EML 4905 Senior Design Project

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IN
MECHANICAL ENGINEERING

Unmanned Aerial Vehicle
25% Report

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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.

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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.

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 Nikola 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

UAV's 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**: Combining information from different sensors for use on board the vehicle
- **Communications**: Handling communication and coordination between multiple agents in the presence of incomplete and imperfect information

- **Motion planning (also called Path planning)**: Determining an optimal path for vehicle to go while meeting certain objectives and constraints, such as obstacles
- **Trajectory Generation**: Determining an optimal control maneuver to take to follow a given path or to go from one location to another
- **Task Allocation and Scheduling**: Determining the optimal distribution of tasks amongst a group of agents, with time and equipment constraints
- **Cooperative Tactics**: Formulating an optimal sequence and spatial distribution of activities between agents in order to maximize chance of success in any given mission scenario [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]

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.

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. It's "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.

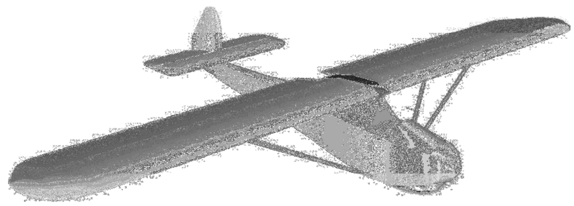

Figure 1: Design Alternative 1

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.

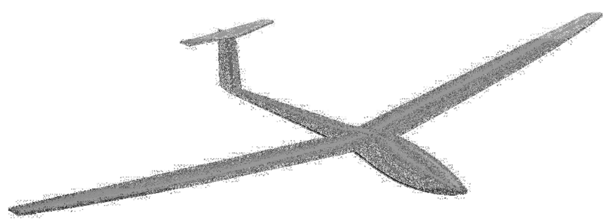

Figure 2: Design Alternative 2

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.

Project Management

Timeline

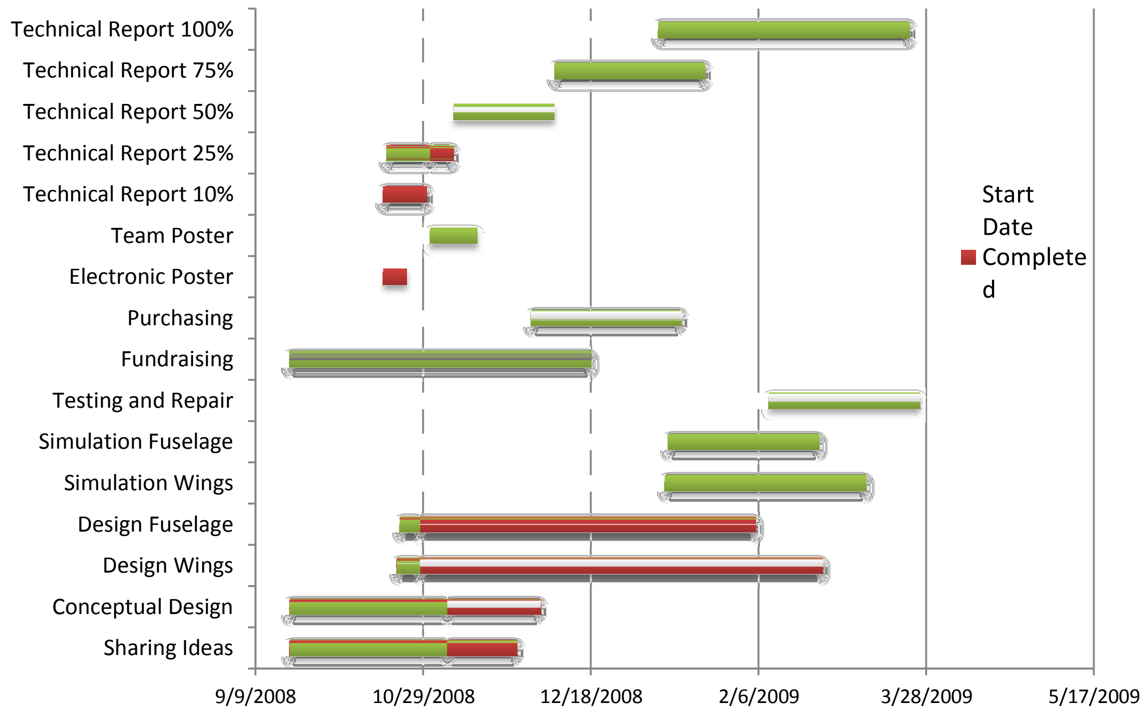

Table 1: Breakdown of Individual Tasks and Hours Spent

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

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.

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.

Computational Methods Strategies

For this phase of the analysis SolidWorks (SW) 2008 software package was selected as the CAD that will be used for this project.

Analysis of the FE Method

At this stage of the process, when working with SW FE codes it is assumed that all decisions have already made on and our software of choice follow a prescribed procedure to produce results.

Post-Processing

Model Verification and Validation: the post processing provides essential information required for the acceptance or rejection of the solution and for modification of the input data in order to obtain a satisfactory solution. 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, Ao, 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, as reference to the original length, lo. Third when a tensile stress σz is imposed on a metal specimen such as the structural frame that hold the POD in place an elastic elongation and accompanying strain ϵz will occur in the direction of the applied stress. As result of this elongation there will be constrictions in the lateral direction perpendicular to the applied stress. From this constriction the lateral compressive strain ϵx can be determined. A parameter named Poisson's ratio, μ, is defined as the ratio of the lateral an 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 reach is approximately 5 degrees Fahrenheit.

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.

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 and the motors (both servos and driving). 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. There are many different wing configurations and geometries that are used today in common airplane designs, these possibilities are displayed in the figures below.

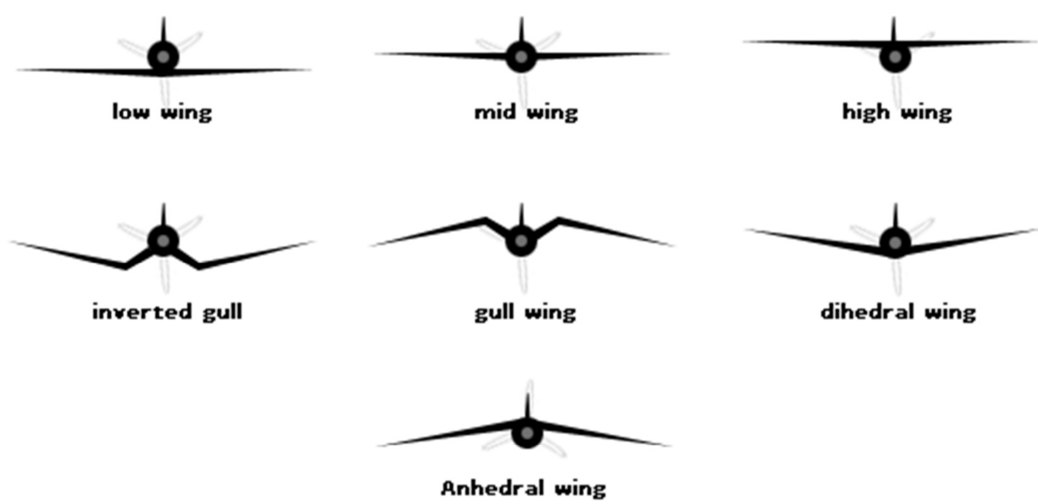

Figure 4: Wing Configurations

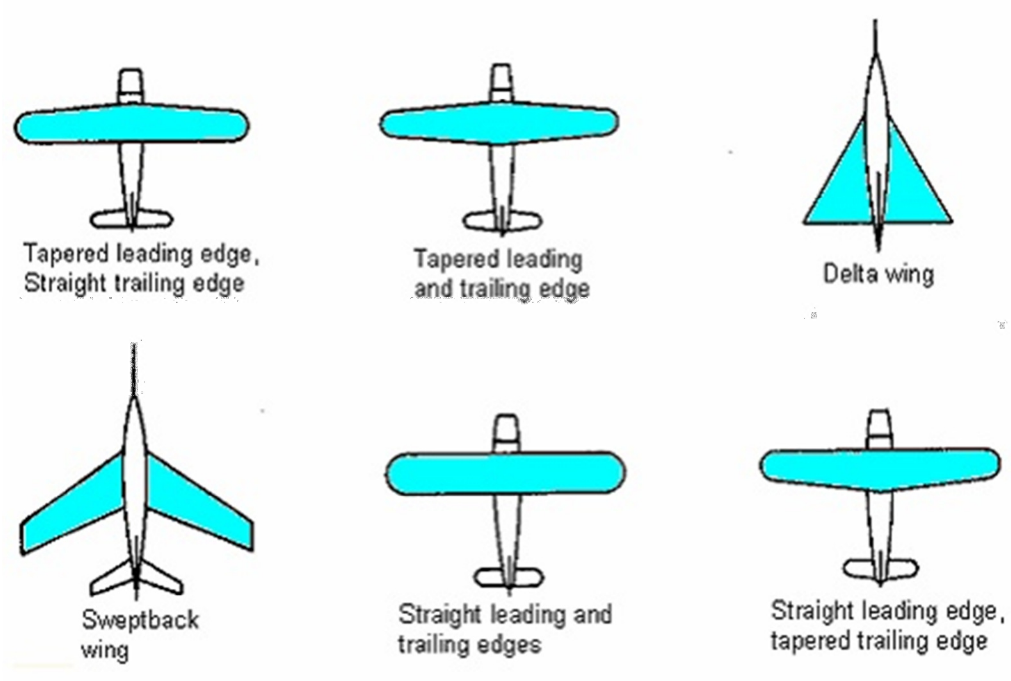

Figure 5: Wing Geometry

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.

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.

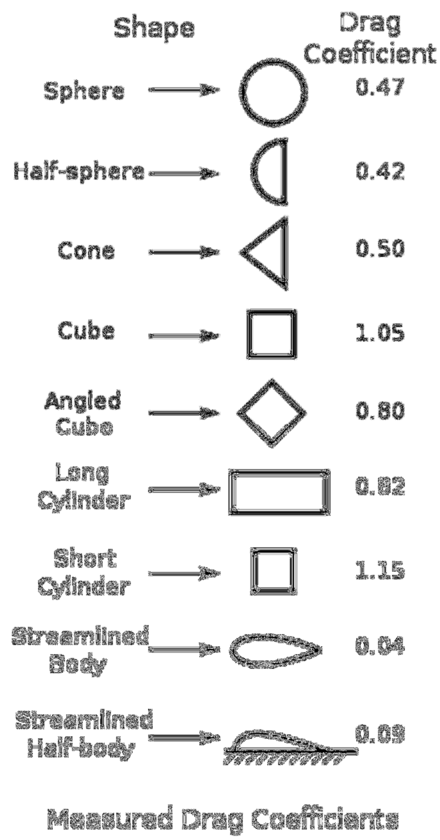

Figure 6: Measured Drag Coefficients

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.

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.

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.

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 can 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 auto-pilot, 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 is 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.

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. Initial funding was provided by NASA. Additional funding will be required in order to avoid or minimize any out-of-pocket expenses to the design team. The team will work closely with its faculty advisor to find potential sources of additional funding.

Table 2: 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 3: Projected Monetary Costs

Project Section	Item	Cost
Materials and Components	RC Plane Body	$200.00
	Engine	$300.00
	Servos	$200.00
	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	$200.00
	Meals, etc.	$100.00
Total Cost Projection		$2,575.00

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 servo motors 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.

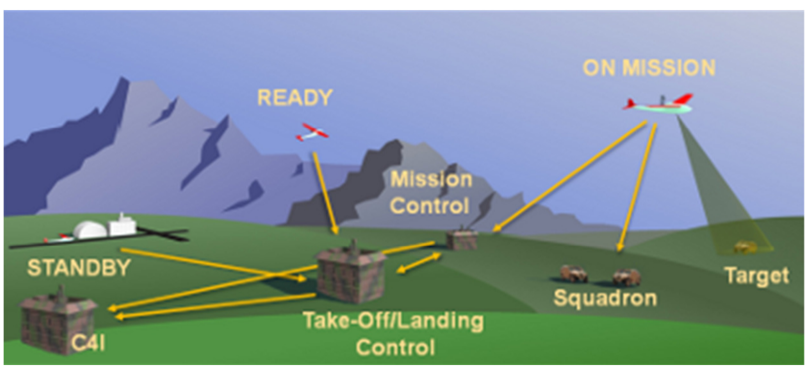

Figure 7: UAV Computer Relays

Also within this system will be a series of sensors to help stabilize plane within its programming interface, these sensors include gyroscopes, pressure gauges, velometers 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.

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.

Conclusion

For the purposes of this project, a top winged airplane with significant amount of wingspan in comparison to the length of the fuselage needs to be chosen. There was some consideration of a helicopter for greater lift and the ability to stop 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.

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