Needs Assessment and Project Scope

EML 4551C – Senior Design – Fall 2011 Deliverable

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Needs Assessment

In recent years, unmanned air vehicles (UAVs) have become part of an increasingly prominent field of study and application. The implementation of UAV's in the armed forces is considered the future for military aviation. UAV's can perform the same tasks as a normal aircraft controlled by an onboard human pilot without putting the pilot's life in danger. The practicality of UAV's can be seen in many applications such as: militant target and decoy missions, reconnaissance, real-time combat, logistics preparation, research/development and also can be actualized in a small, but growing number of civil applications. Flight International reported nearly 8000 unmanned air-vehicles (UAVs) worth $3.9 billion [US$], will be produced worldwide between 1994 and 2003.

The proposed project is to design and build a cargo UAV fulfilling the 2011-2012 regulations and mission requirements as provided and defined by the SAE Aero Design East committee. This design must be documented by means of a technical report and a project presentation given to a panel of judges composed of aeronautical engineers. According to Dr. Leland M. Nicolai (Lockheed Martin engineer), "*The student needs to understand that the analysis and performance of the R/C model is identical to a full scale airplane such as a Cessna 172. The only differences between the R/C model and the full scale airplane are the wing loading, Reynolds Number and the moments of inertia".*

Project Scope

Problem Statement

The purpose of our project involves the design and construction of a remote-controlled aircraft for submission to the SAE Aero Design East competition. The aircraft must perform the specified mission while embracing the integrity of the design as defined in the technical report submitted at the time of competition.

Justification/Background

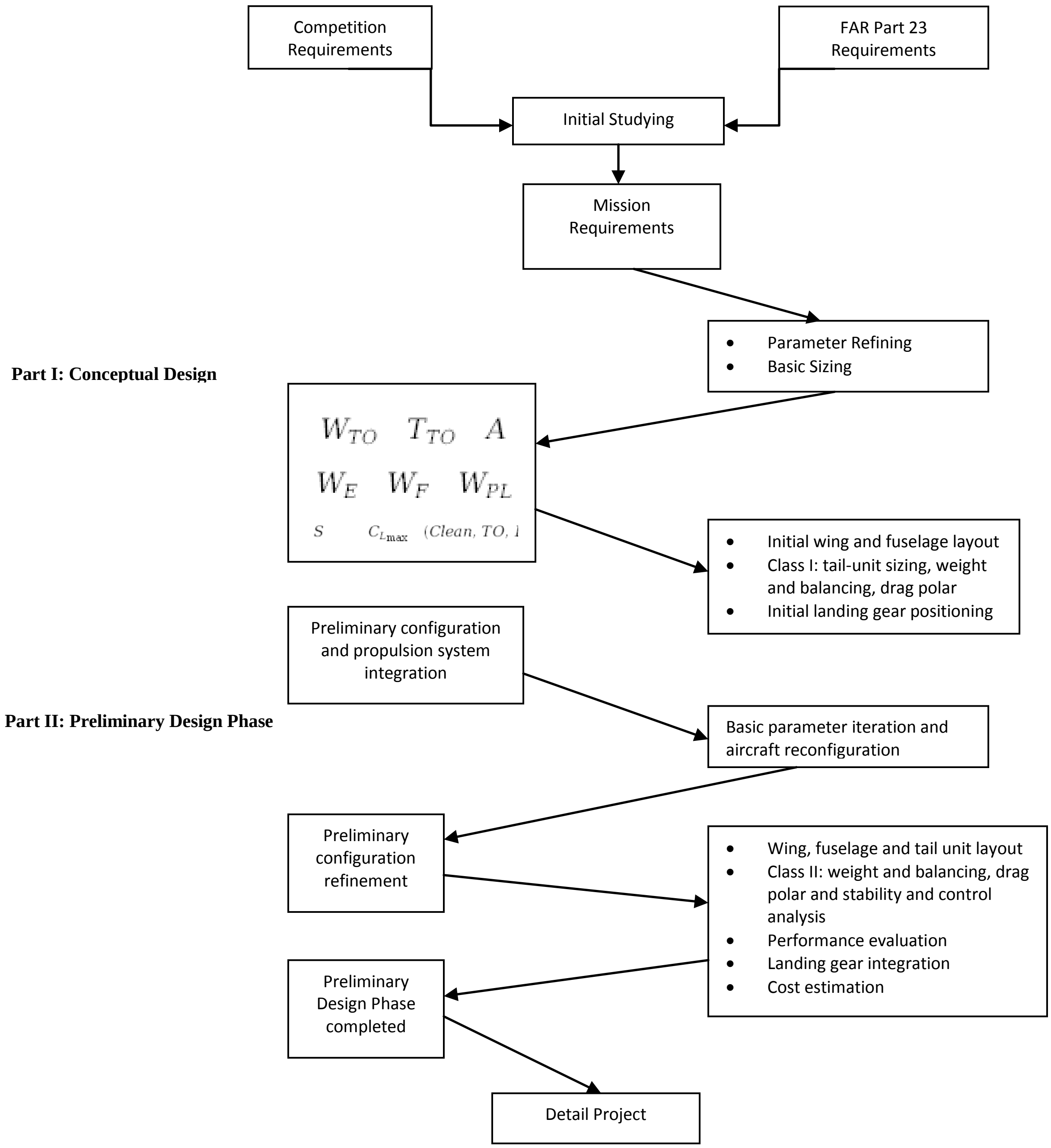
The SAE Aero Design competition is intended to provide undergraduate students with real-life engineering endeavor. It is essential to the success of the project to perform trade studies and make compromises to arrive to a design solution that will optimally meet the mission requirements while conforming to the configuration limitations. The emphasis on interpersonal communication skills, often overlooked by engineers, is reflected in the team's overall score. A completely unique dynamic is evident within our team due to the international collaboration between Brazil and the United States. A strong, developed communication basis will be crucial to the success of the project since a high percentage of our score is devoted to the design report and the oral presentation required for the competition.

Objective

The objective is to design an aircraft that can lift as much weight as possible meanwhile observing the available power and aircraft's length, width, and height requirements as governed by the SAE Aero Design East committee. An important aspect to the design will be determining the lifting capacity of the aircraft as this could have an impact on the placement of different competing teams due to the availability of "bonus" points for correct predictions. With regards to competition guidelines, the project is to be structured around three phases: a technical report, a technical presentation and inspection, and the physical flight competition.

Methodology

The project methodology is based on seven steps: i) the gathering of information ii) preliminary studying iii) conceptual and preliminary studying iv) project development v) building of a prototype vi) ground testing vii) flight testing. The following design methodology is a compilation provided by Barros which originates from a synthesis of a methodology presented by Torenbeek (1981), Roskan (1985), Raymer (1989), Vandaele (1962), Stinton (1983), Wood (1968) and Frati (1946). This methodology presupposes a set of mission requirements and based on these requirements, the design itself will commence. The typical parameters are: payload and type of load, range, cruise speed and altitude, take-off and landing distance, fuel reserves, rate of climb requirements, maneuverability requirements, and certifications basis (i.e. will be adopted based on the FAR part 23 regulation rules as well as the competition`s rules). The data will be collected and estimated using a combination of the competition regulations and studies based on past designs. The team will couple this data using analytical equations that can be solved by means of an optimization tool. The results of said equations are to be plotted in a chart known as a "design chart"—extremely useful in determining the aircraft`s design point. This will provide enough information to calculate the design lift coefficient in which the preliminary design is heavily based. The next step is to perform the empty-weight estimation, takeoff-weight buildup, and fuel-fraction estimation. Having this data, it is possible to calculate the wind loads on the aircraft. Determining these parameters will allow us to estimate the wing load which is a vital variable to couple the aerodynamic/structural equations and thus the wing geometry and its respective aspect ratio and stall speed. The design philosophy will prioritize the L/D parameter; this most likely will be done by selecting airfoils with low drag and by fairing the aircraft. The drag estimation methods at the preliminary phase will be those taken from the series of books from ROSKAM. The next step is to choose a suitable airfoil; there is a vast online database featuring several airfoils from all types of aircrafts. The team will select the airfoil that best suits our criterion. If one is not found, the team will design one using inverse methods. At this point, wind tunnel testing will be conducted. The wing design methodology will start with analytical calculations, providing a first design point which will be modeled on the software Tornado VLM that runs on MATLAB. This software will be used to refine the wing planform and to calculate the most suitable twist and dihedral angle, in order to provide good stall characteristics and control. Having determined the wing geometry and its loads, it will be possible to complete the fuselage and tail-unit sizing. Computational tools will be implemented in the stability and control derivatives evaluation, performance evaluation and cost estimation. If the results are satisfactory, the preliminary design phase will be complete. The prototype design phase will consist of more detailed calculations, CFD analysis and wind-tunnel testing. Ultimately, the final phase will consist of extensive ground and flight testing. The following flowchart gives an overview of the design methodology:



Regular Class Flight Score

Regular Class aircraft receives a flight score based upon the raw weight lifted, the team's prediction of the aircraft's maximum lifting capacity, and the team's Operational Availability (A_o).

The flight score is calculated by the following equation:

$$FS = RAW + PPB + EWB - TP$$

Where,

$$RAW = Raw\ Weight\ Score$$
$$PPB = Prediction\ Point\ Bonus$$
$$EWB = Empty\ Weight\ Bonus$$
$$TP = Total\ Penalty\ Points$$

The Raw Weight Score (RAW) is calculated by,

$RAW = W \times 4$ (W being the weight lifted in Pounds)

$$PPB = 20 - (P_{predicted} - P_{actual})^2$$
$$P_{Predicted} = Predicted\ Payload$$
$$P_{actual} = Actual\ Payload$$

Empty Weight Bonus. EWB can only be obtained in the first flight round of competition. A 10 point Empty Weight Bonus (EWB) will be awarded if a successful flight with zero (0) payload achieved.

Total Penalty Points. Any penalties assessed during Design Report Submission, Technical Inspection, and Aircraft Modifications will be applied to the overall Flight Score.

$$A_0 = \frac{(Successful\ Flight\ Round)}{(Successful\ Flight\ Round + Missed\ Flight\ Round)}$$

$$i = 1 + (A_0 - 40\%) \times .25$$

$$Final\ Flight\ Score = i \times (Best\ Flight\ Score)$$

Expected Results

Upon completion of this project we will have constructed a lightweight, fixed-wing remote-controlled aircraft possessing heavy payload lifting capacity. The aircraft must be able to takeoff in less than 61 meters, climb up and make a right turn completing a 360° lap and finally land carrying its maximum payload. The following are desired characteristics that we hope to achieve for the aircraft: high L/D ratio (thus maximizing the entire flight envelope), high structural efficiency factor (possibly around 6.2), good maneuverability, and a high aspect ratio. We wish to incorporate all of these factors while maintaining a lightweight wing construction that is not significantly susceptible to C.G shifting; thus allowing the aircraft to fly without payload and earn the respective bonus points. It is expected that the aircraft will also have the capability to fly in a high wing load configuration while withstanding wind gusts. This is a major concern of the team because previous competitions several designs failed due to unaccounted wind gusts.

Design Constraints

Landing: During a landing, the aircraft must remain on the runaway between their landing limits to be considered a successful landing. Touch-and-goes are not allowed, and a crash-landing invalidates the landing attempt.

Engine Requirements: Regular Class aircraft can still be powered by a single, unmodified O.S 61FX with E-4010 Muffler.

Aircraft Dimension Requirement: Fully configured for takeoff, the free standing aircraft shall have a maximum combined length, width, and height of **225 inches.**

Gross Weight Limit: Regular Class aircraft may not weigh more than fifty five (55) pounds with payload and fuel.

Material Restriction: The use of Fiber-Reinforced Plastic (FRP) is prohibited on all parts of the aircraft. The only exception is the use of a commercially available engine mount and propeller. Exploration of other materials and building methods are greatly encouraged

Gear boxes, Drives, and Shafts: Gearboxes, belt drive systems, and propeller shaft extensions are allowed as long as a one-to-one propeller to engine RPM is maintained. The prop(s) must rotate at engine RPM.

Competition Supplied Fuel: The fuel for Regular Class entries will be a common grade, ten percent (10%) nitro methane fuel supplied by the Organizer.

Fuel Tanks: Fuel tanks must be accessible to determine contents during inspections. Tanks may be pressurized by a stock fitting on the engine muffler only.

Gyroscopic Assist Prohibited: No gyroscopic assist of any kind is allowed in the Regular Class.

Payload Distribution: The payload cannot contribute to the structural integrity of the airframe, and must be secured to the airframe within the cargo bay so as to avoid shifting while in flight.

Radios: The use of 2.4 GHz radio is required for all aircraft competing.

In-Flight Battery Packs: Regular Class aircraft must use a battery pack with no less than one thousand (1000) mah capacity.

Spinners or Safety Nuts Required: All aircraft must utilize either a spinner or a rounded safety nut.

Metal Propellers Prohibited: Metal propellers are not allowed.

Control Surface Slop: Aircraft control surfaces must not feature excessive slop. Sloppy control surfaces lead to reduced controllability in mild cases, or control surface flutter in severe cases.

Servo Sizing: Analysis and/or testing must be described in the Design Report that demonstrates the servos are adequately sized to handle the expected aerodynamic loads during flight.

Gross Weight Limit: Regular Class aircraft may not weigh more than fifty five (55) pounds with payload and fuel.