milestone 2: January 15
- Prepare 1st spring presentation
- Begin testing the communication system
- Make any changes to the previous assignments if necessary
- Begin the preparation of the mechanical parts of the drone
    - Prepare laser cut guides for cutting the wings
    - Assemble hot wire cutter, test effectiveness
- Attend STEM day

Milestone 3: January 29
- Advisor meeting 1
- Prepare 2nd spring presentation
- Begin to assemble the prototype
    - Cut wings using hot wire cutter
    - Initial cut for the fuselage

Milestone 4: February 28
- Advisor meeting 2
- Prototype testing

Milestone 5: March 16
- Spring Break - March 16th-20th

Milestone 6: March 31
- Create final project poster/presentation

Milestone 7: April 18

- Engineering design day
- Final team presentation
- Final meeting with advisor

Milestone 8: April 29

- Finals week

Milestone 9: May 3

- Graduation May 3rd-4th

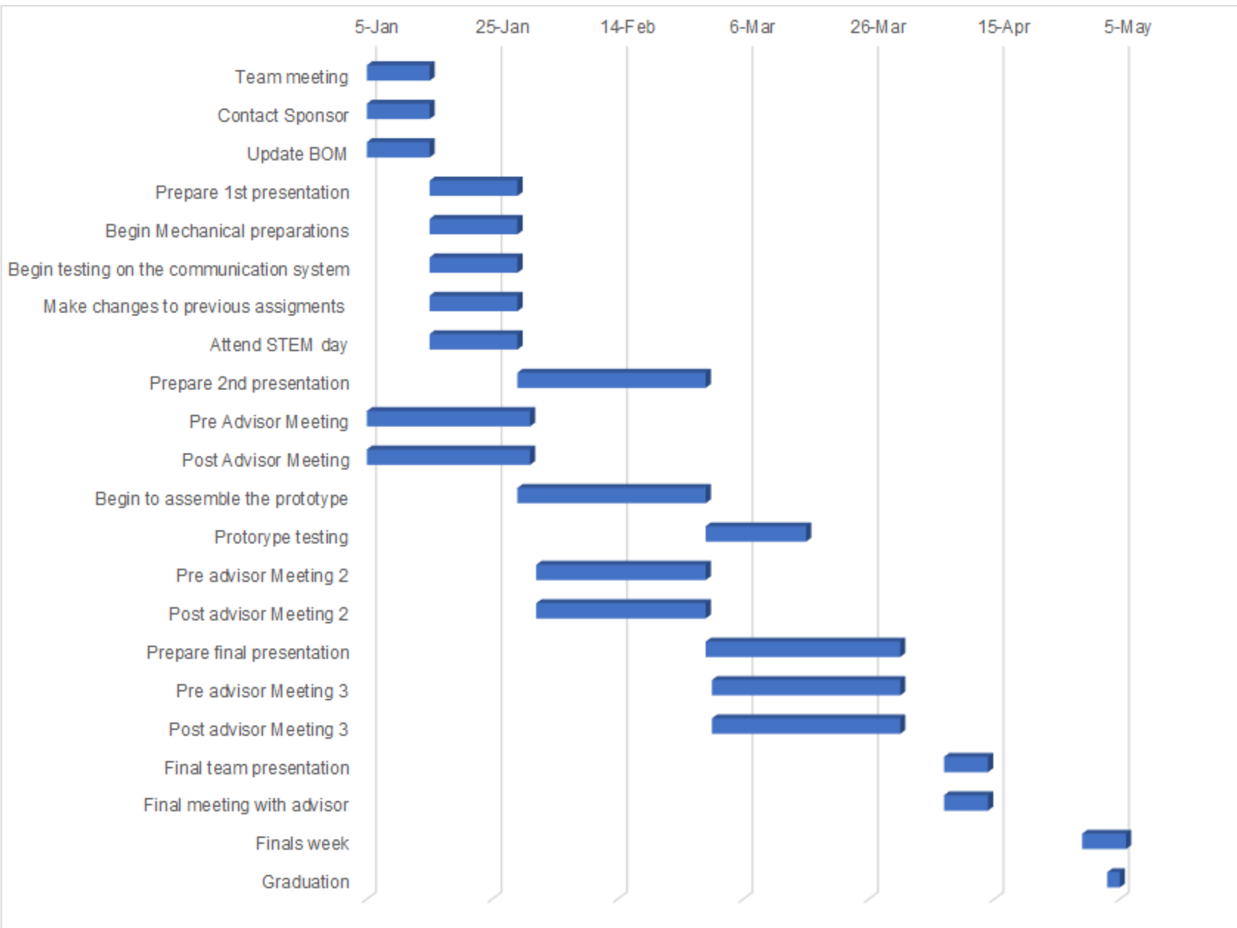


Figure 8 Gantt Chart Spring 2019

Table 14 wraps up the summary of tasks to be completed in spring for both the mechanical and electrical side

Table 14
Summary of Tasks

Electrical To-dos	Mechanical To-dos
1. Test camera & image processing software 2. Test communications 3. Assemble electrical parts in smallest possible footprint 4. Test part interface 5. Test autonomy	1. Make hot wire cutter 2. Create & laser cut guides 3. Cut wings and fuselage 4. Test motors and servos 5. Streamline fuselage after electrical footprint is determined 6. Assemble drone 7. Test drone

Chapter Two: EML 4552C

Appendices

Appendix A: Code of Conduct

Mission Statement

Senior design team 307, Emergency Management Drone, is committed to creating a work environment that supports open communication between FSU's Department of Emergency Management and our team. We are committed to providing a high-quality product that exceeds any client's expectations.

Roles

Each team member is delegated a specific role based on their experience and skill sets and is responsible for all here-within:

Team members:

Project Manager – Haley Barrett

Haley is a senior undergraduate student at Florida State University. She is responsible for coordinating all team meetings and maintaining communication between the group. She will complete revisions of all reports before they are turned in and create an organized agenda of upcoming deadlines to be shared with all group members.

Financial Advisor – Juan Patino

Juan is senior undergraduate student studying electrical engineering at Florida State University. He is responsible for maintaining organized records of all credits charged throughout the project. He will maintain communication with the sponsor, The Department of Emergency Management at FSU, and the College of Engineering while purchasing parts and components pertaining to the project.

Lead ME – Kody Koch

Kody, a senior in mechanical engineering study will take the role as the ME lead. He coordinates the mechanical side of the project, and is responsible for all the mechanical details of the design. He also helps coordinate the mechanical departments interactions with the electrical department in order to work more efficiently. Kody also assist with MATLAB and C++ coding along with refactoring.

Lead ECE – Matthew Roberts

Matthew is a senior undergraduate student studying Electrical Engineering at Florida State University. He also is an intern under the City of Tallahassee Utility Power Division, and as an undergraduate researcher at CAPS, researching Power Electronics under Dr. Li. He is responsible of the EE, IE, or CE design part in support of the project. He maintains line of communication with the lead ME, and manages the construction of the project circuitry.

Lead Designer/Aerodynamic Engineer– Josh Reid

Josh is an undergraduate senior at Florida State University studying Mechanical Engineering. As the Lead Designer and Aerodynamic Engineer, he works to ensure that all aerodynamics are accounted for in the design of the aircraft, while also developing any additional CAD designs needed for the aircraft.

Lead Programmer/Web Developer– Francisco Silva
Francisco (Frank) studies electrical engineering at Florida State University with focus in microprocessors and electronics. As the lead programmer, Frank is in charge of developing the team's website and keeping it up to date with current progress of the project. Along with the help of the other engineers, Frank will take lead on image processing and electronics.

All Team Members:

-Provide input to all aspects of the project
-Show effort in areas of the project that are not their expertise
-Delivers on commitments
-Listen and contribute constructively
-Put forth best effort to be present at all group meetings
-Be open minded to others ideas
-Respect others roles and ideas

Communication

The main form of communication will be through the app Discord, a group messaging platform. The group will stay in contact weekly as needed, and will meet in person once a week at the minimum. Constant communication within the group is a successful tool for timely completion of tasks for the project.

Communication with advisors, sponsors and reviewers will be done mainly through email, but in person meetings will take place as needed with respect to attendee's schedules.

Team Dynamics

Open communication is encouraged between group members, and nobody's ideas should be discouraged before discussion. Teamwork and cooperation are a key focus between group members.

Ethics

Team members are required to follow NSPE Engineering Code of ethics as they are responsible for their obligations to the public, the client, the employer, and the profession.

Dress Code

Team meetings will be held in casual attire, whereas meetings with sponsors, advisors and reviewers will require business casual attire. Dress code for presentations will be held in business attire.

Attendance Policy

Team meetings will be held weekly on Tuesday or Thursday afternoons at the earliest convenience after the ME's senior design class. Throughout the week the group will maintain communication and meet in person as needed. If a member of the group fails to meet excessively, the matter will be brought up to the instructor pertaining to that student's engineering discipline.

Decision Making

In efforts to create a fair decision-making policy, a voting system will be implemented where majority is in favor. Input of all students in the group will be required to dictate an equitable decision.

Conflict Resolution

In the event of a disagreement between a member of team 307 the following actions will be implemented:

-A group meeting will be scheduled to administer a group vote, favoring the majority.

-If a member of the group is still dissatisfied, an instructor will facilitate a resolution.

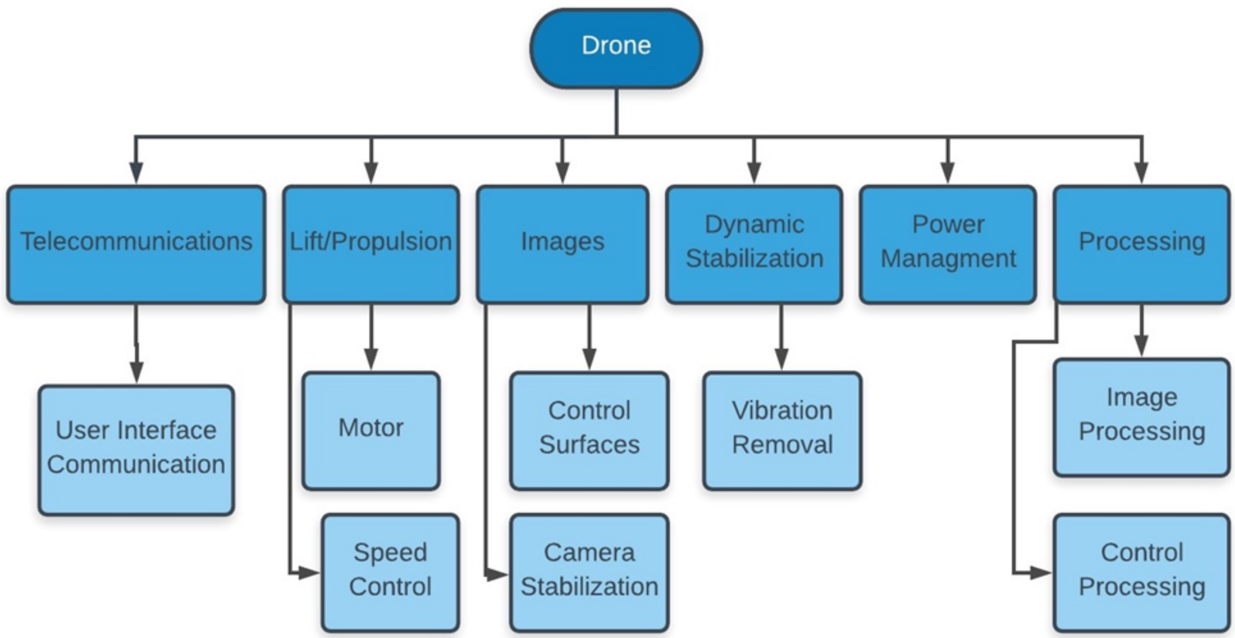
Statement of Understanding

By signing this document, the members of Team 1 agree the all of the above and will abide by the code of conduct set forth by the group.

Name	Signature	Date
Haley Barrett		09/12/18
Kody Koch		09/13/18
Juan Patino		09/13/18
Joshua Reid		09/14/18

Frank Silva		09/14/18
Matthew Roberts		09/16/18

Appendix B: Functional Decomposition



Appendix C: Target Catalog

Target No.	Need	Metric	Weight (1-5)	Units	Marginal Value	Ideal Value
1	Increased range	Range	5	km	1	2
2	Longer flight time	Flight time	5	min	20	30
3	Clear images transmitted to ground device	Camera Stabilization	4	%	80	100
4	Longer flight time	Cruise Speed	1	km/h	30	25
5	Longer flight time	Power consumption	5	W	150	125
6	Autonomous flight options	Levels of autonomy	4	%	50	80
7	Longer flight time	Drone weight	3	kg	2.8	2.5
8	Longer flight time	Payload capacity	3	kg	1.5	1

Appendix D: House of Quality

House of Quality									
		Engineering Requirements							
Customer Requirements	Customer Importance	Power Consumption	Payload Capacity	Camera Stabilization	Image Processing	Weight	Communication	Aerodynamics	
Range	**5**	3	3	0	3	3	9	3	
Flight Time	**5**	9	9	0	3	9	3	9	
Cruise Speed	**1**	3	9	3	0	9	0	9	
Weight	**5**	9	9	6	3	9	6	6	
Image Quality	**4**	3	0	9	9	0	9	0	
Autonomous flight	**4**	3	3	6	0	3	6	3	
Latency	**1**	0	0	0	6	0	9	0	
									Total
Score		132	126	93	87	126	159	180	903
Relative Weight		14.6	14.0	10.3	9.6	14.0	17.6	19.9	
Rank		3	5	6	7	4	2	1	

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