

NextDrone Technology: Temporary Traffic Light Drone

ME 2212 Intro to ME Design- Fall 2017

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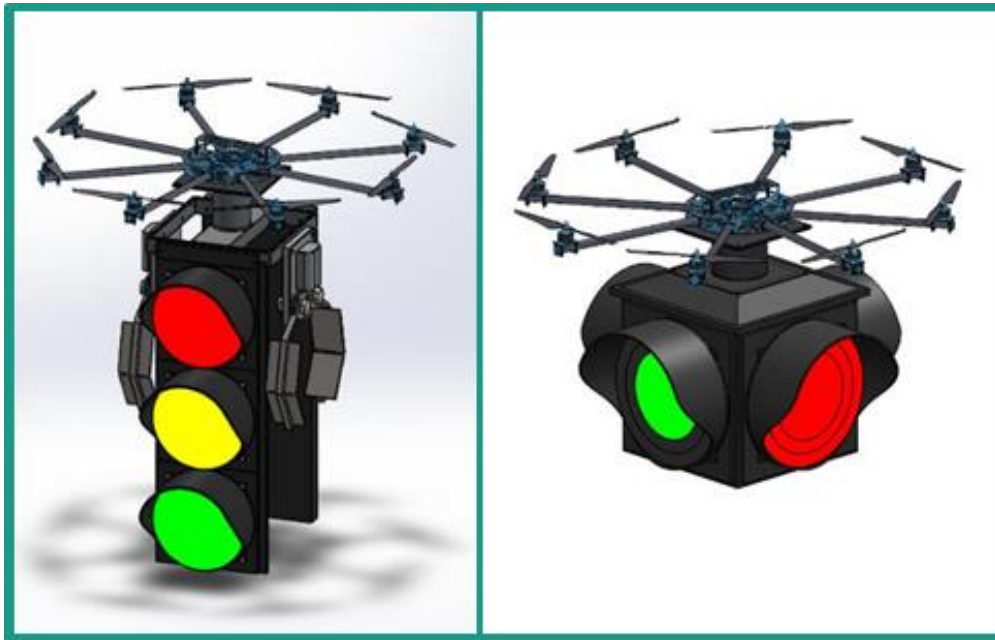


Figure 1: Solidworks Model of Temporary Traffic Light Drone
Mast Attachment (Left), Hover Attachment (Right)

Abstract

In this report, a Traffic Drone to alleviate automotive traffic issues was generated as a new, innovative application for drones. Primary customers would include the Department of Transportation and Development, traffic maintenance companies and construction companies. With over 800,000 signals recorded in the U.S in 2011, limited staff in traffic maintenance, and costs ranging from \$250,000 to \$500,000 to install new traffic systems, a fast, easily deployable and cost effective solution for temporary traffic lights is necessary.

The prototype design generated is a modular Traffic Drone that can address two possible scenarios: attaching to a traffic mast directly or hovering at an intersection when no mast is available. The dimensions of these two designs are 24''x 24''x 48'' for the Mast Attachment and 20''x 20''x 24'' for the Hover Attachment.

The overall design provides a faster, more convenient way to address traffic malfunctioning. Despite the concept being relatively new, the technological and engineering feasibility of the product strongly point to its successful development.

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Project Summary

I. Goals/Objectives

This report seeks to find a new, innovative drone application that abides by FAA guidelines, is modular for drones, and utilizes existing drone technology. Undergoing several decision matrixes, the team determined that a Traffic Drone to alleviate automotive traffic issues is the best solution.

Primary customers would include the Department of Transportation and Development, Traffic Maintenance companies and Construction companies, who would utilize the Traffic Drone on a daily basis during traffic light maintenance and repair or temporary road construction. As product development increases secondary customers will be targeted towards the entire North American market, still mainly focusing on construction and traffic maintenance companies, but also including event coordinators who could utilize the Traffic Drone for temporary, large scale events such as concerts, festivals, and sporting competitions.

II. Project Motivation and Design Constraints

In 2011, 800,000 signals were recorded in the U.S for the 2012 National Traffic Signal Report Card. Despite the large amounts of funding dedicated to traffic light operation and maintenance, the National Transportation Operations Coalition (NTOC) still scored the U.S a D+ for traffic light management and maintenance. Factors that contributed to the low score included limited staff and poor alternative solutions for temporary traffic lights. (2012 National Traffic Signal Report Card Technical Report, 2012) Furthermore, standard traffic signal manufacturing and maintenance can cost taxpayers \$250,000 to \$500,000 to install and \$8000 yearly to maintain (“Traffic Signals”, 2016). Based on these standards, the following key functional requirements for the Traffic Drone product were determined:

1. Effectively control flow of traffic as a temporary Traffic Light
2. Fast and easy deployment with minimal staff
3. Reasonable Cost
4. Safe while active

Other design constraints that were considered included adhering to all FAA guidelines, using existing drone technology, making the design modular to various drones, finding a drone with a carrying capacity of around 15 kg, and limiting the cost to under \$20,000. The \$20,000

budget was determined based on the cost of drones that could carry designated payload and the actual cost to install and maintain standard traffic lights.

III. Prototype Design

The prototype design is a modular Traffic Drone that acts as a temporary traffic light. The modularity of the design allows the Traffic Drone to address two possible scenarios: attaching to a mast and hovering at an intersection (Figure 1).

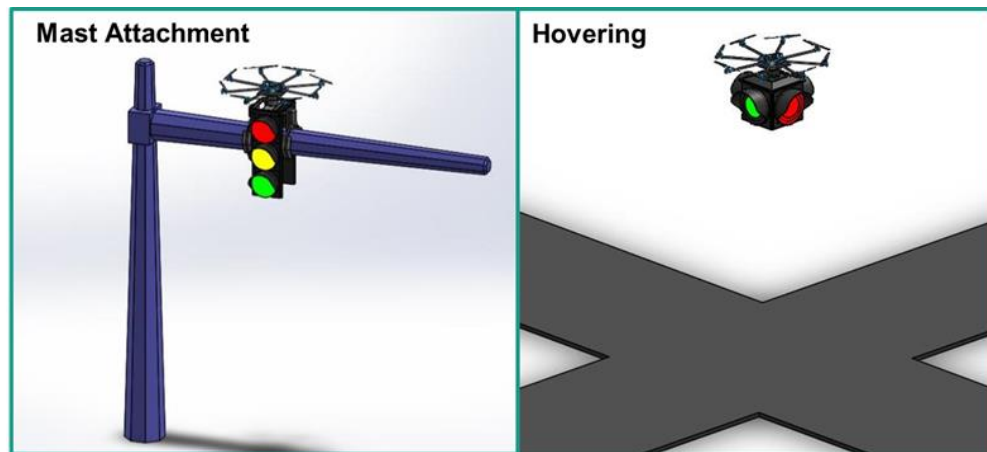


Figure 1: Overview of design in Mast Scenario (Left) and Hover Scenario (Right)

Overall, there are 16 unique parts required for the Traffic Light Mast Attachment and 9 unique parts required for the Traffic Light Hover Attachment as shown in the exploded view (Figure 2). Most of the traffic light parts were made of polycarbonate or aluminum, which contributed to durability, corrosion resistance, and overall increased lightness. Because the designated customer required quick and easy assembly due to limited staff, the number of parts were simplified drastically with a standard Main Screw (8) and Main Nut (9) piece utilized throughout the majority of the assembly to increase efficiency when changing attachments and to minimize confusion.

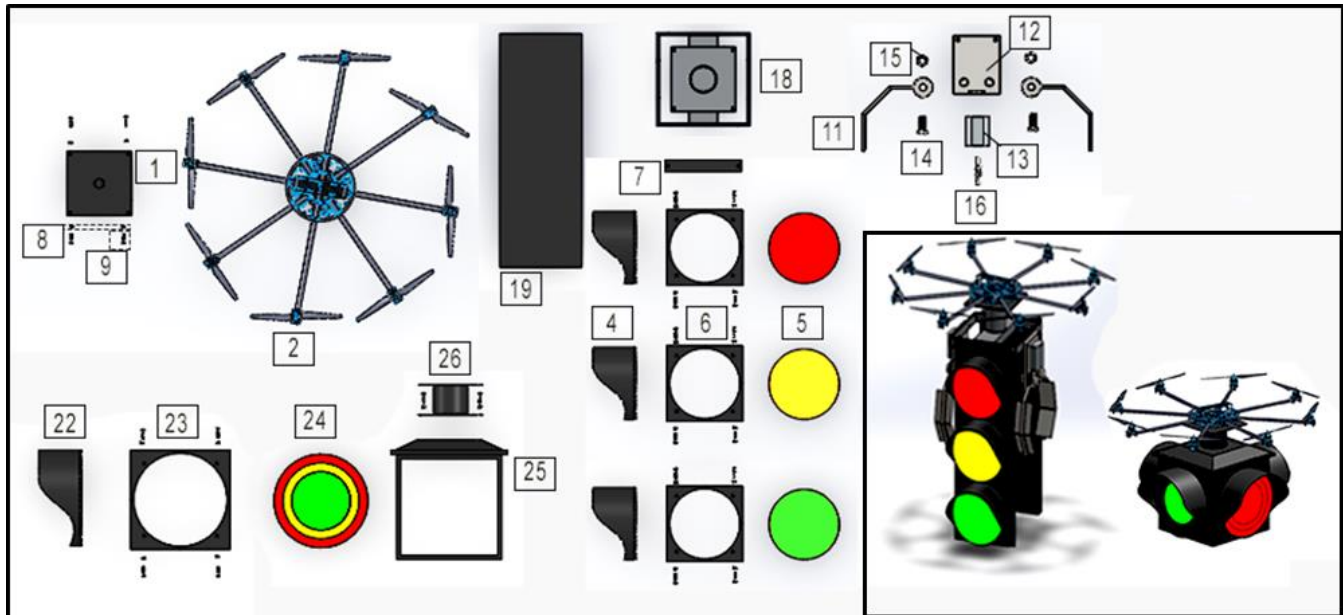


Figure 2: Traffic Drone Mast and Hover Attachment: Exploded View of Parts

The Traffic Light Mast Attachment is made up of four major components: a standard 12'' diameter LED Traffic light front, a battery pack/counterbalance on the back, 2 Clamp assemblies, and a main connection plate to attach to the drone at the top. The overall dimensions would be 24''x 24''x 48'' (Figure 3).

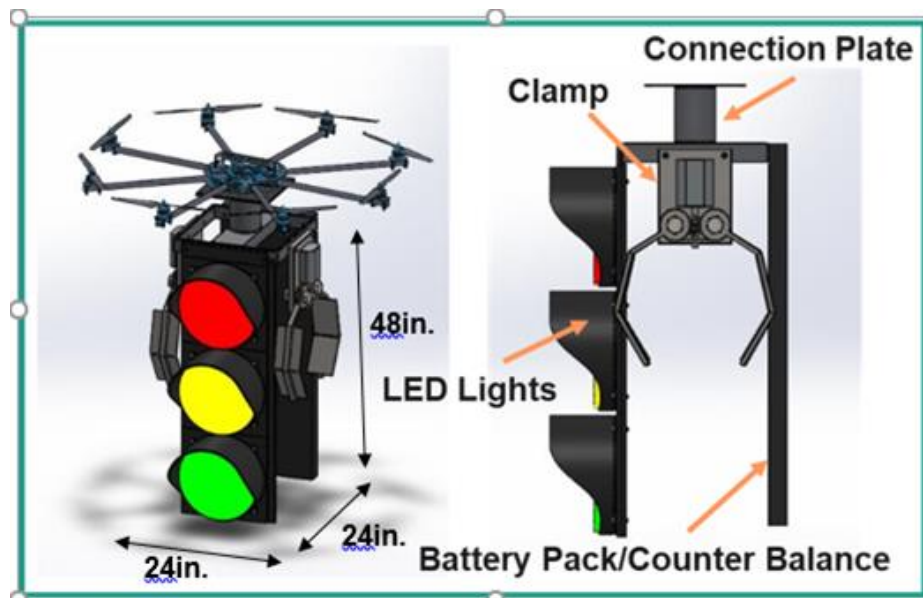


Figure 3: Enlarged Dimetric and Side view of Mast Attachment

The Hover Attachment incorporates an enlarged 16'' LED light with dimensions 20''x 20''x 24'' (Figure 4). A fly-by-wire was incorporated into the design that would connect the drone to a power source located on the ground via wire, allowing the drone to hover for an extended amount of time.

The issue of colorblind people was also addressed with a modified concentric circle light design. As the color changes from green to red, the size of the light increases.

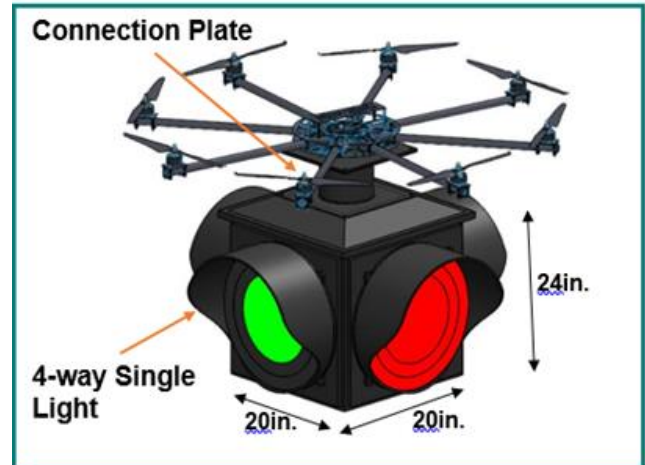


Figure 4: Enlarged Dimetric and Side view of Hover Attachment

IV. Conclusions/Project Status

In conclusion, the design challenge of an innovative application for drones has been reached with the incorporation of a temporary traffic light drone to provide a faster and more convenient way to address traffic malfunctioning and needs. As of now, the current state of the concept is still very immature with additional prototyping and testing needed, particularly with respect to safety. That being said, the technological and engineering feasibility of this project strongly point in a direction of continued development. The end goal would be to patent, advertise, and implement the design in the public market.

Project Description

A: Introduction

I. What is needed?

Unmanned aerial vehicles, also known as UAVs or drones, are becoming increasingly ubiquitous in society. With improvements in battery technology, brushless motors, and machine learning, many societal problems can now be accomplished by drones. Additionally, drones have the capability to transport small items intermediate vertical distances, and operate in confined spaces where a larger craft would be impractical. This report seeks to find a new innovative drone application that abides by FAA guidelines, is modular for drones, and utilizes existing drone technology. Utilizing several decision matrixes that can be found in Appendix D, the team determined that a Traffic Drone to alleviate automotive traffic issues is the best solution.

II. Why is it needed?

In 2011, 800,000 signals were recorded in the U.S for the 2012 National Traffic Signal Report Card. Additionally, from the 219 agencies that responded to the survey, a total expense of \$425,587,717 was spent on operating and maintenance programs for traffic lights and \$303,159,558 on capital projects for traffic signal programs.

Despite the large amounts of funding dedicated to traffic light operation and maintenance, the National Transportation Operations Coalition (NTOC) still scored the U.S a D+ for traffic light management and maintenance. One of the primary factors agencies attributed to the low score in maintenance was a limited staff, which prevented efficient management of all traffic lights.

Current solutions for temporary traffic lights are also limited to mounted traffic lights, personnel on road, flashing red lights, or closing the road. These solutions are substandard because they either do not alleviate traffic flow, are not quick and easy to set up, or cannot be used for long durations of time. With the implementation of drone technology within the realm of traffic, many of these requirements can be reached and a proper solution for temporary traffic lights can be achieved.

III. What is the solution?

The solution is a modular Traffic Drone that acts as a temporary traffic light. The modularity of the design allows the Traffic Drone to address two possible scenarios: attaching to a mast and hovering at an intersection (Figure 1). In the Mast Attachment scenario, the operator can guide the drone to the mast and attach the traffic light directly using a two-clamping mechanism. The hovering scenario addresses situations where there is no mast available but a light is still needed. The drone would fly the single 4-way light system to the center of the intersection to act as a temporary traffic light.

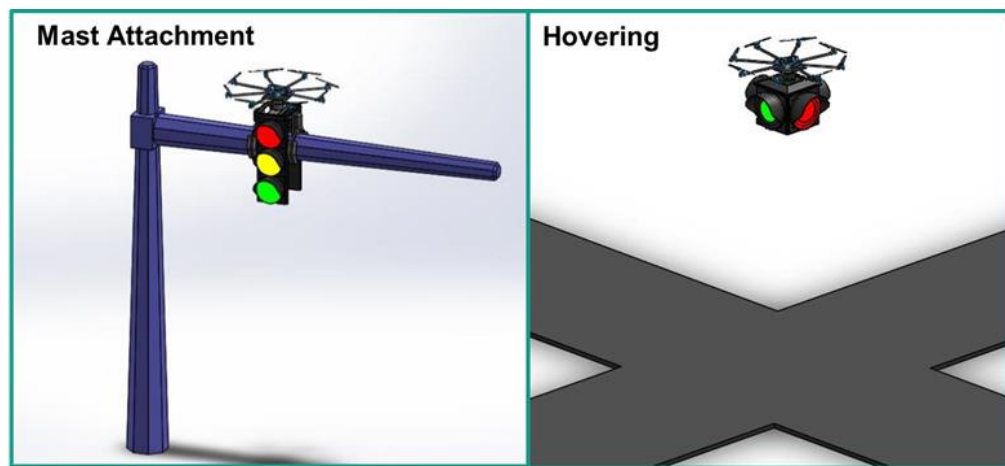


Figure 1: Overview of design in Mast Scenario (Left) and Hover Scenario (Right)

IV. Overview of Report Organization/Layout.

Following this introduction, details concerning the Prototype Traffic Drone design will be addressed, including customer requirements, other competitors, and metrics for performance evaluation. Afterwards, the decision process and concept generation of the Traffic Drone will be discussed, followed by manufacturing, safety, and future testing procedures. A final conclusion will be reached based on performance and technological evaluations to determine whether the design should advance for future prototyping. Solidworks Engineering Drawings, Parts/Materials List, House of Quality, Decision Matrices, Objective Tree, Functional Analysis, Gantt Chart Analysis, Technological Readiness, and FAA guidelines are listed in Appendix A, B, C, D, E, F, G, H and I respectively.

B. Prototype Design

I. Prototype Overview

The Traffic Light Mast Attachment is made up of four major components a standard 12'' diameter LED Traffic light front, a battery pack/counterbalance on the back, 2 Clamp assemblies, and a main connection plate to attach to the drone at the top. The overall dimensions would be 24''x 24''x 48'' (Figure 2).

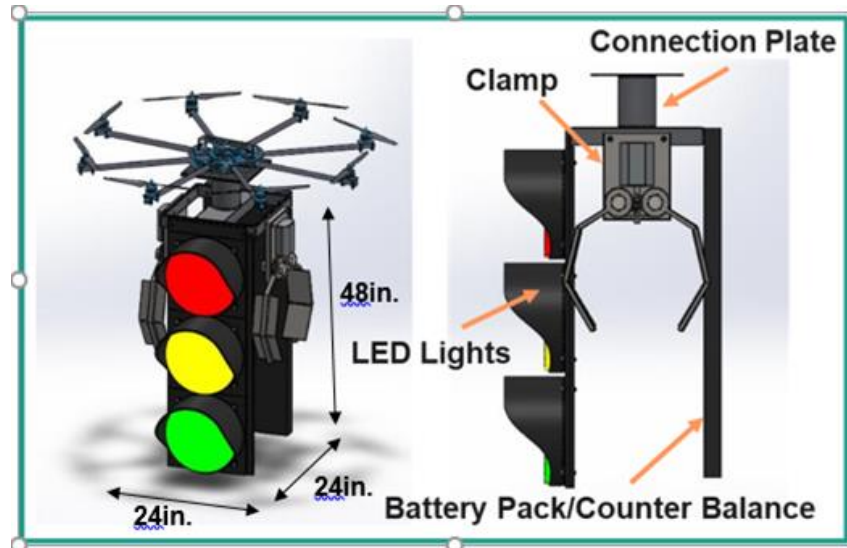


Figure 2: Enlarged Dimetric and Side view of Mast Attachment

The clamp assembly was inspired by robotic arm grippers and utilizes a worm gear and worm screw configuration (Figure 3). An electric engine drives the central worm screw, which rotates the two worm gears in opposing directions. The slightly angled threads on the worm gears and screw also prevent the gears from rotating the screw backwards. As a result, a simple, yet controllable clamping motion is created.

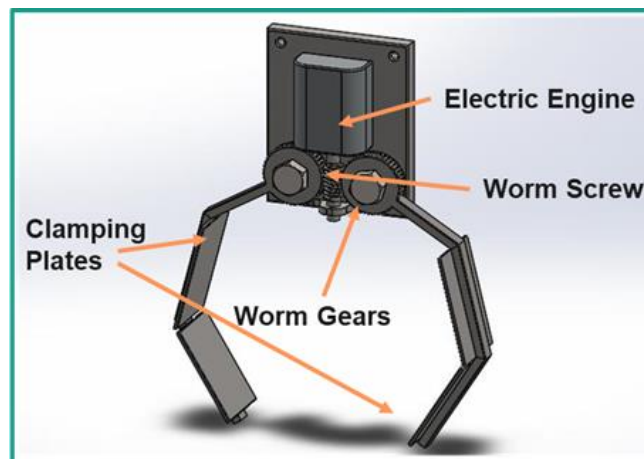


Figure 3: Parts of Clamp Design

The Hover Attachment incorporates an enlarged 16" LED light with dimensions 20" x 20" x 24" (Figure 4). A single light system was selected to reduce weight and improve overall flight time. Additionally, a fly-by-wire was incorporated into the design that would connect the drone to a power source located on the ground via wire, allowing the drone to hover for an extended amount of time.

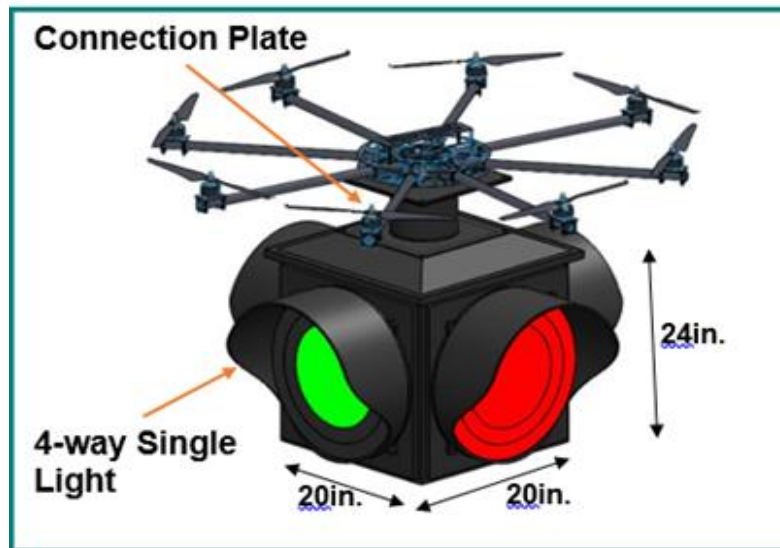


Figure 4: Enlarged Dimetric view of Hover Attachment

The issue of colorblind people was also addressed with a modified concentric circle light design. As the color changes from green to red, the size of the light increases from a standard 12in. diameter to the enlarged 16in. diameter. Other possible modifications for addressing colorblindness include adding a corresponding shape to be displayed in the LED light (Red-Circle; Yellow-Square; Green-Triangle).

II. Engineering Specifications

A. Customers

At the beginning of development, primary customers would include the Department of Transportation and Development, Traffic Maintenance companies and Construction companies, who would utilize the Traffic Drone on a daily basis during traffic light maintenance and repair or temporary road construction. As product development increases, the customer will expand from a purely industrial sphere to include a more public customer base. The goal would be to offer the Traffic Drone to the entire North American market, still mainly focusing on construction and traffic maintenance companies, but also including event coordinators who could

utilize the Traffic Drone for temporary, large scale events such as concerts, festivals, and sporting competitions.

B. Functional Requirements and Constraints

In the 2012 National Traffic Signal Report Card Technical Report, leading transportation professionals designated the following necessary standards for traffic signals:

1. Provide smooth flow of traffic along streets
2. Effectively manage the traffic-handling capacity of intersections
3. Reduce vehicle stops and delays

These requirements would allow for reductions in congestion, fuel consumption, and air pollution.

Furthermore, when surveying traffic agencies, it was noted that a majority of agencies lack adequate staff and training resources and are, therefore, forced to address only the most critical issues rather than proactively maintain the overall signal system (2012 National Traffic Signal Report Card Technical Report, 2012).

In terms of money, it costs taxpayers \$250,000 to \$500,000 to purchase and install a standard traffic signal. And electric bills and routine maintenance amount to about \$8,000 a year (“Traffic Signals”, 2016).

Based on the standards provided by leading transportation professionals, poor performance of traffic agencies due to inadequate staff, and the large amount of money required to install new traffic signals, the following key functional requirements for the Traffic Drone product were determined:

1. Effectively control flow of traffic as a temporary Traffic Light
2. Fast and easy deployment with minimal staff
3. Reasonable Cost
4. Safe while active

Addressing drones in particular, other design constraints that were considered included adhering to all FAA guidelines, using existing drone technology, and making the design modular to various drones. The drone would also have to carry a payload of around 15 kg in accordance with the standard weight of a traffic light (Signalfan, 2015). Additionally, surveying the average cost of drones that could hold a payload of 15 kg which ranged from \$10,000-\$30,000 (“Best

Heavy Lift Drones”, 2017) and considering the actual cost to install and maintain standard traffic lights the budget for the Traffic Drone design was limited to under \$20,000.

C. Competition/Alternatives

Currently, drones have never been incorporated into traffic as a temporary traffic light system. The best alternatives towards controlling traffic flow during electrical failures, road construction, or other situations that require a temporary traffic light include mounted temporary traffic lights, personnel on the road, utilization of the flashing red light, or closing the road entirely (Figure 5).

For mounted temporary traffic lights, there are companies such as Ver-Mac that offer trailer mounted traffic signals for construction and power outages. The system can efficiently function as a traffic light; however, the overall size of the mount makes the system difficult to deploy quickly and maneuver with limited staff (“Temporary Traffic Lights & Portable Traffic Signal”, 2017).

Flashing red lights are a simple installation for standard lights, but they do not maintain steady traffic and are not adjustable for special cases. Furthermore, a study by Cynecki and Spark conducted on the effectiveness of flashing lights in reducing illegal vehicle movements, found that speeds and violation rates of red lights actually increased after flashing beacons were added to advance warning signs at two school crossings (Cynecki, 2013).

Personnel on the road allows for maneuverability during unexpected incidences, but human interaction also fails to efficiently control the flow of traffic, and a single operator cannot direct traffic for extensive lengths of time.

Finally, closing the road would completely cut off flow of traffic, and road closures can also be difficult to set up depending on how far the road extends and also difficult to modify for unexpected events.



Figure 5: Alternative Competitors (1) Mounted Temporary Traffic Light, (2) Personnel on Road, (3) Flashing Red Light, (4) Closing Road

<https://goo.gl/sVGSZ4>, <https://goo.gl/wXf5GJ>, <https://goo.gl/nfbuZ4>, <https://goo.gl/t52hAi>

D. Metrics for Evaluation

Based on the needs of consumers, 14 metrics were determined to measure the performance of the design in comparison to major competitors. These metrics were grouped in five categories: Safety, Handling, Appearance, Expense, and Effectiveness. (Table 1)

Engineering Specs .	Targets	Justification	Score
Safety			
Possible Failure Points	1-3 points	Subjected to multiple uses	4
Weather Resistant	Waterproof	Functioning in varying climates	4.8
Legality	FAA Aproved	Requirement	5.3
Minimal Human Aid	1 Person	Limited Staff	4.1
Lifting Capacity	> 15kg	Standard weight of Traffic light	7.4
Handling/Electronics			
Implementation Time	< 10 min.	Limited Staff/ Customer Need	5.7
Maneuverability	> 80ft	Customer Need/ Standard Road dimensions	6.2
Transmitter Frequency Distance	> 80ft	Standard Road dimensions	6.5
Physical			
Size	< 24" x 24" x 48"	Compact for Portability	10
Parts Number	< 30 Unique Parts	Customer Need	6.6
Weight	< 30kg	Design Constraint/ Customer Need	8.8
Expense			
Cost	Under \$20,000	Design Constraint/ Customer Need	10.4
Effectiveness			
Maintains Steady Traffic	< 3 min wait time	Standard wait time for working light	9.1
Active Time	>12 Hours	Standard time for Traffic Maintenance Response/ Contruction/Events	11.2

Table 1: House of Quality Metrics for Evaluation

Each metric was assigned a designated target that was deemed acceptable, justification for that target, and a weighted score of importance in accordance with the weighted requirements of the customer. The four highest weighted metrics were Active Time, Cost, Size, and Maintenance of Steady Traffic.

Active time was determined as the amount of time the product could remain functioning without human interaction. Standard traffic maintenance response times range from 4 to 8 hours on average; however they can extend to over 24 hours based on available resources and urgency of issue (2012 National Traffic Signal Report Card Technical Report, 2012). Furthermore, construction hours and other temporary events usually last the full day. Therefore, the target of greater than 12 hours was deemed optimal.

III: Design Synthesis

A. Concept Selection

The process of refining the given project problem, innovative application for drones, into the resulting solution, Traffic Drone, involved several brainstorming session as well as multiple decision matrices.

The team's first brainstorming session focused on the subject that the drone would address. Ideas were generated in Decision Matrix 1 in Appendix D and evaluated using criteria based on customer requirements such as market need, innovation, and simplicity for the operator. Given these constraints, the ceiling cleaning drone, guide drone for blind people, and traffic drone all scored high, but traffic drone overwhelmingly dominated as the optimal option.

Next, the function that the traffic drone would complete was decided with Decision Matrix 2 also located in Appendix D. Ideas for functions included: a temporary traffic light, road hazard detection, traffic flow monitoring, accident detection, debris removal, drone-car communication, and police/ambulance/fire truck escort drone to warn traffic of approaching emergency vehicles. While all of these ideas had merit, the critical criteria of technological feasibility and potential for collision (the antithesis of alleviated traffic) in Decision Matrix 2, showed that a temporary traffic signal was the best option.

Finally, a drone was selected based on design constraints of lifting capacity, flight time, and cost. Three drones satisfied the lifting capacity of 15kg: the FreeFly Alta 8, the xFoldDragon x12, and the Vulcan Airlift. In the end, the FreeFly Alta 8 was selected because it satisfied all the requirements and also had the lower cost of \$12,000 in comparison to the other two drones.

B. Concept Generation

After the function of temporary traffic light and designated drone were selected, each member of the team presented a design concept of the Traffic Drone (Figure 6).

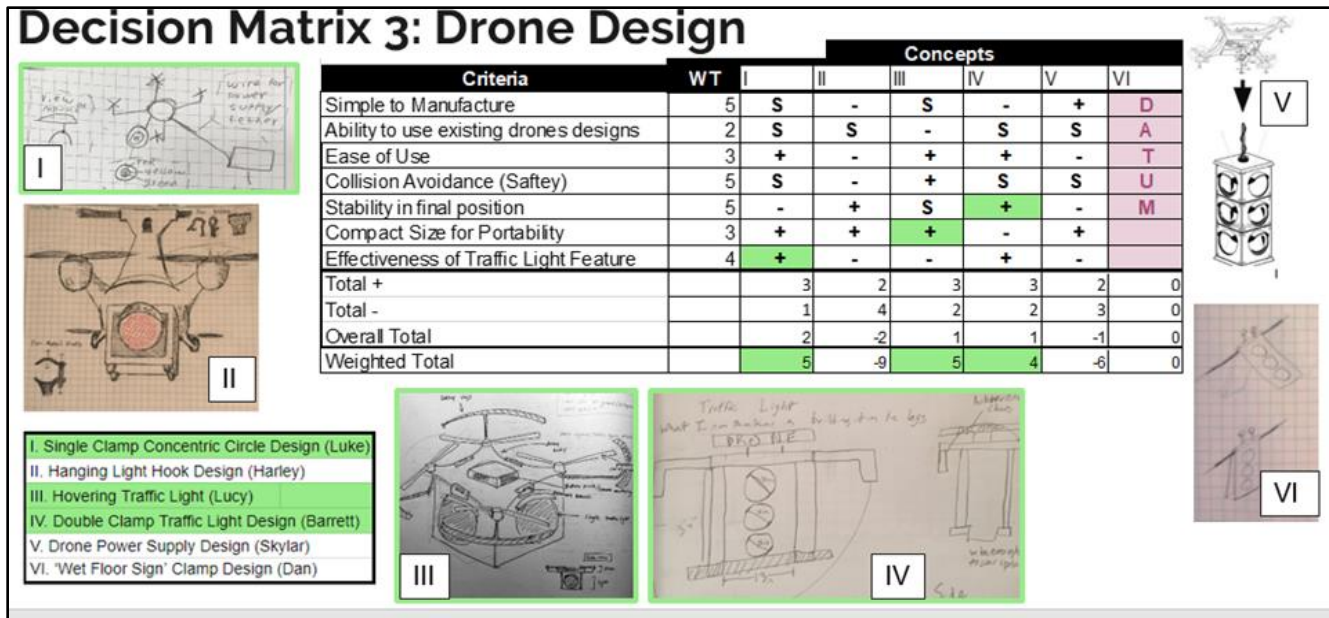


Figure 6: Decision Matrix 3-Drone Design

Three of these designs scored close to one another based on engineering specifications of simplicity, effectiveness and safety. The positive aspects of all three of these designs: (1) the Single Clamp Concentric Circle Design, (3) the Hovering Traffic Light, and (4) the Double Clamp Traffic Light Design were used to synthesis a final modular Traffic Drone design. These aspects included a dual hovering and clamping features, the inclusion of a “fly by wire”, which would allow the drone to recharge via wire from a power source on the ground to maximize flight time infinitely, and a concentric light design to address colorblind people.

C. Functional Decomposition

Once the optimal three designs were selected a functional decomposition and objective tree of the Traffic Drone was conducted to generate refined ideas as shown in Appendix E and F. For the Mast Attachment, the drone had to Launch, Detect the mast, and Clamp onto the mast. Launching would follow similar procedures since the main function of the drone would not be modified. For detecting the mast, optical, infrared and ultrasonic sensors were included in the design. To clamp onto the mast, a worm gear and screw design was generated and modified through several iterations (Figure 7).

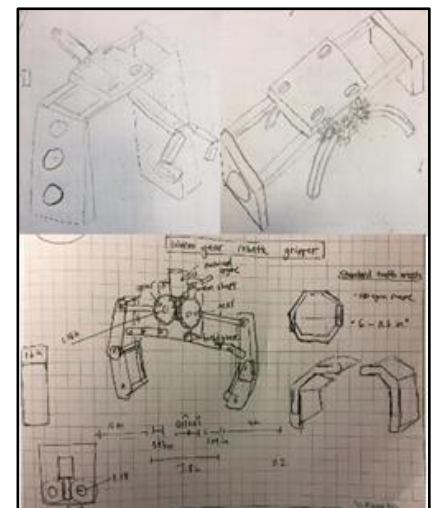


Figure 7: Clamp Concept Generation and Refinement

With the Hover attachment, the Drone would have to Launch, Fly to the center of the intersection, and Stabilize and hover for an extended time. Launching was a similar procedure, and optical, infrared and ultrasonic sensors were also incorporated in this design to locate the center of the intersection. To stabilize flight for a long duration, a power wire is connected to the light, which supplies energy from a power source located on the ground.

C. Manufacturing Considerations & Testing Plans

I. Manufacturing

The pre-assembled FreeFly Alta 8 will only need to be slightly modified by welding on an aluminum connection plate at the bottom. For the framework of the traffic signals attachments, polycarbonate, a lightweight thermoplastic commonly used for traffic light housings, will be used. Polycarbonate parts will be created from molds to simplify manufacturing process, and the lightweight property of the material will allow for a reduction in payload weight.

For the clamping mechanism, which experiences the most stress and is a major point of stability, all parts will be casted using aluminum, because of its lightweight and durable material properties.

To further simplify the manufacturing process, all pieces are joined using a standard main screw and main nut, which will also be machined out of aluminum.

In general, polycarbonate is a non-corrosive material, and aluminum has high corrosion resistance. Aluminum parts will also undergo further corrosion treatment to improve corrosion resistance, since the system will be subjected to varying outside weather conditions. For further details on assembly process of Traffic Drone, refer to Engineering Drawings in Appendix A.

II. Safety

Several safety features will be incorporated to account for major risks that could occur. The traffic signal attachments will have integrated latching systems to lock the drone onto the signal structure to prevent the drone from falling onto cars or people below. The drone will also be equipped with a homing capability, which allows it to return to a preset location using GPS technology if the battery level drops below a certain percentage. This feature prevents the drone from falling mid-flight due to sudden power loss. Furthermore, blade guards will be incorporated on the propellers in order to prevent objects from colliding with the blades during flight.

III. Testing

After the product is generated, four preliminary tests will first be conducted: Durability Test, Payload Test, Flight Time Test, and Controllability Test. These tests will ensure that the drone can carry both traffic light attachments, fly for the designated amount of time, be easy to maneuver, and sustain multiple uses. Once these requirements are met, on-site testing of a Flight Stability Test for the Hover System, and Attachment Test, for the Mast system will be conducted to determine effectiveness of design in stabilizing and acting as a temporary traffic light system. Metrics of evaluation for success would be in accordance with the targets given in the House of Quality Metrics for Performance.

D. Conclusion

To evaluate the concept generated, a Technology Readiness Analysis was conducted which can be found in Appendix H. The study determined the overall technological readiness of the Traffic Drone. Three of the concepts: Mounting the Traffic Light to the Drone, The Clamping System, and the Concentric Light Design were still in the preliminary design stage; however, the technology and resources needed to generate these concepts are all well-developed.

The Traffic Drone was also compared to its competitors based on the metrics of evaluation (Figure 8).

Engineering Specs.	Targets	Temporary Sign	Flashing Red Light	Personnel on road	Closing Road	Traffic Drone
Safety						
Possible Failure Points	1-3 points	Pass	Pass	Pass	Fail	Pass
Weather Resistant	Waterproof	Pass	Pass	Fail	Pass	Pass
Legality	FAA Aproved	N/A	N/A	N/A	N/A	Pass
Minimal Human Aid	1 Person	Fail	Pass	Fail	Fail	Pass
Lifting Capacity	> 15kg	N/A	N/A	N/A	N/A	Pass
Handling/Electronics						
Implementation Time	< 10 min.	Fail	Pass	Fail	Fail	Pass
Maneuverability	> 80ft	Fail	Fail	Pass	Fail	Pass
Transmitter Frequency Distance	>80ft	N/A	N/A	N/A	N/A	Pass
Visibility						
Size	< 24" x 24" x 48"	Fail	N/A	N/A	Fail	Pass
Parts Number	< 30 Unique Parts	Fail	N/A	N/A	Fail	Pass
Weight	< 30kg	Fail	N/A	N/A	Fail	Pass
Expense						
Cost	Under \$20,000	Pass	Pass	Pass	Pass	Pass
Effectiveness						
Maintains Steady Traffic	< 3 min wait time	Pass	Fail	Fail	Fail	Pass
Active Time	>12 Hours	Pass	Pass	Fail	Pass	Pass

Figure 8: Traffic Drone Design and other Competitors vs. Engineering Specification

Overall, the Traffic Drone performed exceedingly well in reaching the targets set by the customer requirements. The dual combination of drone with traffic light allowed the design to maintain the effective communicational characteristics of a traffic light and the maneuverable/portable characteristics of a drone.

Looking into the future, several obstacles need to be considered. Adhering to FAA regulations is the most imminent issue, specifically, maintaining visual line of sight between the operator and drone. The end goal is to get those regulations wavered, but until then, an operator would need to be present during the utilization of the drone.

Battery life is also a problem as it is limited by size of the battery. Until battery technology advances, fly-by-wire is a possible solution to providing the hovering application of the drone continuous power. Other issues such as durability from weather will be refined through further testing.

In conclusion, the design challenge of an innovative application for drones has been met. The traffic light drone is a unique way of approaching traffic problems in a world of increasingly congested cities. It provides a faster and more convenient way to address traffic junctions where a traffic light is malfunctioning or needed.

As of now, the current state of the concept is still very immature with additional prototyping and testing needed, particularly with respect to safety. That being said, the technological feasibility study as well as the performance evaluation of the Traffic Drone compared to other competitors strongly suggest the successful generation of this product with continued development. The end goal will be to patent, advertise, and implement the design to the public market.

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Appendices

Appendix A: Solidworks Models/ Engineering Drawings

Note: Numbers next to parts in Engineering Drawings Correspond with parts in Appendix B.

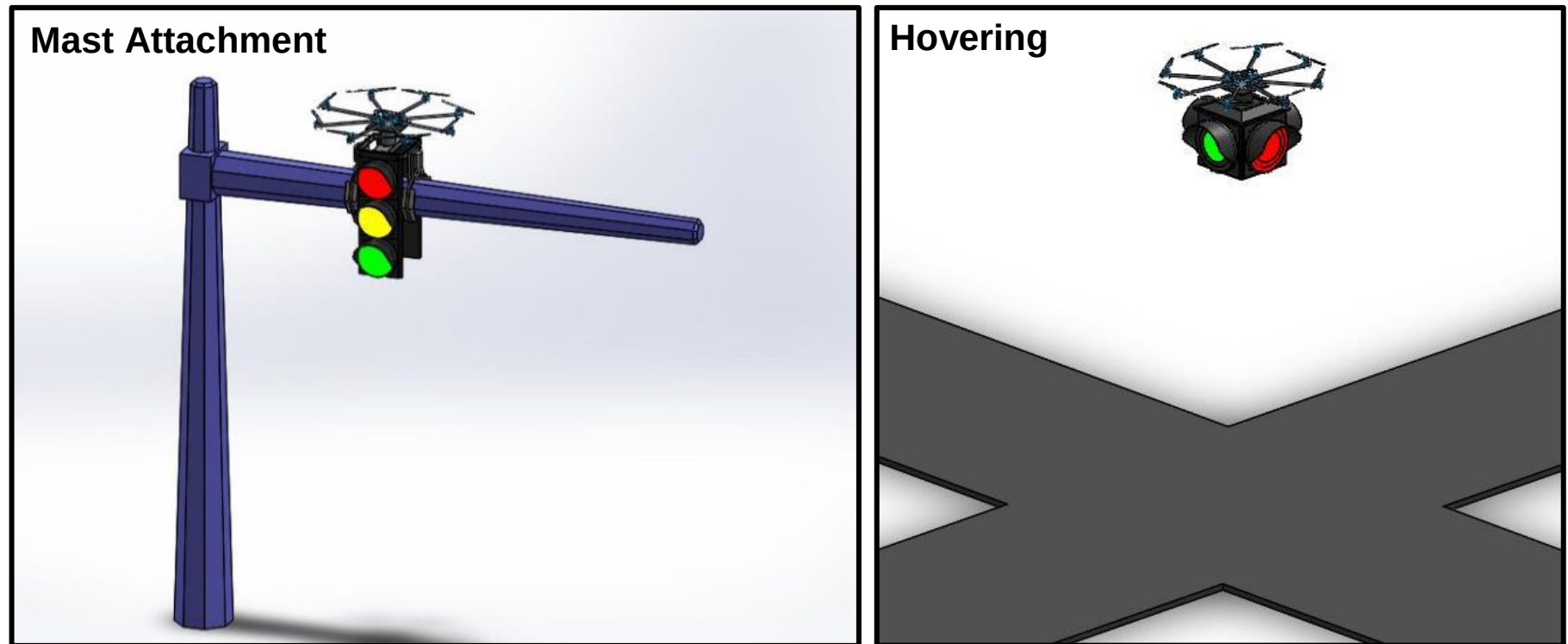
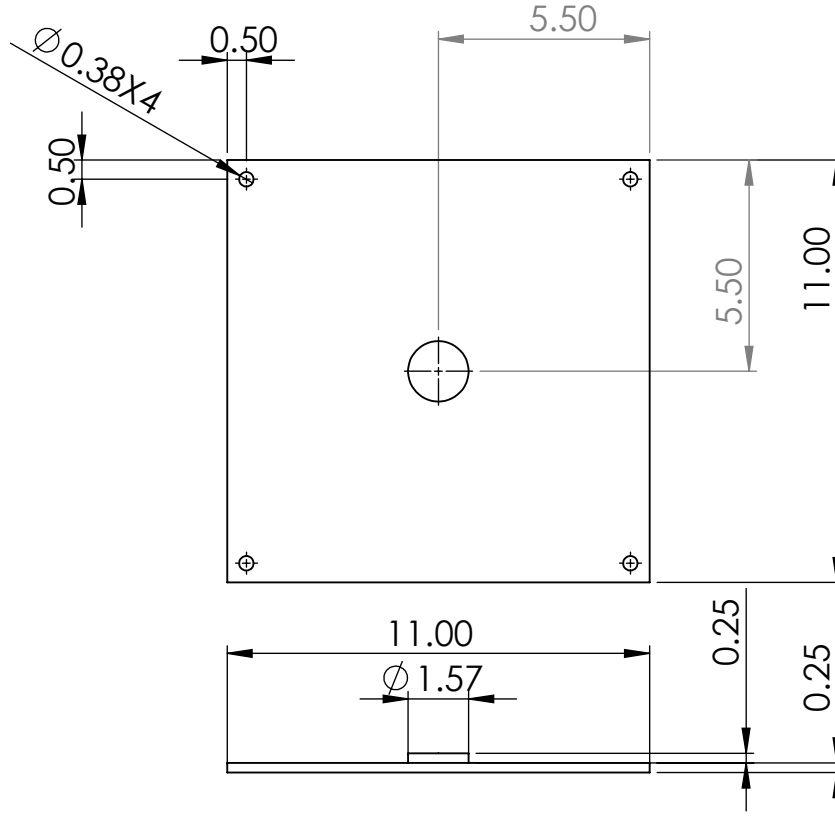


Figure A1: Overview of Solidworks Models in designated scenarios-
Mast Attachment (Left) Hover Attachment (Right)

B

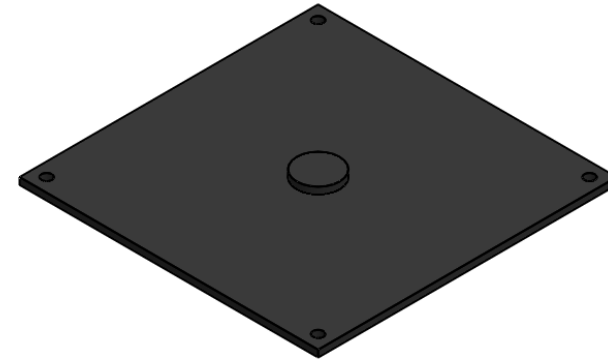
B



1

Drone Connection Plate

- WELDED TO FREE FLY ALTA 8 TO ALLOW FOR TRAFFIC LIGHT ATTACHMENTS
- 1 REQUIRED



A

Team: Team 6: NextDrone Technologies

TITLE: Free Fly Alta 8

Drawn By:
Lucy GuoDWG. NO.
DRONE CONNECTION
PLATEDate:
11/20/17

ME 2212 SEC 1

SCALE: 1:5

SHEET 1 OF 18

A

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Drone Connection Plate	ALUMINUM	1
2	Free Fly Alta 8	ALUMINUM AND CARBON FIBER	1



3 DRONE SUBASSEMBLY

- MODIFIED VERSION OF FREE FLY ALTA 8 WITH CONNECTION PLATE ATTACHMENT
- 1 REQUIRED

Team: Team 6: NextDrone Technologies

TITLE: Free Fly Alta 8

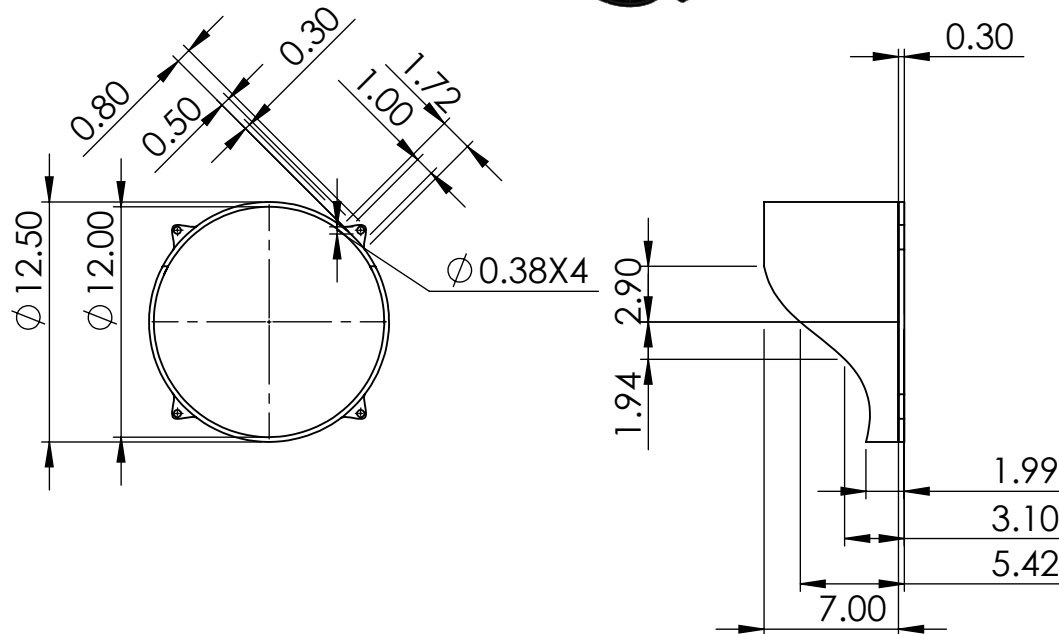
Drawn By:
Lucy Guo

DWG. NO.
Drone
Subassembly

Date:
11/20/17

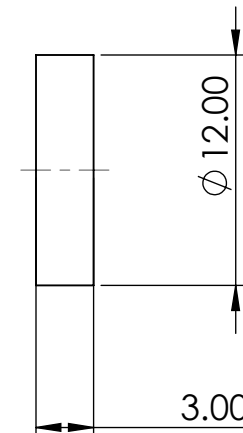
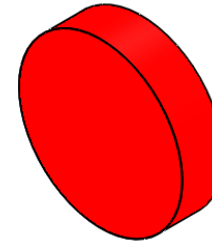
B

B



4 LIGHT COVER

- EQUAL DISTANCE FOR ALL FOUR TABS AND HOLES
- 3 REQUIRED



5 LED LIGHT

- INSERTED INSIDE LIGHT COVER
- MANUFACTURED IN RED, YELLOW AND GREEN
- 3 REQUIRED

A

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Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Mast Attachment

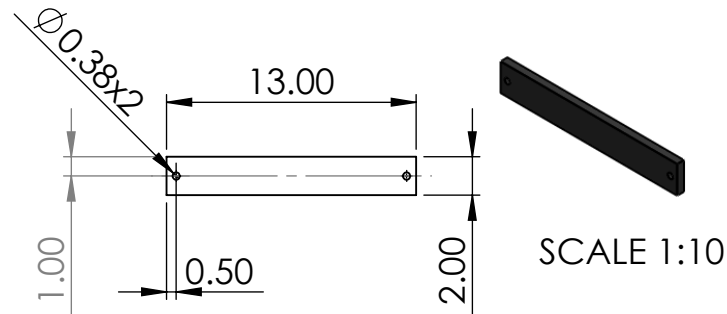
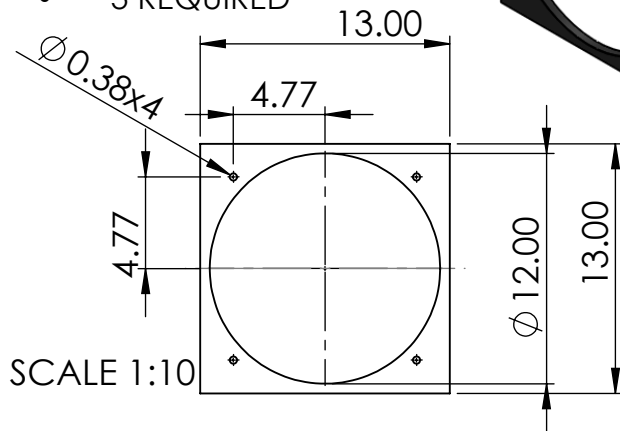
Drawn By:
Lucy Guo

DWG. NO.
Light Cover and
Lights

Date:
11/20/17

6 LIGHT BACK FRAME

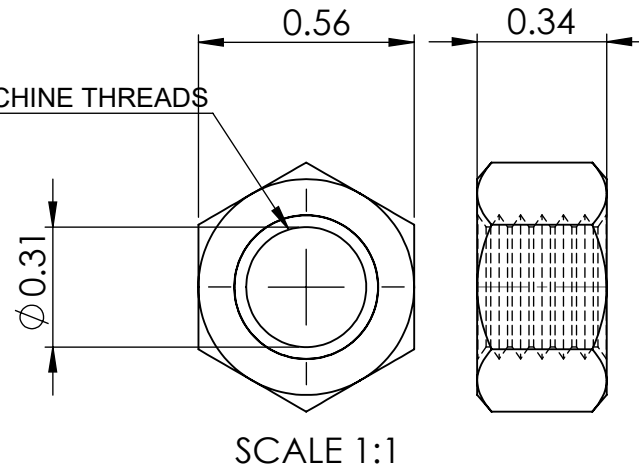
- ATTACHES TO LIGHT FRAME
- WELD 3 TOGETHER TO CREATE MAIN FRAME
- 0.5" THICKNESS
- 3 REQUIRED



7 LIGHT TOP CONNECTION PLATE

- WELDED TO TOP OF LIGHT BACK FRAME
- SERVES AS CONNECTION BETWEEN LIGHTS AND DRONE CONNECTION PLATE
- 0.5" THICKNESS
- 1 REQUIRED

3/8-16 MACHINE THREADS

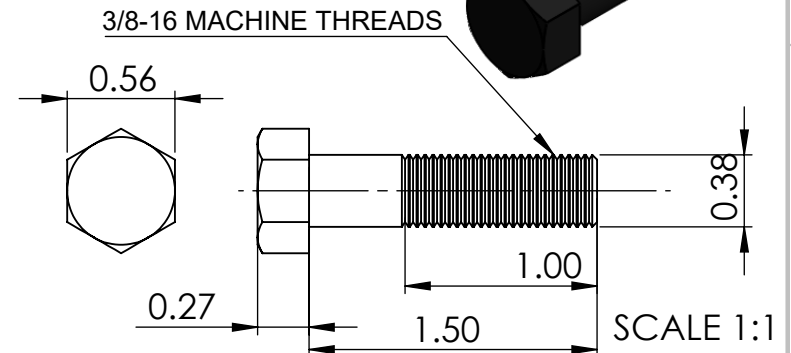


9 MAIN NUT

- HOLDS MAIN BOLTS IN PLACE
- 24 REQUIRED

8 MAIN SCREW

- CONNECTS ALL MAJOR PIECES TOGETHER
- 24 REQUIRED



Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Mast Attachment

Drawn By:

Lucy Guo

DWG. NO.

Light Back Frame,
Light Top Connection
Plate, Screws and Nuts

Date:

11/20/17

ME 2212 SEC 1

SCALE VARIES

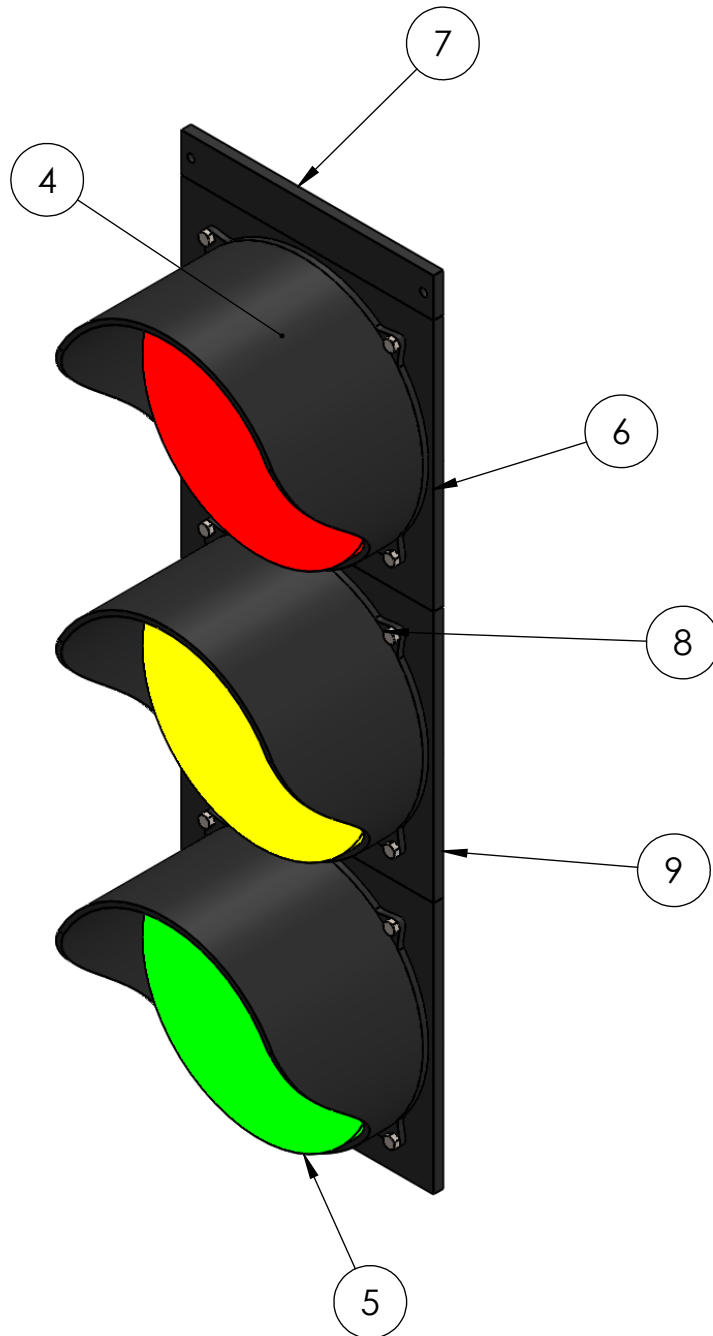
SHEET 4 OF 18

B

B

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
4	Light Cover	POLYCARBONATE	3
5	LED Light	LEDs	3
6	Light Back Frame	POLYCARBONATE	3
7	Light Top Connection Plate	POLYCARBONATE	1
8	Main Screw	ALUMINUM	12
9	Main Nut	ALUMINUM	12

- 10 TRAFFIC LIGHT SUBASSEMBLY
- MAIN LIGHTING SYSTEM OF TRAFFIC LIGHT MAST ATTACHMENT
 - 1 REQUIRED

Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Mast Attachment

Drawn By: Lucy Guo	DWG. NO. Light Subassembly	Date: 11/20/17
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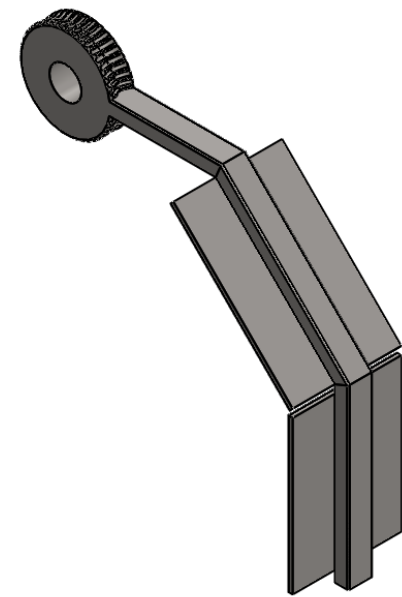
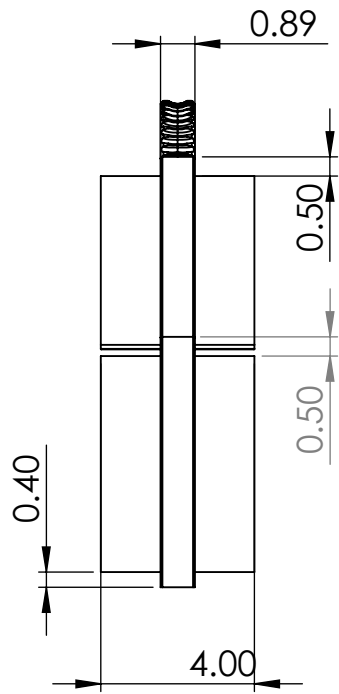
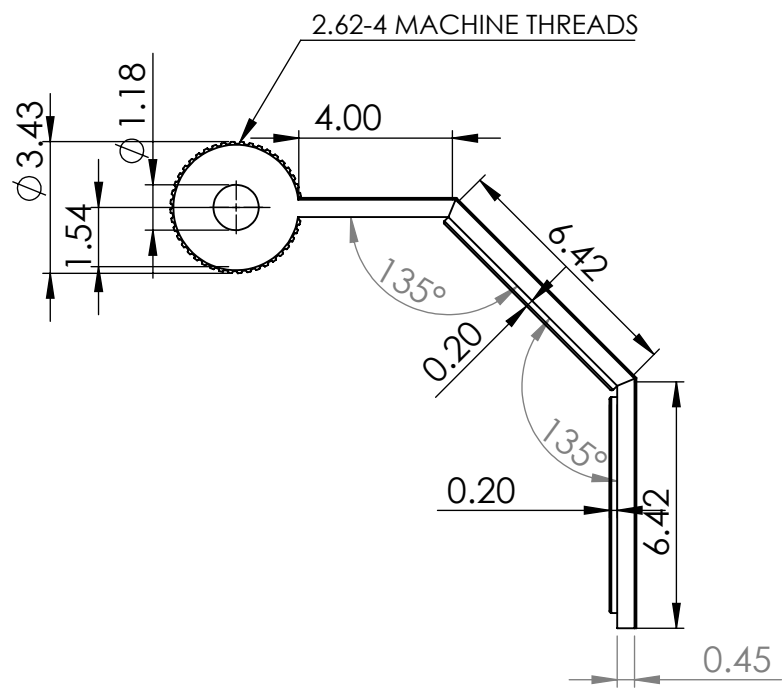
ME 2212 SEC 1

SCALE: 1: 7

SHEET 5 OF 18

B

B



11 WORM GEAR CLAMP

- WORM GEAR WITH ATTACHED CLAMPING ARM
- EXTENDED CLAMPING PLATES ON ARM FOR MAXIMIZED SURFACE AREA WHEN CLAMPING TO MAST
- CLAMPING PLATES IDENTICAL
- 4 REQUIRED

A

Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Mast Attachment		
Drawn By: Lucy Guo	DWG. NO. Worm Gear Clamp	Date: 11/20/17
ME 2212 SEC 1	SCALE:1:5	SHEET 6 OF 18

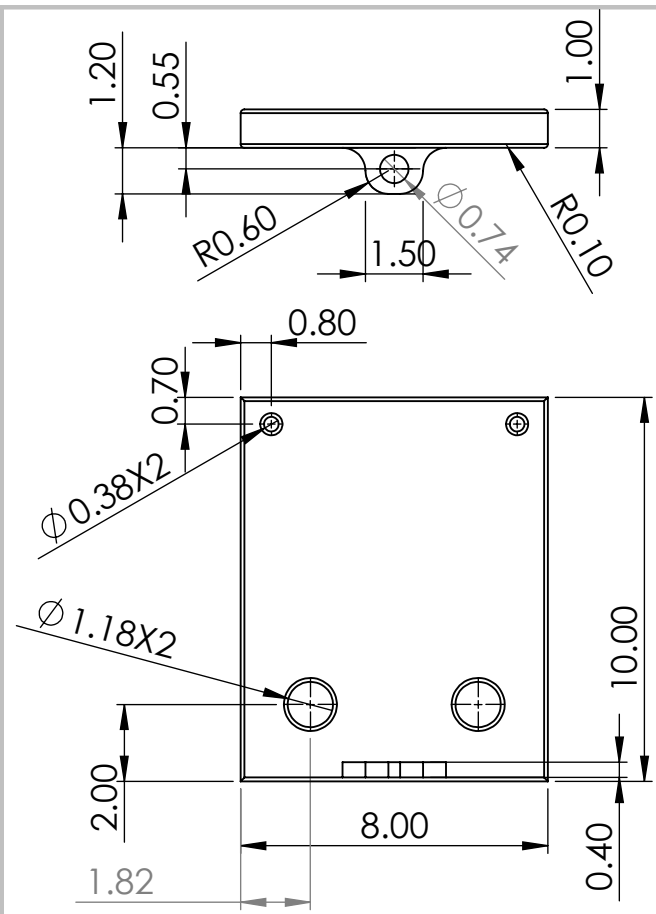
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B

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A

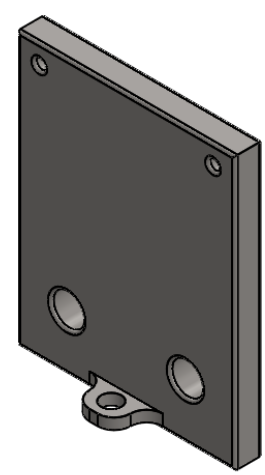
A



12 WORM GEAR MAIN BODY

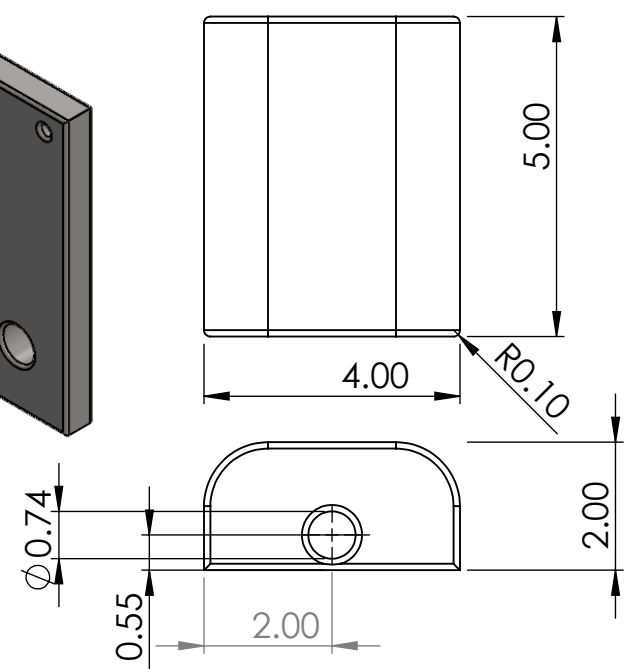
- TOP ATTACHES TO DRONE CONNECTION PLATE
- HOLDS WORM GEARS, ELECTIRC ENIGNE AND WORM GEAR CENTRAL SCREW IN PLACE
- 2 REQUIRED

SCALE: 1:5

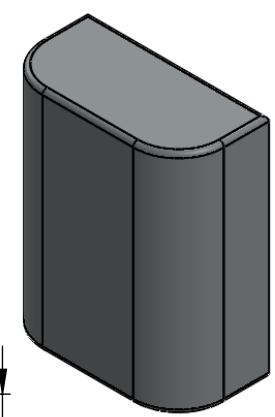


13 ELECTRIC ENGINE

- ATTACHES TO MAIN BODY
- PROVIDES POWER TO DRIVE WORM GEAR CENTRAL SCREW
- 2 REQUIRED



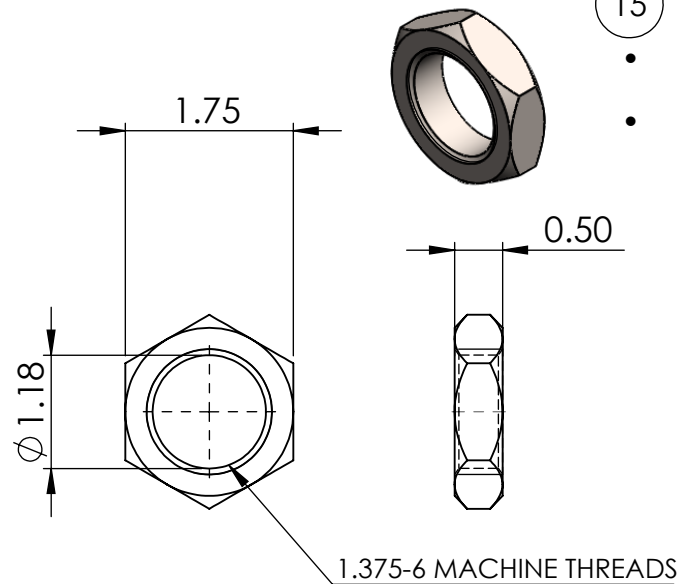
SCALE: 1:3



Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Mast Attachment		
Drawn By: Lucy Guo	DWG. NO. Main Body and Engine	Date: 11/20/17
ME 2212 SEC 1	SCALE VARIES	SHEET 7 OF 18

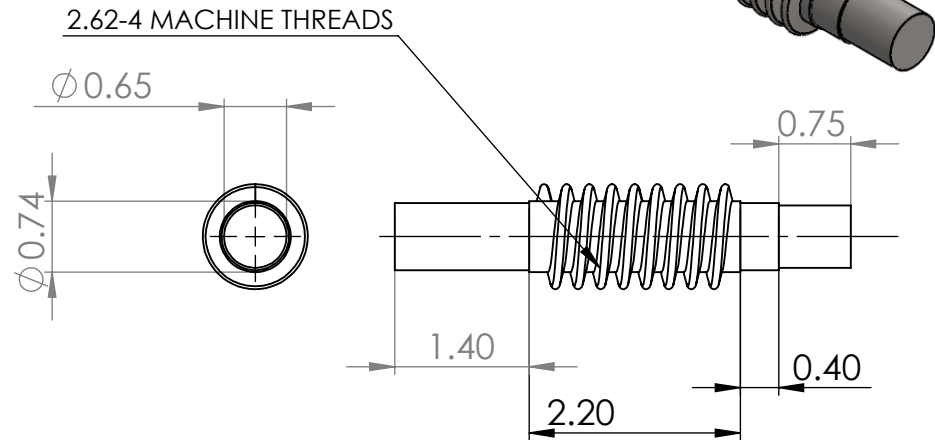
B

B



15 WORM GEAR NUT

- ATTACHES WORM GEAR TO MAIN BODY
- 4 REQUIRED

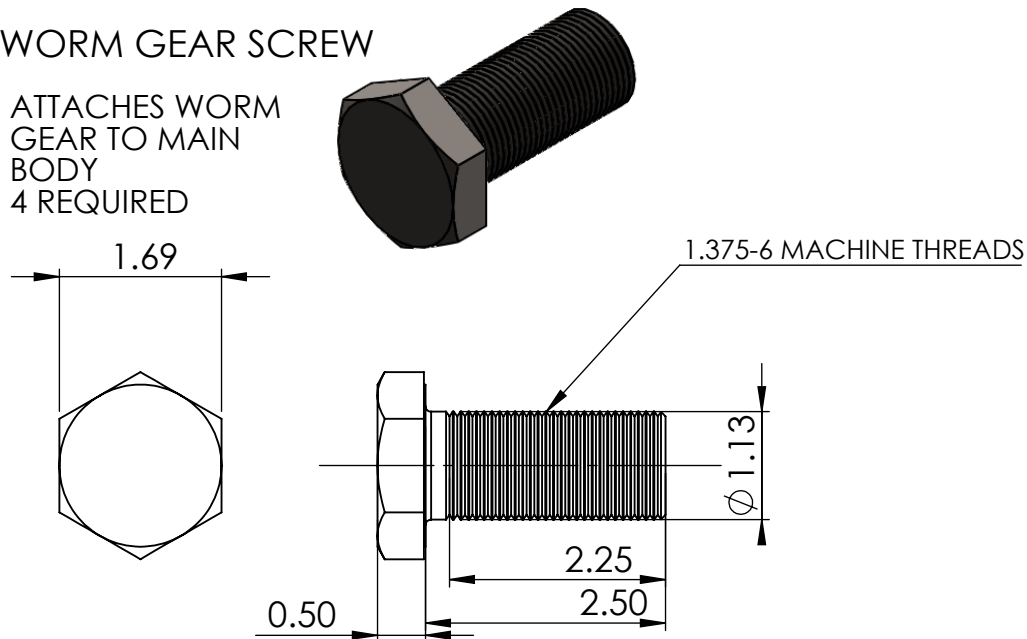


16 WORM GEAR CENTRAL SCREW

- ATTACHED TO ELECTRIC ENGINE
- ROTATES WORM GEARS TO PROVIDE CLAMPING MOTION
- 2 REQUIRED

14 WORM GEAR SCREW

- ATTACHES WORM GEAR TO MAIN BODY
- 4 REQUIRED



A

A

Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Mast Attachment

Drawn By:
Lucy Guo

DWG. NO.
Screws and Nuts

Date:
11/20/17

ME 2212 SEC 1

SCALE: 1:2

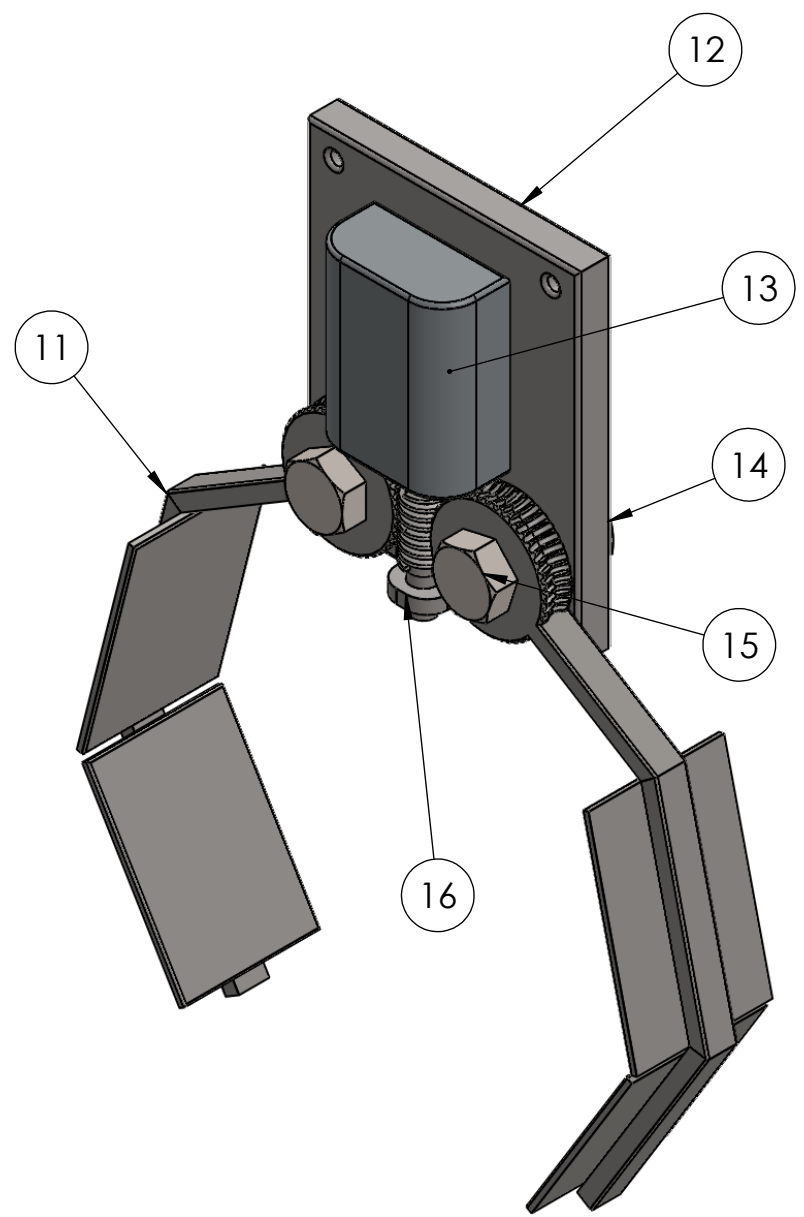
SHEET 8 OF 18

B

B

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
11	Worm Gear Clamp	ALUMINUM	2
12	Worm Gear Main Body	ALUMINUM	1
13	Electric Engine	ALUMINUM	1
14	Worm Gear Nut	ALUMINUM	2
15	Worm Gear Screw	ALUMINUM	2
16	Worm Gear Central Screw	ALUMINUM	1

- 17 WORM GEAR CLAMP SUBASSEMBLY
- MAIN CLAMPING SYSTEM OF TRAFFIC LIGHT MAST ATTACHEMENT
 - 2 REQUIRED

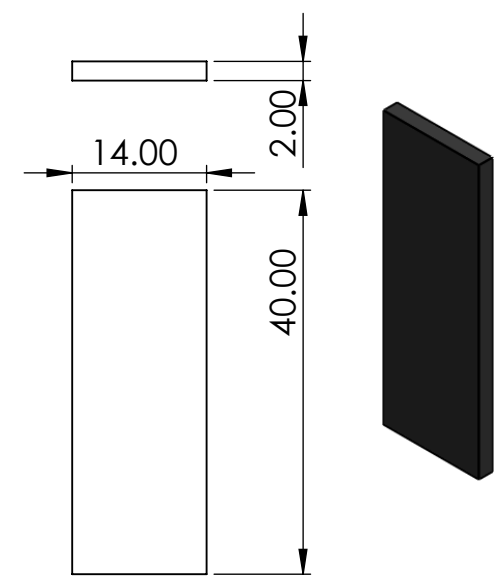
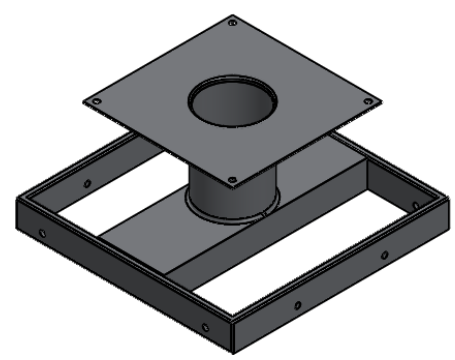
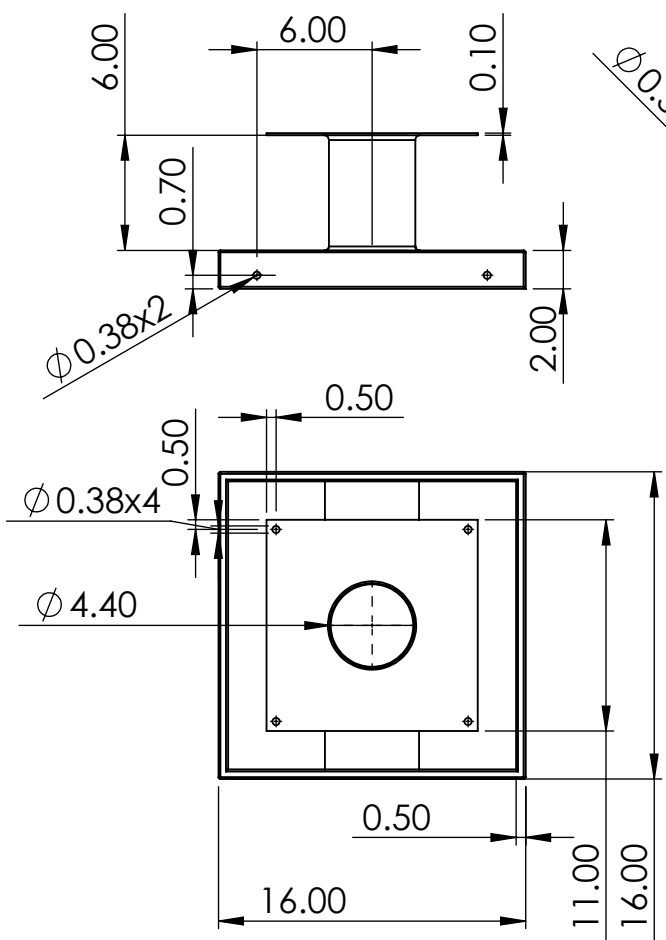
Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Mast Attachment		
Drawn By: Lucy Guo	DWG. NO. Worm Gear Clamp Subassembly	Date: 11/20/17
ME 2212 SEC 1		SCALE: 1:4
SHEET 9 OF 18		

B

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- 19 BATTERY PACK AND COUNTERBALANCE
- ATTACHES TO BACK OF CONNECTION PLATE
 - ACTS AS BATTERY STORAGE SITE AND COUNTERBALANCE FOR LIGHTS IN FRONT
 - 1 REQUIRED

- 18 TRAFFIC TO DRONE CONNECTION PLATE
- ATTACHES TRAFFIC LIGHT SYSTEM AND CLAMPING SYSTEM TO DRONE
 - SIDE HOLES AT SAME HEIGHT
 - 1 REQUIRED

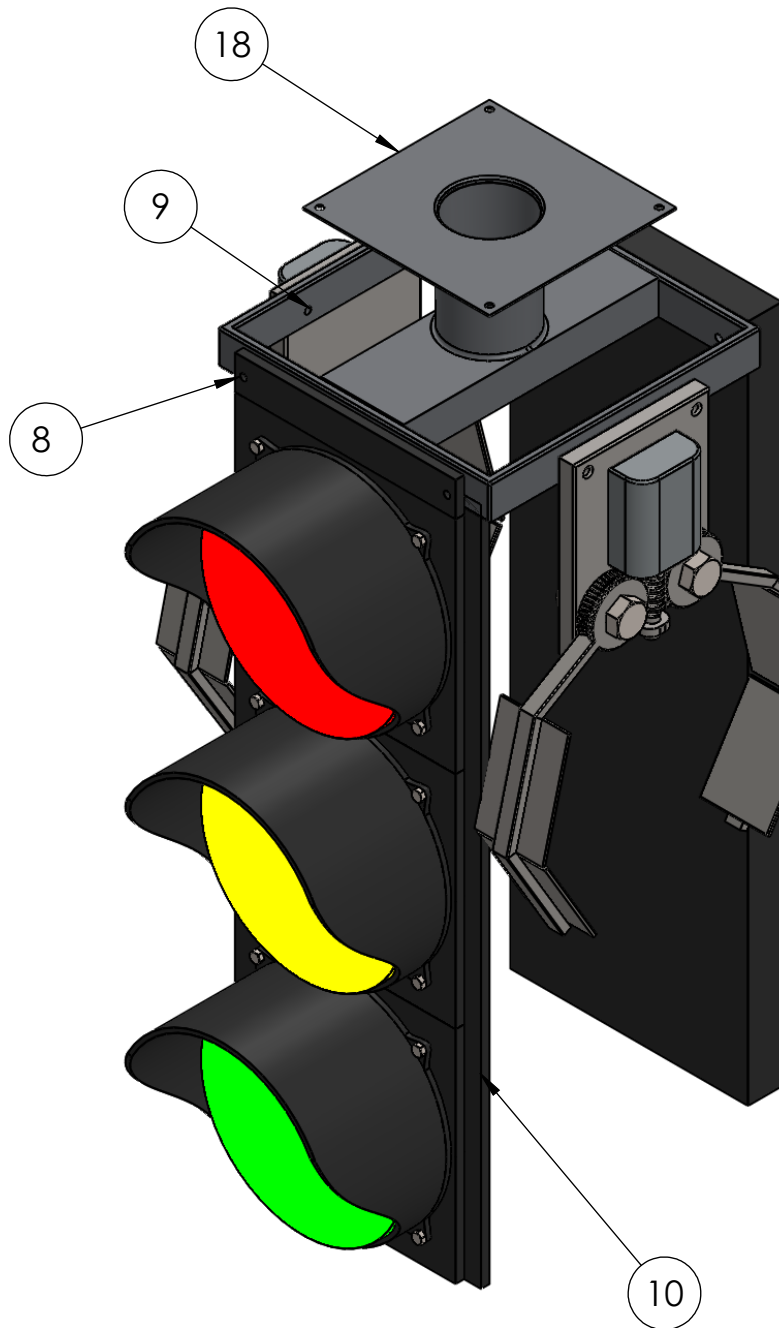
Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Mast Attachment		
Drawn By: Lucy Guo	DWG. NO. Connection plate and Counterbalance	Date: 11/20/17
ME 2212 SEC 1		SCALE VARIES SHEET 10 OF 13

B

B

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ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
18	Traffic to Drone Connection Plate	POLYCARBONATE	1
19	Battery Pack and Counterbalance	POLYCARBONATE	1
10	Traffic Light Subassembly	POLYCARBONATE/LEDs	1
17	Worm Gear Clamp Assembly	ALUMINUM	2
8	Main Screw	ALUMINUM	8
9	Main Nut	ALUMINUM	8

- 20 TRAFFIC LIGHT MAST ATTACHMENT MAIN ASSEMBLY
- COMBINES TRAFFIC LIGHT SUBASSEMBLY, 2 CLAMP SUBASSEMBLIES, AND CONNECTION PLATE AND COUNTERBALANCE 1 REQUIRED

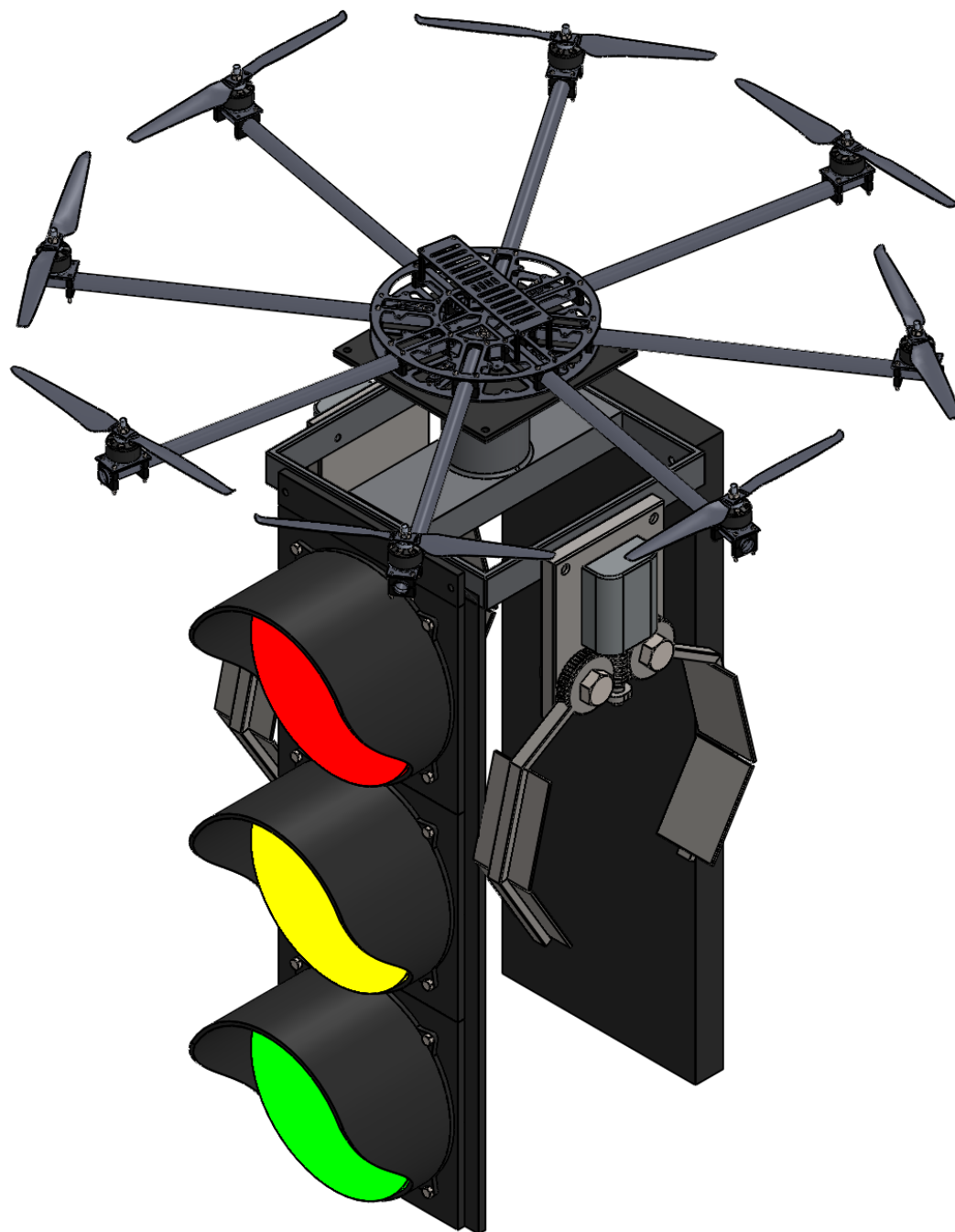
Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Mast Attachment

Drawn By: Lucy Guo	DWG. NO. Light Mast Attachment Main Assembly	Date: 11/20/17
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B

B



21 ASSEMBLY WITH ATTACHED DRONE

- ATTACHES TO DRONE VIA CONNECTION PLATES USING FOUR MAIN NUTS AND FOUR MAIN SCREWS

A

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Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Mast Attachment

Drawn By: Lucy Guo	DWG. NO. Light Mast Attachment Main Assembly	Date: 11/20/17
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ME 2212 SEC 1

SCALE: 1:9

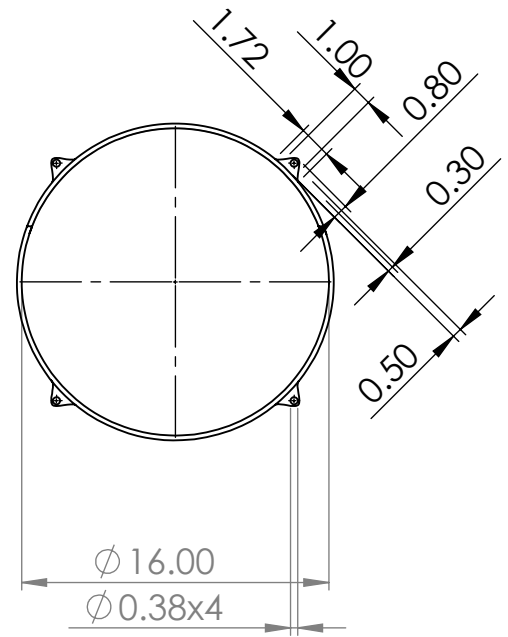
SHEET 12 OF 18

B

B

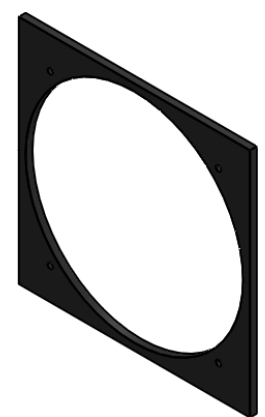
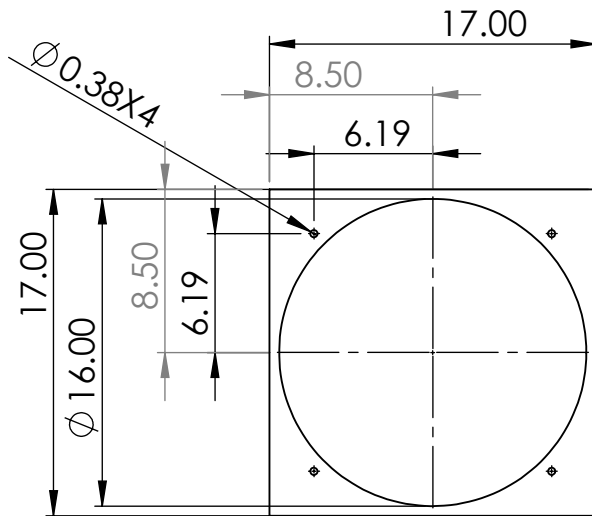
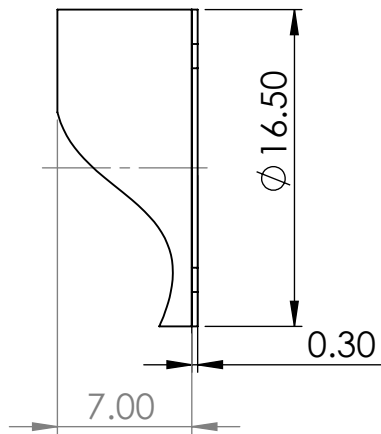
A

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22 ENLARGED LIGHT COVER

- EQUAL DISTANCE FOR ALL FOUR TABS AND HOLES
- 4 REQUIRED

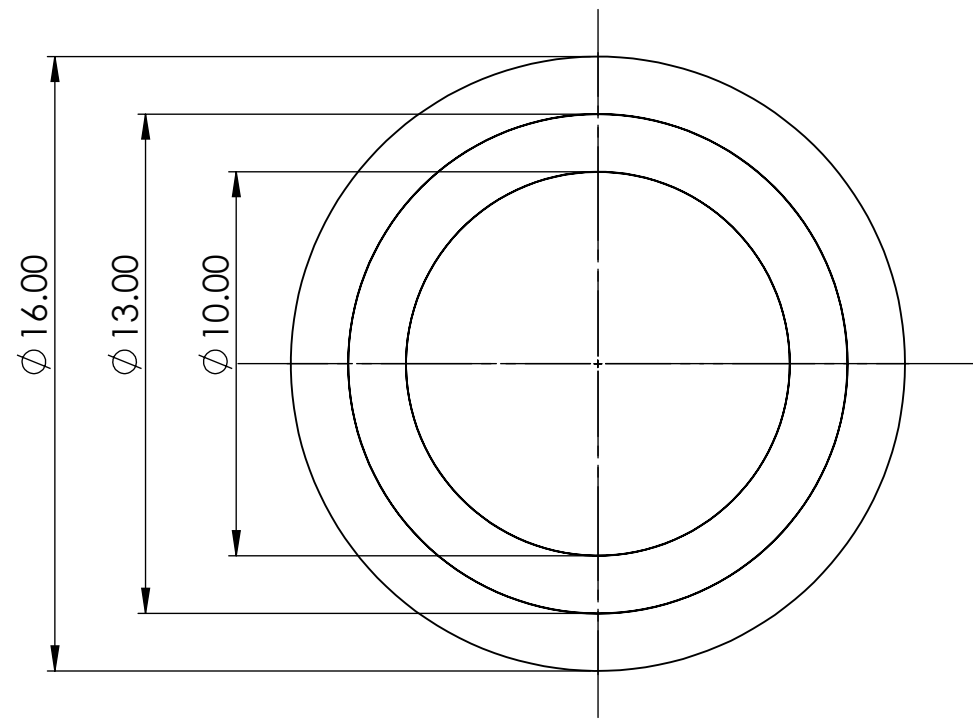


23 ENLARGED LIGHT BACK FRAME

- ATTACHES TO ENLARGED LIGHT COVER
- 0.5" THICKNESS
- 4 REQUIRED

Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Hover Attachment		
Drawn By: Lucy Guo	DWG. NO. Enlarged Light Cover and Back	Date: 11/20/17
ME 2212 SEC 1	SCALE: 1:10	SHEET 13 OF 18

B



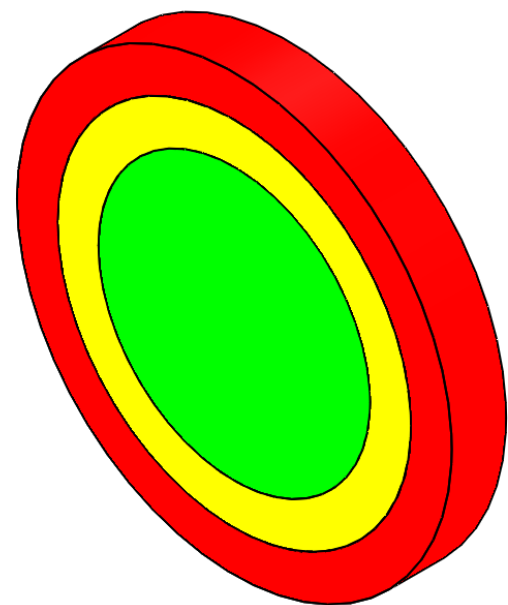
A

24 ENLARGED CONCENTRIC LIGHT DESIGN

- MODIFIED SIZE WITH CORRESPONDING COLOR TO ACCOUNT FOR COLOR BLINDNESS
- 2" THICKNESS
- 4 REQUIRED

2

1



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Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Hover Attachment		
Drawn By: Lucy Guo	DWG. NO. Concentric LED Light Design	Date: 11/20/17
ME 2212 SEC 1	SCALE: 1: 5	SHEET 14 OF 18

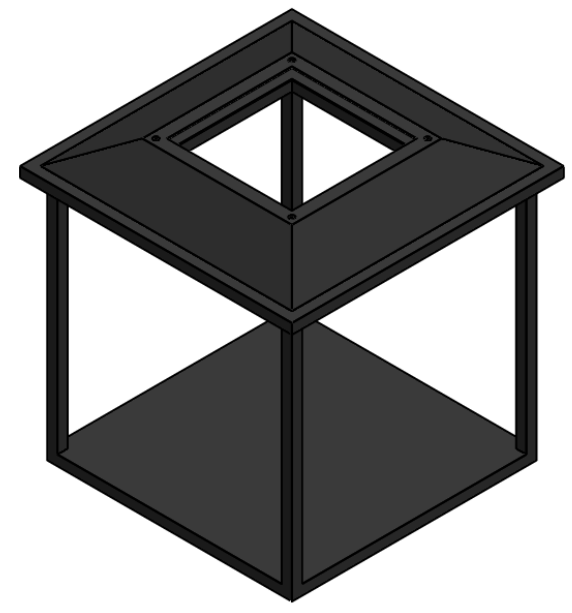
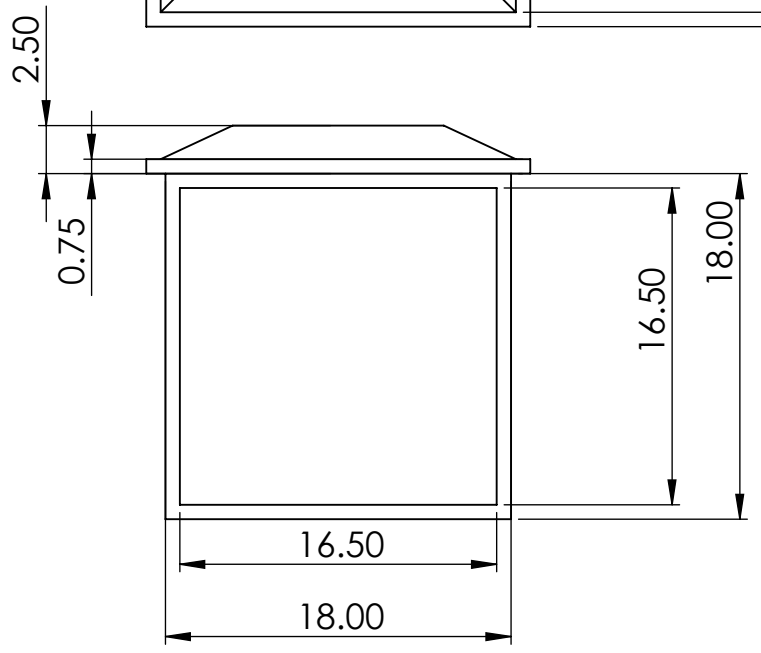
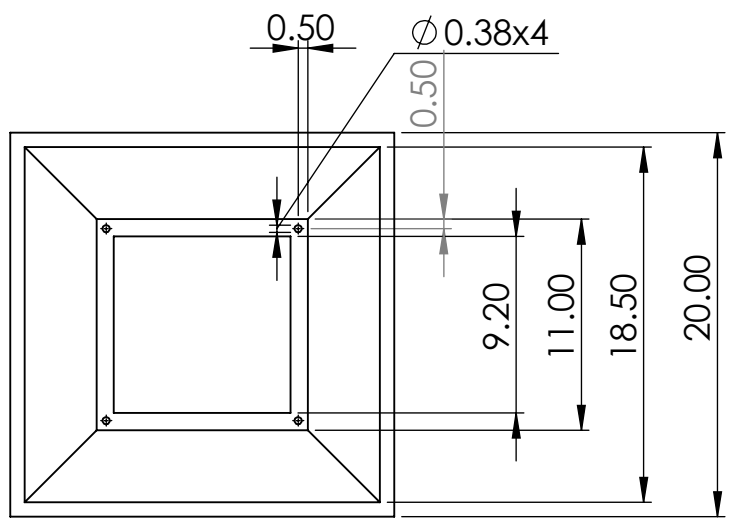
1

B

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- 25 HOVER LIGHT MAIN FRAME
- HOUSES ENLARGED LIGHT COVER, BACK COVER, LED LIGHTS.
 - 1 REQUIRED

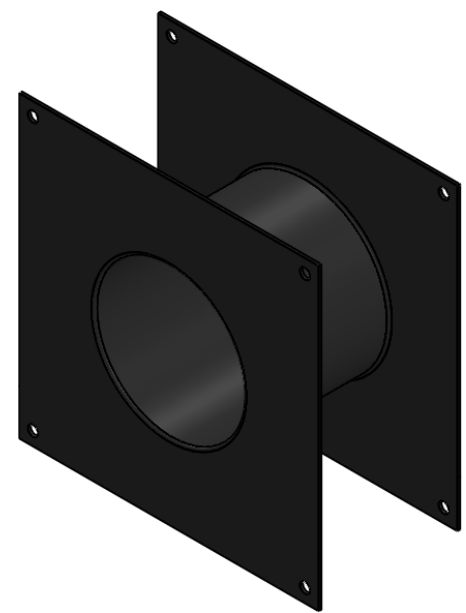
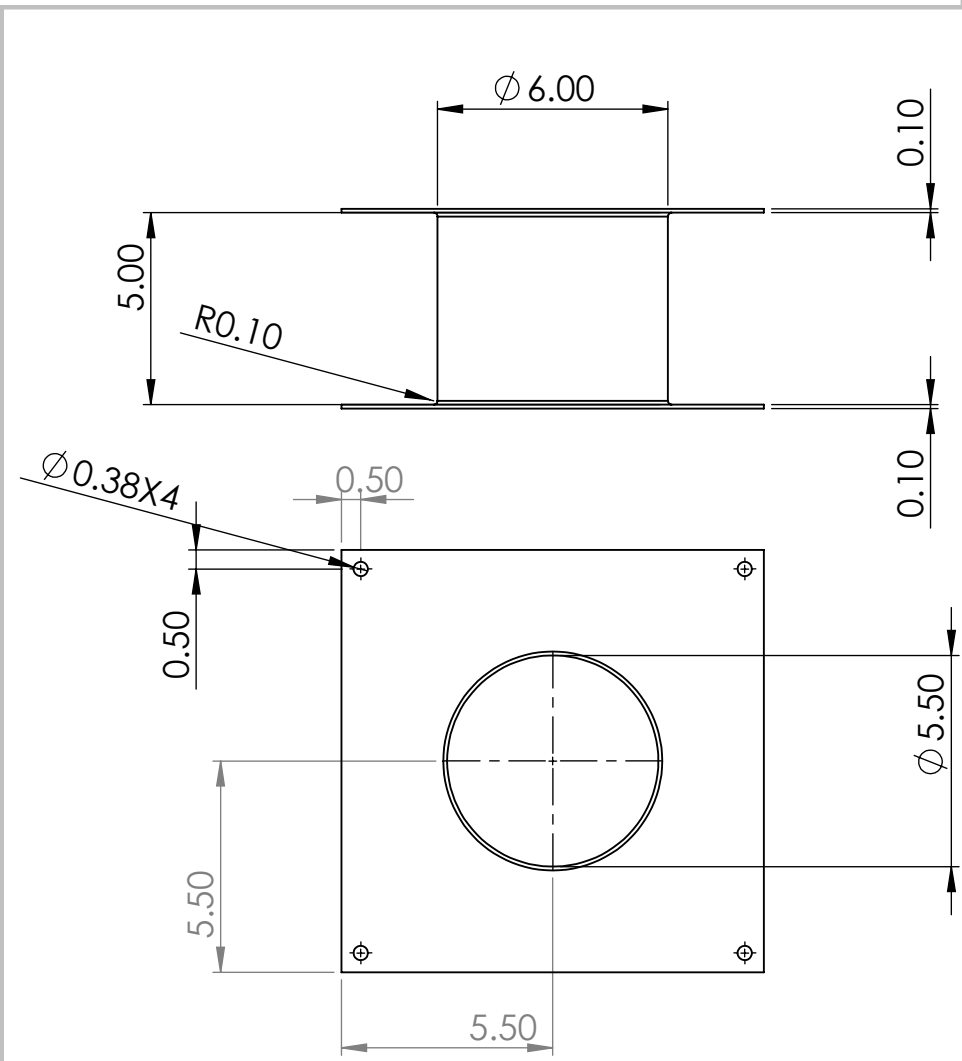
Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Hover Attachment		
Drawn By: Lucy Guo	DWG. NO. Hover Light Main Frame	Date: 11/20/17
ME 2212 SEC 1		SCALE: 1:10 SHEET 15 OF 18

B

B

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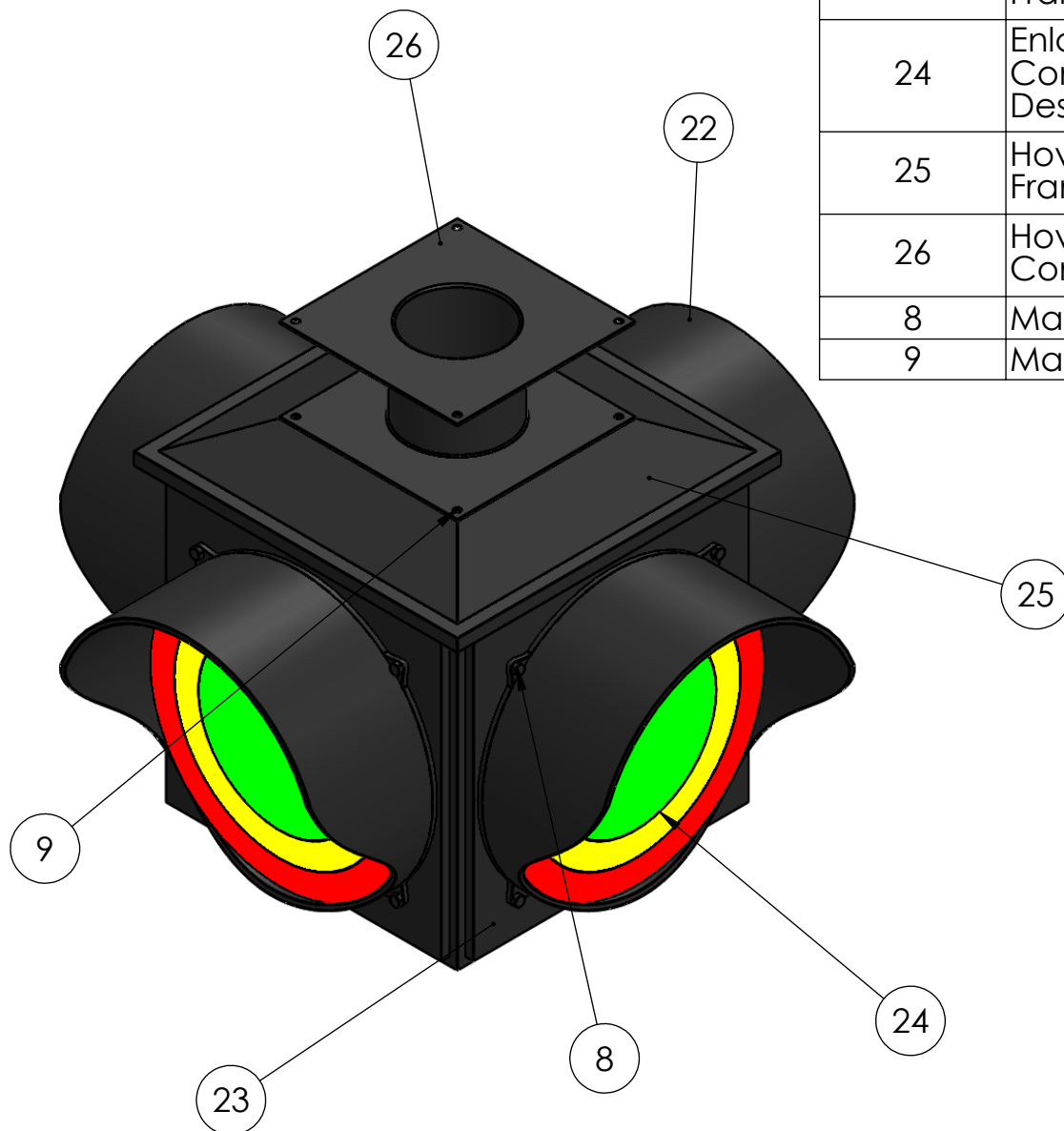
- 26 HOVER LIGHT TO DRONE CONNECTION PLATE
- ATTACHES MAIN HOVER ASSEMBLY TO DRONE
 - 1 REQUIRED

Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Hover Attachment		
Drawn By: Lucy Guo	DWG. NO. Hover to Drone Connection Plate	Date: 11/20/17
ME 2212 SEC 1	SCALE: 1:10	SHEET 16 OF 18

B

B

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
22	Enlarged Light Cover	POLYCARBONATE	4
23	Enlarged Light Back Frame	POLYCARBONATE	4
24	Enlarged Concentric Light Design	LEDs	4
25	Hover Light Main Frame	POLYCARBONATE	1
26	Hover Light to Drone Connection Plate	POLYCARBONATE	1
8	Main Screw	ALUMINUM	16
9	Main Nut	ALUMINUM	16



- 27 TRAFFIC LIGHT HOVER ATTACHMENT MAIN ASSEMBLY
- 4-WAY SINGLE LIGHT CONFIGURATION
 - UTILIZES FLY-BY-WIRE TO MAINTAIN FLIGHT FOR LONG DURATIONS

A

Team: Team 6: NextDrone Technologies		
TITLE: Traffic Light Hover Attachment		
Drawn By: Lucy Guo	DWG. NO. Hover Main Assembly	Date: 11/20/17
ME 2212 SEC 1		SCALE: 1: 8
SHEET 17 OF 18		

A

B

B



- 28 TRAFFIC LIGHT HOVER
ATTACHMENT MAIN ASSEMBLY
WITH DRONE ATTACHMENT
- HOVER TRAFFIC LIGHT ASSEMBLY
ATTACHES TO DRONE VIA
CONNECTION PLATES USING
FOUR MAIN NUTS AND FOUR
MAIN SCREWS
 - INCLUDE LOCKING LATCHES ON
SIDES AS WELL FOR ADDED
SECURITY

A

A

Team: Team 6: NextDrone Technologies

TITLE: Traffic Light Hover
Attachment

Drawn By:
Lucy Guo

DWG. NO.
Hover Main
Assembly

Date:
11/20/17

Solidworks Models/ Engineering Drawings Analysis

Major design constraints considered during the concept generation design process were simplicity of parts, modularity with various drones and scenarios, and weight. Because our designated customer required quick and easy assembly due to limited staff, the number of parts were simplified drastically with a standard Main Screw (8) and Main Nut (9) piece utilized throughout the majority of the assembly to increase efficiency when changing attachments and to minimize confusion. Furthermore, in the Worm Gear Clamp Subassembly, the worm gear was designed with the clamp arm already attached to the main gear (11) with two extended plates to maximize gripping surface area. Though this design requires a more complex manufacturing process, it reduces the number of parts in the Worm Gear Clamp from four to a single part, which effectively increases the overall simplicity while simultaneously decreasing the number of failure points for the clamp.

In accordance with cost and payload requirements, the FreeFly Alta 8 was selected for our design. By utilizing a pre-made drone, the overall manufacturing process was further simplified. To allow for modularity with other drones, a standard connection plate (1) was modeled to attach directly to any drone required. A similar connection plate was created for both the Traffic Light Mast Attachment and Traffic Light Hover Attachment (18, 26).

The reduction of overall parts helped to alleviate the weight of the design. To further, decrease the weight, the materials polycarbonate and aluminum were selected for the majority of the design. These two materials have low densities and high impact resistance, which allow for a smaller overall weight without sacrificing durability of the final product.

Appendix B: List of Parts/ Materials

Note: Numbers in Exploded View Correspond with Parts List and Engineering Drawings.

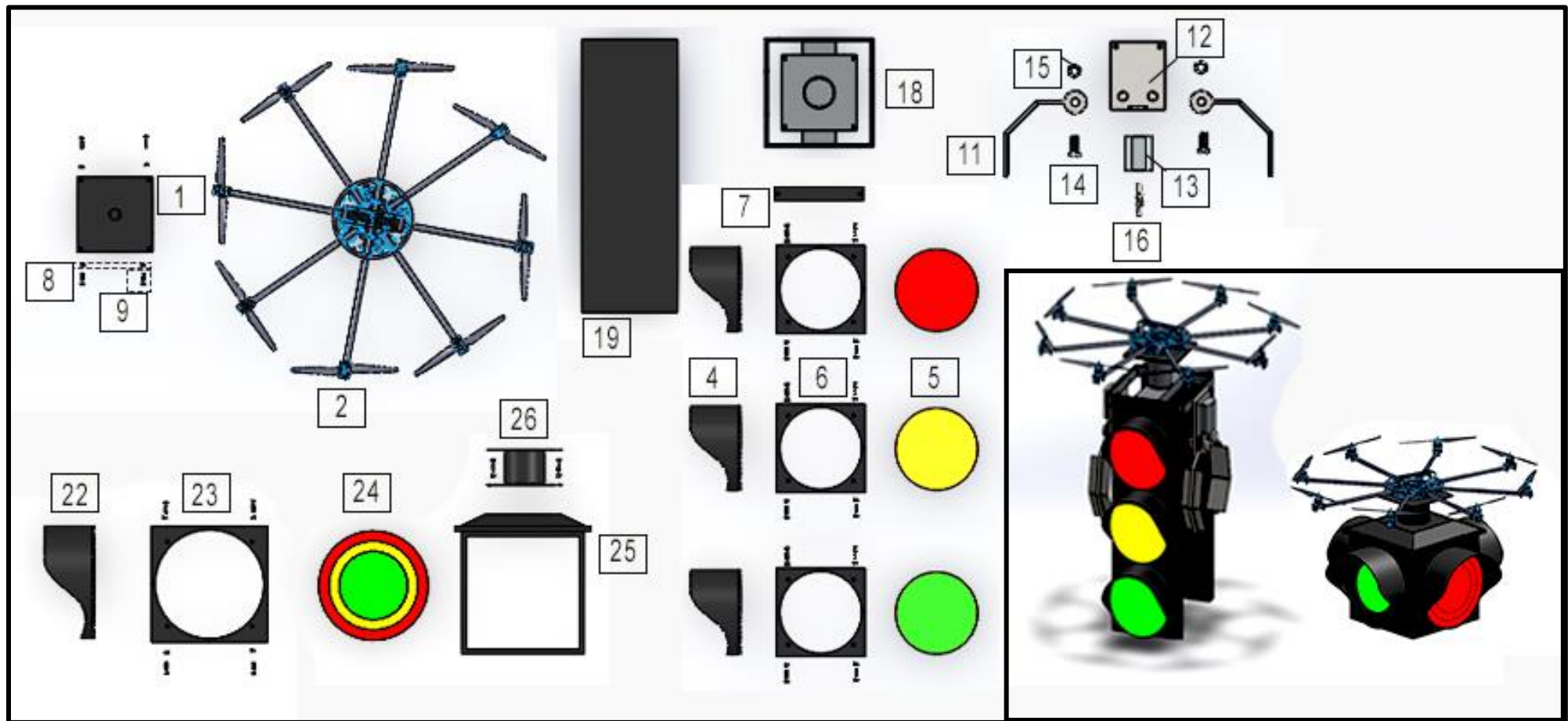


Figure 1: Traffic Drone Mast and Hover Attachment: Exploded View of Parts

			Functional Analysis			DFM Cost Analysis		
Part #	Part Name	Qty	Function	Flows In	Flows Out	Manufacturing Process	Material	Finish
1	Drone Connection Plate	1	Connects Drone to Traffic Light Attachments	Mechanical	Mechanical	Casting	Aluminum	Corrosion Treatment
2	Free Fly Alta 8	1	Carries Traffic Attachment	Air	Thrust and Torque	Mold	Aluminum and Carbon Fiber	X
3	Drone Subassembly	1	x	x	x	x	x	X
4	Light Cover	3	Protects light from weather and sun's glare	Mechanical	Mechanical	Mold	Polycarbonate	X
5	LED Light	3	Communicates Stop and Go functions of traffic light	Electrical	Light	Machine	LEDs	X
6	Light Back Frame	3	Holds Light Cover and Light	Mechanical	Mechanical	Mold	Polycarbonate	X
7	Light Top Connection Plate	1	Mounts Traffic Light to Traffic to Drone Connction Plate	Mechanical	Mechanical	Mold	Polycarbonate	X
8	Main Screw	44	Connects all Major Parts	Mechanical	Mechanical	Machine	Aluminum	Corrosion Treatment
9	Main Nut	44	Connects all Major Parts	Mechanical	Mechanical	Machine	Aluminum	Corrosion Treatment
10	Traffic Light Subassembly	1	x	x	x	x	x	x
11	Worm Gear Clamp	4	Secures Traffic Light to Traffic Mast	Mechanical	Mechanical	Casting	Aluminum	Corrosion Treatment
12	Worm Gear Main Body	2	Houses Worm Gear Subassembly Parts	Mechanical	Mechanical	Casting	Aluminum	Corrosion Treatment
13	Electric Engine	2	Drives Central Worm Gear Screw to Rotate Gear Clamps	Electircal	Mechanical	Casting	Aluminum	Corrosion Treatment
14	Worm Gear Screw	4	Holds Worm Gear Clamp to Main Body	Mechanical	Mechanical	Casting	Aluminum	Corrosion Treatment
15	Worm Gear Nut	4	Holds Worm Gear Clamp to Main Body	Mechanical	Mechanical	Casting	Aluminum	Corrosion Treatment

			Functional Analysis			DFM Cost Analysis		
Part #	Part Name	Qty	Function	Flows In	Flows Out	Manufacturing Process	Material	Finish
16	Worm Gear Central Screw	2	Rotates Two Worm Gear Clamps to produce clamping motion	Mechanical	Mechanical	Casting	Aluminum	Corrosion Treatment
17	Worm Gear Clamp Subassembly	1	x	x	x	x	x	x
18	Traffic To Drone Connection Plate	1	Holds all Traffic Mast Attachment Parts and Connects to Drone	Mechanical	Mechanical	Mold	Polycarbonate	x
19	Battery Pack and Counterbalance	1	Holds Battery and supplies counterbalance to prevent uneven	Electrical	Electrical	Mold	Polycarbonate	x
20/21	Traffic Light Mast Attachment Main Assembly	1	x	x	x	x	x	x
20	Enlarged Light Cover	4	Protects light from weather and sun's glare	Mechanical	Mechanical	Mold	Polycarbonate	x
21	Enlarged Light Back Frame	4	Holds Enlarged Light Cover and Concentric Light Design	Mechanical	Mechanical	Mold	Polycarbonate	x
22	Enlarged Concentric Light Design	4	Communicates Stop and Go functions of traffic light	Electrical	Light	Machine	LEDs	x
23	Hover Light Main Frame	1	Houses Covers, Frames and Lights	Mechanical	Mechanical	Mold	Polycarbonate	x
24	Hover Light to Drone Connection Plate	1	Mounts Traffic Light to Drone Connction Plate	Mechanical	Mechanical	Mold	Polycarbonate	x
25/26	Traffic Light Hover Attachment Main Assembly	x	x	x	x	x	x	x

List of Parts and Materials Analysis

Overall, there are 16 unique parts required for the Traffic Light Mast Attachment and 9 unique parts required for the Traffic Light Hover Attachment. Most of the traffic light parts were made of polycarbonate or aluminum, which contributed to durability, corrosion resistance and overall increased lightness. This choice in material meant that these parts could endure situations involving relative stress and varying temperatures, which are standard for traffic lights. Aluminum and polycarbonate are also low cost materials, allowing the overall manufacturing process to be cost efficient despite the large amount of uniquely designed parts required. Polycarbonate in particular is a shatterproof material with high impact resistance and transparent properties, making it the ideal material for housing LED Lights and creating the majority of the traffic light framework. Aluminum and Polycarbonate also have extremely high corrosion resistance. In this process, Aluminum was treated with a coating after being manufactured to further increase corrosion resistance.

Appendix C: House of Quality

Title: Temporary Traffic Light House of Quality

Author: Skylar Ned, Lucy Guo

Date: 11/10/2017

Notes:

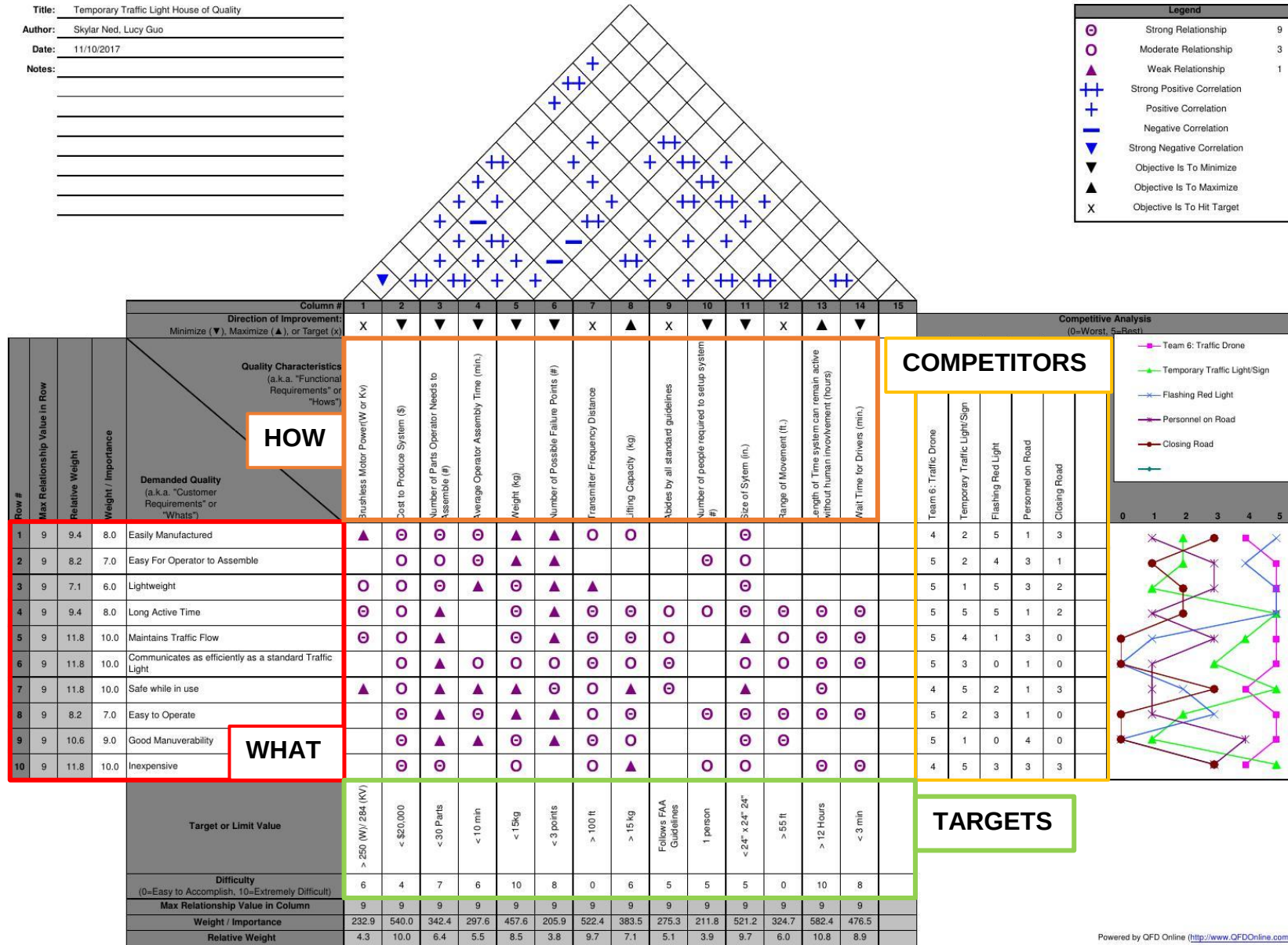


Figure 1: Overview of House of Quality

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Brushless Motor Power(W or Kv)	Cost to Produce System (\$)	Number of Parts Operator Needs to Assemble (#)	Average Operator Assembly Time (min.)	Weight (kg)	Number of Possible Failure Points (#)	Transmitter Frequency Distance	Lifting Capacity (kg)	Abides by all standard guidelines	Number of people required to setup system (#)	Size of Sytem (in.)	Range of Movement (ft.)	Length of Time system can remain active without human involvement (hours)	Wait Time for Drivers (min.)
1	9	9.4	8.0	Easily Manufactured	▲	○	○	○	▲	▲	○	○			○			
2	9	8.2	7.0	Easy For Operator to Assemble		○	○	○	▲	▲				○	○			
3	9	7.1	6.0	Lightweight	○	○	○	▲	○	▲	▲				○			
4	9	9.4	8.0	Long Active Time	○	○	▲		○	▲	○	○	○	○	○	○	○	○
5	9	11.8	10.0	Maintains Traffic Flow	○	○	▲		○	▲	○	○	○		▲	○	○	○
6	9	11.8	10.0	Communicates as efficiently as a standard Traffic Light		○	▲	○	○	○	○	○	○		○	○	○	○
7	9	11.8	10.0	Safe while in use	▲	○	▲	▲	▲	○	○	▲	○		▲		○	
8	9	8.2	7.0	Easy to Operate		○	▲	○	▲	▲	○	○		○	○	○	○	○
9	9	10.6	9.0	Good Maneuverability		○	▲	▲	○	▲	○	○			○	○		
10	9	11.8	10.0	Inexpensive		○	○		○		○	▲		○	○		○	○
Target or Limit Value					> 250 (W)/ 284 (KV)	< \$20,000	< 30 Parts	< 10 min	< 15kg	< 3 points	> 100 ft	> 15 kg	Follows FAA Guidelines	1 person	< 24" x 24" 24"	> 55 ft	> 12 Hours	< 3 min
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)					6	4	7	6	10	8	0	6	5	5	5	0	10	8
Max Relationship Value in Column					9	9	9	9	9	9	9	9	9	9	9	9	9	9
Weight / Importance					232.9	540.0	342.4	297.6	457.8	205.9	522.4	383.5	275.3	211.8	521.2	324.7	582.4	476.5
Relative Weight					4.3	10.0	6.4	5.5	8.5	3.8	9.7	7.1	5.1	3.9	9.7	6.0	10.8	8.9

Figure 2: Expanded View of What, How, and Targets of HOQ

Engineering Specs .	Targets	Justification	Score
Safety			
Possible Failure Points	1-3 points	Subjected to multiple uses	4
Weather Resistant	Waterproof	Functioning in varying climates	4.8
Legality	FAA Aproved	Requirement	5.3
Minimal Human Aid	1 Person	Limited Staff	4.1
Lifting Capacity	> 15kg	Standard weight of Traffic light	7.4
Handling/Electronics			
Implementation Time	< 10 min.	Limited Staff/ Customer Need	5.7
Maneuverability	> 80ft	Customer Need/ Standard Road dimensions	6.2
Transmitter Frequency Distance	> 80ft	Standard Road dimensions	6.5
Physical			
Size	< 24" x 24" x 48"	Compact for Portability	10
Parts Number	< 30 Unique Parts	Customer Need	6.6
Weight	< 30kg	Design Constraint/ Customer Need	8.8
Expense			
Cost	Under \$20,000	Design Constraint/ Customer Need	10.4
Effectiveness			
Maintains Steady Traffic	< 3 min wait time	Standard wait time for working light	9.1
Active Time	>12 Hours	Standard time for Traffic Maintence Response/ Contruction/Events	11.2

Figure 3: HOQ Metrics of Evaluation, Targets, and Justification of Targets

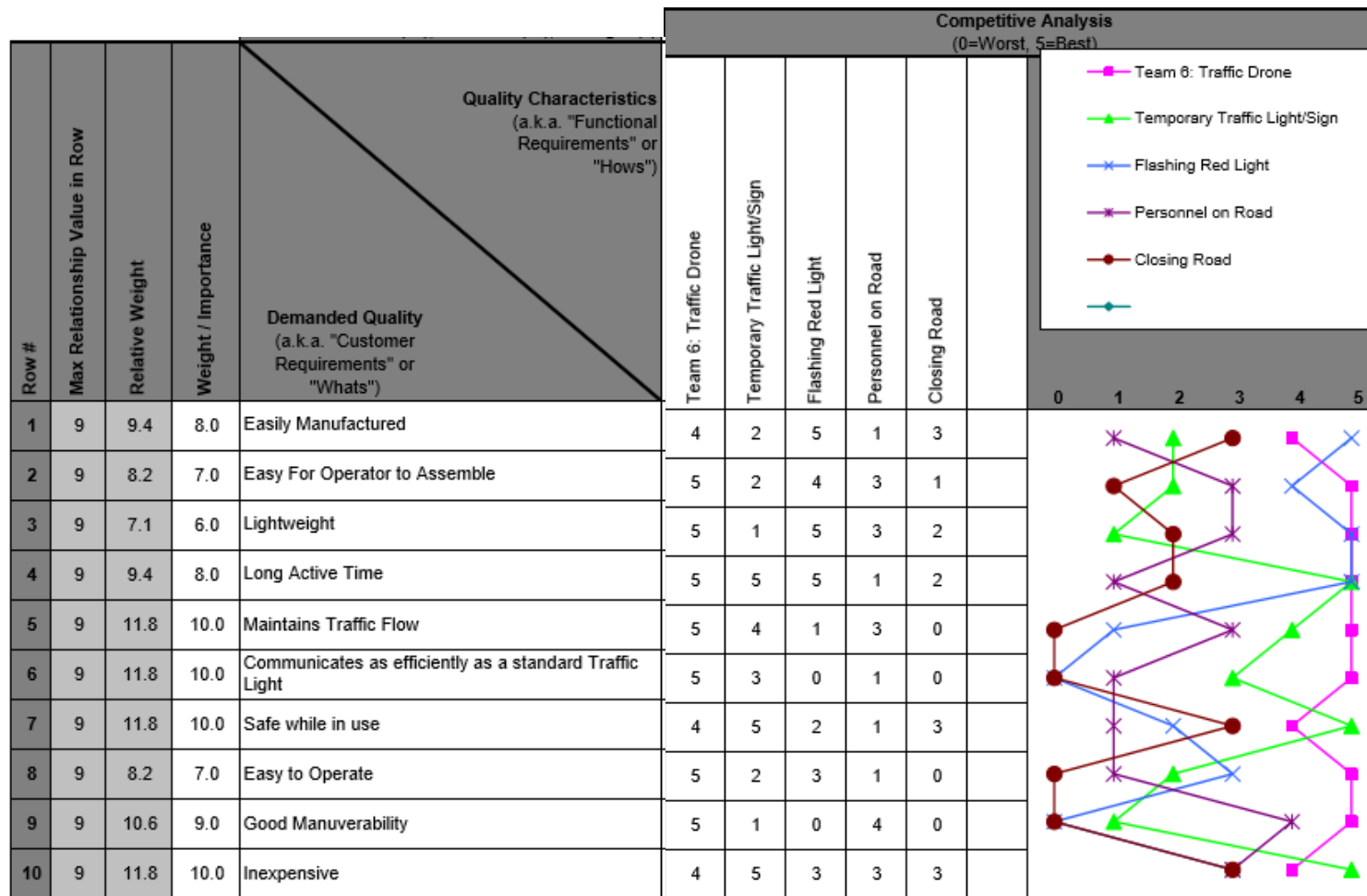


Figure 4: Expanded View of Traffic Drone Design and other Competitors vs. Customer Requirements (What)

Engineering Specs.	Targets	Temporary Sign	Flashing Red Light	Personnel on road	Closing Road	Traffic Drone
Safety						
Possible Failure Points	1-3 points	Pass	Pass	Pass	Fail	Pass
Weather Resistant	Waterproof	Pass	Pass	Fail	Pass	Pass
Legality	FAA Aproved	N/A	N/A	N/A	N/A	Pass
Minimal Human Aid	1 Person	Fail	Pass	Fail	Fail	Pass
Lifting Capacity	> 15kg	N/A	N/A	N/A	N/A	Pass
Handling/Electronics						
Implementation Time	< 10 min.	Fail	Pass	Fail	Fail	Pass
Maneuverability	> 80ft	Fail	Fail	Pass	Fail	Pass
Transmitter Frequency Distance	>80ft	N/A	N/A	N/A	N/A	Pass
Visibility						
Size	< 24" x 24" x 48"	Fail	N/A	N/A	Fail	Pass
Parts Number	< 30 Unique Parts	Fail	N/A	N/A	Fail	Pass
Weight	< 30kg	Fail	N/A	N/A	Fail	Pass
Expense						
Cost	Under \$20,000	Pass	Pass	Pass	Pass	Pass
Effectiveness						
Maintains Steady Traffic	< 3 min wait time	Pass	Fail	Fail	Fail	Pass
Active Time	>12 Hours	Pass	Pass	Fail	Pass	Pass

Figure 5: Traffic Drone Design and other Competitors vs. Engineering Specifications (How)

House of Quality Analysis

The House of Quality examines the customer requirements (what), metrics for evaluation (how), targets for determined success (targets), and the Traffic Drone's performance vs. current competitors (competitors). First, a general overview of these sections as well as their correlation with one another are presented (Figure 1).

Later, Customer Requirements, Metrics for Evaluation and Targets are enlarged in for convenience in viewing (Figure 2). These customer requirements as well as their relative weights of importance were determined based on Traffic Maintenance performance research and surveys conducted by the Department of Transportation and traffic maintenance companies. The most important requirements were maintaining steady traffic flow, communicating efficiently as a traffic light, cost efficiency, and safety while in use. These were weighted highest according to the 2012 National Traffic Signal Report Card Technical Report, where leading transportation professionals set these standards as important requirements for improving overall traffic conditions.

Based on the needs of consumers, 14 metrics were determined to measure the performance of the design in comparison to major competitors. These metrics were also assigned target, which were used to determine successfulness of the overall design. Justification of each target is provided in Figure 3. Active Time had the highest weighting of importance, and the target was set at over 12 hours in accordance with standard response time to traffic malfunctions, and average work time for construction projects and other temporary events.

After the refined concept generation and Solidworks models, the Traffic Drone design was compared with other competitors that act as temporary traffic lights (Figure 4 and 5). In general, no drones have been applied to the field of traffic. The best alternatives were mounted temporary traffic lights, personnel on the road, utilization of the flashing red light, or closing the road entirely. In figure 4, the design and competitors were compared with the customer requirements. Overall, the Traffic Drone performed exceedingly well in reaching a majority of the customer requirements. The areas where the drone did not perform better than the other competitors, included safety, cost, and easy of manufacturing. This can be attributed to the relative newness of the concept; however, as drone technology continues to improve and these factors will not be as much of an issue.

In figure 5, the Drone and its competitors were compared to the metrics of evaluation. Again, the Drone performed strongly in all categories, taking the strong functional properties of each idea and utilizing it to produce the best outcome.

Appendix D: Decision Matrices

Decision Matrix 1: Concept Generation								
Criteria	Concepts							
	WT	I	II	III	IV	V	VI	VII
Does not require too much specialized knowledge	5	+	+	+	S	+	D	S
Innovative-Not too many existing products	5	-	-	-	S	+	A	+
Need for Product in Market	5	+	-	+	-	+	T	+
Can be created using existing technology	5	+	+	+	-	+	U	S
Prototype design can be created in short time	4	+	S	S	-	+	M	-
Existing Research and Studies	4	-	-	+	-	S		+
Personal Interest	3	+	S	-	S	+		+
Capability of using fly-by-wire to overcome battery life	3	+	+	S	-	+		+
Total +		6	3	4	0	7	0	5
Total -		2	3	2	5	0	0	1
Overall Total		4	0	2	-5	7	0	4
Weighted Total		16	-1	11	-21	30	0	16

I. Ceiling Cleaning Drone	
II. Umbrella Drone	
III. Defect Inspection Drone	
IV. Green Roof Drone	
V. Traffic Drone	
VI. Smart Drone	
VII. Guide Drone	

Figure 1: Decision Matrix 1- Concept Generation

Decision Matrix 2: Functional Selection								
Criteria	Concepts							
	WT	I	II	III	IV	V	VI	VII
Market demand	4	+	+	D	+	+	-	-
Technological feasibility	5	+	-	A	-	-	-	-
Ease of Task	4	-	-	T	+	-	-	-
Collision Avoidance	5	-	-	U	+	-	S	-
Cost of Manufacturing	3	+	S	M	S	-	-	-
Abides by FAA Guidelines	5	+	S		S	-	-	-
Personal Interest	2	+	+		-	+	-	S
Total +		5	2	0	2	2	0	0
Total -		2	4	0	2	5	6	6
Overall Total		3	-2	0	0	-3	-6	-6
Weighted Total		9	-8	0	6	-16	-23	-26

- I. Temporary Traffic Light
- II. Road Hazard Detection
- III. Traffic Flow Monitoring
- IV. Accident Detection
- V. Debris Removal
- VI. Drone to Car Communication
- VII. Ambulance/Police Car Escort

Figure 2: Decision Matrix 2- Function Generation

VI

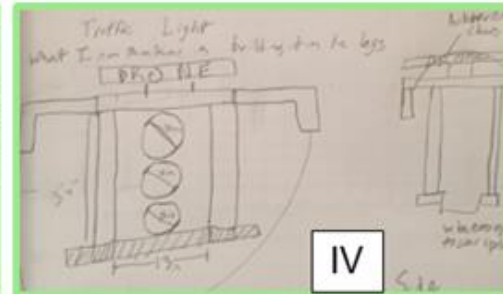


Figure 3: Decision Matrix 3- Design Generation

Figure 3: Decision Matrix 3- Design Generation

Decision Matrices Analysis

Decision Matrix 1 focuses on determining the subject of the Drone project (Figure 1). An evaluation of multiple ideas that could incorporate drone technology was conducted. The ideas given were a Ceiling cleaning drone, Umbrella drone, defect inspection drone, a drone to manage Green roofs, a traffic drone, a drone with smart technology that could act like a helper or cellular device, and a guide drone for blind people. Criteria used were based on customer requirements and design constraints, with Need of product, innovation of idea, and use of existing drone technology being weighted the highest. Many of these ideas were exceptional, but the Traffic Drone idea outweighed all of the others by a significant amount based on these criteria.

Decision Matrix 2 aimed to determine a function related to traffic that the drone could provide. Ideas provided included temporary traffic light, road hazard detection, traffic flow monitoring, accident detection, debris removal, drone-car communication, and police/ambulance/fire truck escort drone to warn traffic of approaching emergency vehicles. The criteria used in this matrix was also determined by customer requirements and design constraints. The highest weighted criteria were Technological feasibility, Collision avoidance and Abiding by FAA guidelines because safety and feasibility were two critical requirements of the overall project. Based on these standards, a temporary traffic light function was deemed the best option.

Decision Matrix 3 is the final decision matrix. It includes an analysis of multiple suggestion about how the Traffic Light Drone could be designed. Critical criteria in this matrix included simplicity of manufacturing product, safety of product, and stability in final position. From this decision matrix a hybrid design that includes inspirations from I, III, and IV was chosen for final Solidworks model generation.

Appendix E: Objective Tree

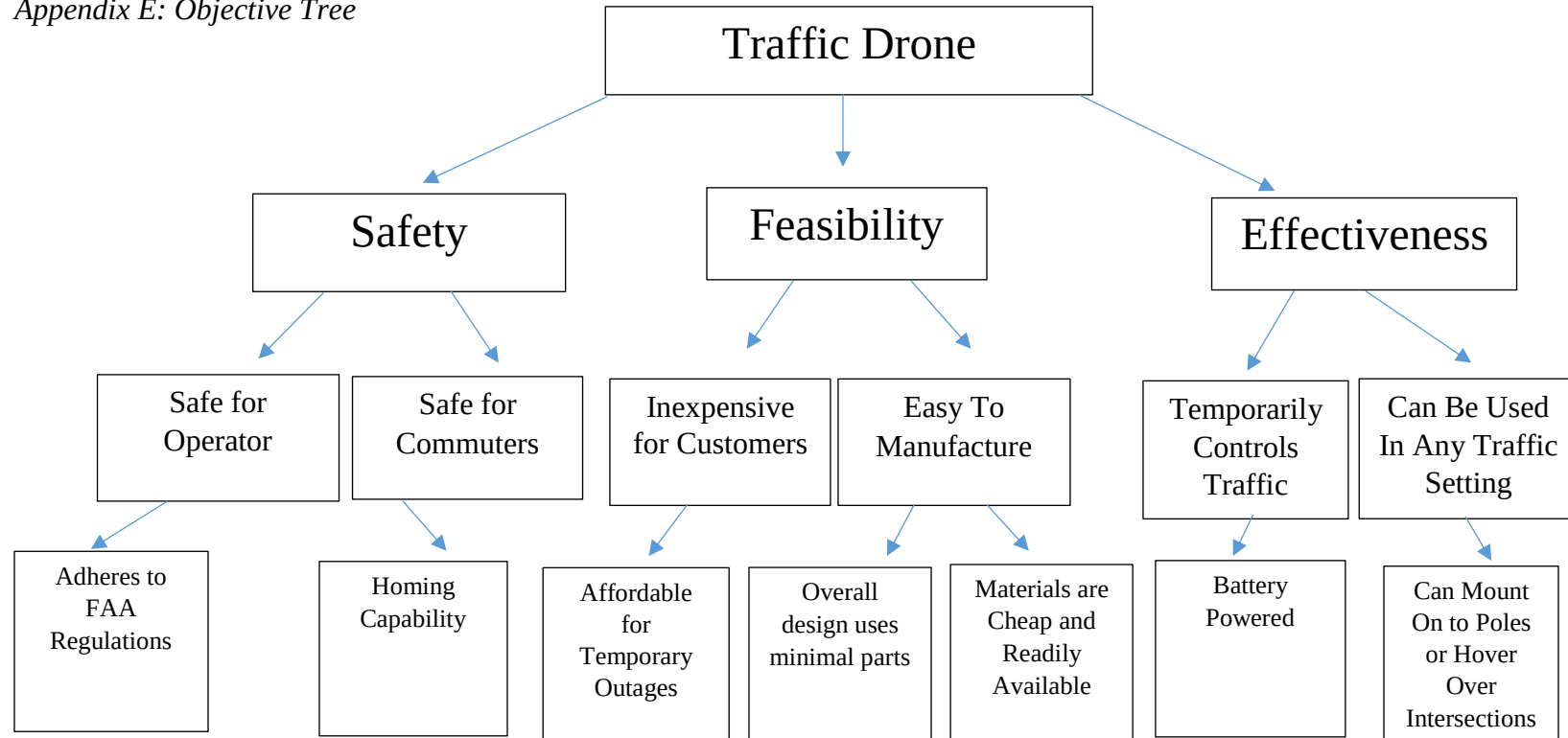
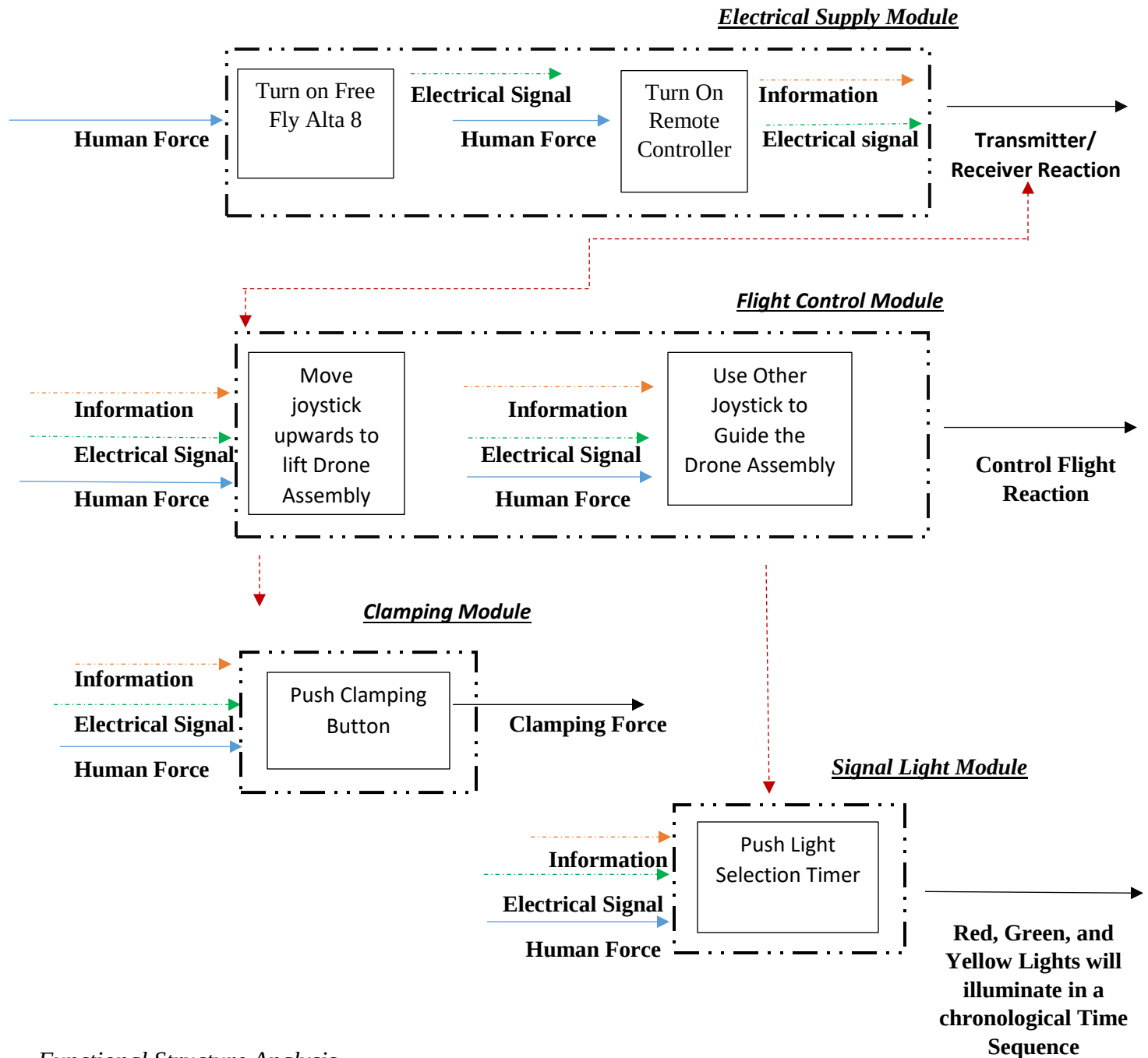


Figure 1: Concept-Refinement Objective Tree

Objective Tree Analysis

Before generating Solidworks models, and Objective tree was created to refine concept ideas. For the Traffic Drone Design this Objective Tree highlighted the critical design requirements of safety, feasibility and effectiveness. These topics were further expanded and ideas were provided to address each of these requirements. For example, in Feasibility, a key requirement is ease of manufacturing. To make manufacturing easier, the objective became to minimize the number of parts in the final Solidworks design and to use cheap and readily available materials for manufacturing.

Appendix F: Functional Structure Diagram



Functional Structure Analysis

During concept refinement, a functional analysis of the Traffic Drone was also conducted to outline the major functions that needed to be addressed in the design. The Functional Structure Diagram above depicts these designated functions. A majority of the required inputs into the systems are relatively simple, using a joystick for main controls, and buttons and timers for control of the clamping and light mechanisms respectively. The desired outcome of the Traffic Drone product is an intuitive design that allows for quick and easy deployment as well as efficient maneuverability.

Appendix G: Gantt chart

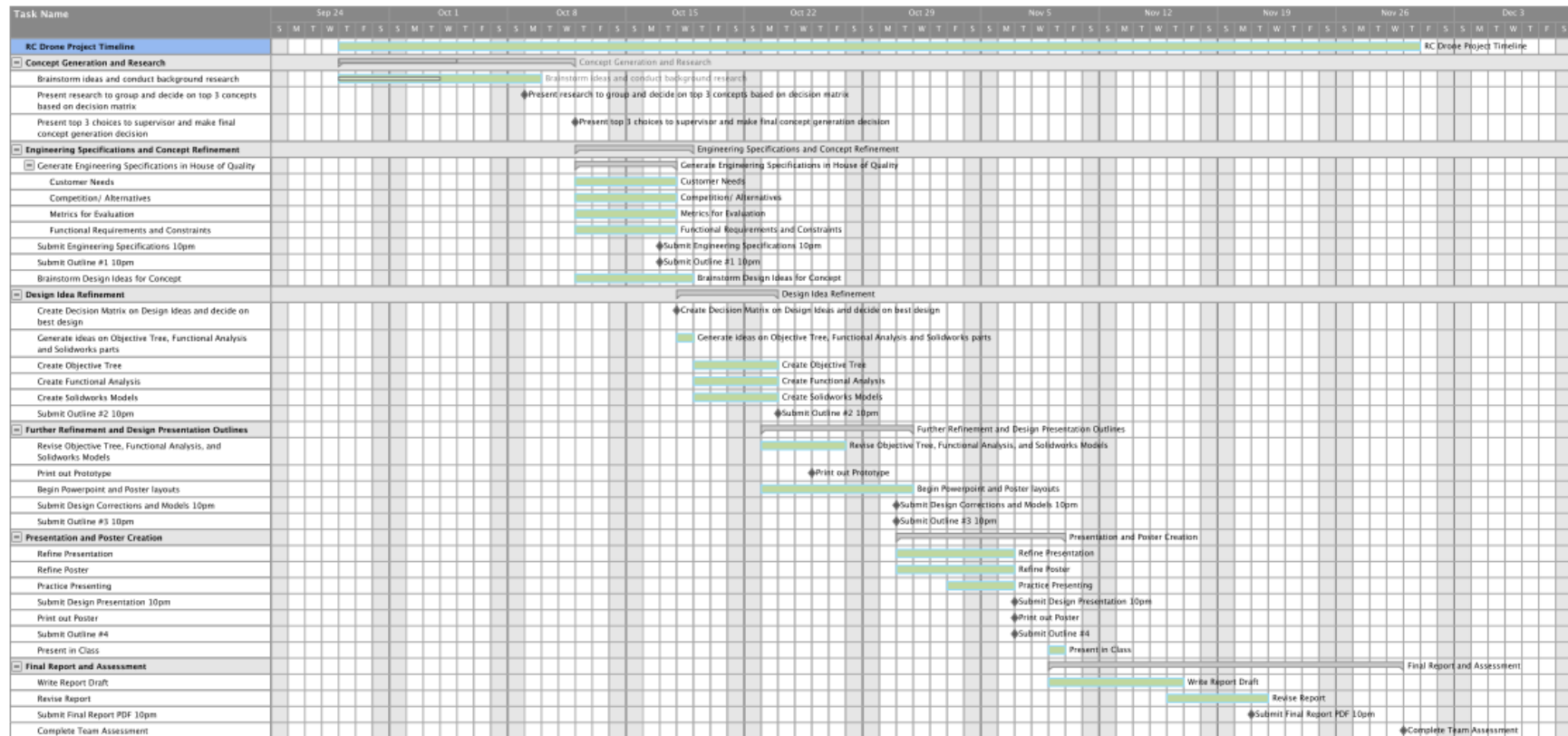


Figure 1: Gantt Chart- Traffic Drone

Gantt Chart Analysis

At the start of the project, a Gantt Chart was generated to keep track of major submission deadlines as well as decision that needed to be made. Diamond markings represented submission that needed to be entered on Moodle, which included outlines, presentation, final report, and team evaluations. During initial concept generation and decision matrixes, the team mainly worked together on all parts of the project, but as time progressed, the team divided into smaller groups to work more efficiently. Lucy and Barrett were the Solidworks leads, Luke and Skylar were the PowerPoint leads, and Dan and Harley were the Final Report leads. By dividing the roles, the team was able to get more work done and evenly distribute the workload.

Appendix H: Technology Readiness Chart

TRL		Technology	Importance for Design	Technology Readiness Level (TRL)
	9	Commercialized		
	8	Field Testing		
	7	Prototype		
	6	Development		
	5	Lab Testing		
	4	Detailed Design		
	3	Preliminary Design		
	2	Conceptual Design		
	1	Basic Design		
		Remote Control Drone	Moderate	9
		Heavy Lifting Drone (30lb+)	Moderate	9
		Self-Stabilization While Hovering	Moderate	9
		Lightweight Traffic Light	Moderate	9
		Mounting Traffic Light to Drone	High	9
		Clamping System for Drone/Pole Mounting	High	3
		Concentric Circles Light Concept	High	3

Figure 1: Technology Readiness Chart

Technology Readiness Chart Analysis

NASA uses a technology readiness scale to determine how mature a particular technology is. The scale and chart above is similar to that of NASA's except the criteria for each level is tailored to the traffic drone concept. It labels the readiness of each technological component of our concept from 1 being a basic design to 9 being fully developed and commercialized. The only technologies that are not fully developed are the specific components of the traffic light attachment that the team designed. Although these components rank 3, meaning they have only reached the stage of Solidworks models, the technology and resources needed to make those parts are all well-developed. With that being said, the technology readiness chart confirms the feasibility of the traffic drone concept from a technological standpoint.

Appendix I: FAA Guidelines

- Unmanned aircraft must weigh less than 55 lbs. (25 kg).
- Visual line-of-sight (VLOS) only; the unmanned aircraft must remain within VLOS of the remote pilot in command and the person manipulating the flight controls of the small UAS. Alternatively, the unmanned aircraft must remain within VLOS of the visual observer.
- At all times the small unmanned aircraft must remain close enough to the remote pilot in command and the person manipulating the flight controls of the small UAS for those people to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses.
- Small unmanned aircraft may not operate over any persons not directly participating in the operation, not under a covered structure, and not inside a covered stationary vehicle.
- Daylight-only operations, or civil twilight (30 minutes before official sunrise to 30 minutes after official sunset, local time) with appropriate anti-collision lighting.
- Must yield right of way to other aircraft.
- May use visual observer (VO) but not required.
- First-person view camera cannot satisfy “see-and-avoid” requirement but can be used as long as requirement is satisfied in other ways.
- Maximum groundspeed of 100 mph (87 knots).
- Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure.
- Minimum weather visibility of 3 miles from control station.
- Operations in Class B, C, D and E airspace are allowed with the required ATC permission.
- Operations in Class G airspace are allowed without ATC permission.
- No person may act as a remote pilot in command or VO for more than one unmanned aircraft operation at one time.
- No operations from a moving aircraft.
- No operations from a moving vehicle unless the operation is over a sparsely populated area.
- No careless or reckless operations.
- No carriage of hazardous materials.
- Requires preflight inspection by the remote pilot in command.
- A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.

- Foreign-registered small unmanned aircraft are allowed to operate under part 107 if they satisfy the requirements of part 375.
- External load operations are allowed if the object being carried by the unmanned aircraft is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft.
- Transportation of property for compensation or hire allowed provided that the aircraft, including its attached systems, payload and cargo weigh less than 55 pounds total;

The flight is conducted within visual line of sight and not from a moving vehicle or aircraft; and

The flight occurs wholly within the bounds of a State and does not involve transport between (1) Hawaii and another place in Hawaii through airspace outside Hawaii; (2) the District of Columbia and another place in the District of Columbia; or (3) a territory or possession of the United States and another place in the same territory or possession.

• Most of the restrictions discussed above are waivable if the applicant demonstrates that his or her operation can safely be conducted under the terms of a certificate of waiver.

FAA Guidelines Analysis

The Federal Aviation Administration (FAA) is an agency of the United States Department of Transportation. It regulates and oversees civilian aviation within the United States with a primary focus on ensuring safety. In regard to regulations, Part 107 is a detailed summary of the regulations that apply to non-recreational use of unmanned aircraft systems - more commonly known as “drones.” Part 107 is enforced to minimize risks to other aircraft, people, and property; however, these regulations can be waived given that the flight of the drone is proven to be safe. Specifically pertaining to our traffic drone concept, the main regulations that present themselves as issues are maintaining visual line of sight between operator and drone and the total weight of the drone and attachments must be under 55 pounds. Until the team can get the necessary waivers for the concept, the plan is to have an operator at each intersection managing the drones to maintain visual line of sight. The team will also have to choose the materials carefully to ensure the weight limit is not exceeded.

Final Outline | NextDrone Technologies

Team 6: Lucy Guo, Skylar Ned, Harley Nguyen, Daniel Segrest, Barrett Serio, Luke Williams

Project Description

A. Introduction (W:Dan; E:Harley)

I. What

- a. Problem: Design an innovative Process for Drone Technology
- b. Describe early concept generations of Drone applications
 - a. Brainstorming session
- c. Explain decision matrix to decide best area to pursue for Drone Technology
 - a. Determined to pursue traffic drone
 - i. What function(s) of traffic management can it serve
 1. Temporary traffic light
 2. Visual traffic monitoring

II. Why

- a. Drone technology is advancing and has a rising place in current markets
- b. Has numerous applications to improve efficiency or safety in existing processes
 - a. Examples
 - i. Structural inspection
 - ii. Agricultural applications
- c. Aerial viewpoint allows unique perspectives for problem solving
 - a. Examples
 - i. Landmine detection (sensors detect chemical leaks)
 - ii. Aerial photography

III. Prototype Overview

- a. Solidworks Models, Schematics, and exploded view with analysis and explanation

IV. Overview of Report Organization/Layout

- a. Outline report: Engineering Specifications, Design Synthesis, Other design considerations, Summary/Conclusion, Appendices

B. Engineering Specifications (W: Lucy; E:Skylar)

- a. Who-Who is affected by traffic?
 - 1) Primary
 - i. Department of Traffic Development (D.O.T.D.)
 - ii. Traffic Maintenance Responders
 - iii. Construction Companies
 - 2) Secondary
 - i. North American Market
 - ii. Event Coordinators
 - iii. Global Market

- b. What-What features does our drone product need to have ?
 - 1) Physical
 - a. Safety features in blades
 - b. Ease in controllability
 - i. Camera for guiding
 - ii. Sensors for preventing impact
 - c. Long flight time
 - d. Durable in impact and weather scenarios
 - 2) Functional
 - a. Properly act as temporary traffic light
 - i. Lights large enough to be viewed
 - ii. Coordinated lights
 - iii. Proper height
 - b. Adjustable in light duration
 - c. Future-proof for upgrades
 - 3) Manufacturing
 - a. Easy assembly
 - b. Compact/Portable
 - c. Cost effective in materials
 - d. Eye-appealing and simple design
- c. Explain Relationship between Who vs. What
- d. How-How do we measure/quantify the efficiency of each solution?
 - 1) Maximum flight times of different drones
 - 2) Cost of total materials for each design
 - 3) Number of parts
 - 4) Average time for assembly
 - 5) Weight that drones can sustain
 - 6) Number of possible failure points
 - 7) Inclusion of safety features in blades
 - 8) Average time for mastery in controlling device
 - 9) Size of overall drone or individual disassembled parts for portability
 - 10) Amount of stress drone can take
 - 11) Maximum height drone can achieve
- e. Explain Relationship between How vs. What
- f. Now-What solutions are currently being used?.
 - 1) Mounted Traffic Light
 - 2) Human stop sign holders
 - 3) Self-guided four way stop- flashing red light
 - 4) Closing road
- g. Explain Relationship Now vs. What

- h. How Much- How much is good enough? What targets are we aiming for that we can use to determine how well the competitors meet specifications?
 - 1) Cost – less than \$20,000 to produce
 - 2) Human interaction - less than 10 min of manual labor for setup
 - 3) Time- Can function for more than 12 hours nonstop
 - 4) Efficiency- Reduction in Crashes and Accidents during duration
 - i. Explain Relationship How Much vs. Now
- C. Design Synthesis (W: Barrett; E: Lucy)
- a. Brainstorming of Drone applications
 - 1) Ideas Generated
 - a. Ceiling Cleaning Drone
 - b. Umbrella Drone
 - c. Drone Structural Inspection
 - d. Green Roof Drone
 - e. Traffic Drone
 - f. Smart Drone
 - g. Guide Drone
 - 2) Decision Matrix
 - 3) Analysis
 - a. Choose traffic drone
 - b. Concept Generation of Drone Designs for Traffic Related Incidences
 - 1) Sketches
 - i. All group members contributed a designs
 - 2) Decision Matrix
 - i. Three designs were combined for final design
 - 3) Analysis
 - c. Solidworks Model and 3D printed prototype of best drone design
 - 1) Design of the drone
 - a. Quad arm/ 8 motor
 - b. <http://vulcanuav.com/aircraft/#airlift>
 - i. Does not have very long battery life, but we can design around it
 - 2) Traffic light feature
 - a. Two light features
 - i. Standard 3 light
 - ii. Larger Single light
 - 1. Varying Inner circle lights for color blind
 - 3) Clamp Design
 - a. Worm gear design
 - i. Electric motor drives gears closed
 - b. Extended sides for increased surface area when gripping
- D. Other Design Considerations (W:Luke ;E:Dan)

- a. Manufacturing
 - 1) Prototype system material specifications
 - a. Lightweight materials
 - i. Aluminum
 - ii. Carbon fiber
 - iii. Polycarbonate
 - b. Safety
 - 1) Safety features
 - a. Extra Latches to hold traffic light to drone
 - b. Homing capability
 - i. Drone returns to base if signal lost or power drops below set percentage based on GPS
 - 1. To prevent drone from falling onto people/ objects
 - c. Testing
 - 1) Types of tests required to validate prototype
 - a. How powerful is engine
 - b. How long can battery last to fly drone
 - c. What is payload of drone
 - d. Maintenance/repair considerations
 - a. User-serviceable
 - i. Replacing light bulbs
 - ii. Replacing drone blades
 - 1. If damaged
 - iii. Replace battery if necessary
 - b. Interchangeable parts
 - i. Multiple signal lights
 - 1. For multiple directions
 - ii. Swappable battery
 - iii. Swappable blades
 - 1. Ties into user-serviceable
- E. Summary/ Conclusion (W: Harley ;E: Luke)

- a. Uniqueness of Prototype
 - a. Competition
 - i. No similar drone concepts
 - ii. Non-drone things that can accomplish same task
 - 1. Universal traffic rules
 - a. Treat malfunctioning lights like 4-way stop sign
 - b. Lights blink red indicating 4-way stop
 - 2. Stationary temporary traffic lights
 - 3. Traffic control personnel with signs
 - b. Design features
 - i. Can fly
 - 1. Not as obstructive as other temporary traffic lights

- 2. More portable
 - 3. Easier and faster use
 - ii. Traffic light on drone
 - b. Anticipated Limitations
 - a. FAA regulations
 - i. Flying over people
 - ii. Visible line of sight
 - iii. Under 55 pounds
 - b. Vandalism
 - i. Small flying device is easy target
 - c. Battery life
 - i. Size vs. capacity
 - d. Weather
 - c. Project status/Future works
 - a. Get approval for prototype
 - b. Testing
 - c. Expand traffic drone uses/capabilities
- F. References/ Bibliography
- a. 2-3 minimum archival references
- G. Appendices (W: Skylar; E: Barrett)
- a. Working Drawings/ Solidworks Models (W: Lucy; E: Skylar)
 - a. Prototype Drawings
 - i. Conceptual view
 - b. Solidworks
 - i. Working Drawings
 - 1. Drone
 - 2. Traffic Mast Attachment
 - 3. Traffic Hover Attachment
 - 4. Analysis
 - b. Parts/ Assembly List (W: Lucy; E: Skylar)
 - i. Subassemblies in correspondence with working drawings
 - ii. Functional Flow
 - iii. Manufacturing Process
 - iv. Analysis
 - c. House of Quality
 - a. What
 - b. How
 - c. Targets
 - d. Competitors
 - d. Decision Matrices
 - a. Concept Generation Matrix

- b. Drone Function Selection Matrix
 - c. Drone Design Selection Matrix
 - d. Analysis
- e. Objective Tree
 - a. Schematics orientation of the Traffic Drone's Objective Tree
 - b. Analysis
- f. Functional decomposition
 - a. Schematic orientation of the Traffic Drone's Functions Structure
 - b. Analysis
- g. Gantt Chart
 - a. Gantt Chart Diagram
 - b. Analysis
- h. Technological Readiness
 - a. Nasa Technology Chart
 - b. Analysis
- i. FAA Guidelines
 - a. List of relevant guidelines
 - b. Analysis
- j. Final Outline