Design Team:
Bradford Powers
Max Nielsen
Dana Howes
Dan Brosnan
Adam Robert

Faculty Advisor:
Dr. Salah Badjou

May 23, 2011
Abstract

The Aetos Unmanned Aerial System is a complete system designed to successfully compete in the 2011 Association for Unmanned Vehicle Systems International (AUVSI) Student Unmanned Aerial System (UAS) Competition. Over the course of the 2010/2011 academic year the five member team designed, constructed, and evaluated the individual sub-systems needed to create a complete UAS, which consists of an Unmanned Aerial Vehicle (UAV) and a Ground Control Station (GCS). The competition will take place in June 2011 at Naval Air Station Patuxent River, Maryland.
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1 System Overview

This paper presents a technical overview of an Unmanned Aerial System (UAS) designed and constructed by students at the Wentworth Institute of Technology in Boston, MA. The system meets the requirements for entry in the Association for Unmanned System International (AUVSI) Student UAS Competition held annually at Naval Air Station Patuxent River, MD.

The Unmanned Aerial System presented here consists of two main components: the Unmanned Aerial Vehicle (UAV) and Ground Control Station (GCS). The UAV is a small, radio controlled aircraft capable of manual, semi-autonomous and fully autonomous flight. It is also equipped with all the necessary sensors to perform automatic flight, navigation and target identification. The GCS is a PC based software program used to interface the human operator with the UAV. All flight, navigation and mission control operations are performed through this component. The complete system is shown in Figure 1.

![Aetos Unmanned Aerial System](image)

Figure 1: Aetos Unmanned Aerial System

1.1 Mission Overview

The Association for Unmanned Systems International (AVUSI) Student Unmanned Aerial System Competition is a collegiate contest held annually at NAS Patuxent River, MD. The 2011 competition will be held from June 15-19. The competition is intended to stimulate student interest in unmanned systems and technology. Design teams are tasked to design, fabricate and demonstrate complete unmanned systems capable of autonomous flight and navigation. Sponsors include many top companies and government agencies.
1.2 Mission Objectives

The goal of this project is to design, build and test a complete Unmanned Aerial System for entry in the 2011 AUVSI Student UAS Competition held annually in Patuxent River, Maryland. This competition is open for college students and challenges them to exhibit a UAV capable of performing a series of ISR tasks with emphasis on autonomy.

The narrative of the competition is the following: A company of U.S. Marines need and unmanned aircraft to support their sweep with intelligence, surveillance and reconnaissance. The UAV must takeoff, navigate and land with limited intervention of the Marines and must be able to navigate to a specified search area. Visual intelligence must be collected and transmitted back for analysis. The search area may be reassigned in flight.

1.3 Design Team

The design team was made of up five Electromechanical Engineering students at the Wentworth Institute of Technology in Boston, MA. Work was divided into two area: Avionics and Instrumentation, and Airframe. The Avionics and Instrumentation team consisted of Max Nielsen, Bradford Powers and Adam Robert. The Airframe team consisted of Dana Howes and Daniel Brosnan. Dr. Salah Badjou served as the projects advisor, and met with the team on a weekly basis for consultations. The research, design, and testing done by each team is outlined in the sections below.

1.4 Unmanned System Overview

The Aetos Unmanned Aerial System is a fully autonomous unmanned aircraft. The system is capable of stabilized manual flight, guided navigation to preset or in-flight transmitted waypoints, and real-time intelligence collection. The system is designed to be light-weight and man-transportable and is capable of up to 45 minutes of flight time. The name Aetos was chosen after the Greek Ateos Dios, or ”Eagle of Zeus”, which served as his protector.

2 Airframe Design

The airframe selection process was the first major issue tackled by the airframe team. From the beginning, the team wanted to design a small, man-transportable UAV as opposed to larger, heavier aircraft. There were two possible routes to a viable airframe: design a custom aircraft and build it from raw material, or choose an off-the-shelf consumer Remote Controlled (RC) aircraft. Since the members of the design team lacked the experience and knowledge needed to design a custom aircraft, choosing an consumer RC aircraft was the best option.

Based on the requirements presented in the competition rules a basic set of guidelines were established to choose a proper airframe. In order to facilitate easy flight control and intelligence gathering, a slow-flying, highly stable aircraft was needed. The aircraft also needed to be large enough to hold all the flight instruments and hardware, a camera and transmitter radio and extra batteries to extend the flight duration. The batteries would occupy the greatest amount of fuselage space. From early on, the team was in favor of an electric powered, foam model. Electric motors require no liquid fuel and offer less vibration and engine noise than gas powered engines. Foam, like Elapor, is light-weight and easy to repair.
2.1 Multiplex Easy Cub

Based on the required guidelines the Multiplex Easy Cub was chosen as the airframe. A picture of this aircraft is shown in Figure 2 below.

![Multiplex Easy Cub model aircraft](image)

Figure 2: Multiplex Easy Cub model aircraft

The Easy Cub is made of Elapor foam and classified as a trainer model. It is powered by a single brushless DC electric motor and requires one servo motor for elevator and one motor rudder control surfaces. The interior of the fuselage also has many open spaces for placement of batteries and flight electronics. However, to make a viable UAV airframe out of this model many modifications needed to be completed.

2.2 Airframe Modifications

While the manufacturer of the Easy Cub provided recommendations for motor, propeller and battery selection, the mission time and payload requirements of the system will add substantial weight making these recommendations inadequate. Considerable design work was done to find the optimal balance between weight, space and flight time.

The construction procedure supplied by Multiplex assembles the aircraft in such a way that it cannot be disassembled. Since the UAV needs significantly more equipment, access to the usable fuselage space of the aircraft is an important requirement. Therefore, modifications needed to be made to the aircraft to allow for easy assembly and disassembly.

As a result of increased weight of the aircraft, high torque servo motors were chosen for the control surfaces. These servomotors were larger than the motors recommended by Multiplex, so the modifications to fuselage were required for installation. Additionally, the size of the main motor was significantly larger than the recommended motor size. To fix the motor to the front of the aircraft, the supplied motor bracket also required modification.

In order for the aircraft body to be disassembled, a replacement for glue needed to be found to keep the aircraft together in flight. A mechanical fastener was created by embedding a U-bolt in the tail section assembly. Screws hold the assembly in place from the underside of the fuselage, fastening into the U-bolt. To complete the modification, a custom aluminum sheet metal part was
fabricated to act as both a load dispersing washer for the bolting as well as a clamping part which holds together the rear section of the fuselage.

Due to the added weight of the aircraft the landing gear also required modification. The manufacturer’s instructions indicate that the plastic landing gear fixture should be glued to the underside of the fuselage. This would permanently mate the two halves of the fuselage. Four holes were drilled through this part and corresponding holes were placed in the fuselage. A metal plate was then fabricated to act as a washer and retain the bolts in the foam. This will allow for the landing gear bracket to be removed and the two halves of the fuselage to be separated.

After a rough landing during flight testing, the modified landing gear failed. A new landing gear was designed from aluminum planes which held the same bend wire in place under the fuselage. This new landing gear consisted of two plates, the first of which had the shape of the landing gear wire machined into it to hold the wire captive. The second plate was kept flat and four bolts were used to clamp the two plates together. This new landing gear bracket is able to hold the gear wire securely fastened to the fuselage.

2.3 Propulsion

Flight of most small unmanned aircraft is sustained by some form of motor and propeller. This device can be either gas powered or electric. The propeller is based on the size, weight, and desired efficiency of the system.

2.3.1 Motor Selection

The required motor size is a function of the amount of payload weight the aircraft must carry. Selection of a motor then depends on choosing the proper "input watts per pound" rating provided by motor manufacturers. Therefore the first step in the motor selection process was estimating the maximum weight of the UAV.

When fully assembled the Easy Cub aircraft weights 1.9 lbs. Since autopilots and other flight electronics are generally very small and light weight the total weight was estimated at 0.5 lbs. The vision payload was estimated to weigh less than 1.5 lbs. The most significant weight component are the batteries. To provide a flight time of up to 60 minutes it was estimated that a battery weight of 3.9 lbs was required. This brought the entire system weight to 5.8 lbs.

Using the watts per pound chart provided by E-Flite a value of 580 watt power input was selected [1]. The closest available device was an 850 watt motor. This would keep the performance of the aircraft in the trainer category but provide sufficient power for flight. This motor would weight 0.4 lbs and required three 4-cell Lithium Polymer (LiPo) battery packs.

2.3.2 Propeller Selection

Another manufacturer supplied sizing chart was used for choosing the correct propeller [2]. The size of the propeller is mainly a function of motor torque, desired forward airspeed and the maximum radius of the propeller based on aircraft size. Based on manufacturer recommendations a 11 inch diameter, 7 inch per revolution pitch prop was chosen. Currently, the team is also experimenting with a 10 inch diameter, 5 inch per revolution prop in an effort to increase efficiency and flight time.
2.4 Power Systems

With the motor selected and battery requirements determined, the battery packs could be designed. On January 30, 2011 the first flight of the Easy Cub airframe was performed. During this flight it was determined that a 50% throttle setting on the RC controller would provide more than enough thrust to keep the aircraft aloft when powered by a single, 3-cell LiPo battery with a nominal capacity of 2100 mAh. In order to obtain a more accurate reading of the motor current draw, a clamp-on ammeter measured a peak draw of 10 A. This value was used to develop the custom battery packs.

2.4.1 Primary Battery Packs

A123 Systems provided the design team with a series of LiIon cells. These cells have a nominal capacity of 2.3 Ah at 3.3 V. To obtain the required 13.2 V four cells were connected in series into a single pack. To obtain 6.9 Ah three of these four cell packs were connected in parallel. A wiring diagram of the batteries is shown in Figure 3. Each cell weighs 0.154 lbs (70 grams) bringing the total weight of the battery system to 1.85 lbs.

![Battery wiring diagram](image)

2.4.2 Secondary Batteries

The main batteries provide power to the motor for propulsion needs. This power can also be used to drive auxiliary devices such as the camera system. In the event this primary power were to be exhausted the aircraft would still be capable of a controlled landing. To ensure that the autopilot and RC receiver unit will continue to work in the event of main power loss they are operated from a 4.8v Ni-Cd battery.
2.5 Technical Details

<table>
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<tr>
<td>Range</td>
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3 Avionics and Instrumentation Design

The Avionics and Instrumentation team was responsible for all electronic and software systems needed for the unmanned aircraft. This included an autopilot, an inertial measurement unit (IMU), airspeed and altitude sensors, Global Positioning System (GPS), and telemetry radio system. These systems are outlined in the following sections.

3.1 Autopilot

The autopilot is the heart of the unmanned system and in the source of all autonomous behavior. This device is what sets the UAV apart from a remote controlled aircraft. The autopilot polls all the flight sensors for information about flight status and orientation, makes any necessary control and navigation decisions, then adjusts the flight control surfaces accordingly. An overview of the autopilot system is shown in Figure 4.

Many different kinds of commercial and open-source autopilot options are available. A few of these options are the Cloud Cap Technology Piccollo, the Procerus Technology Kestrel, the
Paparazzi open-source autopilot, and the ArduPilot. Due to budget constraints, the commercial autopilots were generally too expensive. The open-source options have reached a high level of development and offer many of the same features as the professional autopilots at significantly less cost. The avionics design team choose the ArduPilot Mega as the main autopilot system.

### 3.1.1 ArduPilot Mega

The ArduPilot Mega (APM) is an open-source autopilot based on the popular Arduino microcontroller. The device is designed for use as a stability and navigation controller for unmanned vehicles, boats or aircraft [3]. In addition to being fully programmable, the ArduPilot also interfaces directly with GPS, inertial sensors and others assorted sensors needed to create a functional unmanned aircraft. It is also supported by a detailed online manual and support community [4].

The heart of the ArduPilot is the ATMega328 capable of providing up to 20 million executed instructions per second at 20 Mhz [5]. The autopilot also features a separate 16MHz ATTiny processor to act as failsafe in the event of a failure of the main controller. The device interfaces with common GPS modules and features six analog inputs, six digital input/outputs and a spare serial port for wireless telemetry. The device also features an extremely small profile at just 30mm x 47mm. The APM main board is shown in Figure 5.

![ArduPilot Mega main board](image)

Figure 5: ArduPilot Mega main board

The ArduPilot is capable of providing stabilized flight in five modes. These modes vary in their degree of autonomy and can be used for various functionalities of the UAV.

In its most basic function, it will stabilize an aircraft under manual flight. This means that the aircraft can be completely controlled by the pilot but will return to straight and level flight when the control sticks are released. In fly-by-wire mode the aircraft will still be under manual control but the software limits the range of inputs allowed by the operator. For instance, the operator will not be able to roll the aircraft past a preset safe angle. This allows for easier control of the RC airplane. In autopilot mode the aircraft will fly a predefined route set in its memory using GPS as its main navigation source. The operator can influence the flight path of the aircraft slightly, but the airplane is flying autonomously at this point. This will be the primary flight mode for our system.

In return-to-launch mode the aircraft will set the next stored GPS waypoint as home, and enter a loiter around that point. When in loiter mode the aircraft will circle a given point at a set
distance. The parameters of the loiter are adjustable in the code. Finally, an automated takeoff and landing mode is currently in the experimental phase in the official software release.

3.1.2 Guidance, Navigation and Control

Guidance, navigation and control are provided by a series of software control loops programmed on the autopilot microcontroller. Two cascaded control loops are needed: one to provide flight control, the other to handle navigation. Additionally, the information provided by the flight sensors need to be mathematically interpreted in some meaningful way. This task is handled by a transform known as the Direction Cosine Matrix (DCM). Much of work on the ArduPilot’s control method was done by Robert Mahony [6], [7], [8], [9], [10].

The ArduPilot stabilization method is designed to be a computationally light-weight attitude stabilization method. By combining measurements from the accelerometers and rate gyros, the software develops a accurate sense of the aircrafts orientation. Data from the gyros are used to integrate the nonlinear equations of aircraft dynamics that relate the time rate of change orientation to the present orientation. These calculations are done approximately 40 to 50 times per second. As numerical errors accumulate low-frequency data from the GPS and accelerometers are used to correct.

In addition to the main control algorithm, aircraft stabilization and navigation is controlled by a series of two, cascaded PID loops. The inner most loop handles all control and stabilization tasks. Gains in this loop will alter the sensitivity of pitch, roll and yaw. The inner loop handles the navigation performance.

3.1.3 MAVLink Communication Protocol

MAVLink is a lightweight message marshaling library for micro-air vehicles. The MAVLink protocol can handle communication between up to 255 aircraft. The protocol is very efficient and features drop detection and an ITU X.25 checksum to detect packet corruption. Currently, MAVLink is fully supported by the ArduPilot Mega and available ground stations. All the source code and documentation on MAVLink is open source and is currently being maintained by researchers at Eidgenssische Technische Hochschule in Zurich, Switzerland [11].

3.2 Flight Sensors

The flight sensors are needed to gather information about the aircraft’s state in the air. This information includes altitude, airspeed, pitch, roll, yaw, position and heading. Taken together, this information allows for the creation of a total picture of the aircrafts state. With this picture control and navigation decisions can be made. The flight sensors outlined below are airspeed/pitot tube, barometric pressure, inertial measurement unit, and global positioning systems.

All sensors required for the ArduPilot Mega are contained on the single sensor board shown in Figure 6 below.

3.2.1 Airspeed and Altitude

The airspeed and altitude data are provided by two separate pressure transducers. Altitude is provided by a Bosch BMP085 barometric pressure sensor. This transducer offers 0.03 hPa sensitivity.
and low power consumption. This data from this sensor is used to enhance altitude data received from the GPS.

The airspeed data is provided by a differential pressure transducer and small pitot tube mounted on the right wing. This sensor measures the difference in pressure between the active and static pressure ports on the pitot tube. Readings are also combined with GPS data to provide a more accurate picture.

3.2.2 Inertial Measurement Unit (IMU)

The Inertial Measurement Unit (IMU) is a device capable of measuring velocity, orientation and gravitational forces, using a combination of accelerometers and gyroscopes. The information collected from this instrument is essential for providing control and navigation commands for the UAV. IMU’s are commonly found on aircraft, spacecraft, watercraft and guided weapons.

The IMU used here is entirely solid-state, allowing it to be sufficiently small and light-weight to be placed on the aircraft. These sensors are based on Micro-Electromechanical systems (MEMS) based technologies. An accelerometer and gyroscope is provided for each aircraft axis. One InvenSense IDG-500 dual-axis gyro provides information for the X- and Y-axis. A single ISZ-500 single-axis gyro provides information in Z-axis. Acceleration is measured by a single, triple-axis Analog Devices ADXL-335 sensor.

3.2.3 Global Positioning System (GPS)

While the IMU provides sufficient information for dead reckoning navigation, this data is not relative to any geographical location. The Global Positioning System (GPS) provides a large deal of information including ground speed, altitude, heading, latitude, longitude and time. Many commercial GPS receivers are available and for this application the uBlox GS407 module was chosen. This module interfaces easily with the ArduPilot and is pre-configured for use with that autopilot. Positioning data is received from the module at a rate of 2 Hz, but can be increased to 4 Hz if necessary.
3.2.4 Telemetry Radio Systems

While not technically a flight sensor the telemetry radios are an essential part of the unmanned system. Without some method of transmission of the flight data to human operators, the system would not be useful for real-time applications. The telemetry radio system is main method of communication between the operators on the ground and the aircraft systems in flight.

For this system two Digi XBee Pro 900 RF modules are used. One module is placed in the aircraft while another is kept at the ground station. The XBee modules feature a line-of-sight range of up to 6 miles with a high-gain (3.1 dBi) antenna. The radios operate on the 900 MHz ISM band and are capable of transmitting data up to 230 Kbps. The radios also feature frequency hoping in 8 patterns across 12 channels, and 128-bit AES data encryption.

3.3 Spektrum DX-7 RC Controller

Since the aircraft must be able to be manually overridden and flown by the operator on the ground, a standard RC controller is required. The Spektrum DX-7 RC controller is used to fly the airplane when it is not in automatic mode. This controller is also used to change between the different flight modes on the autopilot. The controller operates on the 2.4 GHz band and features spread spectrum technology and receiver binding to prevent interference. The 2.4 GHz band is avoided by all the other radios to prevent interference in the system. The controller is shown in the Figure 7.

![Spektrum DX-7 controller (without antenna)](image)

Figure 7: Spektrum DX-7 controller (without antenna)

4 Vision and Target Identification System

The vision system only one of many possible payloads that could be mounted to the UAV. Its operation is independent from the operation of the unmanned system and is not required for flight. The vision and target system is used as the primary source of visual intelligence data. Using its camera and radio transmitter, it relays this vital information down to the operators at the ground station.
The vision system consists of a video camera located on the underside of the plane, a transmitter connected to the video camera located in the fuselage of the plane, and a receiver located at the ground station. This system takes an image input from the camera and transmits it to the ground station using the transmitter and the receiver.

4.1 Camera

The camera chosen for our application is the DX201 DPS camera. It is a small, light-weight camera housed in a rigid metal case. The case measures 32x32 mm and weighs 36 grams. The camera features a resolution of 540 TV-lines horizontal which is sufficient to collect visual data from high altitude. To counteract the effect of overexposure the camera software will automatically balance the exposure of each individual picture guaranteeing a clear view in all light settings.

4.2 Video Transmitter/Receiver

The transmitter/receiver is a 900 MHz 500 mW aerial video transmitter. This 900 MHz frequency was chosen to avoid the 2.4 Ghz frequency used by the RC controller. The receiver end of the vision system outputs directly so analog-video output. To digitize this image for later processing an analog-digital video converter was needed. For this purpose the Hauppauge USB-Live 2 was chosen. This hardware successfully interfaces with VLC media player and Matlab.

4.3 Image Processing and Target Identification

To further reduce the burden on the UAV operator it is possible to include a high level of autonomy to aid in target detection and identification. This increase the speed and accuracy of identification, and improve mission success. While this technology is not available in the current unmanned system it is a viable feature in future versions.

Image processing is a highly developed science but independent of UAV specific research. Many different image processing software packages are available as open-source or commercial software. Some examples include Matlab, LabVIEW and OpenCV. On an experimental basis a demo image processing interface was developed using LabView. LabVIEW is a user-friendly approach to doing task like Object Character Recognition (OCR), color, and shape detection. It uses a simple OCR and color training modules to create a library of characters and colors in which to recognize.

A screen shot of the software in show in Figure 8. The image is a simulated picture that was made to test the image processing software.

In this sample, the Region of Interest (ROI) can be seen on the image defined by the green box. After running the program, it is seen under the image that the program recognized the letter N on the target, and it also identified the color as orange. Figure 37 shows the program with a different ROI highlighted. At the time of writing this software is experimental and is not a part of the Aetos UAS.

5 Ground Control Section

The Ground Control Station (GCS) is the primary method of control of the unmanned aircraft. All information regarding the orientation and status of the aircraft and all important navigation is shown on this display.
Originally, the team wanted to create a custom GCS that would meet the needs for the competition in a clear and minimalist fashion. Work started on this software in the beginning of the spring semester, but by the half-way point it was clear that development was not proceeding fast enough to ensure completion before June. It is important that the GCS be thoroughly tested and stable before it is used with the UAV. The team had only one developer and it was clear the undertaking was too large for the given time frame. This software was saved for possible future use.

Several GCS software programs are available for free online. These programs offer many features and are generally highly tested and stable. For the competition the team is investigating two possible options: HK GCS and QGroundControl. Both these systems will meet the requirements for the competition and it is just a matter of choosing the best option. This decision will be made in the coming weeks before the competition.

5.1 QGroundControl

QGroundControl is an open-source ground control station available for Windows, Mac OS and Linux. It fully supports the MavLink micro air vehicle communication protocol. The software features 2D/3D aerial maps with drag-and-drop waypoints, in-flight manipulation of onboard flight parameters and real-time plotting of sensor and telemetry data. The software can support up to 255 air vehicles and features support for UDP, serial modem and mesh network communications. A screen shot of the software is shown below in Figure 9.
5.2 HK GCS

The HK GCS is the software officially support by the ArduPilot project. It features many of the same abilities as the QGroundControl including MAVLink support and in flight modification of flight parameters. Currently, this software is only available on the Windows platform. A screen shot of this software is shown in Figure 10.
6 Flight Testing and Safety Precautions

6.1 Hardware-in-the-Loop (HiL) Testing

An important tool to the team in the initial testing and integration of the system has been the Hardware-In-the-Loop (HIL) simulation. This allows testing to be done in the lab at any time, without worrying about outside factors such as weather and location. An advanced flight simulator called X-Plane is used to create a virtual environment for the hardware. X-Plane has been used in the professional industry to simulate prototype air vehicles before they are tested, and is certified by the Federal Aviation Administration (FAA) as a certified flight simulator [12].

Using the X-Plane Plane Maker software, a model of the Easy Cub was created for testing. The software will approximate its flight characteristics based on the dimensions, allowing the team to get an understanding for how the aircraft will behave. Figure 11 below shows the model in X-Plane compared to a photograph of the Easy Cub.

![Figure 11: Comparison of real aircraft with X-Plane model](image)

6.2 Field Testing

An iterative test plan was created in order to integrate each component independently as to reduce any chance of error. With each flight test, a new component was to be tested, so if any errors arose, the source would be easy to determine.

First, the plane was flown manually without the autopilot to ensure the aircraft flies. Then the autopilot was introduced, to transmit wireless telemetry to a ground station. After the airplane was successfully flown with the autopilot onboard, control of flying the airplane was given to the autopilot. First tested was the stabilize mode, which keeps the pilot on the ground still in control, but when no input is given by the pilot on the ground the plane will level itself. Once it is proven that the autopilot can control the airplane, the navigation will be tested to ensure it will fly waypoints. From there, modifications and tuning would be done to maximize the efficiency.

During each flight, several recording tools are used as a reference to refer back to after the flight. A very small, lightweight CMOS sensor video camera was placed on the plane to give a first-person perspective of the plane in flight. With this video footage, the flight characteristics could be determined from a first person perspective on the plane, and can show exactly what happened. The flights were also recorded with a video camera from the ground for a record of the flight. Once the telemetry data is streaming to the ground station, software called CamStudio is used to record the screen. Using this information, detailed videos of each test flight were recorded and later analyzed.

Several issues needed to be overcome in order to perform successful flight tests. A major issue with the testing of the aircraft is the weather, see Figure 12. Winter in Massachusetts does not yield for many calm, clear days that would allow for a test flight. Several test flights had to be
canceled while in the field as a safety precaution to protect the aircraft and its components. Due to the nature of the project, this has been a significant factor for holding back the test schedule.

Along with the weather, finding a location to fly the aircraft has been very difficult. Since Wentworth is in an urban environment, there are no places to be able to fly an unmanned plane. Since the aircraft is in a test phase one of the main concerns is safety. Precautions need to be taken to ensure that no people or property is threatened. For this reason, a field in Walpole, MA has been used for test flights. It is very open, and there are no immediate people or homes in the vicinity. However, the location is still a 30 minute drive. This means that the team must find a time to go, prepare, drive to the field, and hope for good weather. These two factors have been the significant source for preventing test flights.

6.3 Safety Considerations

Since the Aeto UAV is being flown in a research stage, safety was an important consideration in every design decision. Wherever possible, redundant systems were used to prevent the possibility of catastrophic failure. The autopilot features a secondary backup failsafe system that allows the operator to take control of the aircraft in the event the main autopilot fails due to software or hardware problems. However, since this aircraft is small, redundancy is most of the other systems was not practical.

The power system was broken up into two separate modules. With this design all vital flight electronics are kept separate from the main batteries used to power the motor. This way, even if the main battery is exhausted, the autopilot and RC receiver will still remain powered.

Finally, in the event the RC radio looses contact, the aircraft will automatically execute a Return-To-Launch command. The home waypoint is programmed automatically upon startup of the aircraft systems. Therefore, in the event the aircraft is flown out of the range, the autopilot will return it to this home location.
7 Acknowledgments

7.1 Sponsors and Special Thanks

Team Aetos would like to thank the following sponsors:

The team would also like to thank the following people for their help both technically and financially. Professor Salah Badjou for his help during consultation throughout the development process. Dean Fredrick Driscoll and the Department of Electronics and Mechanical Engineering at Wentworth Institute for provided substantial financial support. Wayne Howes for help choosing, building and flying RC aircraft. Radu Gogoana from the Massachusetts Institute of Technology’s Mechanical Engineering Department for use of their laboratory equipment. Finally, the Student Leadership Program at Wentworth Institute for provided travel funding.
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