A Novel Generation of Autonomous Airplanes AUVSI 2006

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***Abstract*— Embry-Riddle Aeronautical University (ERAU) in coordination with the Advanced Aerial Robotics team initiated plans for developing an Autonomous Aerial Robot (AAR), also known as HATHOR. Making a reliable, affordable, and safe product became the bases of Hathor's construction. In early phases of the project, the team embarked on a possible solution for designing and constructing a unique autonomous system. The complexity of the systems, budget restrictions, and the learning of an unfamiliar technology presented the greatest challenges to the design process. To initially handle these challenges, an MP2028g from Micro-pilot Inc was chosen as the navigation system, thus saving time and money. This allowed the team to focus in other areas such as the video & imagery system quality and reliability. In addition to the MP2028g micro-pilot, which operates at a frequency of 910 MHz, the following off the self components were integrated to form EAGLE 1 and EAGLE 2: a 20mile wireless video system AAR05-4 for real time data and imagery, a 20 mile transceiver for imagery transmission, two Sig Kadet Senior with modified wings and fuselage, a Saito FA100 1.00 (cu. in.) with single cylinder ringed 4-stroke engine, , a Panasonic Lumix Lx1 digital camera, and a Futaba PCM/PPM 7 channel digital proportional R/C system (transmitter & receiver).**

A. Listing of Nomenclature

AAR	Autonomous Aerial Robot
AGL	Above Ground Level
AMA	American Model Academy
CG	Center of Gravity
ERAU	Embry-Riddle Aeronautical University
GPS	Global Positioning System
UAV	Unmanned Aerial Vehicle
μP	Micro-pilot
rpm	Revolutions per Minute
r/c	Radio controlled

I. Introduction

In recent years, there has been a rising interest in the aviation industry towards cost effective Unmanned Aerial Vehicles (UAV). The technological advancements in robotics, avionics, and surveillance equipment have set the stage for UAV's to become a strategic tool in military and domestic use. A UAV by definition is any aircraft that flies without a seated pilot. Some UAV's are the size of a common model aircraft, while others exhibit larger tendencies. UAV's have played a major role in aviation almost since its inception. Similar to ERAU's role in the study of aviation, the Embry-Riddle Advanced Aerial Robot (Hathor) team took initiative and implemented two goals for the 2005-2006 year. The first goal consists in exposing our student population to a better understanding of autonomous systems, including its potential and future benefits. Furthermore, the main goal is to acquire the necessary knowledge and experience in the aspects related to the engineering process of a UAV and consequently apply it to the 4th Annual AUVSI Student UAV Competition.

A. Team Hathor

Team Hathor, which is now called the Advanced Aerial Robotics Team, started in the beginning of the Fall semester of 2005. All members, are undergraduate students at ERAU, with the exception of Mike O'Gara who is a graduate student also at ERAU.The faculty advisor for the team has been Dr. Darris White from the Mechanical Engineering Department. Although the realization of a successful autonomous airplane has been a collective work, we recognize the great leadership of team-member Abraham Chavez. The following, is a list of all active team-members.

1) Abraham Chavez
   ↪ *Aerospace & Mechanical Engineering*
2) Michael O'Gara
   ↪ *Aerospace Engineering*
3) Manuel Calleja
   ↪ *Aerospace & Engineering Physics*
4) Freddy Elorza
   ↪ *Aerospace Engineering*
5) Kyle Griffin
   ↪ *Aerospace Engineering*
6) Wesley Hebert
   ↪ *Aerospace Engineering*
7) Miguel Marmol
   ↪ *Aerospace Engineering*
8) Said Rahimzadeh - kalaleh
   ↪ *Engineering Physics*
9) Stephen Stegall
   ↪ *Aerospace Engineering*
10) Jake Turnquist
   ↪ *Aerospace Engineering*

II. Competition Requirements

The complete mission objectives are for an unmanned, *r/c* aircraft to be launched, transition and/or continue to autonomous flight, execute a specified GPS course, and finally to locate and transmit a series of geometric shapes using an

Fig. 1. Team Hathor; AAR

imagery system, including the coordination and orientation of objects.

A. Takeoff

Takeoff must take place within one of the two designated Takeoff/Landing areas, depending on wind direction. The 100 ft wide paved asphalt surface will have no height obstacles. Extra points will be awarded for autonomous takeoff, but take-off can be either manual or autonomous. The vehicle must then transition to autonomous flight mode before the next mission phase. The air vehicle must maintain steady, controlled autonomous flight at altitudes above 50 feet and under 500ft AGL.

B. Mission Phases

1) *Dynamic Air Vehicle Control*
Dynamic control of the air vehicle during autonomous flight will be proved by changing airspeed, altitude and heading as directed by the judges.

2) *Waypoint Navigation*
Waypoints (GPS coordinates) will be announced the day prior to the competition. Air vehicles will be required to pass over selected waypoints, remain outside of no-fly zone waypoints and search a specified area .

3) *Targets and Interaction*
Specific target information will be announced the day prior to the competition. At some point during the mission, the air vehicle must proceed to a designated area and search the area for specific targets, report GPS location and provide imagery. Resolution will be graded based on:
   - The total number of targets
   - The coordinates of each target
   - The orientation of each target

C. Landing

Landing must occur completely within the designated take-off/landing area. Extra credit will be awarded by autonomous landing but manual control is permitted. The mission will end when air vehicle motion ceases and engine is shutdown.

D. Total Mission Time

Mission must be completed within 40 minutes, and it includes preflight, take-off, mission flight, land and data processing.

E. Weight Restriction

The gross weight of the aircraft with payload at take off must be less than 55 lb.

III. Prototype Aircraft

Since this is the first year all team members are participating in the AUVSI competition, experience needed to be gained before risking the sole aircraft the team had. Therefore, an LT 40 Sig Kadet served as a prototype to the team. This aircraft was mainly used to obtain experience in the engineering process of a model airplane. Valuable experience was also obtained in the process of integrating the camera system in this aircraft. For example, the team learned that the fuselage required modifications in order to have more room for the electronics. The mistakes made during this initial stage of the process served as great experience in order to not make the same mistakes in further stages with the main aircraft. Next, the aerodynamic features of the LT 40 Sig Kadet are presented.

Wing Area (ft^2)	7.52
Aspect Ratio	4.5
Leading Edge Sweep$^{(\circ)}$	0
Taper Ratio	1
Span (ft.)	5.85
Cord (ft.)	1
MAC (ft.)	1.08

IV. Sig Kadet Senior System Description

A. Airframe Description:

The team is utilizing a modified SIG Kadet Senior kit plane to accomplish this year's competition objectives. In fact,two identical Sig Kadets, will be carried to the competition to prevent possible failure that may arise from problems with either aircraft. The front fuselage of the airplanes was extended approximately 3 inches compared to the kit plans in order to allow for more space for necessary components. Also, ailerons of 19 inches were incorporated into the main wings for more control during flight. In addition, the wings were fiberglass reinforced as a safety precaution due to the extra loading on the wing resulting from added payload. The aircrafts are propelled by a Saito FA100 1.00 cu in (17.1cc) Single Cylinder 4-stroke Engine.

B. Aerodynamic Characteristics

In order to determine the aerodynamic parameters, several physical measurements were done to the aircraft. These measurements were were mostly done using devices including metric lines, chords, and rulers.

The main parameters used for calculations are the following:

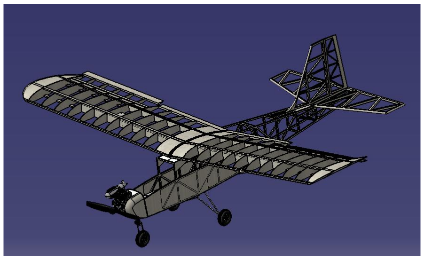

Fig. 2. Sig Kadet Senior: Isometric View

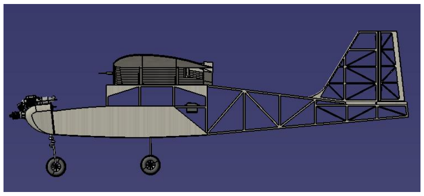

Fig. 3. Sig Kadet Senior: Side View

Wing Area = S

Taper Ratio: $\frac{C_{TIP}}{C_{ROOT}} = \lambda$

Sweep of $\frac{c}{4} = 0$

Wing Twist Angle $= \theta$

Wing Area (ft^2)	8.56
Leading Edge Sweep$^{(\circ)}$	0
Taper Ratio	1
Span (ft.)	6.5
Cord (ft.)	1.5
MAC (ft.)	1.27

Sample Calculations for One Wing
A1= 0.296 ft2
A2= 0.254 ft2
A3= 0.00281 ft2
A4= 2.253 ft2

Equation of the line L1 in 2-D, for *y* as a function of *x*, placing origin at point (0, 0):

$$y = -9E - 5x^6 + 0.0028x^5 - 0.0318x^4$$
$$+0.1699x^3 - 0.467x^2 + 1.0499x + 1.0484 \qquad (1)$$

Integrating across the chord

$$A5 = 0.287ft^2 \qquad (2)$$

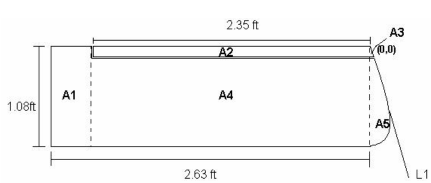

Fig. 4. Wing Dimensions

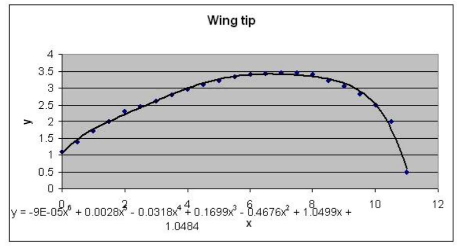

Fig. 5. 2-D Projection of the Wing Tip Described in Equation 1

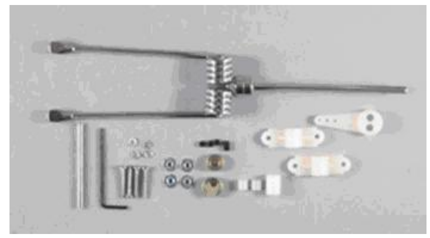

Fig. 6. Dual Strut Landing Gear

We therefore obtain a total area for the two wings of 7.52 ft^2.

C. Landing Gear

Due to the additional weight, a tricycle landing gear with a dual 4”strut nose gear was chosen to support the 10.6 lbs. of gross weight. The strut has an extra large pivot shaft which provides a stronger support. In addition, the back landing gear was also reinforced by tack welding cross-sectional members and thus making it stronger and safer. In order to determine the areas of most stress concentration, finite element analysis tensile tests were done with the help of *NASTRAN*©.

D. Carbon Fiber Propeller

Eagle I and Eagle II utilized a $14x10$ reinforced carbon fiber airplane propeller. This propeller gives the airplane a thinner profile with more ”bite” and less noise, and gives it a higher power output and longer life. The decision to use this kind of propeller was based on previous experience with other propellers of different sizes and materials (glass filled nylon) which proved to be more likely to fail or brake,making them unreliable and less cost effective.

E. Metal Spinner

Both Eagle I and Eagle II required modified metal spinners due to the engine’s size. It was discovered that propellers fastened to the engine with a metal nut spinner are unreliable. This is due to the fact that vibrations from the engine broke away the bond between the lock tight and the threats of the metal nut spinner. Since safety has been the main concern of the team at all times, a 3” metal spinner with dual connector and housing was chosen to allow the propeller to withstand the vibration created by the engine and thus keeping the propeller in place.

Fig. 7. Carbon Fiber Propeller

Fig. 8. Saito 100 4-Stroke Engine

F. Wing Modification

Fiber glass coats were added to the Sig Kadet Senior in order to provide better structure stability and longevity. Along with reinforcing the Sig Kadet Senior wing with fiber glass and adding ailerons, the AGL sensor was also mounted flush inside the wing in order to provide fast and easy access. Based on previous experience with Eagle I, the AGL sensor was relocated farther down the wing to prevent any possible problems that may arise from fuel getting inside the AGL sensor.

In order to expedite the preparation process during the 40 minute time limit, $\frac{1}{4}-20$ bolts were added to fastened the wing to the plane's fuselage. Through experience, it was discovered that using rubber-bands was inefficient, time consuming, and unsafe for the electronics.

G. Fuel Tank and Engine Upgrade

The Saito 100 4-stroke (Fig. 8) engine was chosen due to its fuel efficiency and power. Several different engines, like the 46 LS, were tested. However, these engines were found not to have the necessary endurance, power, and aircraft performance needed to complete the mission. Several trials simulating the 40 minute course were completed with the Saito 100 engine. On an average, the 24 oz fuel tank ran for approximately $30-35$ minutes in each flight.

SAITO 100 FEATURES

Horsepower	1.8
Muffler Type	Cast
Mounting Dimensions	115 x 60 x 128mm
Fuel Consistency (f_c)	$10\% \leq f_c \leq 30\% Synthetic$
Benchmark Prop.	14 x 8 APC
Total Weight	21.1 oz.
Cylinders	Single, Chrome Plated
Type	4-Stroke
Displacement	$1.10in.^3$
Bore	1.14 in.
Stroke	1.02 in.
Engine(Only) Weight	19.5 oz.
Muffler Weight	1.6 oz.
Crankshaft Threads	M$8x1.25$ mm
Prop. Range	$13x9-14x10$
RPM Range	$2,000-11,000$

V. Navigation System

A. Autopilot / Navigation System

The aircraft utilizes a Micro-pilot MP$2028^{©}$ (Fig. 9) autopilot to offer complete autonomous flight. This system comes equipped off the shelf with the ability to maintain altitude and airspeed and accept programmable GPS waypoint navigation. The MP2028 uses an omnidirectional antenna, which is mounted on the left-side near the rear of the fuselage, to report accurate position and altitude to the ground station. An AGL sensor, included with the MP2028, provides the altitude information needed for autonomous takeoff and landing. The AGL is mounted on the right wing, away from the engine. The Pitot tube, located on the left wing's leading edge and connected to the MP2028 provides the airspeed information by measuring the dynamic pressure. The μP contains a built in IMU unit with integrated GPS signal decoder. It weighs 28 grams, and is 10 cm. long by 4 cm. wide.

B. Ground Control Station

To communicate with the UAV, the team is using the *Horizon*© software, which is included in the MP2028 packet. Through *Horizon*, we can load/create flight programs, change feedback gains, and configure our sensors and servos to observe and interact with the UAV in flight. Among the advantages of the Horizon software lies the fact that current sensor values are displayed in an easy to read gauge format, in which warning and danger levels can be set for each gauge. Horizon tracks the progress of the UAV in real time allowing the team of access critical mission data such as altitude, attitude, air speed, and position. To run *Horizon*, we use a Dell Latitude Pentium 4 1.8 GHz computer with a Windows XP operating system.

Originally, the team was using a receiver included with the Micro-pilot which operated at a frequency of 2.4 GHz. , with a 20km range. However, since the surveillance system was operating at the same frequency, the was severe destructive interference that was affecting both the surveillance and the navigation systems. Therefore, the μP's receiver has been

Fig. 9. MP2028^g Micro Pilot

Fig. 10. AGL Board and Transducer

changed for a similar one operating at 910 MHz. During manual flight, we utilize a 7CAP / 7CHP 7 channel PCM/PPM selectable radio control transmitter and receiver equipped with failsafe mode.

C. AGL Board and Transducer

The AGL board is an optional ultrasonic altimeter that provides high resolution altitude information. It also allows for autonomous takeoff and landing because it gives an altitude reading accurate to one inch. This accuracy is needed to make a safe and successful autonomous take off and landing.

D. Radio Modems

Microhard radio modem was included in the Micro-pilot package. This modem serves the purpose of communicating the team with the UAV. Once the team has established the waypoints in the Horizon software at the ground station, this modem sends the signal with the data to the UAV at a frequency of at 910 MHz. This modem also serves as a downlink from the micro-pilot to access the sensor data and monitor the state of the UAV. This modem provides an excellent range (20 km) and high data rates.

Fig. 11. Radio Modems

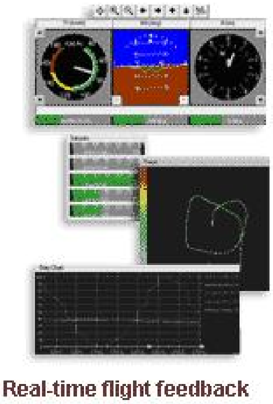

Fig. 12. Real Time Flight Feedback

VI. Surveillance System

A. Onboard Wireless Camera

To fulfill the onboard vision capabilities of the aerial robot, a closed circuit television system has been employed. The surveillance system used by the team is a AAR$05-4$ video system which was bought online at http://www.wirelessvideocamera.com. The package comes with an analog camera, transmitter, and a receiver with a grid dish. The transmitter/receiver system is rated for ranges up to 20 miles. The camera included in this package was a 450 CCD with focus capabilities and a lens filter to help the camera image in direct sunlight. The camera sends the analog system to the transmitter, which sends out the signal at 2.434 GHz. However, this camera was only used in the prototype airplane. In the next phase, when utilizing the Sig Kadet Senior, the team upgraded to a better camera which is described in the next section. The power supply for the camera and transmitter are 12 vdc battery systems at 180mA and 500 mA respectively.

B. Camera Upgrade: Panasonic Lumix LX1

The team's parameters for choosing a camera for the aircraft were: quality of image, size and weight of the camera, and the ability to provide an external stream. The most economical choice for this project is the Panasonic Lumix LX1. It is capable of a 4x zoom and 16x digital zoom, with a maximum zoom of 22.5x. It has a 8.4 megapixel CCD that provides clear and detailed image. It also contains advanced image stabilization which prevents the vibrations of the airplane from blurring the image. The camera is small and light weight (less then half a pound), which allows the team to accommodate it properly inside the aircraft. Another advantage is the fact the camera has a response time of one hundredth of a second when capturing an image and is capable of capturing two to

Fig. 13. Lumix LX1 Front View

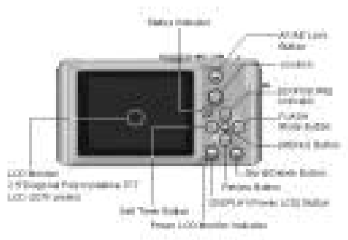

Fig. 14. Lumix LX1 Back View

three images per second. At its maximum memory capacity, it is capable of storing approximately one thousand high quality images.

Some modifications were made to the camera so the team may remotely control image capturing. The camera was disassembled and three leads were attached to the capture button; One to the ground, another to auto focus, and the last one to capture the image. Another set was attached to zoom switch for optimum control of the camera.

C. Ground System

To operate the autopilot and receive the transmitted video, the ground station is centered on a PC notebook. The μP software installs directly onto the notebook to interface with the autopilot. The software with the autopilot also handles the sending and receiving of GPS coordinates to and from the plane. Additionally, the notebook will also receive the video uplink from the receiver.

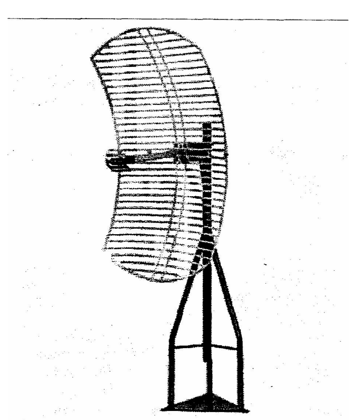

Fig. 15. 2.4 GHz Receiver Antenna

Fig. 16. Left to Right: Freddy Elorza, Miguel Marmol, Said Rahimzadeh

Fig. 17. PCICIA Card

The receiver system consists of the receiver itself and a grid dish. The grid dish is directional, meaning that for optimal reception, the dish needs to be oriented horizontally or vertically for the correct polarity. The signal is sent to the receiver and the receiver sends the signal to a television system. To process the video signal onto the notebook screen, a PCICIA card is used. With RCA jacks, the signal is sent from the receiver to the PCICIA card.

The PCICIA card is the device which will send the signal from the receiver/antenna system of the wireless video camera to the notebook. The card plugs directly in the PCICIA port of a notebook. The card supports both PAL and NTSC video formats such that it will also support European standard video. Once the video is displayed on the notebook monitor, it is now in a digital format. The video can now easily be processed by image processing software and possibly even MATLAB©.

D. 7CAP / 7CHP 7 channel PCM/PPM selectable radio control

The 7CAP/7CHP7 was chosen for its fail safe mode as required by the competition as well as for interference purposes. It was noticed with this radio control that the range was improved and interference was diminished.

Features: 10-model memory and 6-character model naming. Same Dial n' Key programming found on Futaba's 9C systems. Basic menu for everyday sport flying, Advanced menu for more complicated routines. Heli. and airplane control

layouts in FM or PCM
Mode Select feature: Three programmable mixes, adjustable throttle cut, fail safe (in PCM mode only)

E. power supply

Batteries	10 cell 12V Ni-Cd 1200mAh (video) 5 cell 6V Ni-Cd 1100 mAh (micropilot) 5 cell 6V Ni-Cd 1100 mAh (servos) 4 cell 4.8V Ni-Cd 600 mAh (receiver)

VII. Aircraft Modification

A. MP2028g Dampening System

The Saito engine, being so powerful, creates a lot of vibrations in an aircraft as light as the SIG Kadet Senior. These vibrations interfered with the gyroscopes in the μP. To correct this problem, several designs of systems to absorb vibrations were tried. First rubber bumpers, and later rubber-bands proved to be very unstable and insufficient. The solution that was able to reduce the vibrations to an acceptable level was to mount the μP on a platform of memory foam and foam weather stripping, thus allowing the gyroscopes to function properly.

B. Electrical Wiring and Antenna Locations

Several interference issues were found as a result of wiring. Therefore, all of the wire components were wrapped in aluminum foil and then wrapped with electrical tape. Different locations were tested to determine the location that will diminish the most interference between the transmitting antennas and electronics. The GPS patch antenna was attached to the top of the plane near the CG . Below the patch antenna, a thick sheet of copper plate was glued to the plane to prevent any radiation from this antenna to affect the other electronics. The μP modem antenna has been located in the front of the aircraft, just behind the engine. Originally, this antenna, which is omnidirectional had been place on the left side of the fuselage near the CG. However, the team needed to change the location of this antenna since it was creating destructive interference with the antenna from the surveillance system. For the same reason, the dipole antenna from the surveillance system was also moved to the tail of the aircraft. Finally, the r/c antenna runs from the middle of the fuselage to the tip of the right wing.

As a result of these modifications, our radio control range increased from a few hundred feet to almost a mile in manual mode. Other components like the MP2028g μP, extended range receiver, and r/c receiver were self-contained in aluminum boxes also wrapped with copper in order to minimize interference. At one stage of the project, the 2.4 GHz transceiver used for the camera system was also wrapped in aluminum foil and placed as far as possible from the 2.4Ghz μP antenna. Nevertheless, interference could not be avoided between these two components.This resulted in the previously mentioned change of μP modem to a similar one transmitting at a frequency of 910 MHz.

C. Frequency Requirements

The surveillance system on board of the airplane will be transmitting at a frequency of 2.434 GHz and with 1 W of output power. The $2.400 - 2.450$ GHz band is not only an amateur allocation, but it is also used by other services, including unlicensed low-power devices, such as cordless telephones and radio local area networks (RLANs). These include IEEE 802.11b and Bluetooth. In order to prevent interference, it is important to verify that neither of the above electronic devices is in use close to the receiving antenna. Since the transmitting power of the surveillance system is within the limits established by the FCC in Part 97.311 (d), no requirement other than a licensed user is needed. Team member Said Rahimzadeh, callsign KI4NKP, currently holds a technician class license allowing him to operate in this band. Since the surveillance system complies with the rules established by the FCC in Part 15, in accordance to part 15.19, labeling requirements, the following statement was attached to the transmitting payload: This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

During the initial stage of the project, the team suffered from severe interference issues which delayed progress. Based on that experience, the following steps were taken in order to diminish loss of signal and range between the r/c transmitter and the receiver while in manual and autonomous modes. Eagle 1 utilized an analog transmitter in which it's receiver antenna ran perpendicular to the plane's fuselage. Eagle II, on the other hand used a PCM digital transmitter as well as digital servos. In addition, all wires including the PWM servo cables, radio modem connectors, GPS antenna, 910Mhz μP antenna, and 2.4 GHz wireless camera dipole antenna were wrapped with aluminum foil and electrical tape, thus diminishing interference and doubling our transmitter range while in manual mode.

VIII. Flight Testing

Despite the encountered obstacles, several autonomous flights have been completed. Autonomous landings and take-offs are still the greatest challenges the team holds. Currently, progress is being made on the reconnaissance system which includes image quality, zooming capabilities and object location while in flight. Once the imagery and landing issues have been solved, constant and frequent testing will be done.

IX. Safety

Since the assembling of the first wood sticks that would later make the aircraft, safety has been of paramount importance to the team.Therefore, the following rules have been designed by the team for the safety of the team members, others, and the equipment of course. Every team member was notified that any violation of any of the rules deemed suspension from club activities and benefits. The safety regulations have been divided as follows.

A. Procedural Precautions

1) No drinks will be allowed near any computer or digital multimeter.
2) All flammable products must be kept in a locked fire-proof storage cabinet.
3) All hand tools must be signed out for each use and stored inside the tool box after.
4) Any members using any type of hardware or power-tools must were safety glasses at all times.
5) Any type of fuel spill must be notified to the team leader and must be cleaned up properly.
6) R/c plane testing must be performed outdoors and away from crowds.
7) Only approved personnel will be allowed to transport the r/c planes.
8) All members must be aware of the location of fire extinguisher and its proper use.
9) Only two members will be allowed to prepare the plane during testing (including competition). One to start the engine and the other one to place plane in runway. (only an AMA certified pilot will be allowed to start the engine).
10) Battery charging must be done properly and all leads must be connected properly.
11) When traveling to testing area, only certified drivers with proper insurance will be allowed to participate.
12) Only active members or approved visitors will be allowed to enter the Daytona Beach r/c field.
13) The Daytona Beach r/c gate must be locked at all times
14) After each flight, planes must be de-fueled, cleaned, and all trash must be disposed properly.
15) Appropriate safety equipment must be used while welding.

B. Aircraft Performance Precautions

The most obvious safety issue that arises from the flight of an autonomous airplane is the possibility of loosing control of the aircraft during autonomous mode. Therefore, the team has used a PCM transmitter as a manual backup control. This system allows to take control of the aircraft should the μP cease to function. It will also activate the failsafe mode, as depicted by AUVSI student competition rules thus preventing any accidents.

1) A range check must be performed before and after each testing. If any signs of malfunctioning are found, the plane will be grounded until such problems are fixed.
2) Failsafe mode must be on at all times
3) Plane will only be flown with newly charged batteries installed
4) Any spectators must be well clear of the airplane while the propeller is rotating.
5) All flight testing must be done by an certified and experience AMA pilot.
6) AMA pilot will take immediate control if there exist any danger while is in autonomous mode

X. Concluding Remarks

Although plenty of issues were encountered throughout all phases of the project, collectivism, creativity, and good leadership counter balanced all obstacles. Therefore, Team Hathor is a living proof that a first time student engineering team can achieve anything as long as there exists a strong desire and a commitment to succeed. In the preliminary stages of this project, each team member assumed different roles according to his capacities. However, as the project evolved, several team members took initiative and learned from areas never seen before, thus making this project a more comprehensive educational experience.

It is relevant to the process of this project the fact that all team members volunteered to participate on top of a full-time academic load, and in some cases, a part-time job as well. Nevertheless, the team enjoyed the great experience of obtaining a highly valuable education in the engineering process of UAV's. Close to the conclusion of this project, the team is convinced that the best way to learn about autonomous vehicles is by making one. Team Hathor feels great pride in the successful completion of an autonomous airplane with surveillance capacities which would have not been possible without the collaboration of all team members, faculty advisors, and sponsors. As a historic fact, it is remarkable that the team's hard work and dedication has placed it as the first team or club organization at ERAU to successfully complete an autonomous flight.

Embarking in this project has been highly rewarding for all team members. It has allowed each individual to experience different aspects of the engineering process. It has also familiarized the team with the real world engineering environment. Competitions and experiences sponsored by government officials and other entities will allow new generations to grow academically and as individuals, thus assuring a better quality of life for future generations.

XI. Acknowledgements

Team Hathor is very thankful to all the individuals and organizations that made possible the construction of an autonomous plane. The team also highly appreciates the existence of the AUVSI competition, which allows for students to learn practical engineering applications while having fun. The following lists represents the people and organizations which without them this project would have been impossible. Special Thanks to:

A. Organizations & Institutions

- Micro Pilot Inc.
- Embry - Riddle Aeronautical University
- http://www.wirelessvideocameras.com
- ERAU Engineering Department

B. Individuals

- Dr. Darris White (Faculty advisor)
- Jennifer Bell (Micro-pilot Inc)
- Joe Brannan (Naval Air Systems Command)

- Mark Pilling (Eagan McAllister Associates, Inc.)
- Jim Curry (AUVSI)
- ERAU President: Dr. Johnson
- Dr. Liu (ERAU Engineering Department)

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