Project Plan & Product Specifications

Team 8

Design an Unmanned Tilt-Rotor Aircraft for Multi-Mission Application

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1. Introduction

The definition of this project is to focus on the design for the Association for Unmanned Vehicle Systems International Student Unmanned Aerial Systems (AUVSI SUAS) competition. With a total budget of $1500 Team 8 is required to build an Unmanned Aerial Vehicle capable of fulfilling the tasks of the AUVSI USAS competition which is to autonomously navigate waypoints and search and classify ground targets. These classifications would include their GPS location as well as shape, color, letter or number. This project is meant to compete in the AUVSI SUAS competition. As an additional requirement from their sponsor Dr. Shih is to make the aircraft capable of vertical takeoff and landing.

2. Project Scope

The scope of this project was originally to compete in AUVSI SUAS competition. This competition requires an aircraft that is capable of autonomous waypoint navigation and as well as the search and characterization of ground targets. Team 8 was on track in order to request additional funding for the entrance fee of $1500 when they were told registration closed a month earlier then was officially stated due to an excess amount of teams. Team 8 will continue generating an aircraft that will be able to compete in future AUVSI SUAS competitions as well as fulfill the additional requirement by their sponsor, Dr. Shih, to introduce a VTOL component to the aircraft. As it stands, Team 8 has an aircraft complete with its VTOL component which just needs some internal and external modifications to be tested in horizontal and vertical flight. The scope for this Spring semester is to make this project a continuation project that will be capable of the reconnaissance tasks that these AUVSI SUAS competitions require. Team 8 will generate an aircraft capable of autonomous waypoint navigation, autonomous VTOL, and be a user friendly and adaptable platform for future competitions.

3. Product Specification

3.1 Customer Needs

Our team's goal is to provide a functioning platform for future AUVSI SUAS competitions. This means our customer needs are not only given by our sponsor but also by the AUVSI competition rules. Early in the design process our team met with our sponsor Dr. Shih to discuss our new design proposal and we were given a lot feedback on how to carry out our project successfully. Furthermore, our team participated in an AUVSI conference call, where competition officials clarified the rules and objectives for participation. Since these AUVSI SUAS rules will change next year, we are focusing on making an adaptable platform for the reconnaissance tasks that these SUAS competitions usually require. Below are some of the standard requirements of the AUVSI SUAS competition.

- **Autonomous Flight-** In order to successfully compete in the AUVSI competition the vehicle must be able to fly autonomously in order to collect points.
- **Visual-**The AUVSI competition has an objective that will require our vehicle to search for targets which will require a video feed.
- **Payload Delivery-**The AUVSI competition has an objective that will require our vehicle to drop a water bottle from a specific height and land on a target area.
- **Obstacle Avoidance-** The AUVSI competition officials want teams to design an aircraft as if it would be used out in industry. In accordance with this they desire vehicles to have obstacle avoidance systems.
- **Heavier –than-air-flight-** The AUVSI competition prohibits vehicles from competing with lighter than air flight methods
- **VTOL Flight-** The project advisor desires our vehicle to be capable of Vertical Take Off and Landing.
- **Time of Flight-**The AUVSI competition does not have a flight time requirement but the battery life needed for the completion of competition objectives is an assumed requirement.

3.2 Constraints

Based on the 2016 Seafarer Association of Unmanned Vehicle System (AUVSI) competition, the Unmanned Aerial Vehicle (UAV) is expected to sustain autonomous flight.

3.2.1 General Constraints

- The maximum takeoff gross weight of the aircraft shall be less than 55 pounds, when fueled and weighed with a calibrated scale; unless in compliance with the AMA Large Model Airplane program. (AMA Document 520-A.)
- The maximum airspeed of the UAV shall not exceed 100 KIAS
- The UAV shall sustain flight within 100 and 750 feet. Flight of about 400 feet above ground level within three (3) miles of an airport without notifying the airport operator is not allowed.
- The UAV should not interfere with operations and traffic patterns at any airport, heliport or seaplane base except where there is a mixed use agreement.
- The UAV should not operate aircraft with metal-blade propellers or with gaseous boosts except for helicopters operated under the provision
- The UAV should not operate model aircraft carrying pyrotechnic devices that explode or burn, or any device which propels a projectile or drops any object that creates a hazard to persons or property.
- The UAV should not operate a turbine-powered aircraft, unless in compliance with the AMA turbine regulations. (AMA Document #510-A.).
- Based on the competition flying time is 30 minutes maximum.

3.2.2 Other Requirements

- The UAV should sense, detect and avoid moving or stationary obstacles along its path
- Radio Control model aircraft must use the radio-control frequencies currently allowed by the Federal Communications Commission (FCC). For the competition, transmission is allowed on Wi_Fi (2.4/5.8GHz), (except for 900 MHz) on multiple Radio Frequency (RF) communications bands at the same time.
- The UAV is expected to achieve controlled take-off and properly changeover to autonomous flight. In the same manner, transit from autonomous flight to a properly achieved controlled landing.
- Aircraft must be able to navigate using GPS coordinates
- The UAV shall upload position information at a target rate of 10Hz from the first takeoff until the last landing with an average upload rate of 8Hz or more.
- Aircraft should be able to operate in winds up to 15 knots, gusts up to 20 knots and surface temperatures up to 110 degrees Fahrenheit

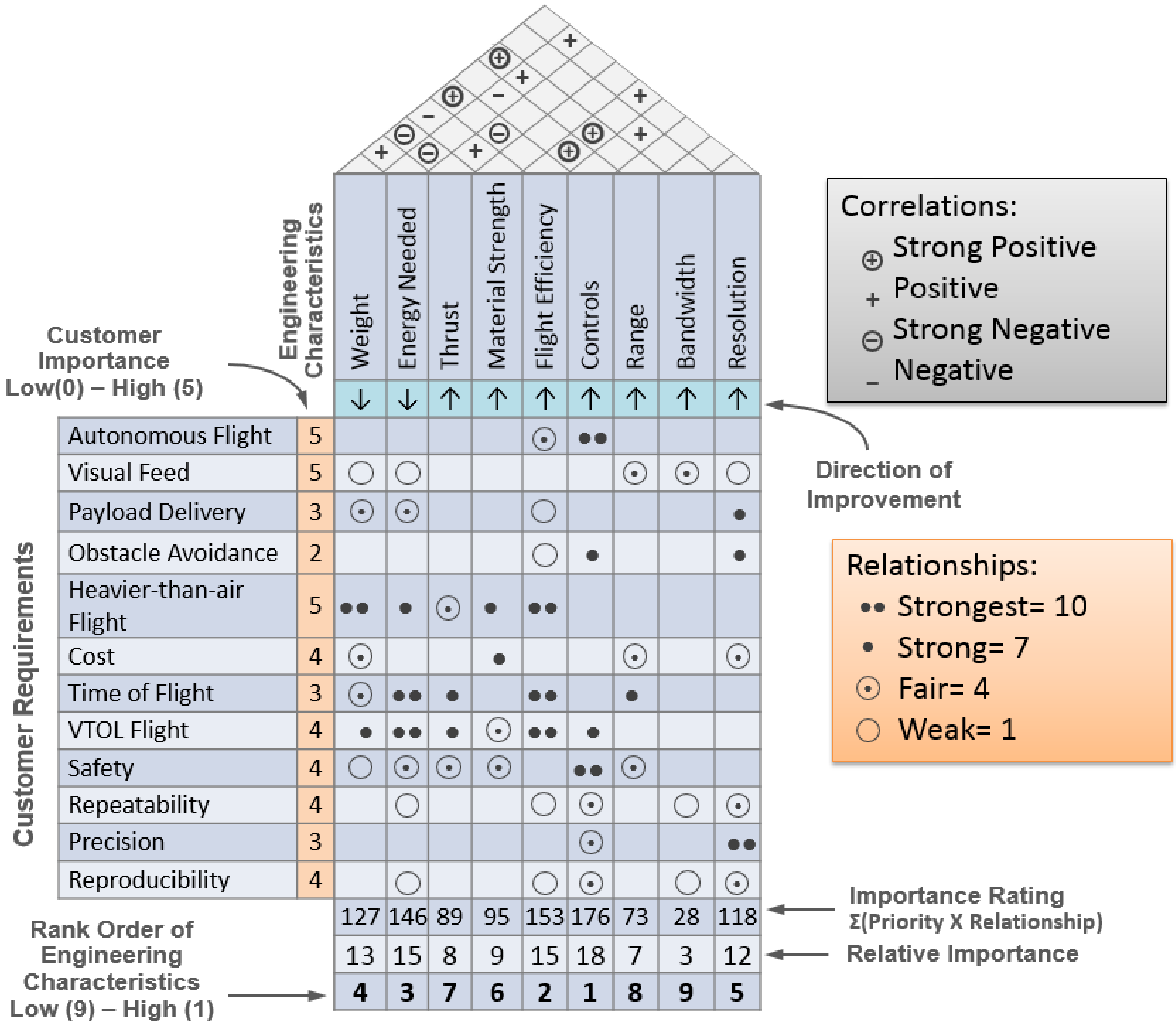

Figure 1 - House of Quality

The above is the HOQ comparing the engineering characteristics to the customer requirements. From this HOQ Team 8 found that the most important engineering characteristics are flight efficiency, controls, and energy needed in that order.

3.3 Components

3.3.1 Airframe

The airframe is the main structure of the aircraft. Our airframe will incorporate a Skywalker X8 Flying Wing, as seen in Figure 1. The Skywalker X8 Flying Wing is an Expanded PolyOlefin (EPO) foam flying wing. A flying wing differs from a traditional styled plane as it lacks a tail. The Skywalker X8 boasts a two meter wingspan. This wingspan allows for a heavier payload and increased stability. The airfoil used by this aircraft is known as the Sipkill 1.7/10B. This particular type of airfoil is used primarily for flying wings made from foam. The foam body allows for easy modifications to take place.

Figure 2 - The Skywalker X8

Additions to the Skywalker X8 will be implemented to allow for both horizontal and vertical flight. The most notable additions are carbon fiber tubes that will house the motors away from the body of the aircraft. One tube will be placed in the nose, perpendicular to the forward direction of the aircraft. This tube will house two motors and be capable of transitioning said motors between flight modes. The other tube will be responsible for holding the back motor. Unlike the two front motors, the back motor will attach to the tube using a specialized mount that will allow the motor to tilt. This mechanism is vital for stability while in the vertical flight mode.

Additional modifications on the airframe will take place for the AUVSI competition. The airframe must be able to hold extra cargo as well as a sensor package. Most of the needed components will easily fit in the airframe's internal storage.

3.3.2 Propulsion

The VTOL Tilt-Rotor aircraft uses a total of three Cobra 4510/420kV motors. The "kV" value refers to how many revolutions the motor turns per volt supplied. The aircraft uses all three motors during vertical take-off and landing, but after it transitions to horizontal flight it uses only the two front motors of the motors.

The motors will rotate three carbon fiber 16x5.5 propellers, which are the most efficient size of propeller to use for this specific motors. Propellers come in two basic types one provides lift spinning clockwise and the other counterclockwise. The VTOL Tilt-Rotor Aircraft will be using one clockwise and one counterclockwise propeller for the front to cancel the moment generated at the front for both horizontal and vertical flight. The rear motor will be powering either a clockwise or counterclockwise propeller and using the tilt mechanism to cancel the moment generated at the center of gravity.

These motors are fueled by three 6-cell 22.2V batteries containing 5000mAh of charge each. What regulates the flow of the batteries to the motors are the electronic speed controllers (ESCs). The speed controllers used in this design are the Cobra MR60 Speed Controllers which allows are the maximum output of voltage from the batteries while staying within the limits of the motors. A diagram of the electronics can be seen in Figure 5.

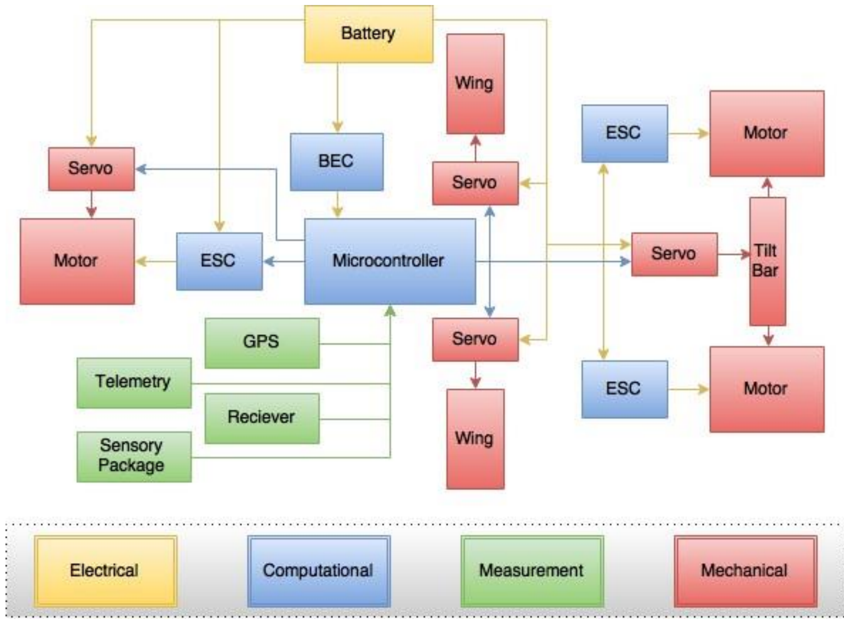

Figure 3 - Propulsion and Electronic Layout

3.3.3 Electronics

The tricopter to fixed wing design we will be implementing will require 4 servos. One will be used for rotating the front carbon fiber tube. This servo will cause the motors to tilt forward and allow horizontal flight. Two other servos will control the elevon on each wing, while the last servo will control the orientation of the back motor. This servo is very important as it will be what keeps the UAV stabilized.

The decision to use a Pixhawk as a microcontroller for our design was a unanimous one. An autonomous transition from a VTOL multicopter to a fixed wing is not a popular design, meaning we would need a microcontroller that was flexible enough to meet our needs. The Pixhawk offers that solution, as it is under open hardware development mostly involving high-end research. Many different and unique designs can be supported by the Pixhawk because of the community it is built around, one where firmware designs are shared constantly.

The firmware offered by the Pixhawk comes in the form of a Master node that has many Branch nodes. By requesting to pull a specific branch, a developer can make changes to that folder and the source code it contains. Most of what will be altered are branches specific to our design, mostly with our own developed Autostart. The Autostart initializes the parameters used by our aircraft, as well as the main and auxiliary Mixers. Mixers take already defined operations and fine tunes them to work with other designs. Our main mixer will initialize the Multicopter mode (tricopter) used by our motors, and the aux mixer will control the tilt rotor and elevon parameters.

The Pixhawk offers all of the necessary IO required by our design, and operates at 168 MHz with 256 KB RAM and 2 MB Flash. Important sensors such as a 3D accelerometer, gyroscope, barometer, and magnetometer are built into the flight controller. It is capable of autopilot as well as manual control, has abundant connectivity for peripherals, and is capable of in-flight recovery that will override and keep the aircraft in flight if a connection is lost.

The original GPS module that was going to be used in our design was the 3DR Ublox GPS with Compass Kit, however it was found in the rules of the AUVSI Competition that our GPS had to updated at a minimum of 10Hz. The 3DR Ublox updates at 5Hz, meaning that it will have to be replaced. We originally chose this GPS module because it was available from a previous project.

For radio communication, we chose the Spectrum DX8 transmitter and an AR8000 receiver. The DX8 built-in telemetry feature gives real-time information that help maximize performance while in flight. It uses a band of 2.4 GHz Digital Spectrum Modulation (DSM) with 8 channels. This transmitter has a large 128 x 64 backlit screen, which displays the quality of the signal coming to the receiver; a Spektrum Data Interface for expanded model memory, model sharing and firmware updates. The Receiver uses the same band, number of channels and same modulation type as the transmitter.

3.4 Material Selection

When developing our vehicle design, improving on the previous project groups design was a critical point. During this phase the materials selected for the aircraft components were made a point of emphasis. As with most aircraft development, we sought to minimize the weight of our vehicle while either maintaining or increasing our vehicle’s durability. While the previous groups design incorporated aluminum and wood as the main materials for the aircrafts structure; our design uses ABS plastic, carbon fiber, garolite, and Expanded PolyOlefin (EPO) foam. Almost all of these materials were selected for their high strength and low weight. In addition to material properties, the ease of manufacturability of these materials was highly desirable. Most if not all of our materials can be laser cut on site. Our materials however are not without their own complications. By using such specific materials, acquisition is usually done over the internet meaning obtaining any of our materials requires time and extra cost for shipping. However, these are complications that can be circumvented with thorough planning of the design and a strict adherence to the project schedule.

4. Budget

Our design is sponsored by Florida State University Aero-propulsion Mechatronics and Energy Center and Fund for the Improvement of Postsecondary Education (FIPSE). These organizations have allocated a budget of $1,500 for the completion of our unmanned VTOL Title-Rotor Aircraft with Sensor Package. We have envisioned a new design for the needs of both our sponsor and competition requirement; this design has been built around a majority of the previous teams components. Therefore, our cost has been greatly reduced and our budget has been set forward to make necessary adjustments. At this time it is hard to define the total cost of the VTOL Aircraft and sensor package, so we have divided up the budget by major required components. Table 1 below provides these estimates.

Table 1 - Budget Outline

Components	**Estimated Cost**
VTOL Aircraft	$900
Ground Control Station	$600
Total	**$1500**

The cost associated with the aircraft will include a new fuselage, rotor structure, and flight controller. The sensor package cost will include all necessary wiring, controller, and camera components. The ground station is a required component to this design, and not much discussion has taken place for this component at this time, but we know that it will include an antenna array, visual component for judges, and possibly a separate visual feed for operator. At this time the budget does not include the cost of registration for competition, as we have not provided a viable product

5. Project Plan

As for the Project Plan, we have divided the task for into three categories; VTOL Tilt-Rotor Aircraft Design and Senior Design deliverable,. Below is a detail description of each sub component of these categories. In the appendices you will find a Gantt chart representation of these task and the associated dates and progression algorithm.

5.1 Aircraft Design

For the design category we have decided to focus solely on providing an operation aircraft by the end of the semester, to make this possible we will be holding off on the ground station, sensor package, and payload delivery system until next semester. Though we are holding off on these components, we will be keeping in mind all requirements that these components have, for example: power consumption, necessary space, and associated weight.

5.1.1 Spring 2015

- **Administrative Tasks** – Securing large field for horizontal flight and registering with the FAA.
- **Internal Modifications and Additions –** Includes all the necessary modifications to internal components to complete the designs.
- **External Modifications and Additions** – Includes all the necessary modifications to external components to complete the designs.
- **Test Flight –** Testing horizontal, vertical, and horizontal to vertical flight.
- **Flight Optimization –** Gain tuning for smooth flight capabilities.

5.2 Deliverables

5.2.1 Spring 2016

- **Restated Project Definition and Scope/Project Plan**
- **Presentation I**
- **Web Page Update**

- **Midterm Presentation I**
- **Midterm Presentation II**
- **Operational Manual, Design Report for Manufacturing/Relability and Economics**
- **Walk-Through Presentation**
- **Final Report**
- **Final Web Page**
- **Final Presentation**

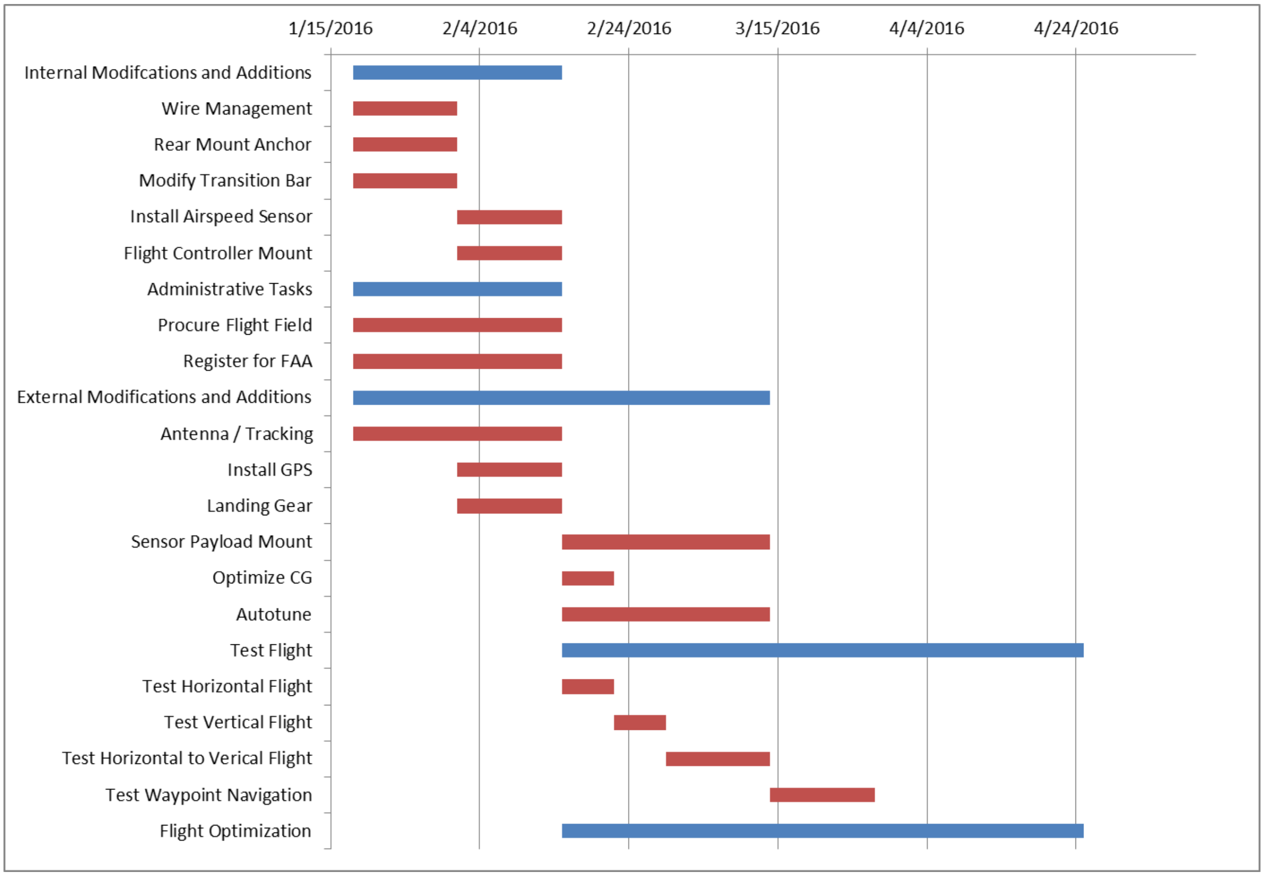

Figure 4 – Gantt Chart

Above is the Gantt chart for this Spring 2016 semester. This chart details specifically what Team8 will be doing throughout the Spring semester.

6. References

[1] Pixhawk.org, 'Pixhawk Autopilot - PX4 Autopilot Project', 2015. [Online]. Available: https://pixhawk.org/modules/pixhawk. [Accessed: 09- Oct- 2015].

[2] AUVSI, DRAFT 2016 Rules for AUVSI Seafarer Ch (n.d.): n. pag. AUVSI. AUVIS, 16 Sept. 2015. Web. 16 Sept. 2015 (http://www.auvsiseafarer.org/documents/2016Documents/2016_AUVSI_SUAS_Rules_Rev_0.9X_DR