Team 6 - Autonomous Aerial Vehicle Operations Manual

Due Date: April 4, 2013

Department of Mechanical Engineering:

Ken Anderson, Arielle Duen, Eric Milo,

Ernandes Nascimento and Matthew Yasensky

Department of Electrical Engineering:

Cristopher Timmons and Robert Woodruff

Project Advisors:

Department of Mechanical Engineering

Dr. Chiang Shih, PhD

Department of Electrical and Computer Engineering

Dr. Michael P. Frank, PhD

A FIPSE Sponsored Project

Table of Contents

Function Analysis / Flow Diagram 3

Product Specifications / Performance 5

- Airframe 5
- Propulsion System 5
- Radio Transmitter/Radio Receiver 5
- Image Processing Software 6
- Image Processing Hardware 6
- Video Communication Hardware 6
- Auto Pilot Operational Ranges: 7
- Safety Features: 7
- Arduino Uno & Wi-Fi Shield 8
  - Competition Rules 8
- Hardware 8
- Wi-Fi Expected Performance 9
- Gimbal System 9

Procedure for operation 10

- Preparing the plane for a flight: 10
- Wireless video communication / real-time image processing: 11
- Autopilot Startup Procedure: 11
- Gimbal Procedures 12

Troubleshooting 13

  - Troubleshooting guide 13

Routine Maintenance 14

Itemized Parts List 15

- Plane Caddy 15

Economics 18

Function Analysis / Flow Diagram

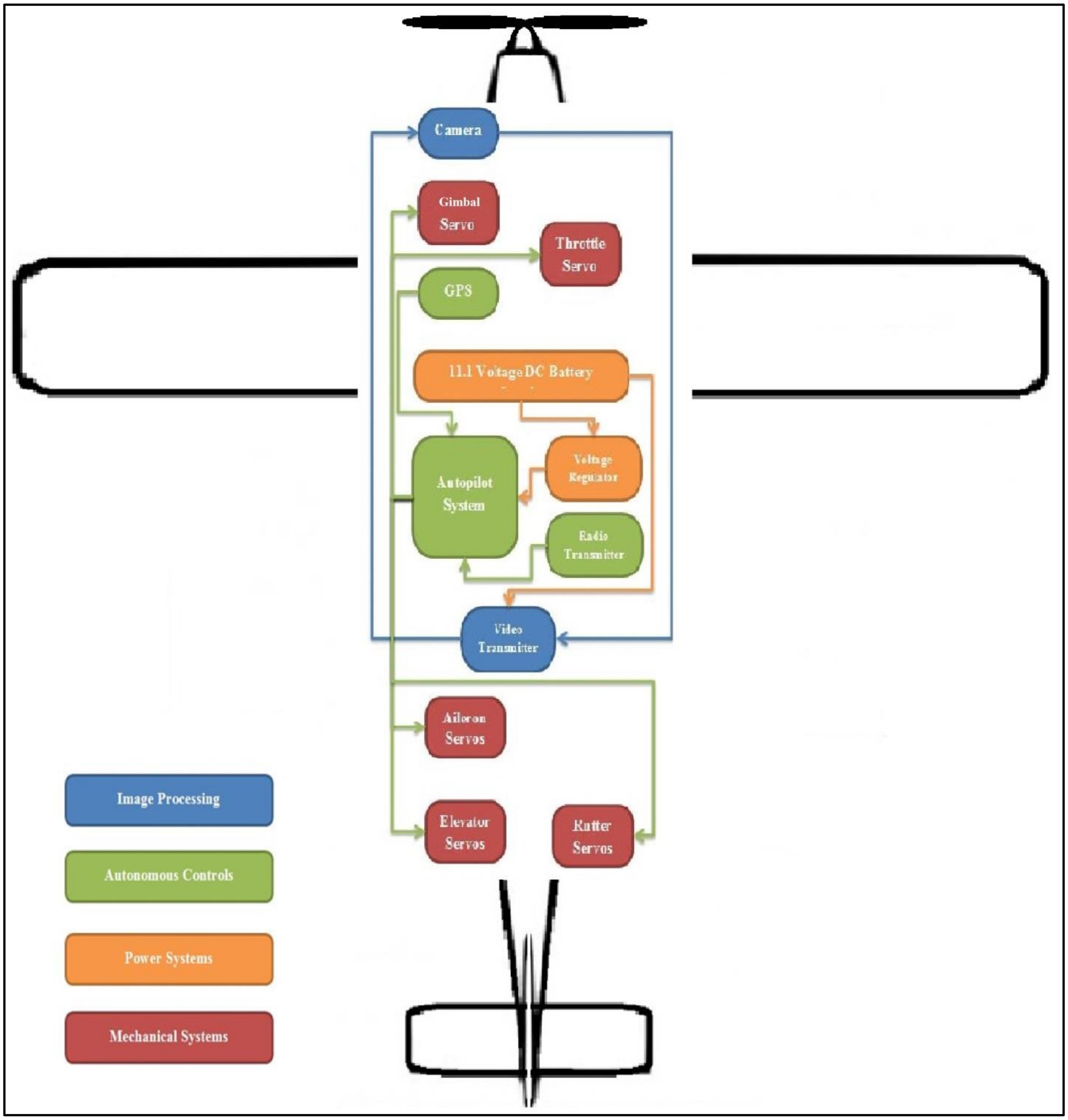

Figure 1: Top Down Flow Chart of Plane Components

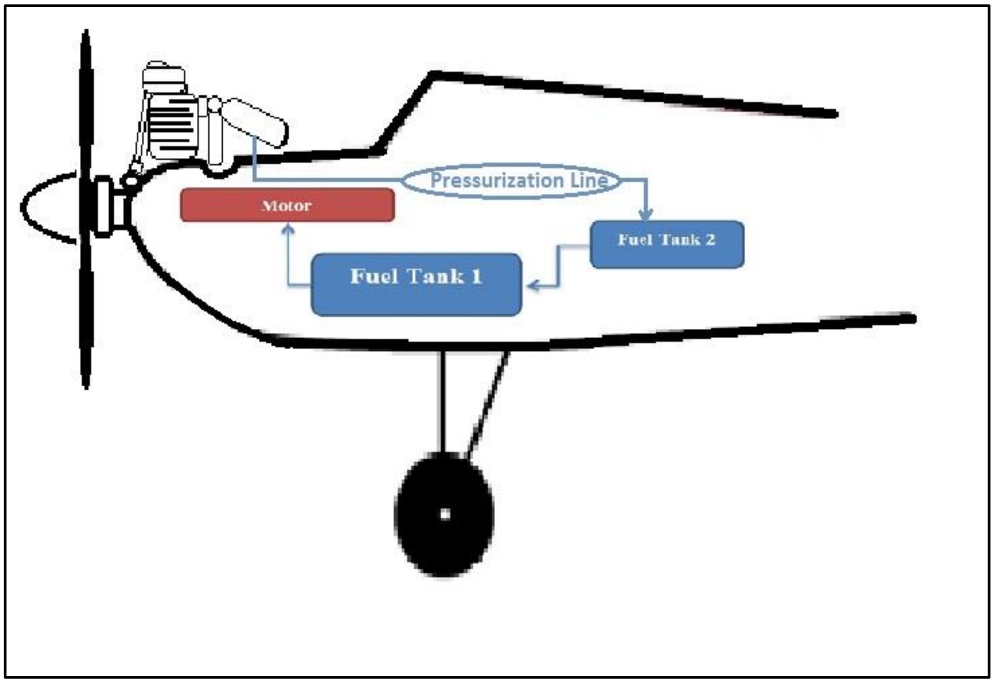

Figure 2: Side Profile Fuel System

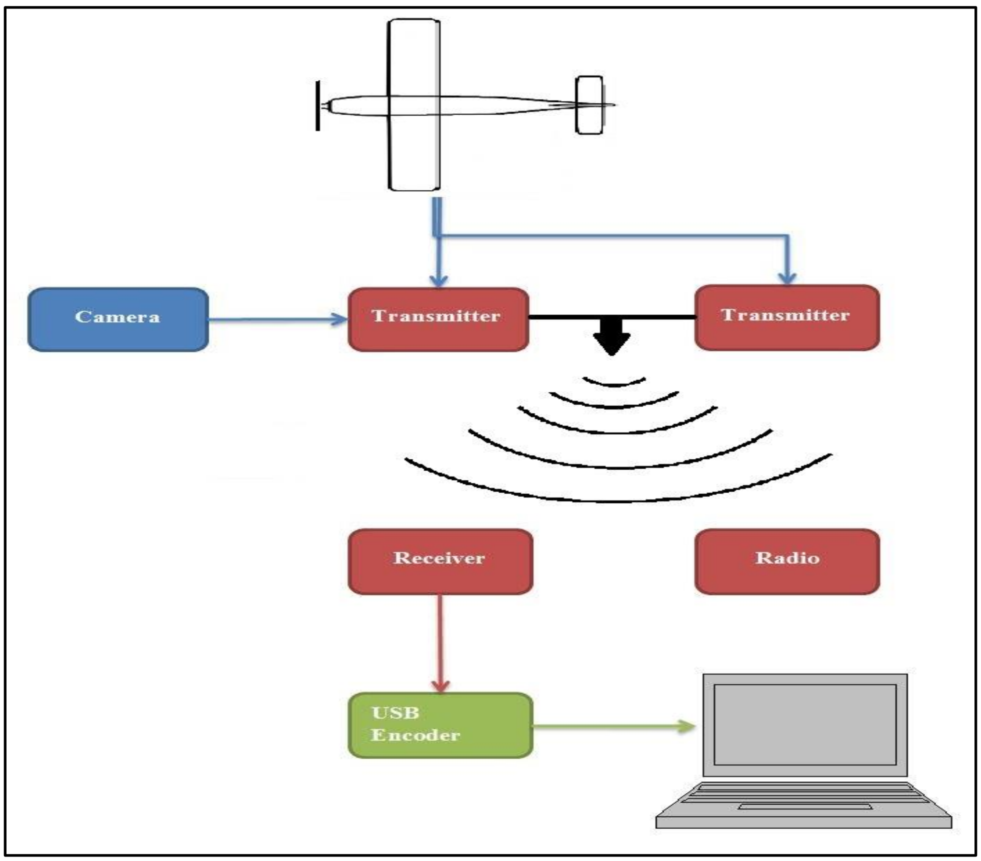

Figure 3: Wireless Communications

Product Specifications / Performance

Airframe

a. Senior Telemaster
    i. Specs:
        1. Wingspan: 94 in
        2. Length: 64 in
        3. Wing area: 1330 sq. in
        4. Flying weight w/ components: 17 lbs
    ii. Operating ranges:
        1. Flight speeds range from 22-56 mph
        2. Flight capable in winds up to 20 mph (not recommended)

Propulsion System

b. Magnum XL 0.91 cubic inch 4-stroke
    i. Specs:
        1. Displacement: 0.91 ci (14.95 cc)
        2. Bore: 27.7 mm
        3. Stroke: 24.8 mm
        4. Weight: 22.4 oz
    ii. Operating ranges:
        1. Practical RPM: 2,000-12,000

c. Additional components
    i. 15x6 APC propeller
    ii. 16 oz main fuel tank (15% blend)
    iii. 6 oz feeder tank (15% blend)

Radio Transmitter/Radio Receiver

d. Futaba 6J 2.4 GHZ transmitter
    i. Specs:
        1. Voltage input: 4.8V-7.4V
        2. Current drain: 170 mA

e. R2006GS 2.4 GHZ radio receiver
    i. Specs:
        1. Voltage input: 4.8V-7.4V

2. Current drain: 80 mA

Image Processing Software

f. OpenCV – Computer Vision Software
    i. Specs:
        1. Language: C++
        2. Design Environment: Visual Studio
        3. Operating System: Windows 7

Image Processing Hardware

g. Asus Laptop Computer
    i. Specs:
        1. Displacement: 0.91 ci (14.95 cc)
        2. Bore: 27.7 mm
        3. Stroke: 24.8 mm
        4. Weight: 22.4 oz
    ii. Operating ranges:
        1. Practical RPM: 2,000-12,000
h. Sony KX-700SHQ Camera
    i. Specs:
        1. 700TVL resolution
        2. Signal System: NTSC
        3. Total Pixels: 1020x508
    ii. Operating Ranges:
        1. Input Voltage: 12V DC
        2. Temperature: 14-122 F

Video Communication Hardware

i. TX-V584 Transmitter
    i. Specs:
        1. Output Power: 400mW
        2. Transmitting Frequency: 5.8GHz
        3. Current draw: 280mAH
        4. Weight: 28g
    ii. Operating Ranges:

1. Input Voltage: 7-12V DC
2. 8 operating channels

j. R5800DX Receiver
   i. Specs:
      1. Receiving Frequency: 5.8GHz
      2. Current draw: 120 mAH
      3. Weight: 89g
   ii. Operating Ranges
      1. Input Voltage: 12V DC
      2. 8 operating channels

Auto Pilot Operational Ranges:

k. Auto Pilot
   i. Desired input voltage = 5.37V +/- 0.5V
   ii. Absolute max voltage = 6V
   iii. Current draw = 200mA range

Safety Features:

l. Auto Pilot Safety
   i. Ability to manually override autopilot at any time during flight
   ii. Execute return to home command if there is a loss of transmit of up to 20 seconds
   iii. Terminate flight if there is a loss of transmit of more than 3 minutes

Arduino Uno & Wi-Fi Shield

Competition Rules

The AUVSI competition requires data transfer from the Simulated Remote Information Center (SRIC) to the competing team's UAS. The SRIC will comprise of a laptop computer running Microsoft Windows 7, a Wireless Broadband Router, a 10 dB attenuator, and a High-gain directional antenna.

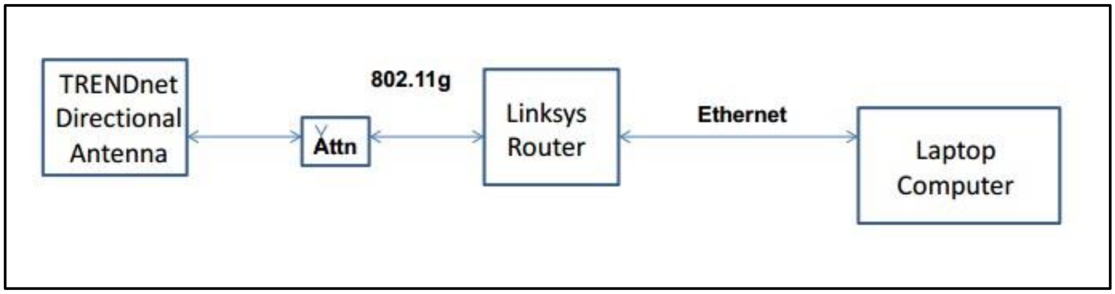

Figure 4: SUAS SRIC Block Diagram.

Hardware

In order to download the data, an electronic device mounted using Arduino Uno and Arduino Wi-Fi Shields can be installed in the autonomous aerial vehicle and programmed to accomplish the task.

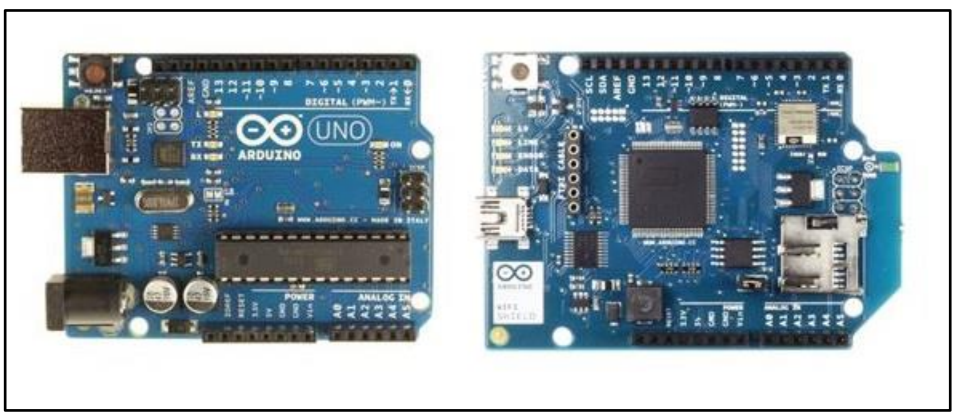

Figure 5: Arduino Uno and Wi-Fi Shield boards.

The Arduino Wi-Fi Shield allows an Arduino board to connect to the internet using the 802.11 wireless specification (Wi-Fi). It is also powered by the Uno board and can be programmed using open source software. As the Wi-Fi shield board will be connected to a wireless router, it has a micro SD slot for saving the downloaded file.

Wi-Fi Expected Performance

- The mounted system should be capable of accomplishing the following tasks:
- When flying in the specified area, connect to the network. The router will be located on wireless channel 1 at 2.412 GHz;
- Enter the provided network passphrase;
- After network connection is confirmed, enter the provided IP address. An example is: FTP://192.168.1.110/auvsi/team1.
- Open the folder and read the included text file to receive the code phrase. This folder will be read only.
- Provide the code phrase to the SUAS judges.

Gimbal System

The gimbal is the device that allows the camera to point in a direction independent of the UAV. The expected performance of the gimbal is that it will correctly account for the pitching and rolling of the UAV as it maneuvers to maintain course and heading throughout the flight. The camera should point directly at the ground to reduce perspective distortion for image processing. It is composed of a servo that is mounted directly to a bulkhead within the air frame, followed by a two-bracket linkage that houses a second servo, with the camera mounted to the protruding edge of the outermost bracket. The operating range is physically limited by the geometry of the airframe on the roll parameter, and the servo mechanism itself on the tilt parameter. Both of these parameters are well within the acceptable limits to allow for a successful mission. Electrical limitations are imposed by the general aircraft electronics power source.

Procedure for operation

Preparing the plane for a flight:

Prior to flight (usually the day before) all of the on-board battery systems should be charged and/or checked to make sure they have sufficient power for operation.

The glow plug that is used on the engine during starting needs to be charged along with the battery for the starter motor (the starter motor is what is used to spin the prop). The batteries in the Futaba 6J (radio transmitter) should also be checked/replaced to ensure proper functionality. A radio transmitter range test should be performed at the air field on the flight day using "Power Down Mode" in the radio's mode settings.

At the airfield prior to starting the engine, Fill the fuel tank with fuel, then turn on Mission Planner and the radio transmitter. Make sure that the plane is leveled correctly because when the autopilot system is powered on, the stabilize values are calibrated, set, and saved. Flip the front switch up on the plane to turn on the autopilot system. Give the system 10 seconds to calibrate, then "Connect" in Mission Planner.

Once the APM and the Mission Planner are linked, it is time to calibrate the radio transmitter and verify that all the flight surfaces are moving in the appropriate directions. Calibrate the radio in the "Calibration" tab in Mission Planner while simultaneously verifying that the flight surfaces are moving in the correct directions, e.g. "elevator up" on the radio transmitter actually moves the elevators up. Now that the radio transmitter moves all of the flight surfaces in the correct directions, the autopilot's calibration needs to be tested. Turn the switch on the radio transmitter putting the plane in "Stabilize" mode. Now lift the plane and begin to manually vary the pitch and roll (i.e. nose up, nose down, turn side to side) and verify that the flight surface are compensating in the appropriate directions.

To start the motor manually turn the propeller through one power stroke to check to make sure it is not hydro-locked. Place the glow plug in the appropriate place on top of the engine (CAUTION: Once the glow plug is put on the engine it is able to start!) and use the starter motor to turn the propeller. If needed you can add a FEW clicks to the throttle to help the motor get started. Once the motor is started use EXTREME caution when removing the glow plug from the motor.

Wireless video communication / real-time image processing:

Prior to departing for the airfield, ensure the transmitter battery (on-board the air frame) is fully charged and prepared for full operation (usually better to charge the night prior). Ensure all necessary image processing equipment has been stored in transporting vehicles, this includes but is not limited to:

- Asus Laptop & power adapter
- R5800DX Receiver & power adapter & antennae
- Sample ground target
- External monitor & power adapter & VGA cable
- Composite-to-USB encoder

Once at the airfield and all the above equipment has been unloaded, begin preparing for video communication by first starting the laptop and connecting the external monitor. Ensure, the display is functioning properly before continuing.

After this is accomplished, your focus should shift toward ensuring the receiver is prepared for full operation. First provide power to the receiver with the AC-DC power adapter; make sure the blue LEDs light up, indicating the receiver is in fact powered on. Next, install the receiver's antennae and connect the female composite cable (from the receiver) to the male composite cable on the composite-to-USB encoder. Finally, insert the encoder into the laptop. You have now prepared your ground station for wireless video communication.

Next, build your OpenCV solution in Microsoft Visual Studio and hit the switch on the air vehicle to give power to the video transmitter. If the above has been executed properly, a video signal should now appear on the screen. If successful, power down the transmitter until just prior to flight in order to conserve precious battery power.

Autopilot Startup Procedure:

First the autopilot must get turned to on using the power switch located on the plane. The next step is to turn on the APM mission planner on the ground station. Once this is complete the ground telemetry module is connected to the computer and verifying that the antenna for the onboard telemetry module is connected to the aircraft. Once this is completed the autopilot can connect to the mission planner.

Next the minimum and maximum values need to be set for the servos, throttle, and the switches on the remote also when calibrating, to allow the mission to alternate between flight modes. It is important to make sure that the servos and throttle are turning in the correct direction while calibrating. Otherwise this could lead to catastrophic failure . Once this is complete, the servos on the gimbal are next be calibrated. This is done by calibrating the minimum and maximum values on the gimbal servos which will result in the camera being pointing normal to the ground. This will assure that the camera will remain in this position for the duration of the flight.

Once these tasks are complete the hardware and software will be ready to create, or upload a flight and execute the mission. Lastly, before the mission can be executed the waypoints need to be written from the Mission Planner and read from the autopilot. It is now time for takeoff.

Gimbal Procedures

The gimbal, and more so the camera, are sensitive pieces of equipment. Before each flight, the calibration of the gimbal should be checked by ensuring the camera is pointed downward while the plane is level and the gimbal is in stabilize mode, as well as maneuvering the airframe and observing that the gimbal is behaving appropriately. The apparatus should be kept in the retracted position upon takeoff and landing to maximize the clearance between itself and the ground.

Troubleshooting

For our project, the competition specifies that the autopilot must be able to be manually overridden at any time, return home if there is a loss of transmit signal up to 30 seconds, and terminate the flight if there is a loss of transmit signal for more than 3 minutes. The Ardupilot Mega 2.5 is able to be manually overridden at any time and will execute the return to home command if there is a loss of transmit signal of up to 20 second, but it does not terminate flight if there is a loss of transmit signal for more than 3 minutes. This can be fixed by adding this condition into the open source firmware with Arduino. Other various troubleshooting methods are listed below.

Troubleshooting guide

- No connection between Mission Planner and Ardupilot:
    - Flip Ardupilot power switch on UAV to 'OFF', restart Mission Planner software and reconnect
    - Ensure all connections are secure and properly engaged
    - Check voltage from battery supplying power to Ardupilot onboard the UAV
- No connection between camera and controlling computer:
    - Flip telemetry power switch on UAV to 'OFF', restart video software and reconnect
    - Ensure all connections are secure and properly engaged
    - Check voltage from battery supplying power to camera and telemetry system onboard the UAV
- Engine rotates, but does not start
    - Remove glow plug as engine could start unexpectedly with glow plug attached
    - Ensure glow plug is charged
    - Ensure proper throttle position from throttle servo
    - Ensure fuel is in the fuel lines leading to the engine
    - Wait a few minutes to allow excess fuel to leave engine and try again
- Engine propeller not rotating upon engine start:
    - Remove glow plug as engine could start unexpectedly with glow plug attached
    - Manually rotate propeller in reverse direction to alleviate hydro lock
    - With glow plug removed, continue to rotate backward and forward until propeller rotates as desired
- UAV not flying level- by roll:

    - Adjust roll-trim in flight for minor corrections
    - Ensure accurate calibration of flight controls on ground
- UAV not flying level- by pitch:
    - Adjust pitch-trim in flight for minor corrections
    - Check weight-and-balance on ground
    - Ensure accurate calibration of flight controls on ground
- Gimbal not calibrating to proper limits:
    - Recalibrate positions and movement envelopes, as gimbal position may become disoriented from previous calibrations through removal and replacement

Routine Maintenance

Routine maintenance for the plane is conducted prior to each test flight. The list below is an overview of the main checkpoints that are evaluated before the plane can fly.

a. Exterior of plane
    i. Fix tears in Monokote wrap
    ii. Propeller properly balanced
    iii. Check for any splints in wood and unhinged joints
        1. If found: Replace, fix or seal
b. Interior of plane
    i. Check fuselage for any lose debris
    ii. Check fuel hoses for tears
        1. If found- Replace
    iii. Check all wiring and connections
    iv. Routinely tighten any crucial screws on entire craft

Itemized Parts List

Plane Caddy

The plane caddy is not only used to support the fuselage and house various items needed for the maintenance of the plane but it also contains the devices needed to start the engine propeller. The caddy is carried to the RC Airfield whenever test flights are taking place to hold these necessary items while also accommodating travel ease. Figure 5 below shows the Master Caddy without the fuselage and just a few of the main items in the Caddy.

Figure 6: Master Caddy

The following list is the main items located in the Caddy that are needed for the test flights that are:

- 12V Battery
- 6V 2000mAh Battery Pack
- A Fuel bottle to crank wheel (see Figure 6)
- Engine starter (see Figure 8)
- Extra Fuel Hoses
- Glow Plug (see Figure 7)
- Glow Plug Charger
- Lipo Battery charger
- Plane Bands
- Safe Propeller Starter
- Starter Motor Battery

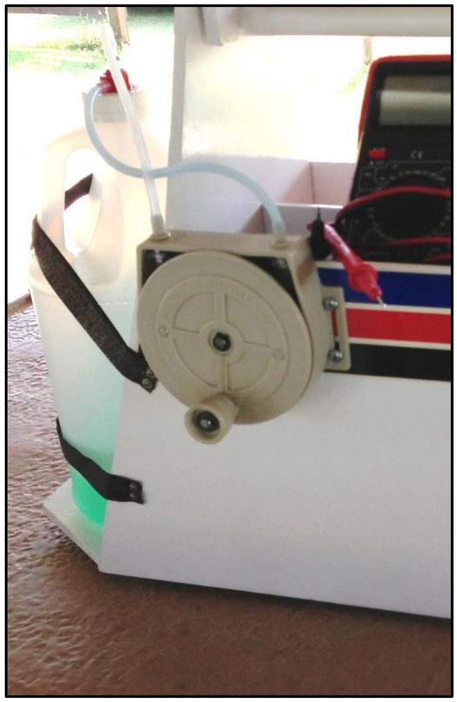

Figure 7: Crank Wheel

Figure 8: Crank Wheel

Figure 9: : Engine Starter

Portable 405

In order to have an adequate workspace for our nearly 8 feet wingspan airplane, we were able to use one of the FAMU-FSU College of Engineering portables. The senior design team that was also producing an Unmanned Aerial Vehicle last school year occupied the portable as well. From this team we were able to gain some useful items to contribute to our project. Since the start of our project were we able to add to this collection of items in order to then pass down to the teams that comes the following years to come. The relevant items in the portable from both this year and last year's contribution are as follows.

- Box of cables
- Box of tools, screws, nuts, bolts, etc.
- Camera
- Carbon Fiber
- Dremel Kit
- Excess Styrofoam, plastic, etc.
- Extra fuselage
- Extra Monokote
- Foam insulation
- Monitor
- Power Tools
- Soldering tool
- Spray adhesive
- White Board (2)
- Wood glue, styro glue, epoxy
- Workbench and Two Tables
- Zip ties

Economics

In order to analyze the most cost effective method to construct the Autonomous Aerial Vehicle, there must be a comparison between buying the airframe from a vendor and buying the necessary materials to build an airframe as well as manufacturing and assembly. The airframe of our choice is the Senior Telemaster, which cost approximately $350. On the other hand, to build and design an airframe, the cost for all the factors mentioned earlier is about $. Buying the airframe is more cost effective as well as time efficient which is what is needed for this project with a budget of $2000 and only two semesters to complete.

Fortunately, the Senior Telemaster airframe was given to our team for free. This left our budget mainly consisting of the equipment needed for the autonomous take off and GPS navigation. This equipment can become a little bit pricey, especially the constant purchase of batteries. In order to avoid buying an abundant supply of batteries, the most cost efficient solution would be to have a battery charger and downsize to one battery.

Competition cost consists of not only a registration payment but travel to and from the site and lodging during the competition. The travel options would be to drive or fly to the destination of Pax River, Massachusetts. The flying option factors in airfare for seven people as well as packaging and shipping for a 8 feet wingspan airplane. Driving only entails the price of gas and a rented vehicle. It was decided that driving a rented vehicle, preferable a large seven seated van, would be the most cost efficient for our traveling purposes.