**Sr. Design Project #6**

**Soldier Portable UAV**

**Product Specification & Project Plan**

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Josiah Shearon

TJ Worden

Matthew Martin

David Niera

Joshua Mellen

Onachukwu Okonkwo

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**Introduction**

The objective of this project is to design, fabricate, and implement a lightweight fixed-wing MAV which has adequate speed, high payload capacity, and large storage volume. It must be less than 55 lbs and, when disassembled, must be able to fit into a suitcase that is no larger than 45 total inches. A design report will be written outlining the entire design and manufacture process and the MAV will be flown and competed against other universities.

**Product Specifications**

The project can be broken down into five main subsystems: Electronics and Controls, Power and Propulsion Systems, Wing Design, Materials and Fabrication, and Overall Layout. Each subsystem needs to be optimized based on certain parameters which are specified in the mission profile of the AIAA Design/Build/Fly Competition. There are many constraints to consider when designing this aircraft; they are listed in the table 1.

|  |  |
| --- | --- |
| **Subsystem** | **Constraint** |
| Electronics / Controls | * Battery must weigh less than ¾ lbs.
* Motors and batteries will be limited to 20 Amp current draw using 20 Amp ATO or blade fuse.
* Must use NiCad or NiMH batteries.
* Radio Fail-Safe Check.
* All battery disconnects must be fully insulated.
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| Power / Propulsion Systems | * Battery must weigh less than ¾ lbs.
* Motors and batteries will be limited to 20 Amp current draw using 20 Amp ATO or blade fuse.
* Must use NiCad or NiMH batteries.
* Must be propeller driven using commercially available propellers. Must use electric motors.
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| Wing Design | * The aircraft cannot be rotary wing or lighter-than-air.
* Disassembled wing must fit within suitcase
* Wings must be able to generate high lift at low velocities with low drag.
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| Materials / Fabrication | * The aircraft must be lightweight and durable.
* No major repairs can be made between missions.
* Must be able to be assembled in 5 minutes.
* Must be simple to manufacture.
* Must be able to withstand a 2.5g load at wing tip.
* The aircraft must weigh less than 55 lbs.
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| Overall Layout | * The entire aircraft must weigh less than 55 lbs.
* The aircraft must fit in a suitcase of 45 total linear inches.
* The design must be simple so that it can be assembled in 5 minutes.
* The aircraft must adhere to all safety specs.
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Table : List of Constraints

**Electronics & Controls Design**

The primary challenge in electronics and controls is to allow a user to remotely control the MAV through a Spektrum DX7 RC Transmitter that utilizes a specific frequency mandated by the Federal Communications Commission (FCC) [72.01-72.99 MHz]. There are several specifications that the MAV must meet. First, the aircraft must be battery powered with a total battery weight no more than 12 ounces. The electric motor may be either brush or brushless, but must be commercially available and may not be modified or draw more than 20 amps. This, in turn, limits the power and voltage that can be drawn from this source. In addition, we are limited to implementation of NiCad and NiMH batteries only. The batteries must be commercially available and cannot be altered in any way. The battery connectors must also be fully insulated. In the event that the MAV loses radio contact with the RC transmitter, it is required to immediately perform a specific grounding maneuver.

The equations below show the maximum amount of power the batteries are capable of delivering to a load.

**NiCad**

**NiMH**

The power of the motor will determine the total torque that is available to provide the propellers to generate thrust. Motor torque and rotational velocity have an inversely proportionate relationship. This requires the motor and propeller selection to be performed in tandem in order to obtain the most efficient thrust generation.

**Power & Propulsion Systems**

There are several constraints in the power and propulsion system that the aircraft must satisfy. These requirements will determine the propeller, motor, batteries, and heat dissipation systems. The MAV must be propeller driven. The MAV may use multiple motors and/ or propellers which will either be direct driven or gear/belt reduced. The propeller hub, blades, and pitch mechanism must all be commercially available. The propeller may be modified by reducing diameter or painting the blades. For take-off, all energy must be provided by the on-board propulsion systems; no externally assisted take-offs are allowed other than hand launch.

**Wing Design**

The wing and tail designs implemented on the final aircraft are constrained by several parameters as outlined in table 1. The final wing chosen must be fit inside the suitcase along with all other components of the MAV without being damaged. Depending on the method of fabrication and storage, this could limit the wing span to twice the suitcase’s greatest linear dimension, unless each wing can be assembled in sections. The wing must also be able to handle the distributed loading applied by the total weight of the aircraft and its payload. The estimated aircraft weight is between 10-20 pounds. Satisfactory structural integrity will be verified during the pre-flight safety inspection through application of a 2.5g point load onto the wing tips. The wing design will also encompass the lifting capability of both the wing and tail, i.e. the lift coefficient. The ideal wing will produce enough lift to support the aircraft at its maximum payload weight and desired cruise velocity while minimizing the induced drag. Based on existing RC aircraft and previous AIAA DBF competitions, the estimated velocity is approximately 20-60 mph. The design specifications also require that the weight of the wing be minimized.

**Materials Selection & Fabrication**

The design specifications are generated with consideration of the constraints listed in table 1. These constraints limit the material usage and fabrication methods to ones that are within the capabilities of our group. There are many materials that can be used for these purposes, however, the constraints also require that the selected materials display both high strength and low weight properties.

The material selection process involves mathematically analyzing the desired properties and deriving the proper modulus for application to the supplied Figure 1. In order to do this, a set of root equations must be selected, combined, and rewritten in terms of constraints, constants, and material properties. Once the equation is in this form, the material properties must be isolated and inverted to determine the modulus (E). Variables 'L' and 'P' will be treated as constraints. The material property variables are and .

Root Equations:

∴

Solving:

Figure : Strength - Density Chart

The modulus defines the slope of the line of interest and its value must be maximized. The results show that carbon fiber and ceramics are the material with the most desirable characteristics. Due to the brittle nature of ceramics, these materials will not be considered. The second most desirable materials include various lightweight wood and natural materials.

With the primary materials selection completed, the next step will be to explore the most effective and efficient methods of loading and implementation. The yield strength of carbon fiber is much greater in tension than compression and wood is far stronger when loaded in the longitudinal direction than transverse. With these things in mind, the most efficient support structures can be determined. To this end, implementation of both hybrid structures and shape factors will be considered. The High Performance Materials Institute is an asset that we also intend to utilize. This will provide more effective means of fabrication and implementation of carbon fiber and hybrid/shaped structures.

**Overall Layout**

The overall aircraft layout integrates all subsystems into one optimized design. When finalized, the aircraft can weigh no more than 55 pounds and must be able to fit, disassembled, into a standard carry-on suitcase of 45 total linear inches. The design must also be simple so that it can be assembled in less than 5 minutes. The first aspect to consider is the fuselage. Several different fuselage designs will be tested in a wind-tunnel for drag characteristics. The fuselage which produces the least amount of drag while maintaining a large storage volume capacity will be selected. Another important parameter to consider relates to the control surfaces. These surfaces allow for the aircraft to maneuver during flight. Larger surfaces produce more maneuverability but also induce more drag. Smaller surfaces have less drag but also aren’t as maneuverable. Based on the mission profile, we have determined that speed and maneuverability are not as critical to the competition score as other parameters such as payload and storage capacity. Other significant aspects of the overall layout include size of components, wing spacing, storage locations, center of gravity and lift, and assembly techniques. Each aspect will be analyzed for optimal flight characteristics, low weight, structural integrity, and simplicity of design.