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Unmanned Aerial Vehicle
100% Report

Josh Bayliss
Francisco Bolanos
Richard Martinez

Advisor: Professor Ibrahim Tansel

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Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Josh Bayliss, Francisco Bolanos, and Richard Martinez and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

Josh Bayliss Team Leader	Francisco Bolanos Team Member	Richard Martinez Team Member

Dr. Ibrahim Tansel
Faculty Advisor

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Abstract

The goal of this project is to design an unmanned aerial to be entered into the 2013 Student Unmanned Aerial Systems (SUAS) competition that is organized every year by the Association for Unmanned Vehicle Systems International. This design project does not entail manufacturing UAV from the ground up. Rather, it requires adequate selection, customization, and modification of a pre-fabricated product. The SUAS competition consists of several factors, which determine components that will need to be added to the UAV body. The final design will be able to achieve sustained flight for a minimum of 40 minutes with the added payload of GPS, altimeter, computer, autopilot, camera, etc. The body of the UAV is an RC plane. Several designs are being considered. The final design choice will hinge on manufacturer specifications. Additionally, an adequate motor (liquid fuel vs. electric) will be chosen depending on the thrust-to-weight ratio required and the necessary range. The fuselage of the design needs to be sufficiently large enough to accommodate the electronic components necessary for autonomous flight. Wing loading is also of concern, thus the wing design needs to be appropriate.

I. Introduction

Problem Statement

An unmanned aerial vehicle (UAV for short; also known as a drone) is any aircraft that does not have a human pilot onboard. UAVs have their origins as early as 1915 when Nikolai Tesla wrote a dissertation in which he described "an armed, pilotless-aircraft designed to defend the United States." [1] UAVs come in a variety of sizes, designs and purposes. Initially, UAVs were merely remotely piloted; however, autonomous control is becoming more widely utilized.

The Association for Unmanned Vehicle Systems International holds an annual Student Unmanned Aerial Systems competition. The competition involves many teams of university students from all across the United States and abroad. Several different types of UAV are often used such as airplanes, helicopters, and quadrotors. The competition consists of a pre-determined course that the drone must follow autonomously. Targets are set up along the path for the UAV to identify, photograph, and relay coordinates to the ground. At the end of the course, the UAV will enter a search area where it must autonomously search for additional targets.

The competition details design and operation parameters that need to be taken into consideration during the design process. Maximum takeoff gross weight needs to be less than 55 lbs. The vehicle must be capable of manual override by a safety pilot. Additionally, the maximum airspeed of the UAV cannot exceed 100 knots indicated air speed. The UAV design needs to accommodate competition guidelines while performing well enough to complete the course as quickly as possible in order to achieve victory over the other competitors.

Motivation

Developing an unmanned aerial vehicle has been one of the main points of concern by many counties all over the world; about 70 different countries have some sort of UAV technology. UAV expenditures reached more than US$ 3 billion and constituted a growth of more than 12% in 2010. Approximately 70% of global growth and market share is in the US. UAVs are used to gather information from the air in hostile areas. They can also be used in devastated areas where man support may not be available. These types of UAVs must be portable by ground and very reliable for recurrent use. With these types of uses by the military the UAVs designed are very costly and have very specific uses designed for each. The goal for the UAV design is to provide a cheaper alternative to these very costly military products. The UAV will be equipped HD camera with target recognition, a weight under 55 lbs., and a GPS guided autopilot to fly desired flight path.

Literature Survey

UAVs have been in production since before the Wright Brothers first took their historic flight. The earliest account can be traced back to the American Civil War, when an inventor patented an unmanned balloon that carried explosives that could be dropped after a time-delay fuse mechanism triggered a basket to overturn its contents [2]. While this is a relatively primitive idea of what the world has come to know today as “drones” it goes to show how early man began thinking about unmanned aerial systems. This technology began taking small leaps in the years following the American Civil War - the first military aerial reconnaissance photos were taken in 1898 during the Spanish-American War via a camera attached to a kite [2]. As the trend shows, many of the advancements in this technology arose during times of war, whether it was used to help with an offensive strike or just to acquire intelligence on enemy locations and activities. This is seen throughout the history and progress of unmanned aerial technologies. Advancements took place in Britain during the 1930s, where a radio-controlled UAV (dubbed the Queen Bee) served as aerial target practice for British pilots, and also during World War II, during which time the Nazi's developed an unmanned flying bomber known as the V-1 [2]. It wasn't until the 1970s that Israel developed the Scout and the Pioneer, which started the development toward the more widely known glider-type UAVs [2]. It was from this design that the Predator drone came to be; the Predator is the most sophisticated UAV in existence to date, these drones have come a long way from the "balloons" of the past. It's autonomous control networks show just how much this technology has evolved.

The structural design of UAVs has changed over their developmental history in order to serve a variety of purposes. UAV design and advancement is a global activity. As technology and needs change, UAVs can be improved to serve these needs. There are several design considerations that are constant.

The first of these design criteria is the degree of autonomy. Early UAV designs were mostly set to fly a specified path until they ran out of fuel. They carried a camera onboard, which would be recovered after the UAV landed. Later, the advent of radio control systems allowed UAVs to be piloted from the ground. Modern UAVs often combine these two basic functionalities. These two modes of operation do not strictly signify autonomy. True autonomy suggests the ability of the aircraft to operate without human interaction. In this regard, UAVs are still very immature. UAV autonomy technology is divided into the following categories:

- **Sensor fusion**: On board the vehicle a combination of sensors are used.
- **Communications**: Communication and coordination will be handled between multiple sources in the existence of curtailed and imperfect information
- **Motion planning (also called Path planning)**: Determining the optimal path for the vehicle in accordance with specific objectives and constraints such as obstacles go
- **Trajectory Generation**: Designed for optimal control and maneuverability to follow a particular route or to go from one place to another.
- **Task Allocation and Scheduling**: Set the optimal distribution of tasks between a group of agents, with time constraints and equipment limitations.

- **Cooperative Tactics**: The optimal sequence and spatial distribution of activities between agents in order to make the most of the chances of success in any case or situation. [3]

The ultimate goal of UAVs is to replace human pilots altogether.

Another major design criterion is UAV endurance (range). Since there is no human pilot onboard, there is no concern for pilot fatigue. UAVs can be designed to maximize flight times to take advantage of this fact. Different systems can afford a wide variety of maximum range. Internal combustion engines require relatively frequent refueling and in-flight refueling is a major obstacle for this type of propulsion system. Photovoltaic UAVs offer the potential for unlimited range and there is much research in this field. One more type of fuel system is hydrogen, which is proposed for use with certain models of stratospheric persistent UAVs. The AeroVironment's Global Observer is one such UAV. This aircraft runs on hydrogen and has a range of 7 days. The idea is for two of such UAVs to be used in tandem to provide continuous, uninterrupted operation 365 days a year. [5]

With the sophistication that these systems have arrived at, the market for them has grown astronomically. While the United States still has the largest stockpile of unmanned aircraft, the rest of the world is beginning to follow suit. More than 50 countries have purchased surveillance drones, and many have started in-country development programs for armed versions [4]. More than two-dozen different models were shown at a recent aviation show in China [4]. Due to the changing landscape of the theater of war, many nations are leaning toward unmanned aircraft to handle delicate situations in which human lives need not be put at risk. Also, taking into account the fact that drones sell for a fraction of the cost of manned airplanes, the amount of UAVs a nation can purchase at once has enticed many nations into entering the drone zone.

In general, UAVs fall into one of six functional categories:

- **Target and Decoy:** simulating enemy missiles or aircraft for ground and air gunnery
- **Reconnaissance:** battlefield intelligence gathering
- **Logistics:** cargo and logistics application
- **Research and Development:** used for UAV technology development

- **Civil and Commercial:** specifically designed for civil and commercial applications [6]

Competition details:

The basis of the competition is a reconnaissance mission for the US Marines for specified target accusation as well as added fight directions mid-flight. The story is that an island has had storms and pirates have invaded the island. The UAV is to stay within a specified area and transmit the images back to base as well as locations for desired targets. [7]

Students are judged on how well the UAV performs the desired task and top teams receive prize money. The competition requires a submittal of a final journal paper, oral presentation, and demonstration of UAV capabilities. At the start of the competition a statement of work will be provided and it is the team's job to figure out the best system design and development to complete the task. [7]

A fact sheet will be needed by committee to review prior to competition of each plane to verify qualifications for the competition. Also well as the journal paper describing in detail each aspect of the plane with a detailed description of functions. The oral presentation is not an overview of the journal paper but rather a briefing of the plane and safety checks, Static checks, and testing development descriptions. Afterwards there will be a preflight brief done by safety inspectors. [7]

The flight demonstration will consist of taking off and landing in specified landing/takeoff zones as well as autonomous flight within given flight path, guided by GPS being able to stay out of no-fly zones. Targets should be recognized along this path and will be different geometric shapes, of different color and size. This mission should be able to be completed within 40 minutes and will receive extra points for any saved time down to 20 minutes. [7]

The requirements and parameters of the plane are a few to insure the safety of the competitors. The gross weight should not exceed 55 pounds. GPS location and flight height must be transmitted to judges at all times to ensure that plane is not in a no fly zone or altitude. There must be a manual override by the safety pilot in case of emergencies. The plane should have a return home activation if loss of signal for more than 30 seconds as well as being able to be activated by an operator. If signal is lost for more than 3 minutes a terminate flight system should be activated automatically by the plane as well should be able to be activated by the operator. The speed of the plane should not exceed 100 KIAS. Batteries and plane should have some bright colors in the case of a crash the materials can be found easily. [7]

II. Design Alternatives

Overview

In order to decide upon a design for this UAV, certain limiting factors had to be taken into consideration, namely the payload of electronic equipment that would need to be incased and secured somewhere within the fuselage. Also by taking into account the necessary minimum flight time this plane would need to see, while carrying this load, the possibilities were narrowed down further. After conducting a little research into the designs of commonly used UAVs and comparing their uses with those that this plane would see, it was decided that a conventional glider design would be used. Being that this plane would need to see at least twenty minutes of flight time the glider seemed like the most feasible option. In the design of a glider long periods of flight can be sustained due to the aircrafts lift to weight ratio; as the wings of a glider are lengthened it becomes capable of bearing more weight during flight. Since gliders fly mostly at low speeds, choosing a glider also indirectly helped to alleviate some of the confusion in choosing between electric and gas powered engines. Due to the fact that gliders come in a variety of configurations, below are a few conceptual designs that were weighed out before deciding upon the final design.

Feasibility

When the designer/engineer meets the client, the needs are defined from the clients' point of view. Thus, clients' statements might have errors, they are typically limited as well as biased, and they might imply solutions etc. All these are performing from the point of view of the client.

Thus, the designer accomplishes these tasks and activities by interviewing the client, conducting surveys, and conducting brainstorming. Also to better understand the goals of the design, additional activities need to be included such as interviewing marketing, management, and experts, as well as reviewing similar products, industry reports, literature, patents, market data, etc.

The outcome of this analysis is revising the project statement, and refining objectives, user requirements, and constraints. In the following two sections, the team introduces the "Needs Analysis" and "Feasibility Analysis" of the project.

- ***Association of Unmanned Vehicle System International (AUVSI)***

The team agreed to participate in the Unmanned Aerial System Competition. Therefore, the design follows the specifications from the

Association of Unmanned Vehicle System International (AUVSI) in which they proposed in the Draft Request for Proposal or Draft RFP. Descriptions and specifications are outlined in the “Statement of Work” of Section C in the Draft RFP.

In general, in the section content, the concepts of operations of AUVSI

- Unmanned Aerospace System Sensor operators, UAS must comply with special instructions (SPINS) for departure and arrival procedures, and remain in airspace. SPINS are operations and procedures for qualified personnel that they must follow.
- UAS, Unmanned Aerospace System Sensor operator, must be able to support mission with intelligence, surveillance, and reconnaissance (ISR) (search areas of interest) complying with SPINS.
- ISR task maybe request outside the current assigned airspace in which causes UAS operators to request deviations.

- ***Section C part 3***
  - Air vehicle should take off and land within a paved asphalt surface 100 ft. wide.

- The autonomous vehicle shall overfly select waypoints (GPS coordinates (ddd.mm.ssss) and remain inside assigned air space avoiding no-fly zones. Air space is a predetermined course that includes changes in altitude heading to search area.
- Must fly specific altitudes while identifying several targets within 250ft.
- Flight path deviations are not permitted.
- Take off flight must maintain steady controlled flight at altitude above 100 ft. and under 750 ft. MSL (Mean Sea Level)
- Vehicles should search the area at any altitude between 100 and 750 ft. MSL upon entry and exit of predefined search area.
- UAS shall stay within flight path tolerance in order to obtain an image of the target during mission planning. In other words, the off-center target will be given and the UAS flight path should not vary tolerance.
- Should be able to recognize basic geometric shape and color. The shapes has dimensions of length or width forming which this shapes contain different alphanumeric.

- Alphanumeric will be the size between within the length and width of the target and thickness with varying color and contrast from the target.
- Bonus points for deciphering the secret message coded in the alphanumeric by arranging them.
- System should be able to detect and record characteristics of objects such location, shape, color, orientation, alphabet, alpha color. System should provide this data.
- The SRIC comprises of a router, an high gain directional antenna, and a laptop computer
- The position of Simulated Remote Information Center (SRIC) is given prior to takeoff and extra points will be given if the appropriate data is passing from the SRIC to the ground station via the airplane.
- There will be a “new search area” within the no-fly zone boundaries allowing locating “pop-up” targets of human form.
- Missions should be accomplished up to 40 minutes. After that points will be deducted

- 40 minutes will be given to the team to prepare their equipment and flight. If teams have no start the air vehicle to flight jet mission will be terminated.

- ***Section C part 4***
  - Air vehicle must pass inspection. Safety that involves a level of risk to personnel and property and other safety requirements that are not meet listed below will not be permitted to fly.
  - Max takeoff gross weight of the airplane shall be less than 55 lbs.
  - System should display no-fly zone and provide information to ensure that it is operating within the no-fly/altitude boundaries on a continuous basis.
  - The air vehicle shall be capable of manual override by the safety pilot during any phase of flight.
  - The air vehicle shall automatically return home or terminate flight after loss of transmit signal of more than 30 sec.
  - The air vehicle shall automatically terminate flight after loss of signal of more than 3 minutes.

- The return home system, if installed, shall be capable of activation by the safety pilot.
- The flight termination system shall be capable of activation by the safety pilot.
- Flight termination for fixed wing aircraft without an alternate recovery system (like a parachute) shall select:
- Throttle closed
    - Full up elevator
    - Full right rudder
    - Full right (or left) aileron
    - Full Flaps down (if so equipped)
    - For other than fixed-wing air vehicles, similar safety requirements will be assessed which result in a power off recovery in minimum energy manner at a spot on the ground no more than 500 ft. radius over the ground from the point of the termination command.

- Max speed should not be more than 100 KIAS.
- Take off cannot be from moving vehicles.
- Aircraft shall comply with the 2007 Official Academy of Model Aeronautics (AMA) National Model Aircraft Safety Code except:
    - Autonomous operation
    - Take-off weight of less than 55 lb.
    - Radio Control
    - Gas turbine.
- System should be able to complete mission objectives in temperatures up to 110 degrees F and up to 10 hours.
- System should be able to operate under fog conditions of visibility of 2 miles or grater with no precipitation.
- UAS will not operate during thunderstorms

There are many other requirements for the competition however those mentioned above are the clients' requirements that deal most with the design of the system.

- ***Survey / Client needs***
  - Product should be able to operate easily, however if not possible, there should be appropriate train personnel, for example, UAS team for completion.
  - The system must be able to recognize objects within a specify range distance to a target
  - The system must be able to be autonomous
  - System follows designated path by user inputs of coordinate system, or the system must be able to receive a complete path of coordinate's information through a subsystem receiver.
  - The system must be able to receive new commands or an over write of a new assign path.
  - Should able to received commands of object recognition or perform a mission reconnaissance.
  - The system must be able to perform manual over-ride RC from the autopilot.

- The sources of energies of the systems must be able provide enough energy and power to finish and accomplish a specific mission by the user.
- The product should be safe to used, in other words, must pass safety procedures guidelines for civilian UAV.
- The system should be autonomous.
- The system should be affordable for companies
- A goal is to reduce the cost by a middle class family or at least the benefits that the benefits of owning a system can out weight the cost.

- ***Brainstorming***
  - The product must be able to operate in some adverse conditions such as normal strong wind, light rain, and internal or external vibrations produce by system or environment. The mechanical team is in charge in this area.

- The system must have the internal space capacity to carry the appropriate electrical and mechanical components designated by the electrical team.
- The system must be able to carry the weight of the mechanical and electrical internal and external components designated by both mechanical and electrical teams.
- The internal components must be placed in an order that does not stabilizes the system according to the center of mass support it by the plane.
- The system must be able to display its GPS coordinates and other information related to mission reconnaissance.
- The system must be able to switch from autonomous to manual appropriately minimalizing any disturb and errors in the system.
- The system must have a ground control station which connects to the autopilot

From the client Interview, conducting a survey, and brainstorming the object attributes and a list of objectives is obtained a follows.

Characteristics and Attributes List
Source 1: AUVSI Draft RFP
UAS must be able to support mission with intelligence, surveillance, and reconnaissance (ISR) (search areas of interest) complying with SPINS.
ISR task maybe request outside the current assigned airspace in which causes UAS operators to request deviations.
UAS team must be able to conduct UAV system in which it must be able to detect objects
Air vehicle should take off and land within a paved asphalt surface 100 ft. wide.
The autonomous vehicle shall overfly select waypoints (GPS coordinates (ddd.mm.ssss) and remain inside assigned air space avoiding no-fly zones. Air space is a predetermined course that includes changes in altitude heading to search area.
Must fly specific altitudes while identify several targets within 250ft.
Flight path deviations are not permitted.
Take off flight must maintain steady controlled flight at altitude above 100 ft. and under 750 ft. MSL (Mean Sea Level)
Vehicles should search the area at any altitude between 100 and 750 ft. MSL upon entry and exit of predefined search area.
UAS shall stay within flight path tolerance in order to obtain an image of the target during mission planning. In other words, the off-center target will be given and the UAS flight path should not vary tolerance.
Should be able to recognize basic geometric shape and color. The shapes has dimensions of length or width from in which this shapes contain different alphanumeric.
Alphanumeric will be the size between within the length and width of the target and thickness with varying color and contrast from the target.
Bonus points for deciphering the secret message coded in the alphanumeric by arranging them.
System should be able to detect and record characteristics of objects such location, shape, color, orientation, alphabet, alpha color. System should provide this data.
The SRIC comprises of a router, a high gain directional antenna, and a laptop computer

The position of Simulated Remote Information Center (SRIC) is given prior to takeoff and extra points will be given if the appropriate data is passed from the SRIC to the ground station via the airplane.
There will be a “new search area” within the no-fly zone boundaries allowing locating “pop-up” targets of human form.
Missions should be accomplished up to 40 minutes. After that points will be deducted
40 minutes will be given to the team to prepare their equipment and flight. If teams have no start the air vehicle to flight jet mission will be terminated.
Air vehicle must pass inspection. Safety that involves level of risk to personnel and property and any other safety requirements that are not meet listed below will not be permitted to fly.
Max takeoff gross weight of the airplane shall be less than 55 lbs.
System should display no-fly zone and provide information to ensure that it is operating within the no-fly/altitude boundaries on a continuous basis.
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The air vehicle shall automatically return home or terminate flight after loss of transmit signal of more than 30 sec.
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The return home system, if installed, shall be capable of activation by the safety pilot.
The flight termination system shall be capable of activation by the safety pilot.
Flight termination for fixed wing aircraft without an alternate recovery system (like a parachute) shall select: Throttle closed, full up elevator, full right rudder, full right (or left) aileron, and full Flaps down (if so equipped)
For other than fixed-wing air vehicles, similar safety requirements will be assessed which result in a power off recovery in minimum energy manner at a spot on the ground no more than 500 ft. radius over the ground from the point of the termination command.
Max speed should not be more than 100 KIAS.
Take off cannot be from moving vehicles.

Aircraft shall comply with the 2007 Official Academy of Model Aeronautics (AMA) National Model Aircraft Safety Code except: Autonomous operation, takeoff weight of less than 55 lb., Radio Control, Gas turbine, etc.
System should be able to complete mission objectives in temperatures up to 110 degrees F and up to 10 hours.
System should be able to operate under fog conditions of visibility of 2 miles or grater with no precipitation.
UAS will not operate during thunderstorms
Source 2: Survey/Client
Product should be able to operate easily, however if not possible, there should be appropriate train personnel, for example, UAS team for completion mention above.
The system must be able to recognize objects within a specify range distance to a target
The system must be able to be autonomous,
System follows designated path by user inputs of coordinate system, or the system must be able to receive a complete path of coordinate's information through a subsystem receiver.
The system must be able to perform manual over-ride RC from the autopilot.
The sources of energies of the systems must be able provide enough energy and power to finish and accomplish a specific mission by the user.
The product should be safe to used, in other words, must pass safety procedures guidelines for civilian UAV.
Source 3: Brainstorming
The product must be able to operate in some adverse conditions such as normal strong wind, light rain, and internal or external vibrations produce by system or environment. The mechanical team is in charge in this area.
The system must have the internal space capacity to carry the appropriate electrical and mechanical components designated by the electrical team.
The system must be able to carry the weight of the mechanical and electrical internal and external components designated by both mechanical and electrical teams.

The internal components must be placed in an order that does not stabilizes the system according to the center of mass support it by the plane.
The system must be able to display its GPS coordinates and other information related to mission reconnaissance.
The system must be able to receive new commands or an over write of a new assign path.
The system must be able to switch from autonomous to manual appropriately minimalizing any disturb and errors in the system.
The system must have a ground control station which connects to the autopilot

Table 1: Characteristic and Attributes List

Constraints and functions are removed from Table IV-i leaving only objectives in the list, as seen in Table IV-ii below.

UAV Pruned List of Objectives
UAS must be able to support mission with intelligence, surveillance, and reconnaissance (ISR) (search areas of interest) complying with SPINS.
ISR task maybe request outside the current assigned airspace in which causes UAS operators to request deviations.
UAS team must be able to conduct UAV system in which it must be able to detect objects
Flight path deviations are not permitted.
Bonus points for deciphering the secret message coded in the alphanumeric by arranging them.
There will be a "new search area" within the no-fly zone boundaries allowing locating "pop-up" targets of human form.
Air vehicle must pass inspection. Safety that involves level of risk to personnel and property and any other safety requirements that are not meet listed below will not be permitted to fly.
The air vehicle shall be capable of manual override by the safety pilot during any phase of flight.
The return home system, if installed, shall be capable of activation by the safety pilot.
The flight termination system shall be capable of activation by the safety pilot.
Product should be able to operate easily, however if not possible, there

should be appropriate train personnel, for example, UAS team for completion mention above.
The system must be able to recognize objects within a specify range distance to a target
The system must be able to be autonomous,
System follows designated path by user inputs of coordinate system, or the system must be able to receive a complete path of coordinate's information through a subsystem receiver.
The system must be able to perform manual over-ride RC from the autopilot.
The sources of energies of the systems must be able provide enough energy and power to finish and accomplish a specific mission by the user.
The product should be safe to used, in other words, must pass safety procedures guidelines for civilian UAV.
The product must be able to operate in some adverse conditions such as normal strong wind, light rain, and internal or external vibrations produce by system or environment. The mechanical team is in charge in this area.
The system must have the internal space capacity to carry the appropriate electrical and mechanical components designated by the electrical team.
The system must be able to carry the weight of the mechanical and electrical internal and external components designated by both mechanical and electrical teams.
The internal components must be placed in an order that does not stabilizes the system according to the center of mass support it by the plane.
The system must be able to display its GPS coordinates and other information related to mission reconnaissance.
The system must be able to receive new commands or an over write of a new assign path.
The system must be able to switch from autonomous to manual appropriately minimalizing any disturb and errors in the system.
The system must have a ground control station which connects to the autopilot

Table 2: The pruned List of Objectives

- ***Feasibility Analysis***

The project feasibility analysis predicts and estimates the future course of action of the project. The following is the weighted scale analysis. Feasibility assessment is measure against attributes. Feasibility assessment along with the Risk analysis aids the team to determine the project risks as it approaches to the completion of the project.

- ***Technical Feasibility***

The project is possible since a previous team has developed it. Moreover, there are several competitions were universities, colleges, and schools participate. The planes and components are either designed or purchased from remote control (RC) plane hobbyist. A few companies that develop components are MicroPilot, Boeing, Northrop Grumman Corporation, Insitu, Latitude and Engineer Group. There is also "ArduPilot" which is an autopilot design from Arduino using Arduino components. A few stores that sell RC planes are Hobby Lobby, Hobby King, and several others available for purchase online. Thus, there exists a market available. Either it can be obtain at local market or bought thorough the Internet.

- ***Economic and Resource Feasibility***

The team is capable of learning the electrical technology, and the team has been working with a mechanical engineer team for all the mechanical design. The equipment is available from previous teams, which have being sponsor. They received funds and participated in previous competitions. The equipment is available at the Mechatronics lab. The team already received approval from the department of Mechanical Engineer to use the equipment. The number of team members is four and the team has been seeking contact with previous year's teams'. Also, the team is preparing a proposal letter, and it is working on submitting to corporations such as NASA, in order to request more funds. NASA sponsored the previous teams' design.

As amateur UAV and RC vehicles are becoming more available in the market and production increases, parts become less expensive. Another factor that reduces cost is open source licenses. Moreover, in benefit vs. cost, cost reduces as the benefit increases especially for students, hobbyist, researchers, and intellectuals in this area.

There is economic risk in developing this product as a whole; however, the components have many applications. The first development has been to satisfy survival or military needs. Thus, the narrow functionality of this product has led to have high economic risk since the developmental companies compete for a government contract. Therefore they do not solely dedicate to develop this product. The components can be applied in many areas such as security, science research, exploration, robotics, artificial intelligence, autonomous systems, etc.

- ***Schedule Feasibility***

Each team member posts their schedules online in excel spreadsheet, which includes classes, work, study time, organizations, etc. A team member organizes all schedules into one schedule labeling all the time that team member cannot meet in black. The remaining time was the available time that the team can meet. The team was able to arrange not only meeting times but also times that it can meet together and work in the equipment.

- ***Cultural and Legal Feasibility***

Since there are competitions available at university / college level and other competitions related to avionics and robotics, the team realizes that there is an important impact on society and community. There are many rules to follow, which are shown to the amateur avionics and robotics in competitions. These are listed as constraints in tables IV-i and IV-ii above in this section. For example, when vehicle loses signal or transmission it must abort mission and return to base. Other rules are that vehicle should not fly faster than 150 knots. It must safety rules inspection before flight, which is similar to how other vehicle automobiles cannot operate if they do not pass minimum standards ratings. Moreover, standards are higher than RC avionics because there is no pilot and may impose some safety issues. For example, autopilots plane must reach a study flight altitude no less than 100 ft. and no more than 750 ft. As long as these rules are followed, the government will not impose severe laws, fees, license, etc.

Design Alternative 1

The first design that was looked at is shown below in Figure 1: Design Alternative 1. This design employs the use of a high wing attached to a conventional single-engine type fuselage finished off with a standard tail to control elevation. The main advantage behind using this design is its solid foundation. In turbulent or otherwise undesirable conditions during flight, the struts connecting the wings to the fuselage prevent any damage from occurring and also aid in supporting a steady flight path. Its "teardrop" shape also adds a great deal to the plane's aerodynamics by cutting down on its drag coefficient. The disadvantages in using this design, however, stem mostly from the desired specifications of the plane itself. Since this plane is being designed to perform a reconnaissance mission the best place to mount a camera to provide feedback of location and target recognition is in the nose; but the body of this design also requires a front-centered propeller which would conflict with the electronics powering the camera, as well as the camera itself.

Figure 1: Design Alternative 1

Design Alternative 2

The second design that was considered can be seen in Figure 2: Design Alternative 2. This design proposes a middle-wing configuration, attached to a fuselage that is rounded towards the front to be able to contain all of the electrical components, but thins out until it is met with a t-tail that is used to stabilize its flight. This design has great aerodynamic capabilities due to the shape of its fuselage and long, thin, and rigid wings. The extended wingspan also allows for greater overall lift with the least amount of drag, which means that a greater load may also be supported. Also with the removal of the support struts, this design is significantly lighter than the previously suggested design. But although there are a lot of valuable aspects, the same problem arises, and that is the location of the motor. Due to the fact that the fuselage thins out so much towards the rear of the plane, it is feasible to place a propeller there. So while the aerodynamics were significantly improved upon with this design, the fact that this is still a plane requiring a front-centered propeller takes away from its feasibility for the desired specifications.

Figure 2: Design Alternative 2

Design Alternative 3

The third design, seen below in Figure 3: Design Alternative 3 has become the most commonly employed design for UAV technology today. This design consists of a glider-type fuselage that has a round nose that is lofted into a thin, circular shape that is met by a V-tail used for increased maneuverability. Similar long, thin, rigid wings are seen in this design as were seen in the glider. The difference between this design and that of the glider comes from its extended fuselage, which allows for a back-centered propeller to be used. This is a significant improvement from the other designs, because it allows for the camera to be placed in the nose of the plane, as well as all of the other electrical components, without being interfered with by the propeller.

Figure 3: Design Alternative 3

Proposed Design

After looking into many possible options and comparing the pros and cons between overall weight, flight time, and competition specifications, it was decided that the 3rd design alternative was the best design to go with. With its rigid frame, light weight, and adherence to design criterion this plane was the best possible choice to use to enter into the competition next year, the last thing that needs to be decided upon is the type of engine that will be used to fly it. There are both positive and negative aspects related to an electrical motor and a gasoline powered motor, the greatest factor rests in the weight that would be added to the system. Once an estimate on the weight of all of the internal components for the on-board autopilot, batteries and processing equipment is received a decision will be made on the type of engine to be used for this design.

III. Analytical Analysis

Understanding problem

At this step the team task was to identify all the distinctive features of the structure and the principles of the design objectives. The type of loading inherent in the problem and the importance of any other environmental influences are also taken into account.

Operating Environment

The following table is the operating environment for the system in order to perform safely and properly.

Operating environment table.
Safety Considerations.
Air vehicle must pass inspection. Safety that involves level of risk to personnel and property and any other safety requirements that are not meet listed below will not be permitted to fly.
Max takeoff gross weight of the airplane shall be less than 55 lbs.
System should display no-fly zone and provide information to ensure that it is operating within the no-fly/altitude boundaries on a continuous basis.
The air vehicle shall be capable of manual override by the safety pilot during any phase of flight.
The air vehicle shall automatically return home or terminate flight after loss of transmit signal of more than 30 sec.
The air vehicle shall automatically terminate flight after loss of signal of more than 3 minutes.
The return home system, if installed, shall be capable of activation by the safety pilot.
The flight termination system shall be capable of activation by the safety pilot.

Flight termination for fixed wing aircraft without an alternate recovery system (like a parachute) shall select: Throttle closed, full up elevator, full right rudder, full right (or left) aileron, and full Flaps down (if so equipped)
For other than fixed-wing air vehicles, similar safety requirements will be assessed which result in a power off recovery in minimum energy manner at a spot on the ground no more than 500 ft. radius over the ground from the point of the termination command.
Max speed should not be more than 100 KIAS.
Take off cannot be from moving vehicles.
Aircraft shall comply with the 2007 Official Academy of Model Aeronautics (AMA) National Model Aircraft Safety Code except: Autonomous operation, takeoff weight of less than 55 lb., Radio Control, Gas turbine, etc.
Temperature \ Environmental Considerations.
System should be able to complete mission objectives in temperatures up to 110 degrees F and up to 10 hours.
System should be able to operate under fog conditions of visibility of 2 miles or grater with no precipitation.
UAS will not operate during thunderstorms

Table 3: Operating environment considerations.

Intended User(s) And Intended Use(s)

- ***Intended user(s).***

The primary users of the unmanned aerial vehicle (UAV) are mostly military, but not limited to the work of civilian personnel. Many researchers use UAV to survey locations for mapping purposes, pipeline security, and homeland security. The use of UAV in commercial aerial surveillance is expanding rapidly. Police department can use the UAV if an IR/Heat sensor is attached to find “Grow Houses”. Other possible users are teams of investigators that need to enter environment that might be contaminated with harmful toxins, because a UAV is unmanned it eliminates some chance of contamination.

- ***Intended use(s).***

The primary use of this project is to compete in the 2013 undergraduate Students Unmanned Aerial Competition. The team will be creating an UAV that will follow a path and it will seek and identify colorful and alphanumeric targets, possible by using camera and sensors. Other uses can be focus on the aid of local police department, using a UAV that has alphanumeric capability it can find targets that can range from a simple license plate to even a missing person. Since the UAV can be given a path to follow and it is also quite when compared to helicopter, it can also be used as an eye in the sky for multiple purposes, such as, surveillance of a woodland area where noise can have negative affects. Unmanned Aerial Vehicles can be used to enter contaminated environment, and can be used to scan the area. With the right sensors attached to the UAV, a UAV can scan for levels of contaminates.

An excellent example of a possible use of a UAV could have been in Japan after the earthquake. A UAV could have aided in the search of human life. Also, it could have been used to know the level of radiation in areas of interest that came from the damages of power plants with the proper sensors.

Mathematical Model

Once the team determined the essential features of the physical problem have been identified it was necessary to translate these features into a mathematical representation of the problem. For our problem this two stages involved two major tasks firstly, definition of the problem domain and secondly, selection of a mathematical formulation which best represented our physical behavior of the structure.

The main equations to look at are those of lift and drag. In the two

Equation 1: Drag and Lift Force Equation

$$F_D = \frac{1}{2} \rho v^2 C_D A \qquad L = \frac{1}{2}\rho v^2 A C_L$$

equations, A is representative of the surface area generally associated with the wings of the aircraft. The terms C_D and C_L are the coefficients of drag and lift, respectively. These coefficients are dimensionless numbers whose values have become almost standard through years of testing. In the free body diagram below, the various forces acting on an aircraft at any given time can be seen.

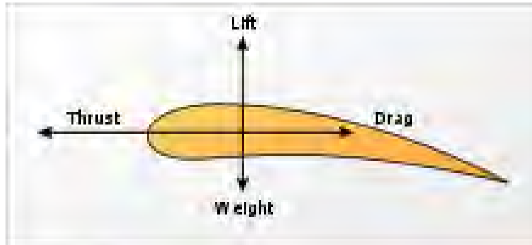


Figure 4: Free Body Diagram of an Airfoil

It can be seen that in order for an aircraft to achieve flight it must first overcome the forces of drag and its own weight via thrust and the lift associated with the design of the airfoil. The thrust of these planes is dependent upon the engines used to power them. Thus, when designing a plane, the right geometry and size must be chosen for the fuselage and the airfoils, in order to calculate the drag and lift that would be associated with them; once the drag, lift, and weight are know the proper size engine can be chosen to power the plane.

Finite Element Analysis

To ensure the validity of this design before implementing it as our desired end product, a finite element analysis was conducted in SolidWorks. For this analysis the fluid flow over the airfoils, as well as the fluid flow over the fuselage, were tested to observe the aerodynamic properties of the aircraft.

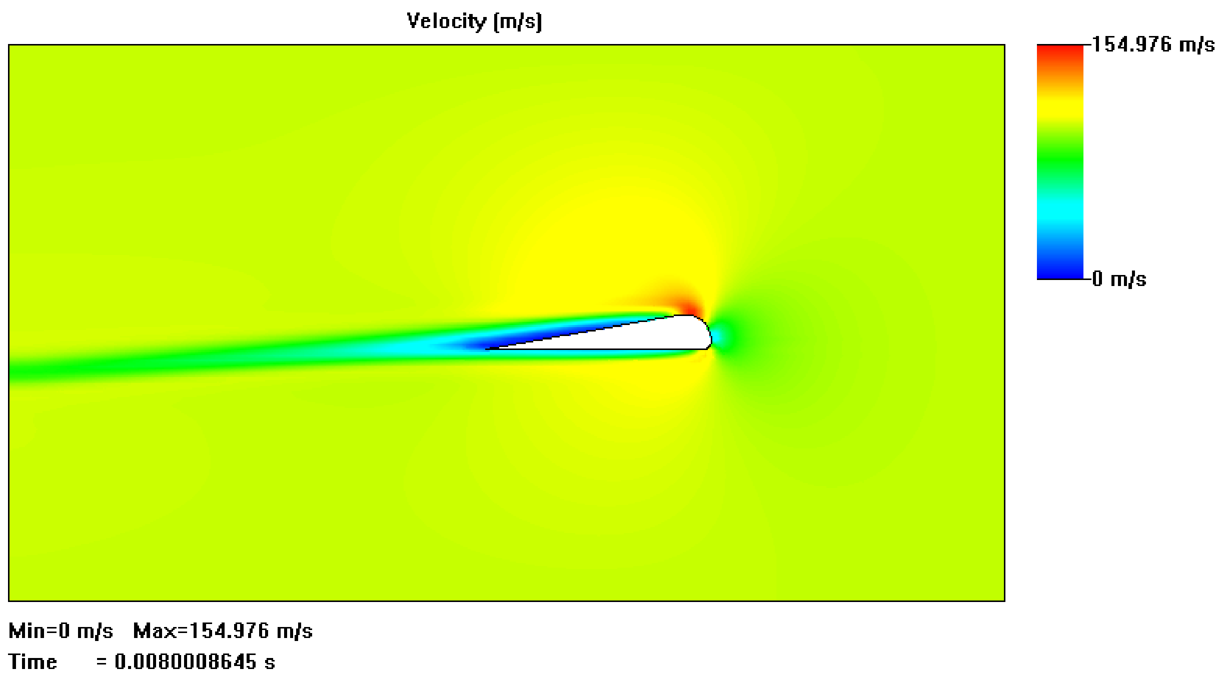


Figure 5: Velocity Flow over the Airfoil

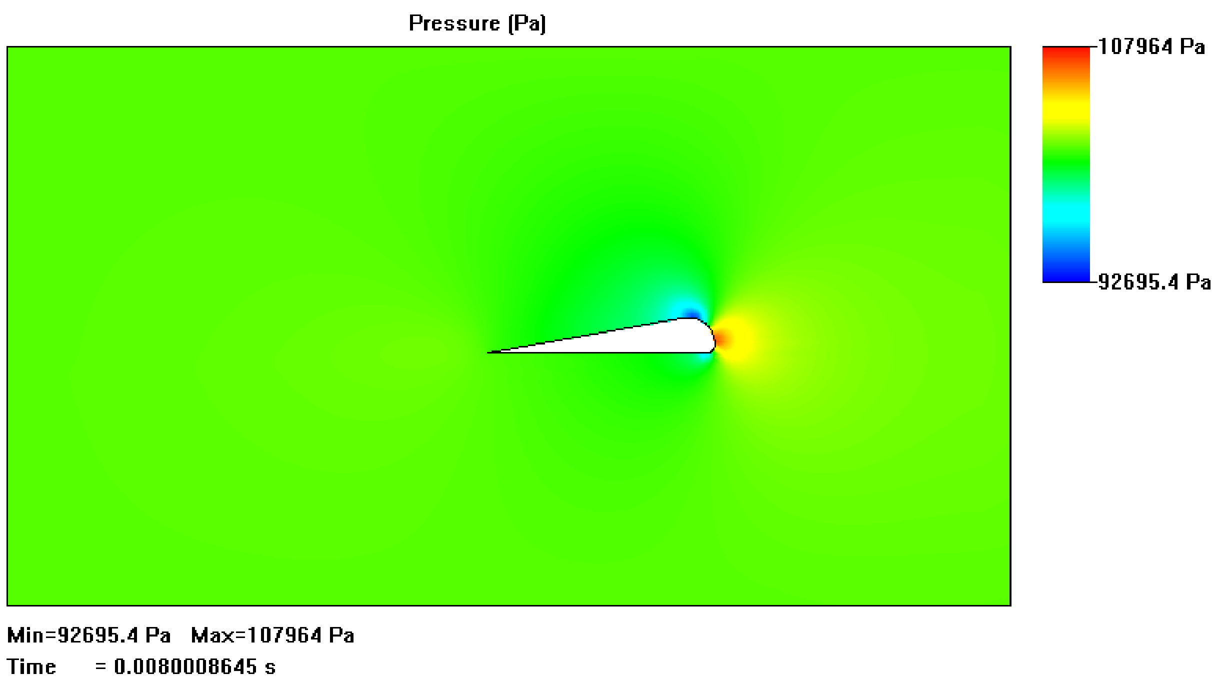


Figure 6: Pressure Distribution over the Airfoil

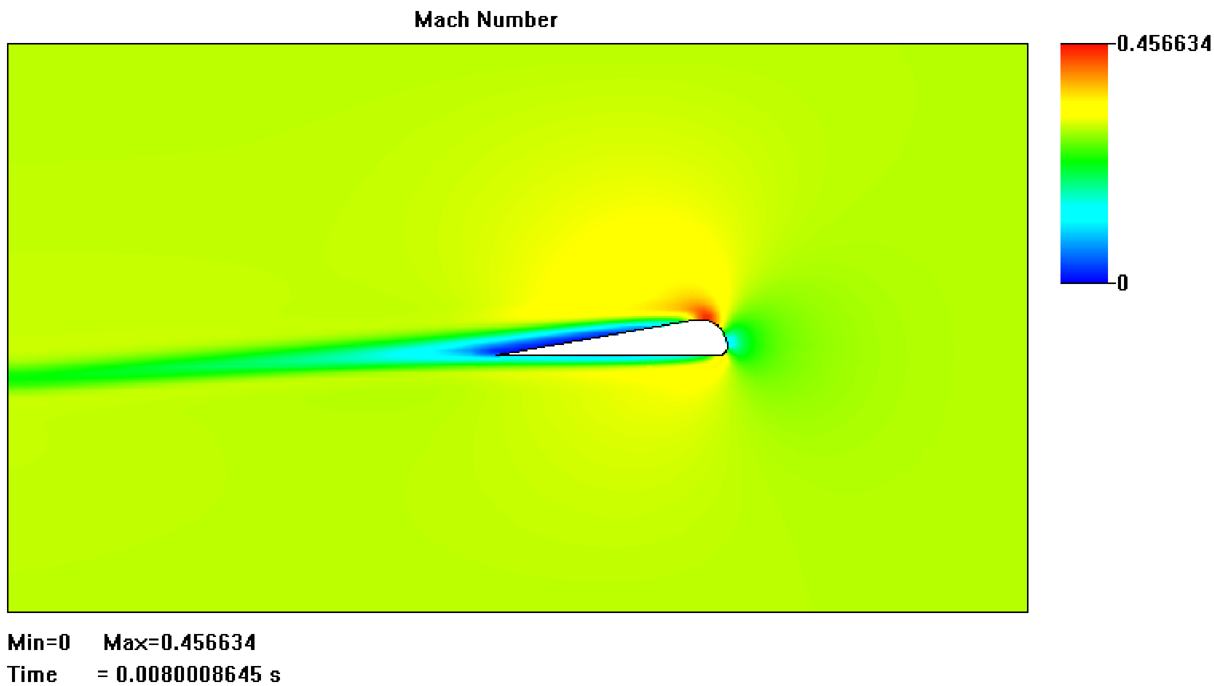


Figure 7: Mach number Achieved

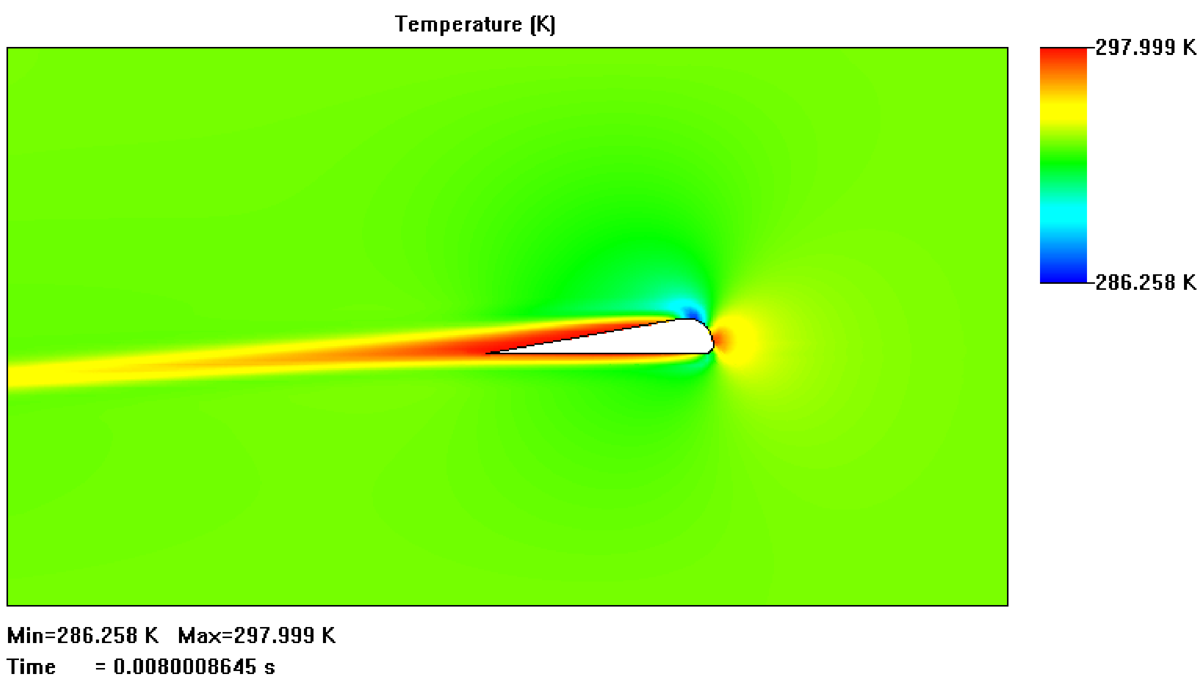


Figure 8: Temperature Distribution over the Airfoil

What these first few simulations show are the velocity, pressure and temperature distributions over the airfoil. From these results it can be seen that the design of the wing displays excellent aerodynamic properties; the first image (Figure 4) shows that the highest rate of velocity occurs at the top of the airfoil, which is the desired outcome because this shows a lower pressure region exists at this point (as depicted in Figure 5). From this low-pressure region above the wing, the principle of aerodynamic design is received – lift is generated when the pressure below an airfoil is greater than that of the pressure above it. Figure 7 has been included to justify the use of any material deemed fit by the group; since the temperature does not exceed a few degrees above ambient, it can be noted that the heat generation will not affect the composition of the wing and therefore just about any material may be used.

For the fuselage the main focus was on creating a body that could effectively distribute the airflow around it without creating significant amount of drag. Below are the results from the fluid flow analysis of the fuselage.

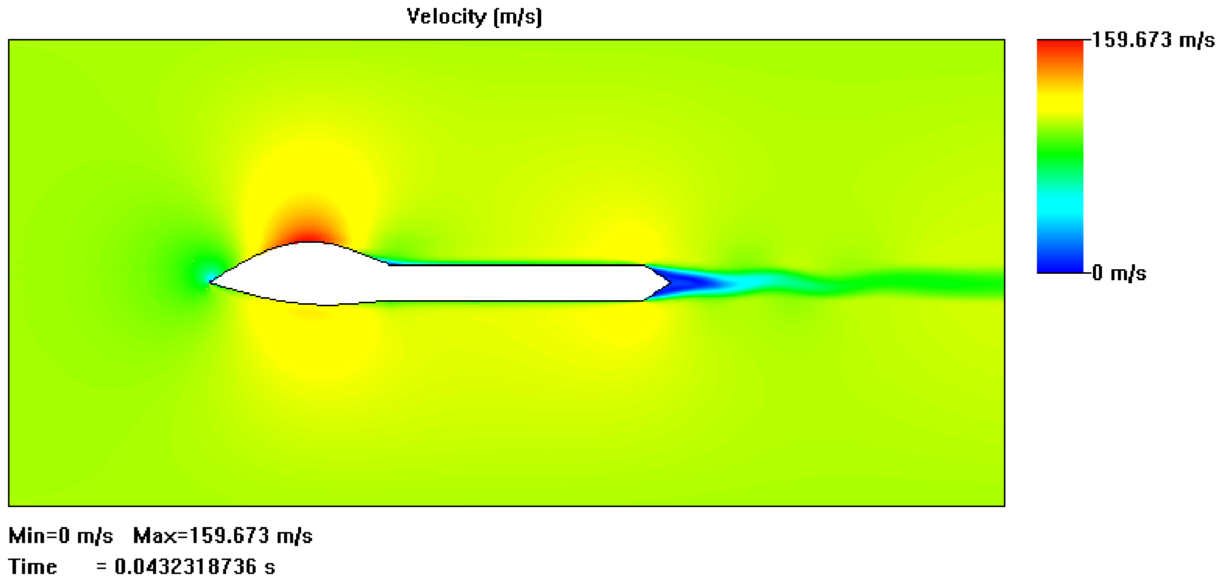


Figure 9: Velocity Distribution over the Fuselage

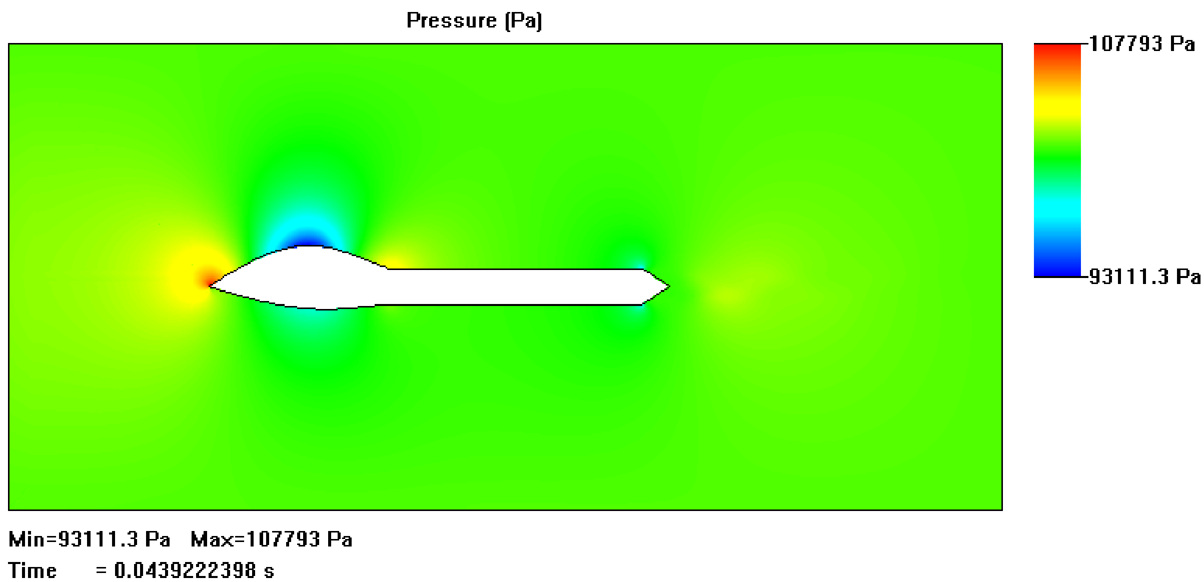


Figure 10: Pressure distribution over the Fuselage

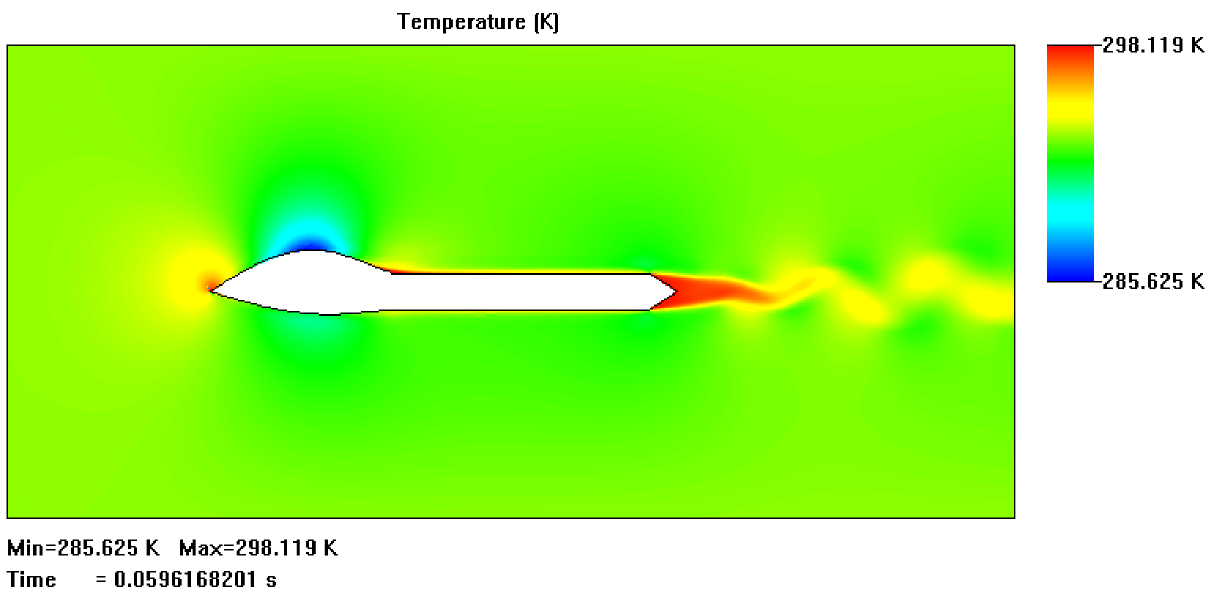


Figure 11: Temperature Distribution over the Fuselage

These simulations prove that the design of this fuselage is sufficient to gain and maintain flight when paired with the airfoils seen earlier. Just as described earlier, the lower pressure region above the front dome of the fuselage signifies that there will be some amount of lift attributed to the design of this body.

The overall design of the plane, including the wings, stabilizers and fuselage is seen in the images below.

Figure 12: Front View of Plane Assembly

Figure 13: Isometric View of Plane Assembly

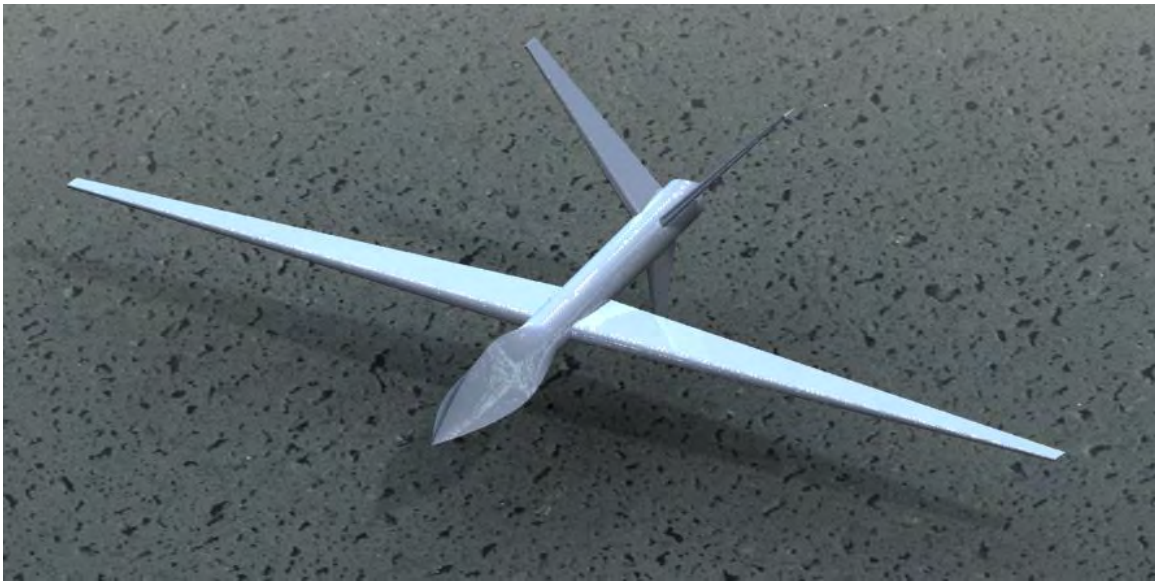


Figure 14: Rendered Image of UAV

Post-Processing

Verification and validation of this model: Post-processing provides valuable information needed to accept or reject the resolution and solutions to change the inputs. For this project in particular this design team will used a post processing via a graphical user interface, which is consider the most straightforward part of the FE process, off course have identified the important aspect that must be consider at time of evaluating our FEA results.

Furthermore, the FEA analysis for most of our design will be based on 3D-Solid representational mathematical model as result that our geometries, materials, loading required results that cannot be satisfactorily modeled with any of the simpler mathematical models.

Force Analysis

For the study of the force component for the different analysis a static distributed force and a time varying distributed force were consider for this part of the FEA analysis. The static distributed loads are important at time of analysis how our system is load and what are the effects of this type of forces. As result, this type of loading assumes that a force is applied and distributed over a certain length such as the top and bottom frame of our design. The form of the distribution vary from simple linear to more complex time varying distributed force also explore in this design project. For example for the fatigue analysis this type of load consider greatly, even though this type of loading can be complex as one function may describe the distribution of load on the structure and a second function may describe how this variation changes with time.

Stress and Strain Analysis

For the stress analysis study it is important to define some of the engineering principles taking into account. First of all the relation between engineering stress and strain, which engineering stress, σ, is defined as applied load, P, divided by the original cross sectional area, A_o, to which this load applied. Second the concept of engineering strain, ϵ, is defined as the deformation elongation or change in length, Δl, at some instant, in comparison to the original length, lo. Third when a tensile stress σ_z is imposed on a metal specimen such as the structural frame that holds the POD in place an elastic elongation and accompanying strain ϵ_z will occur in the direction of applied stress. As a result of this "elongation" there will be constrictions in the lateral direction perpendicular to the applied stress. From this "constriction" the lateral compressive strain ϵ_x can be determined. A parameter named Poisson's ratio, μ, is defined as the ratio of the lateral axial strains.

Thermal Analysis

For the thermal study the effect of heat conduction were analyzed. The result of that thermal study once completed can be used to determine the resulting thermal stresses on the structure. The result below show the thermal study conducted on the top and bottom frame of the POD. The two study cases reflect the two temperature profiles that were taking into consideration, which reflect the two possible scenarios. First when the frame is on a desert environment where temperature can reach 120 degrees Fahrenheit; second when the frame is at a high altitude due to the flying profile of the UAV the max temperature reached is approximately 100 degrees Fahrenheit.

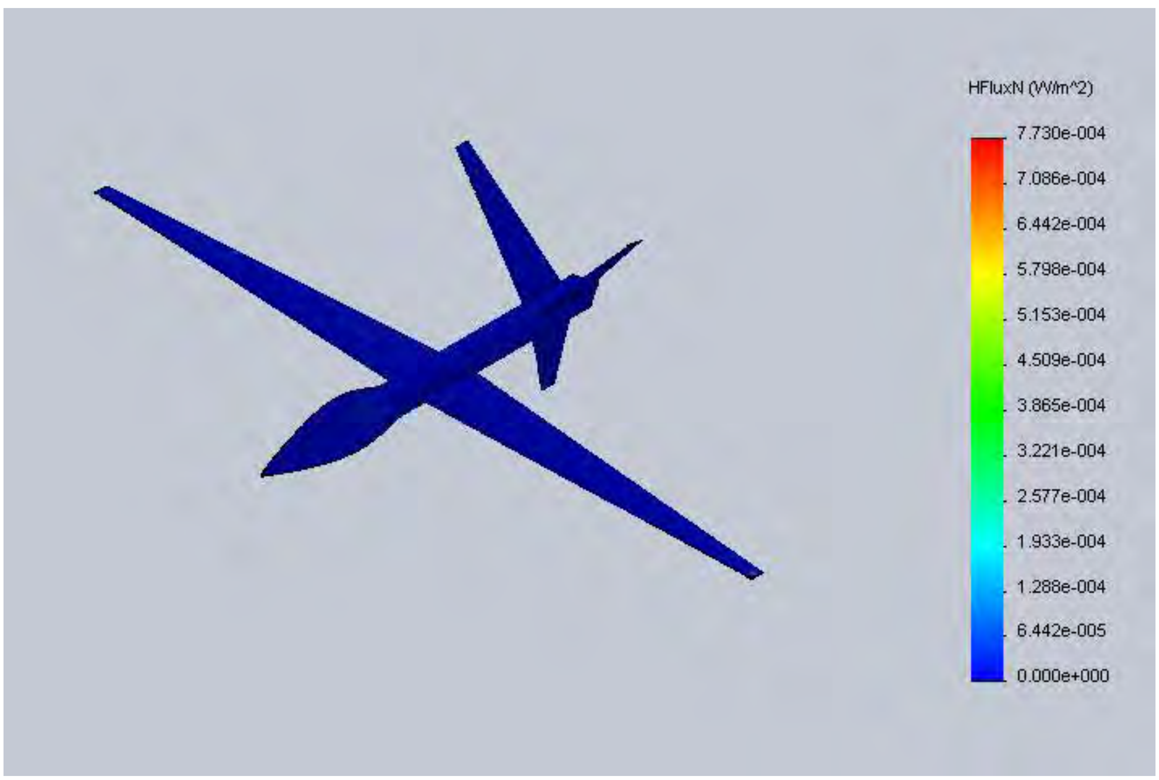


Figure 15: Heat Flux Resultant

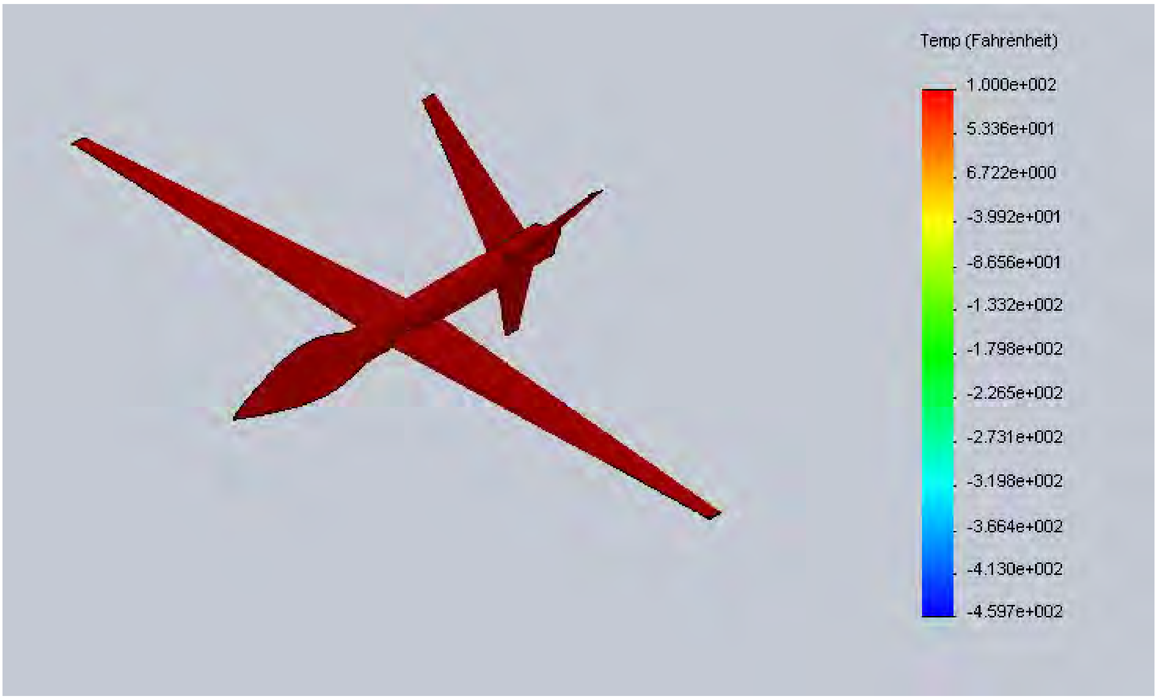


Figure 16: Temperature Analysis

Fatigue Analysis

The structure under consideration was exposed to a sustained cyclic load in order to analyze the life response by using SW FEA software package. Fatigue theories tell us that failure almost begins at a local discontinuity such as a notch, crack or other area of stress, concentration. When the stress at the discontinuity exceeds the elastic limit, plastic strain occurs. If a fatigue fracture occurs, then cyclic plastic strain exists. Thus we have to investigate the behavior of our design subject to cyclic load in the main component of our design project such as: frames, bolts, brackets, etc.

Vibration Analysis

Another important study that concerns our design is the vibration analysis, which occurs as result of the dynamic input. This type of analysis provides the natural frequency of the design component and modes shapes that the component naturally vibrates at. These are called the Eigen values and eigenvectors of the component. In addition, the solution obtained can be transferred (as the thermal stresses) to the Solid Works for force vibration analyses. The primarily study conducted is called mode shape analysis, which is based on the stiffness the resulting deflection. A modal analysis of the frame model was performed using the fine mesh size, the result as shown as follow.

IV. Major Components

There are many important aspects to put into perspective when designing this aircraft the main components to take into account, however, are the fuselage, the wings, the stabilizers and the motors (both servos and driving). Each of these components has a contributing factor in some form of aerial rotation, also known as yaw, pitch, and roll.

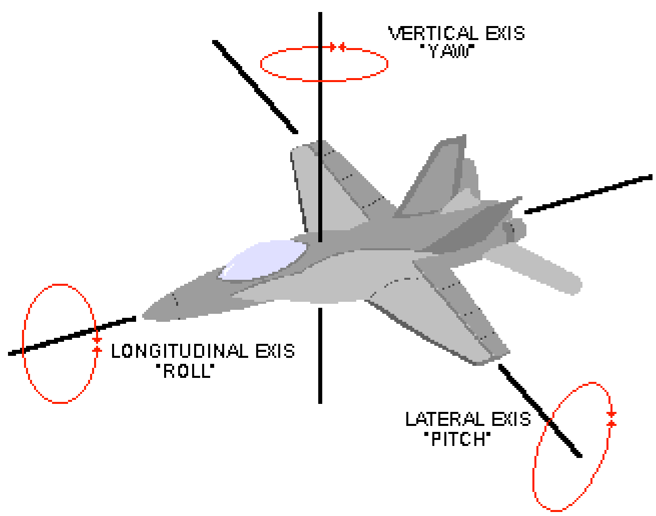


Figure 17: Yaw, Pitch, and Roll

The pitch of an airplane is the nose up or down action of the airplane and is taken in relation to the axis running from wing to wing. The yaw component of rotation describes the motion of the nose of a plane from either left or right in relation to a vertical axis running through the aircraft. Measured in relation to an axis running from nose to tail, roll is the rotation of a plane about this axis.

By examining each of these components individually a conceptual design may be achieved.

Wings

The wings of a plane are necessary to provide lift and essentially allow the plane the ability to fly. In addition to creating the lift force that allows a plane to fly, the wings also control the roll of an airplane through the ailerons attached to their trailing edges. There are many different wing configurations and geometries that are used today in common airplane designs; these possibilities are displayed in the figures below.

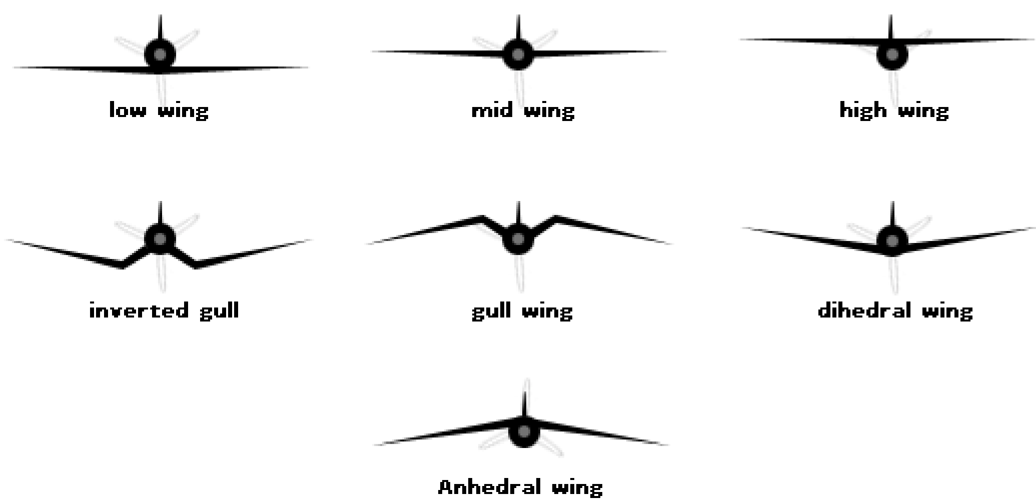


Figure 18: Wing Configurations

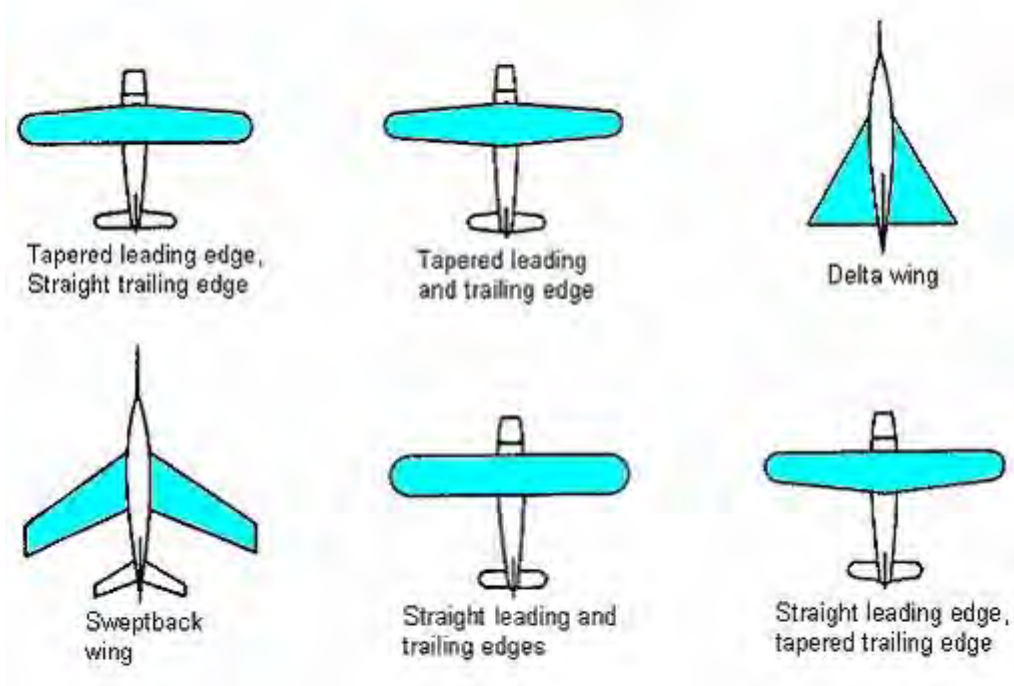


Figure 19: Wing Geometry

The main thing to take into account when choosing the right wing configuration is the function that the plane will be tasked to perform. Sweptback wings and delta wings are generally used for high speed flight and do not perform as well as straight wings in the regime of low, cruising speeds. Wing geometry is also largely based on the type of propulsion system that is used to power the aircraft because the thrust provided by this system provides a good idea of the planes maximum speed capabilities. For these reason a mid-plane, straight wing design was used.

- **Straight Wing:** Contains features desirable for UAV based on low speed performance and stability during flight. This configuration has no forward or backward inclination that makes it optimal for our project.

Stabilizers

Along with contributing to the overall lift gained during flight, the stabilizers of an aircraft help to maintain a straight and level path, facing into the direction of the wind, throughout the course of flight. There are multiple designs that may be implemented and their functions will differ based upon the geometry of their configuration. A few configurations are displayed in the figure below.

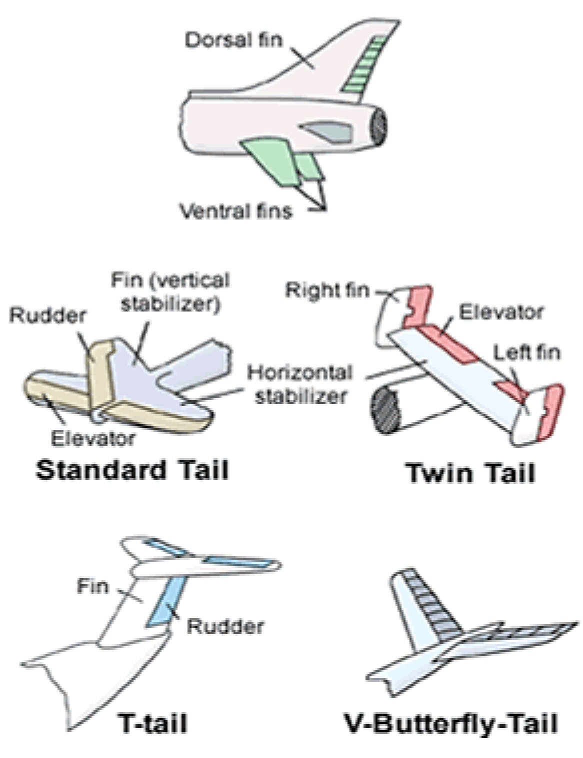


Figure 20: Stabilizer Configurations

As seen in the image the tail section of a plane is composed of a vertical and a horizontal stabilizer. Attached to the horizontal stabilizers are the elevators, which dictate the airplane's pitch; on the vertical stabilizer the rudder will be found. The job of the rudder is to control the yaw motion of the airplane. For this design we decided to go with the V-tail configuration because of its sharp maneuverability, which will be necessary if a target is missed during the first approach and the plane must circle back to locate the object.

Fuselage

The main functions of an airplanes fuselage are to carry the crafts payload and to hold all the pieces of the plane together. Just like the wings, the design of the fuselage is dependent on the duties that the plane will be commissioned to perform. For a plane being designed to reach high rates of speed a slender, streamlined fuselage will be used to reduce drag associated with high-speed flight [8]. A plane being built to operate at low speeds while transporting a payload may be long and hollow, the shape all depends on the drag coefficient that comes along with it. The figure below shows the relationship between a few common shapes and their drag coefficients.

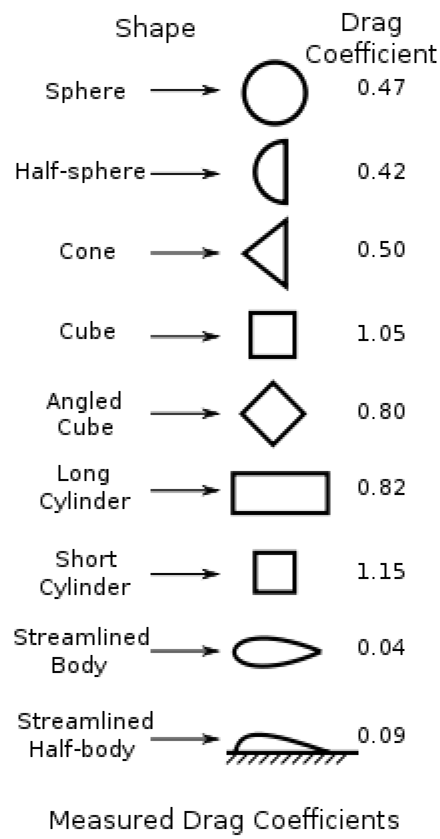


Figure 21: Measured Drag Coefficients

For this design a hollow cylindrical shell with a spherical dome at the front was used; the dome is used to house the on-board camera and all of the electronics used to power and control it.

Motor

The motor is the most important component on an airplane; it provides the thrust necessary for the plane to be able to fly. Small remote controlled planes operate with either gas-powered motors or electric motors. There is no major difference between the two; both are capable of offering the high levels of power and torque and lengthy flight times. The major difference between the two lies in the start-up cost (of which electric motors are significantly cheaper) and the price of upkeep (where, again, electric motors are cheaper). From the cost perspective it would seem that an electric motor would be the best option for this design, but after taking weight into consideration and understanding that the power to weight ratio for a battery operated electric motor is less than that of a gas powered engine. This fact allows gas-powered engines to stay in flight longer at a lighter overall weight, which is extremely important for the required specifications of this design. After weighing all of these factors, it was decided to choose a gas-powered engine to drive this system.

Electrical System

- ***Level 0 Unmanned Aerial Vehicle***

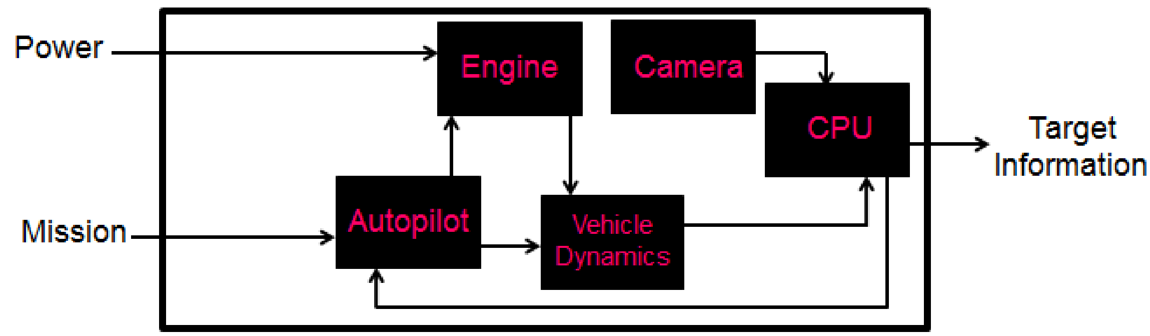
As illustrated in Figure 22 below, the UAV is supplied with two input data for the components inside to process. The main function of the UAV is to be a body for the electrical component found within the UAV and with the two data the algorithm and the power to be able to identify targets.

Module	UAV
Inputs	• Mission • Power
Outputs	Target Information • Target images • Target location • Target characteristics
Functionality	Input algorithm for target identification and for the transfer of data to the base station.

Figure 22: Level 0 UAV Functionality

- ***Level 1 Unmanned Aerial Vehicle***

A more in depth look at the UAV functionality displays the input power (battery) powering the engine. It also shows that the camera is not powered by any external power, but that it will have its own internal battery. The autopilot has two inputs, the algorithm and the engine, this is important because the input mission allows the autopilot to follow the designated path. The second input to the autopilot is from the engine; this input helps the autopilot know the speed of the UAV and the in return the autopilot can reduce the speed to stay in the constraint speed. The Vehicle Dynamics is the action in which the autopilot reacts to the speed, angle, and other physical movement of the aircraft. Adding all the components together the system output will be able to identify targets.



Module	UAV
Inputs	• Power • Mission
Outputs	Target Information
Functionality	Input algorithm for target identification and for the transfer of data to the base station.

Figure 23: Level 1 UAV Functionality

- ***Level 0 Autopilot***

The autopilot is composed of multiple components; the primary inputs are the mission and power being sourced by the power engine. The outputs consist of rudder, elevator, throttle and CPU. The mission will provide the specifications in relation to the overall functionality of the autopilot and the power from the engine will be the source of energy for the autopilot. The out puts have an overall functionality of assisting with the flight path of the

UAV as well as gathering information in relation to the problem statement of this project.

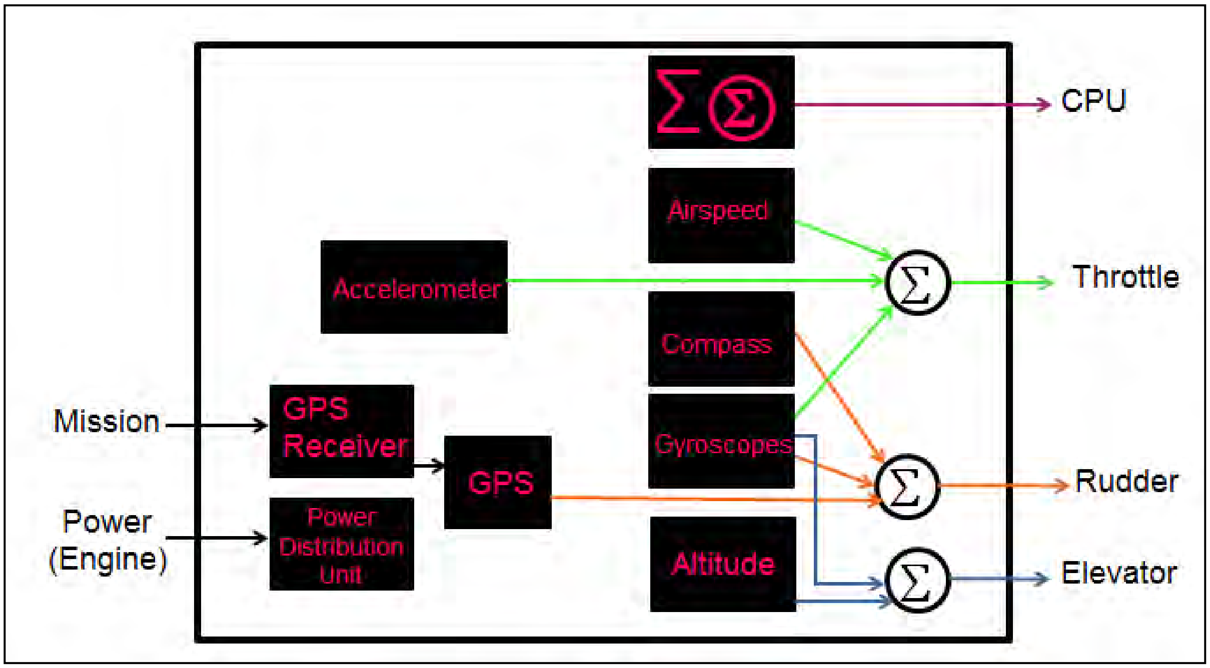
Module	Autopilot
Inputs	• Mission • Power (Engine)
Outputs	• Rudder • Elevator • Throttle • CPU
Functionality	• Gather information using the sensors and GPS to provide vehicle position and orientation. • Assist in with the flight path calculation.

Module	AutoPilot
Inputs	· Mission · Power (Engine)
Outputs	· Rudder · Elevator · Throttle · CPU
Functionality	· Guide the UAV to through the path designated by the competition.

Figure 24: Level 0 Autopilot Functionality

- ***Level 1 Autopilot***

A further insight into the autopilot show that it is composed of multiple components, the accelerometer has the ability to control the speed of the aircraft, the mission will have a command telling it to slow down when the camera spots a possible target and it will have another command the will not allow the UAV to fly faster than the constraint speed of 100knots. The power from the engine will power the entire autopilot system. Another important component found inside the autopilot is the GPS and GPS receiver, both parts is used to locate the UAV and to give location of targets. Putting together all these internal components assist with the flight path calculation that is called the vehicle dynamics.



Module	Autopilot
Inputs	• Mission • Power (Engine)
Outputs	• Rudder • Elevator • Throttle • CPU
Functionality	• Gather information using the sensors and GPS to provide vehicle position and orientation. • Assist in with the flight path calculation.

Figure 25: Level 1 Autopilot Functionality

- ***Specifications***

Marketing Requirements	Engineering Requirements	Justification
1, 2, 4, 5-	• System must be able to find targets	Undergraduate Student Aerial Competition main

A, C, D	on its own	objective.
1	• Should be able to fly without manual controller	Competition requirements
4 - A	• Weight should not exceed 55 pounds	The before flight weight must not excide a specified weight.
4,5-B	• System must be able to take-in new code at while in flight.	This is based on the rules the competition.
Objectives • The system should have autonomous performance. • The system should identify all targets • The system should have real time results. • The system should have operational availability • The system should have in-flight re-tasking capability **Constraints** • The system total weight should not surpass 55lb; • The system is bounded by the target determination range; • The system will have limited mission time • The system can not excited air speed		

Table 4: Project Specifications

UAV Autopilot	
Course Accuracy	Does not exceed 400ft per FAA restrictions on autonomous RC planes, while in automatic flight mode.
Altitude Limit	Does not exceed 400ft per FAA restrictions on autonomous RC planes, while in automatic flight mode.
Waypoints	Does not exceed 400ft per FAA restrictions on autonomous RC planes, while in automatic flight mode.

Manual control	Provided by a mode switching system controlled from the Ground station.
Ground Station	Laptop PC running Windows XP and serial communication Software.

Table 5: Auto Pilot Specification

UAV Sensors	
inertial measurement	1- 3axis MEMs Accelerometer
	3- 1 axis MEMs Gyroscopes
Position	EM-406A SiRF III GPS Receiver or
	50-Channel GS407 Helical GPS

Table 6: UAV Sensors

- ***Other Deliverables***

It is our goal to provide the client with adequate information about the UAV capabilities. Thus our deliverables include:

- A final report with details about UAV
- Power point presentations to illustrate the functions and specifications of the system.
- Demonstration of the UAV system in the 2013 Undergraduate Student Unmanned Aerial Competition

This section describes the levels of the UAV components, specification of the UAV, functionality of the UAV, and the deliverables. This section can be used as a tool to show at certain outreach for the influencing and developing of young minds in the community. Also knowing the functionality of specific components can be very useful later if there is a malfunction or if something is going wrong.

- ***PLAN OF ACTION***

Planning and coordinating resources and tasks to achieved project goals is project management. In this section, project management and project plan is develop in order to achieve a plan of action. Microsoft Project and Open Workbench software's tools are used for project management. Moreover, project management techniques tools are statement of work and work breakdown structure. The statement of work explains each tasks, activities, deliverables, and timelines. Work breakdown determines the scope of activates in the hierarchical order. Moreover, description of the tasks the project comprises is shown through work breakdown structure. Finally, the Gantt chart and pert chart are shown of timeline of phases and tasks along with each team member responsible and resources assign to each task.

- ***Statement of Work (SOW)***

Statement of the work defines the work activities, deliverables, and timelines for the vendor or team must execute in performance of specific work for a client.

- ***Scope of Work***

The work that must be perform, the objective, is to create an autonomous vehicle that detects basic shapes and transmits and receives information or signals to a ground station. The hardware components are:

1) Autopilot, ArdupilotMega- APM 2.5 board	2) Camera	3) Mini CPU
4) Transmitter/receiver (RS232-RF/ RF-RS232)	5) Servo motors	6) Sensors

The autopilot is composed of input sensors:

1) One 3 axis gyroscope	2) one 3 axis accelerometer
3) One 3 axis magnetometer	4) one barometric pressure sensor altitude
5) One receiver 10 Hz GPS module	

The software component manages the components as follows:

1) Object detector software sends by the camera output port and process by the CPU plane.
2) Synchronization and management software between input and output signals from camera, Transmitter/Receiver (Rx/Tx), and autopilot.
3) Communication software for the RS232-RF and RF-RS232 (Radio Frequency and Pulse Width Modulation, PWM), which manages signals from the autopilot and the results of processed image for both one for CPU plane and the ground station
4) Autopilot hardware and software, which signals the servo motors, aileron, elevator, and rudder, according to feedback from the input sensors and the GPS receiver calculating the coordinates and altitude X,Y,Z corresponding to GPS point relative to the point of origin. No realistic GPS
5) Ground station software, Ardupilot Mission planner, which interacts with Rx/Tx in sending and receiving plane locations, commands, and waypoint, coordinates.

Finally, data obtained through GPS and sensors controls the plane's direction, altitude, level and speed. The autopilot mode is switch to safety autopilot if signal or transmission is loss, and it can be switch to remote control, RS. The development of each component is specified in the WBS each level as tasks.

V. Structural Design

When designing a part it in important to reflect on the idea on how shape could be used to modify the ways in which material behave. Furthermore, a design must comply with key principle known as the F3 or “form, fit and function”, which is based on the principle that if the specifications, or criteria, for from, fit and function of a particular item are met, all other attributes, from a an engineering design process, are moot or extraneous. In this section we will focus our attention on how the form or shape of the material can be used effectively in other to achieve a design goal. By “shaped” we mean that the cross section carry bending, torsional, and axial-compressive loads more efficiently than solid sections. The idea of shape is was very important to our project as result that all our designs have weight limitations. Therefore, it is essential that every design made can carry a given load condition by using the as little material as possible. An example of this idea of reducing weight or material by using “simple shapes” such tubes, I-sections and hybrid panel is visible on most of the component design for the completion of this project. As result of that we have T-beam cross section for the main structural frame, carbon fiber honeycomb structures for floor and walls of the POD, titanium brackets for a higher structural integrity. In addition to the shape element of any design process, there is another important aspect to the structural design, which is related to the principle of manufacturability. This aspect of the design process that has to do with the manufacturing process is very important when design something which will be explain in great detail on the subsequent section of this report.

VI. Cost Analysis

Project cost analysis is important in design projects. Failure to properly analyze costs can lead to missed deadlines and subpar performance of designs. The Unmanned Aerial Vehicle project cost projection focuses on five areas:

- Design costs
- Prototype costs
- Report and presentation costs
- Travel and competition costs
- Funding

Design Cost

Design cost includes estimates of money a team of engineers would be paid to perform a design job. Since the engineering team for this project is comprised of students, a traditional design cost analysis is not possible. Instead, design costs are simply an exercise in estimating the cost of time and labor as opposed to salaries or overhead actually paid out.

Based on the tables below an estimated 400 engineering hours is needed for this project. At the average rate of $38.09 an hour, this project will take approximately $15,236 if the exact projected hours are met. Of course this is all based on theory if a paid engineering team was actually doing the project.

Prototype Cost

Prototype cost analysis is of major concern for this design project. Currently sourced funding is limited and out of pocket expense would ideally be avoided. The largest up-front cost component for the UAV prototype is the engine. For purposes of necessary thrust, range, and weight, a gas engine needs to be chosen. Several potential choices for engines are being considered. Prices for gas engines are in the range of $150 - $500. Price is not the only concern. Careful attention must be placed into each model's specifications, reliability, and ease of repair (e.g. availability of replacement parts).

Power, rotational speed, and thrust output are all vital engine specifications that need to be considered. Final weight of aircraft with all added components must be factored in before minimum required specifications could be calculated. Once the initial calculations have been performed, the choice for a suitable engine can be made. The engine must provide enough thrust to achieve and maintain flight for the prescribed time and with the prescribed load while staying within budget.

Another concern for the engine is its reparability. It is inevitable that the first few iterations of the prototype will crash and the engine might be damaged. If this is the case, it is very important that the engine can be easy repaired and replacement parts are readily available and low-cost.

The second largest cost concern for the aircraft is the shell. Shells come in a variety of sizes, designs, quality, and price. The can range anywhere from $150 - $500 much like the engines. Multiple factors come into play with the aircraft body. The fuselage must be large enough to accommodate the electronic component that must be added in such a way that the aircraft can be adequately balanced. Proper balancing is necessary for stable flight. The plane is to be controlled by autopilot, and stability increases odds of successful control.

The wings must be large enough to provide sufficient lift to compensate for the added weight. Typically, these radio-controlled planes are not flown with an added payload. A larger/more expensive shell might need to be purchased. Just as with the engine, crashes are a major concern. Since a crash is very likely to occur and a wing or other external component might break, it is important to select a model with readily available replacement parts so the plane can be repaired in a cost-efficient manner (as opposed to complete replacement).

Report and Presentation Costs

Costs associated with reports and presentations are twofold. First are actual material costs associated with report generation such as printing of reports, printing of posters, and any other presentation aids. Indirect costs are another exercise. These are an indication of real world business expenses that might be incurred by a company presenting their prototype or final design.

Travel and Competition Costs

The actual SUAS competition has costs associated with it. First of all, there is in application with a registration fee required to enter the competition. Besides that, other competitions costs that must be taken into consideration are airfare, lodging, and meals. Air fair rates consist of $275 tickets each way. Lodging runs at approximately $125 per night per room for two students. Each student will need at least $10 per meal each day.

Funding

As with any real world project, funding is vital to development of any project. Without money, the team cannot perform their duties and the project will fail. NASA provided initial funding, for the amount of $1500. Additional funding will be required in order to avoid or minimize any out-of-pocket expenses to the design team. For additional funding the team has asked the Mechanical Engineering department for an amount of $500. The NASA Student Department has also pledged an extra $500 of the project. As well GoPro has been contacted for extra funding, but they still have not responded for the project. As of right now the funding for the project is enough to cover the cost but not travel.

Table 7: Projected Time Cost Analysis

Category	Task	Time (hours)	Category Total
Research & Design	Wing Design Research	10	117
	Fuselage Design Research	8	
	RC Plane assembly Research	8	
	RC Plane maintenance Research	6	
	Conceptual Design Alternatives	8	
	Reviewing SUAS competition rules	5	
	Literature Survey	10	
	Engine Design	8	
	Aircraft Material Evaluation	8	
	Flight Training	10	
	SolidWorks Modeling	8	
	Conceptual Drawings	12	
	SolidWorks Prototype	16	

Analysis, Assembly & Testing	Wing Testing (static and wind tunnel)	30	140
	Fuselage Testing	12	
	Landing Gear Testing	6	
	ANSYS Simulations	15	
	SolidWorks Simulations	15	
	Material Testing	6	
	Joint Testing	8	
	Wing Construction	4	
	Aircraft Assembly	8	
	Component Installation	10	
	Balancing	6	
	Flight Testing (human and auto-pilot)	20	
Reports & Presentations	Senior Reports	80	143
	SUAS Journal Report	40	
	Presentations & Rehearsals	5	
	Engineering Drawings	8	
	Posters	10	
Total Time Cost (hours)			400

Table 8: Projected Monetary Costs

Project Section	Item	Cost
Materials and Components	RC Plane Body	$150.00
	Engine	$100.00
	Servos	$100.00
	Radio Receiver	$50.00
	Batteries	$10.00
	Propellers & Misc.	$100.00
	Replacement Wings	$100.00
	Transmitter (salvaged)	$0.00
Report and Presentation	25% Report	$15.00
	50% Report	$30.00
	75% Report	$40.00
	100% Report	$50.00
	Poster	$80.00
Competition and Travel	Registration	$500.00
	Travel	$600.00
	Lodging	$900.00
	Meals, etc.	$180.00
Total Cost Projection		$3,005.00

Full funding for this project was not able to be collected. Only the initial $1500 from NASA and a $500 pledge from the Mechanical and Materials Engineering Department at FIU were obtained. Due to this reason, the project was unable to compete in the SUAS competition. However, the majority of the project (including components from the Electrical Engineering team) could be completed with the $2000 budget as many components were obtained for less than previously projected and others could be salvaged from the UAV from the previous year's competition. Final project costs are presented in the table below.

Table 9: Final Project Cost

Project Section	Item	Cost
Materials and Components	RC Plane Body 1	$129.90
	RC Plane Body 3	$187.88
	Engine (salvaged)	$0.00
	Servos	$30.00
	Radio Receiver (salvaged)	$0.00
	Batteries	$48.98
	Propellers & Misc.	$50.00
	Replacement Wings	$0.00
	Transmitter (salvaged)	$0.00
	Construction materials for Plane Body 2	$59.35
	Misc	$50.00
Report and Presentation	25% Report	$5.00
	50% Report	$5.00
	75% Report	$5.00
	100% Report	$25.00
	Poster	$90.00
Total Project Cost		$686.11

VII. Prototype System Description

As an unmanned aircraft, this system will contain many electrical and computer components used to stabilize and control its flight. This system will be subjected to user-controlled takeoff and landing, but during flight it will maintain complete autonomous control. An autopilot will be housed in the core of the craft controlling all of the servomotors and reacting to data being fed to its processor via the camera, as well as changing wind speeds and directions. This system will contain a series of relays, which keep a line of contact with mission control on the ground as seen in the figure below.

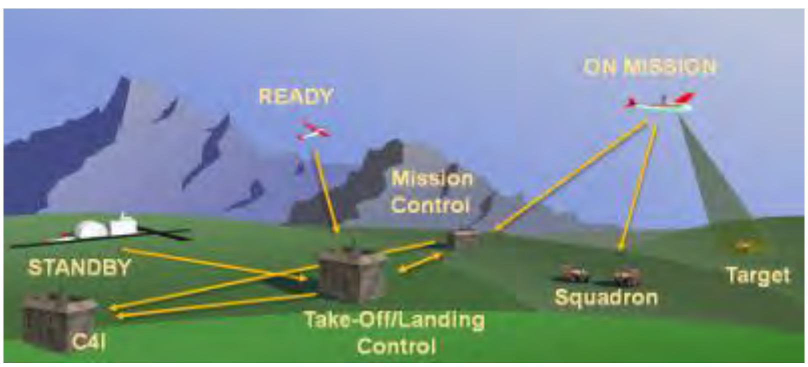


Figure 26: UAV Computer Relays

Also within this system will be a series of sensors to help stabilize plane within its programming interface, these sensors include gyroscopes, pressure gauges, Pitot tubes and an image recognizing camera. These sensors will be mirrored on the programming interface so that the flight can be monitored at all times from an auxiliary location; a safety cut-off will allow the monitor to remotely operate the plane if anything seems out of the ordinary. These sensors will provide a constant feedback to the operators on the ground to ensure that all of the systems are operating correctly and to make sure that the target images are being accurately collected to abide by the rules of the competition.

VIII. Plans for Test on Prototype

The testing of this craft will focus mainly on its ability to fly while bearing the desired payload aboard. Being that computer simulations will only portray the flight of this vehicle in ideal conditions, test flights will need to be conducted to gauge its actual performance. In order to test the maximum weight this system can bear a series of flights will be conducting during which the weight on-board will be increased incrementally until a point of system failure is reached. The aim for this phase of testing is to decide how much torque is necessary to carry the overall weight of the system – which includes the on-board computers, autopilot and sensors. Once this maximum torque is found the system will be modified to operate at this power rating. Following this phase of testing, the plane will be subjected to field test flights to ensure that all of the on-board computers are working. In this phase, the image recognition of the software will be tested, as well as the system's ability to respond to its installed programming. Any problems that arise will need to go through troubleshooting to ensure the structures readiness to operate and perform the desired tasks it will need to complete during its competition.

IX. Manufacturing

There were many factors contributing to how this plane was to be designed. The team first had to take into account the fact that this plane would have to undergo test flights, of which it might not return in one piece. Adding to this, the weight of the materials used in making the plane had to be carefully examined so that the weight limit for the competition would not be exceeded. Finally, the design had to be created in a way that was easily reproducible, in case of a crash, weather damage, or any other form of weathering that this plane might take on. In light of these restrictions a few manufacturing options had to be eliminated, but many still remained available. But due to the most crucial factor, the time limit available for production, it was decided to use cutting, joining and sanding of foam (polystyrene) boards. This process was determined to be the quickest and the most easily reproducible, if need be.

Figure 27: Material to be Formed

The first step in this process was to lay out the schematics of the plane (these were created using SolidWorks). The foam was purchased in three fourths of an inch boards, four feet in length. From the side and top views of the CAD drawing, the plane was separated into layers which were drawn onto the boards, slightly exaggerated passed their actual measurements; this exaggeration was necessary for the final sanding process. Each layer was then cut to the right specification and then joined to its subsequent layer. Once all of the layers were attached, the shell was then sanded down to create the smooth contours that are crucial for the planes aerodynamic design.

After the fuselage was constructed it needed to be modified so that the internal component could be easily inserted and removed when necessary. For this, a section on the top of the nose cabin was cut out and fitted with hooks on its right and left sides. These hooks were mated with two bars connected to the fuselage so that this “hood” could be taken off when need be, while also being held securely in place during flight. A similar fix was made to a portion in the midsection of the plane so that the batteries and receivers could be inserted in the lengthy midsection.

The final process to complete this design was to create sturdy bases beneath the fuselage, in order to attach the landing gear. This was done by removing small section of the foam body and replacing the holes left behind with wooden blocks. The screws associated with the landing gear are much sturdier when mated within wood than they would be in foam.

After the body was in order, the wings were attached and the servos connected to complete the build.

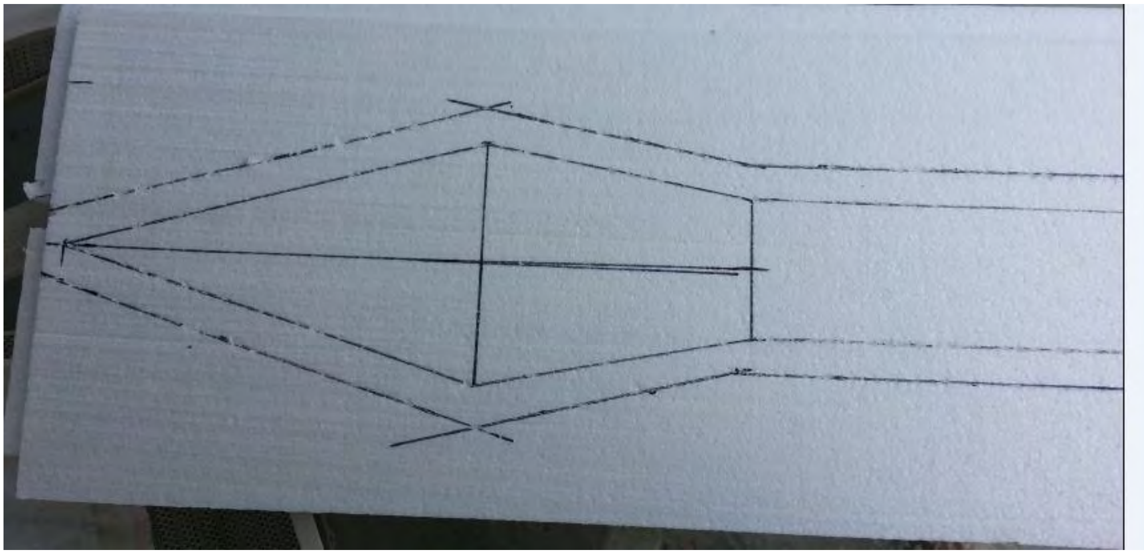


Figure 28: Drawing Patterns to Cut

Figure 29: Cutting out Designs

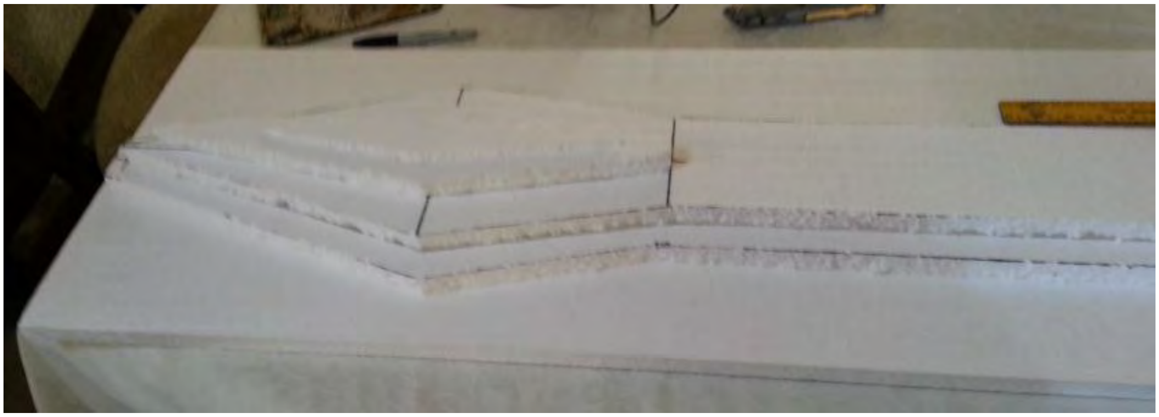


Figure 30: Fuselage Taking Shape

Figure 31: Completed Fuselage Ready for Sanding

Figure 32: Wings, Elevators and Rudder

Figure 33: Raw Parts

Figure 34: Side Profile of Sanded Fuselage

Figure 35: Top View of Fuselage with Open Sections

Figure 36: Sanded Airfoil

Figure 37: Extended View of Sanded Airfoil

Figure 38: Sanded Elevator with Flap

X. Testing

Plane 1

Due to a significant shipping delay, initial testing was performed on a commercially available RC plane model similar to the body that was being built. Several test flights were performed on this plane. It is important for one or several of the team members to be well versed in RC flight controls in case the automated systems were to fail or a loss of communication with the system were to occur.

Figure 39: First Test Plane Assembly

Figure 40: Test Plane Assembly

Training started with a commercially available flight simulator at a local hobby shop. Since we were told that this particular flight simulator, called

Real Flight R/C Flight Simulator, is the next best thing to actually piloting a real life R/C plane, it seemed a good place to start.

After brief training with the simulator software, we contacted the president of a local R/C club. We were invited to the club's airfield in Homestead, FL to learn the basics on one of his "trainer" aircrafts. Real life flight proved to be slightly more challenging than the simulator but not overtly difficult. We felt confident enough to test our own aircraft.

As expected, our aircraft survived its maiden flight. The chosen design proved fairly stable and maneuverable. In order to simulate flight with added components (to be added later) we began gradually increasing the load inside the fuselage. 100g weights were incrementally placed inside the fuselage. Great care was taken in order to make sure that the aircraft was properly balanced in both the fore/aft and lateral directions.

As weight was added to the body of the plane, it became increasingly less maneuverable, though not to any great extent. However, while performing a test flight with 800g added, we encountered unfavorable wind and the plane crashed nose-first into the ground. We attempted to repair the fuselage with tape but handling proves to be greatly compromised. Furthermore, the canopy (which provides access to the electrical components) would no longer attach correctly to the fuselage further reducing the aerodynamic performance.

At 800g, we decided that the test plane's design was not adequate enough to carry the payload of electronic components which would need to be added to the plane in order to make it a UAV. Testing on a second body (built by the team) would need to be performed.

Figure 41: Crash Damage on Plane Body

Shortly after this plane was damaged we received our second plane from our distributor. Once assembled, this plane was comprised of a flyinf wing fuselage with two stabilizers on the end of each wing. Even before any testing, the plane seemed to be quite a bit sturdier than the previous plane we had tested. But due to the timing of the arrival of this plane, a test flight had to be rushed in order to capture an on-board video that would be showcased at the 4th annual *Smithsonian National Air and Space Museum Robotics Event*. On the day we chose to fly this plane there were gust of wind reaching approximately 30 miles per hour, it was unfavorable to say the least. In pursuance of this strict deadline, though, we decided to go ahead with the test flight. After a few unsuccessful attempts, we finally managed to get the plane into the air, but it was a short-lived flight. After about 5 seconds of flight, the left stabilizer was ripped off of the wing. We managed to regain control for a period, until the right stabilizer was also pulled from the body. At this point the plane, out of our control, took a nosedive and was destroyed on impact with the ground. Nothing from the wreck was salvageable. What we did get out of this test flight, though, was the justification that the weight of the plane was balanced at the centroid and that, if it had survived its initial flight, it would have been able to sustain much more weight than the previous plane.

XI. Project Management

Timeline

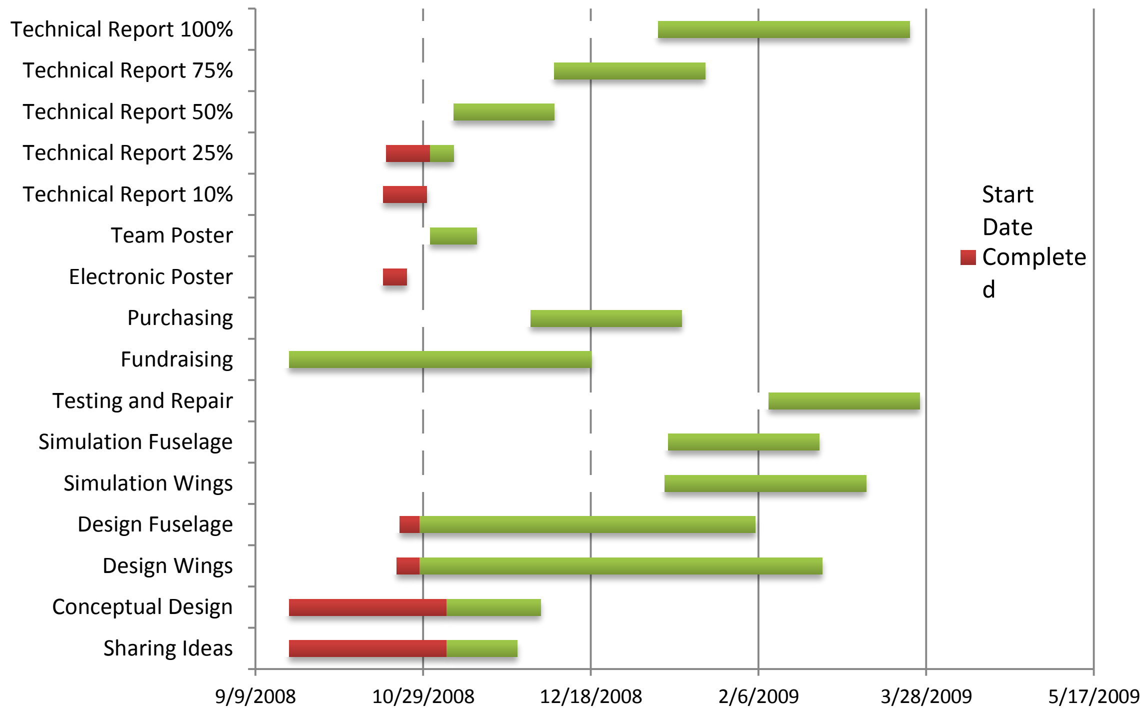


Table 10: Breakdown of Individual Tasks and Hours Spent

Task	**Team Member(s)**	**Hours Spent**
Prototype Design	Josh	34
Modeling	All	8
Structural Analysis	Francisco and Richard	12
Testing and Analysis	All	50
Simulations	Josh and Richard	30
Cost Analysis	Francisco	15
Assembly	All	8
Component Research and Ordering	All	20
Flight Testing	Richard	20

Property Considerations

In order to overcome patent infringement, below are summaries of three similar patents and explanations why they are not infringed upon. Intellectual property was taken into consideration, and measures to avoid patent infringement have been taken to a great extent. The concepts and their implementations within the claims are different from the claims in other patents.

- ***Real-Time, Model-Based Autonomous Reasoner and Method of Using the Same***

  United States Patent

  Application number: 12/876,647

  Publication number: US 2011/0060569A1

  Filing Date: September 7, 2010

  This patent by Christopher C. Lynn et al was granted on March 10 2011. The patent is described in the following section.

- ***Summary***

The patent refers to an apparatus and method for detecting and classifying in real-time a characteristic of a system component. The method is initiated by a sensor detecting a system component and outputting a first quantity of data corresponding to a characteristic of the system component. A modeler then receives the first quantity of data, converts it to a numerical value and runs a computer model simulation to detect an anomalous behavior of the system component. The detected anomalous behavior is optimized and expressed as a second quantity of data. An autonomous reasoner then collects the second quantity of data and compares the data to signatures related to predominant modes of the system component. After the autonomous reasoner identifies a signature that matches the second quantity of data, an output indicative of the cause of the anomalous behavior of the system component is provided.

- ***Claims Summary***

The patent claims at least one sensor positioned on the apparatus to sense the system component and output a first quantity of data corresponding to at least one characteristic of the system component. The patent then claims that a computer modeler is in communication with the sensor to receive the data and convert it into a numerical value to be run on a computer model simulation. The data corresponds to at least one characteristic of the system component. The system component may be any type of device having a measurable property and is located within a system. The computer model simulation compares the modeled present performance to an actual performance of the system component to detect an anomalous behavior of the system component. The apparatus that is used may be from a variety of different types of system components on a variety of systems. The systems may include any type of system, machine, device or series of devices that uses computerized, mechanical, electrical and/or electro-mechanical components. This may include systems such as aircrafts, watercrafts, trains, vehicles, robotic machines, programmable machines, industrial tools or any other type of system subject to component degradation.

- ***Measures for avoiding infringement***

Our project does not infringe upon the claims in this patent because the process of communicating and using the data received from the sensor we use is different. The sensor we utilize is a form of heat sensor that uses Plank's Law to measure the temperature of a system several feet or several miles away. Plank's Law relates to the amount of thermal radiation released by a heat source. By measuring the thermal radiation from an object, a temperature can be determined. When a temperature is determined, we follow a different procedure to collect data in order to make conclusions pertinent to the objectives of the project.

- ***COMMUNICATING NAVIGATION DATA FROM A GPS SYSTEM TO A TELECOMMUNICATIONS DEVICE***

  United States Patent

  Application number: 12/190,776

  Publication number: US 2010/0039314A1

  Filing Date: August 13, 2008

  This patent by Shekhar Gupta was granted on February 18, 2010. The patent is described in the following section.

- ***Summary***

The patent refers to a method for communicating navigation data from a Global Positioning System (GPS) device to a telecommunications device. A communications link between a GPS device and a telecommunications device is established via a telecommunications system. GPS coordinates are then sent from the telecommunications device to the GPS device where a destination location is selected. Based on the selected destination location, directions are then calculated by the GPS device and communicated to the telecommunications device.

- ***Claims Summary***

The patent claims that the user of a GPS device initiates this method of communication. When the GPS device has received the selected destination location, multiple operating navigation processes are simultaneously computed to send directions to the user of the telecommunications device. The method then displays a selectable option to calculate the directions from both the current location of the GPS device and the current location of the telecommunications device. After the directions are calculated, at least one SMS message is generated with the directions and then communicated to the telecommunications device. An audio message with the directions is also generated and communicated to the telecommunications device by the GPS device. Receiving updated GPS coordinates of the telecommunications device, re-calculating the directions, and communicating the re-calculated directions to the telecommunications device is also claimed.

- ***Measures for avoiding infringement***

This patent describes a method of communication using both telecommunications system and a GPS system. Our project does not infringe upon the claims in this patent because our method of communication differs in respect to the procedure and devices being used. The devices used in this project includes a MicroPilot that is GPS enabled, we utilize a computer software to run a program that will allow the air vehicle to autonomously overfly select waypoints, or GPS coordinates. The program will set the air vehicle system to follow the designated path by user inputs of the coordinate system. The system will also be able to receive a complete path of coordinate's information through a subsystem receiver.

Standard Considerations

Standards considerations pertain to agreements on how a project must be produced or used in order to safely sell in the market. The benefits that standards provide include; allow to define an accurate measurement; lower the product cost; improve the product functionality, performance, operation, and quality; and provides a method to improve health, safety, the environment, communications, international trade and quality of life.

As engineers and inventors we must be aware of existing standards related to the design of our project and ensure we comply with the relative standards.

When designing the UAV, we found the standards we would to follow in order to sell our product in the appropriate market region. These standards originate from the following organizations: Institute of Electrical and Electronics Engineers (IEEE), Federal Communications Commission (FCC), and American National Standards Institute (ANSI). IEEE is the world's largest professional organization.

- ***IEEE 802.11aa-2012 Telecommunications and Information Exchange between Systems***

The objective of this standard is to support robust audio and video streaming for IEEE 802.11 applications. It specifies time enhancement to the base standard and expands the use in more business and residential applications around the globe. This standard was updated in 2012 to contain important new Quality of Service (QoS) features such as, group-addressed transmission service, stream classification service, manage overlapping networks for support. The benefits of this standard include improve management of audio/video quality, reliable links and performance when channel capacity is insufficient or when WLANSs overlap on the same channel.

The scope of this standard is to specify enhancements to the IEEE 802.11 medium access control (MAC) for robust audio video (AV) streaming and still maintain existence with other types of traffic. This helps define the proper transmission of AV from the aerial vehicle to the base station.

- ***IEEE 802.15.4 Wireless Personal Area Networks (WPANS)***

The purpose of this standard is to define low data rate specifications for the physical layer (PHY) and the medium access controller (MAC) sub-layer for wireless connectivity directly relating to portable, moving devices with limited power consumption requirements operating within the personal operating space of 10m. It should be noted that a longer range using a lower data rate is an acceptable trade-off. This standard provides the immunity to electromagnetic interference and non-interference with Radio Frequency systems; it provides additional security that will allow different users to view the communication channels, and communication augmenting and complementing existing services.

The scope of this standard is to define data rate specifications for wireless connections. This standard defines the data rate and communication range between the aerial vehicle and base station. The standard can deliver numerous amounts of data to support audio and video multimedia services.

- ***FCC Radio Frequency Safety***

The purpose of this standard pertains to the safety hazards of human exposure to radio-frequency (RF) energy. The FCC adopted the National Council on Radiation Protection and Measurements recommended maximum permissible exposure limits for field strength and power density of devices operating within close proximity to the body at frequencies of 300 kHz to 100 GHz.

The scope of this standard is to define appropriate safety requirements for the frequencies used in the implementation of the aerial vehicle.

The standards mentioned above have enabled us to determine guidelines and restrictions to follow to successfully design our UAV for the possibility of future market production. It also sets a standard measure for the quality of our work as well as ensures safety of use.

The Team will comply with the following standards for the production of the UAV:

- **IEEE 802.11a**
- **IEEE 802.15.4**
- **FCC Radio Frequency Safety**

Health and Safety Considerations

In today's business, consumers are the main priority in marketing any products being created. Without a consumer there wouldn't be a reason to bother creating a product. The consumer health is an important role to the production of any design being used. There are a few health risks that come with the deployment of unmanned aerial vehicles (UAVs).

UAV technology is becoming more cost efficient and readily available, a primary obstruction to deployment is safety. While UAVs eliminate the risks to onboard personnel, accidents involving UAVs are still dangerous because they can harm other aircraft in the air, and people as well as property on the ground.

The Unmanned Aerial Vehicle will follow a set of protocols to ensure the health and safety of the users of our UAV system. For this to be done, our system must follow strict and safety guidelines and standards. These standards and protocols have been set by organizations such as the Occupational Safety & Health Administration (OSHA) and the Institute of Electrical and Electronic Engineers (IEEE).

- ***Health***

As engineers, it is part of our duty to consider the health and safety of our clients. The following are health and safety considerations to maintain the security of our users.

- ***Unmanned Aerial Vehicle Design***

In relation to safety, we have considered health management techniques that will improve the system performance during mission operations. Our UAV design is very complex and as a result our UAV mission infrastructure is composed of several tasks relating to specific activities that are managed by different components to meet real-time computational deadlines. In the case of any error in the autopilot, a manual override will be prompted to ensure that the user themselves will have the complete control to pilot the UAV. The size of the plane allows for safe and manageable control over the plane to be manageable.

- ***Harmful Materials***

The plane primarily consists of balsa wood, which has no major impact on health and safety since it is capable of degrading easily. The plane's engine is composed of aluminum and thus therefore contains no lead that may have been a harmful material to the user.

- ***Personnel Safety***

It is important for our product to be safe for any user in order for our product to be successful. The following are rules for the user relating to the proper use of the UAV system.

1.1 No broken electrical equipment can be used at any time.

1.2 No disconnecting integrated circuit (IC) components while they are on.

1.3 No contact with the engine/propeller while it is running.

1.4 Careful handling the operating vehicle to prevent accidents at all times.

1.5 If device is not in use, the entire UAV system must be turned off.

- ***Public Safety***

Additionally, the UAV system must also be safe in public when being employed. The following is a list that was compiled of ways that the UAV system will be made safe for any future, potential customers.

2.1 Provide an algorithm to take the UAV back to starting, take off position if it reaches the maximum distance or reads a low percentage of power available for the system via a current reader.

2.2 Aircraft must not be flown in a reckless or careless manner.

2.3 Circuitry will be held at a maximum voltage to avoid harmful electric shock.

2.4 All wires are held inside the airplane and encased, therefore not easily accessible.

2.5 Circuitry is not easily accessible to the user, keeping vital circuitry safe from tampering.

2.6 Sensors are placed in secure locations, so that they will remain safe in the events of a possible non-major crash.

2.7 Components have low power consumption to avoid any radiation effects.

2.8 Provide with an algorithm to take the UAV back to starting, take off position if reach the maximum distance.

- ***Liability and Foreseeability***

The capability of being able to foresee any problems that can be caused by malfunctions, accidents, and even users so that they don't harm themselves or others. The following list is composed of possible failures of using our UAV system.

3.1 Do not use the Guardian Angel UAV to harm people or animals.

3.2 Do not fly the UAV under the influence of alcohol or any drugs that could impair the driving ability of the user.

3.3 All users should avoid flying over unprotected people.

3.4 Aircraft should only be flown by frequencies allowed by the Federal Communications Commission (FCC)

3.5 Do not wait to land the aircraft once critically low on fuel.

3.6 Do not operate vehicle under rainy conditions.

3.7 Keep out of reach of children.

Ethical and Social Considerations

The intention of this section is to explore ethical issues that are related to our project and to demonstrate our capability to solve the related ethical issues and dilemmas when the Code Model is insufficient to solve these issues by themselves.

- ***Ethical Considerations***
- Ethical considerations developed in this project may have an impact with the society and should therefore be carefully decided upon during the design, implementation, and completion stages. This group understands that during these stages of our project, we must remain in compliance with the IEEE Code of Ethics which clearly states - … *members of IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct. (IEEE 2006)*

Our group hereby will abide by the above statement and will resolve present ethical dilemmas through the use of the Theory Model. We understand the value of the Code of Ethics which was written with the purpose to ensure the safety of the public and which will hold engineers accountable for any unethical behaviors.

- The design of our unmanned aerial vehicle is to be efficient, easy to use and safe. The intentions of our project are to fly over an area, which will be programmed by an end-user from the ground-station, to locate and report targets along with their characteristics. We hope to accomplish a successful UAV project to be used in the future for further purposes beyond the scope of the UAV competition. Even though we have good intentions for our UAV to be used in legal situations, it may be possible that a user with malicious intentions will employ a UAV to perform illegal missions. When a problem is encountered and becomes too uncertain to resolve by applying the IEEE Code of Ethics, the situation results in an ethical dilemma. These ethical dilemmas are beyond the scope of the Code of Ethics and can therefore be resolved by the means the Theory Model via the Line Drawing decision system.

The ideal solution for an ethical dilemma is to find an option that will benefit the most stakeholders and cause least harm. Four different ethical theories are considered in the analysis of the ethical dilemma: Utilitarianism, Ethical Egoism, Right Ethics, and Kantian Ethics. The following are different solutions that will be analyzed for the ethical dilemma mentioned above.

Possible solutions:

- Limit the sale and use of the UAV system to military and government agencies.
- Clearly state the penalties that would result from undesired employment of the UAV system.
- Prevent self-installation and perform a screening process and background check directed towards potential clients and users.
- Ignore the chance of an end-user employing the UAV system with malicious intent.
- Discontinue the design and implementation given the ethical dilemma.

- ***Social Impact***
- In regards to local culture, our project may contribute to the detection and the prevention of crime and to search for missing persons. With an ability to remain undetected during observation missions, as well as having rapid availability compared with other systems, the UAV could be used by police personnel. Police forces have even used mini- or micro-UAV systems for reasons regarding cost issues. However, the size of the UAVs has limit the operating regulations pertaining to the UAV systems. These regulations, in turn, restrict the use and performance of the system. Police reports to this date, indicate the hardships of this approach. The success of this project could propose a new approach of using a strong, all-weather, fail-safe UAV system.
- In regards to global culture, the military role of Unmanned Aerial Vehicles is growing at unprecedented rates. The rapid advances in technology are enabling the capability to be placed on smaller air frames which in turn increases the number of unmanned aerial vehicles and systems being deployed and used on the battlefield worldwide. Furthermore, as the capabilities grow for all types of Unmanned Aerial Vehicles, nations continue to subsidize their research and deployment leading to further

advances, which enables them to perform a multitude of missions. Their roles have expanded to assist in different missions such as:

- Target and decoy – providing ground and aerial targets to simulate an enemy aircraft or missile
- Reconnaissance – providing battlefield intelligence
- Combat – providing attack capability for high-risk missions
- Research and development – used to further develop UAV technologies to be integrated into field deployed UAV systems
- Civil and Commercial UAVs – UAVs specifically designed for civil and commercial applications.

When successful, our project will further contribute to the implementation of innovative UAV systems to assist in being used for the different roles above.

XII. Global Learning

As UAV technology becomes more prominent in the global market, many areas of concern will begin to arise, some of which are already under scrutiny in the public eye. While the implementation of these craft in the military sector has led to a lower occurrence of human casualties, the question will still remain as to how these covert strikes will change the rules of engagement. Many of the targeted attacks being carried out today, in this countries war on terror, are being touted as assassinations; there has to be a strong case for justification, if not what would stop other countries from committing the same acts? While the United States was once known to have a monopoly in the military robotics industry, that time has come to an end. It is cited that between 75 and 87 countries have used unmanned aircraft in their militaries. Facts like these make it increasingly important to understand the repercussions that systems such as these can have on the world. It has been stated by some remote operators of such aircraft, that the use of this sort of technology has removed, completely, any sense of humanity associated with death while conducting a strike on a target. If combat at this level has become as surreal as these operators suggest, what will happen to the field of war? It is imperative that a series of rules be put into place on an international level to regulate the use of these vehicles during combat.

Another concern facing the industry of unmanned aerial vehicles is the level of autonomy available within them. As these systems move closer and closer towards complete autonomy how will their duties become affected? In 1942 Isaac Asimov, a science fiction author, fashioned a list of laws regulating robotic behavior. These “Three Laws of Robotics” exist in the following order:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

While these laws were created merely as a theme for a science fiction novel, the message they present still remains apparent – at what point will it became acceptable procedure for an autonomous robot to decide the value of a humans life? And if the algorithms that run these systems become more and more sophisticated, will we eventually lose control over them? This idea has been portrayed in movies such as “I, Robot” and “Eagle Eye” merely to show that as the circuitry and programming developed for these robots becomes more sophisticated an artificial intelligent may in turn become prevalent. While this topic may be years ahead of its need for examination the threat that it may pose could be great. It is our duty to make sure that the gap between human interaction and autonomy never becomes too big that we may lose control.

XIII. Future Work

At this point in its development, the UAV is in an unfinished state for several reasons. This project is a joint venture with a team of electrical engineering students. The electrical engineering team is tasked with the design and implementation of the electronic components that will allow for autonomous flight and target acquisition. Their timeline for reporting differs from this mechanical engineering team. At this stage, they have not completed their portion of the UAV project and the automatic control portion cannot yet be implemented.

Another reason for the incompleteness is due in part to failed testing of the plane we had ordered for this project. Due to our group's participation in an event occurring at the Smithsonian, the initial test flight of this plane had to be expedited and thus we were forced to fly our plane in foreboding weather conditions. And consequentially after the crash of this plane we were forced to try and quickly finish building the prototype that we had been designing. The time frame available made it necessary for us to cut corners and inevitably ruin the structural integrity of the plane.

At this juncture, we must now decide whether to go forward and buy another plane or to redesign the model for the prototype.

XIV. Conclusion

For the purposes of this project, a mid-winged airplane with significant amount of wingspan in comparison to the length of the fuselage was chosen. There was some consideration of a helicopter for greater lift and the ability to hover in mid-air. Due to the many variables that must be programmed for helicopter stability, it was decided to stay with an airplane design for ease of programming and reduced cost.

FEA simulations of the selected design yielded promising results. The design would be adequate in carrying the necessary load to achieve the designated task. Ideally, the plane body was to be constructed by the engineering team. However, vendor supply issues hampered development. A locally acquired commercial model with similar characteristics was used for initial testing without all electronic equipment installed. Initial testing yielded good aerodynamic capabilities. However, the first design was not capable of reliably handling a payload above ~800g. Additional flight testing is to be performed on the student-built plane in order to ensure its flightworthiness. Additionally, a third plane body has been purchased in the case that the second design fails. We are confident that these newer designs will perform much better than the initial iteration and the project will be considered a success.

For this project, funding fell short and so, it was not possible for the team to compete in the AUVSI SUAS competition. However, funding was sufficient to design a UAV capable of completing the necessary tasks of the competition. As long as the final design can perform all the necessary tasks required in the competition, this project will be considered successful.

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