

Final Design Report

Team # 6:

Autonomous Aerial Vehicle

EML 4551C – Senior Design – Fall 2012 Deliverable

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Table of Contents

Table of Figures.....	i
Table of Tables	ii
Problem Statement.....	1
Justification and Background.....	1
Concept of Operations	1
Objective	2
Constraints.....	2
• Gross Weight Limit.....	2
• Radios	2
• Takeoff.....	2
• Waypoint Navigation	3
○ Waypoints	3
○ Enroute Search.....	3
○ Targets.....	3
• Area Search.....	4
• Landing	4
• Total Mission Time.....	4
• Real Time Actionable Intelligence	5
Key Performance Parameters.....	5
• Autonomy	5
• Imagery -	5
• Target Location	5
• Mission Time	5
• Operational Availability.....	5
• In-Flight Re-Tasking -	5
Safety Precautions.....	6
RC Licensing and Regulations.....	7
Model Aircraft Rules and Regulations	7
Major Components Overview.....	9

Image Processing.....	13
Purpose & Top Level Design.....	13
Image Processing Algorithms	14
Target Color & Character Color Recognition.....	17
Target Shape & Character Shape Recognition.....	19
GPS Location Extraction	20
Image Processing Output	21
Image Processing – The Final Semester	21
Gimbal.....	22
Aerodynamic Characterizations.....	26
Budget.....	28
Autonomous Controls.....	29
Environmental Concerns.....	36
Looking Ahead	36
Works Cited.....	A
Appendix 1	B
Team 6 Gantt Chart.....	B
Appendix 2	C
Team 6 Code of Conduct	C
Appendix 3	F
Acknowledgments.....	F

Table of Figures

Figure 1: Search and Rescue Targets.....	4
Figure 2: Senior Telemaster - Acquired from last year's team	9
Figure 3: (Left) Helicopter with mounted camera(Angelo, The Flying Eye Project).....	10
Figure 4: Sony FCB Block Camera, (Shagieva, Singularity HUB)	11
Figure 5: ArduPilot Mega 2.5 (fully assembled)(Technologies, HCLTech.com)	12
Figure 6-top level design for the image processing system	13
Figure 7- Example Competition Target.....	14
Figure 8- Modular image processing system	15
Figure 9- Example targets	17
Figure 10- Algorithm output with blur filter	18
Figure 11- Example algorithm.....	20
Figure 12-Axes of rotation (Carnegie) The Axes of an Airplane.....	22
Figure 13- Image capture cycle.....	24
Figure 14- A square distorted due to perspective distortion (Logic-Orthorectification).....	25
Figure 15: Lift, Drag and Moment Plots (Stack) (left)	26
Figure 16: Lift Coefficient vs Alpha (right).....	26
Figure 17- ArduPilot Mega 2.5 (Anderson).....	29
Figure 18- Arduino Software	30

Figure 19- 3DR GPS uBlock LEA-6 (Anderson)	30
Figure 20- 3DR Radio Telemetry Kit (1)	31
Figure 21- APM Flight Planner	32
Figure 22- APM Flight Data	33
Figure 23- APM Simulation	34
Figure 24- Futaba 7CAP 7-Channel Transmitter and Receiver (Jantzen, Blackmon and Carr).....	35

Table of Tables

Table 1: Aircraft Decision Matrix	10
Table 2: Imaging system decision matrix 2	11
Table 3: Autopilot decision matrix	12
Table 4: Budget	28

Problem Statement

The purpose of this project is to design and construct an autonomous air vehicle for the submission into the 2013 Undergraduate Students Unmanned Aerial Systems Competition. The aircraft must adhere to specific tasks which will be outlined within this report and will be evaluated on how well it performs these tasks, as well as maintain consistency with the associated design and technical report. Upon successful completion of these specified tasks and design class parameters, Team Six will take this autonomous aircraft to Maryland in the summer of 2013 to compete.

Justification and Background

Unmanned Air Vehicles are an increasingly valuable asset in various applications. UAVs eliminate the need for on-board pilots and as such, the limitations associated with providing a livable environment for the pilot. Their use has increased significantly since their inception, and the next step in this developing interest is to apply complete automation to the systems already being used. The current UAV accident rate is 100 times that of manned aircraft, which reveals the current level of this technology as compared to manned flight. The benefits for furthering this technology are plentiful in the private and public sector alike. Scenarios for data tracking, weather crafts and first responder missions have all utilized the UAV. The Association for Unmanned Vehicle Systems International (AUVSI) has created an objective-based competition that will enable undergraduate students to be introduced to the field of unmanned air vehicles, automation, and image processing. This competition will encourage the development of this technology and give engineering students an opportunity to facilitate an engineering project.

Concept of Operations

An earthquake has impacted a small island nation in the Caribbean. Several boatloads of pirates who have been operating in the area have landed and are attempting to take advantage of the ensuing chaos. The overwhelmed local government has put out a call for help and the US Marines have responded. Their tasking includes humanitarian relief and security. Your unmanned aerial system (UAS) is supporting their mission with intelligence, surveillance and reconnaissance (ISR). In order to support them, your UAS must comply with Special Instructions

(SPINS) for departure and arrival procedures, and then remain within assigned airspace. It will be tasked to search an area for items of interest, and may be tasked to conduct point reconnaissance if requested. Additionally, the UAS may be tasked to relay data from a third party Simulated Remote Information Center (SRIC). Immediate ISR tasking may be requested outside currently assigned airspace, causing the UAS operators to request deviations.

Objective

This is a performance-based competition which will be evaluated in three major criteria: a technical report, a pre-flight presentation and inspection, and the execution of the mission itself. The objectives for this mission are clearly outlined by the SAE Aero Design East committee. The team must design and construct an autonomous UAV that will launch, fly a predetermined path as well as search a specified area, identify targets, provide images of the targets, send these images and location information about the target to a home station, and finally return and land. A time of twenty minutes is allotted for maximum points. The degree of autonomy and quality of launch and recovery will also earn points.

Constraints

The constraints for this project are outlined in the 2013 Undergraduate Students Unmanned Aerial Systems Competition. According to the Seafarer chapter the constraints may change once the final rules and regulations are posted. The following list is given in this report exactly as it is written by the Seafarer Chapter in order to give the reader as much detail possible to understand what is necessary for this design project to meet its goal of competing (AUVSI; International).

- **Gross Weight Limit** - The aircraft may not exceed fifty five (55) pounds in weight.
- **Radios** - The use of 2.4 GHz radio is required for all competing aircraft.
- **Takeoff** - Takeoff shall take place within one of two designated Takeoff/Landing areas, depending on wind direction. This area will be paved asphalt surface, roughly 100 ft wide, with no height obstacles. Systems utilizing launchers and/or not performing wheeled landing may utilize the grass immediately adjacent to the runway; however, grass area will not be prepared. Takeoff from moving vehicles is prohibited. Launchers will be inspected by competition safety inspectors before they are allowed for use in the

competition. After takeoff, the air vehicle shall maintain steady, controlled flight at altitudes above 100 feet and under 750 ft MSL (Note: airfield elevation is approximately 10 ft MSL). Takeoff under manual control with transition to autonomous flight is permitted. Extra credit and a cash award will be provided for autonomous Takeoff.

- **Waypoint Navigation** - Air vehicles must autonomously navigate to selected waypoints, and will be restricted to assigned airspace and avoid no-fly zones. A predetermined course which includes changes in altitude and in heading will be followed. Teams will fly a predetermined course that includes changes in altitude and in heading, to the search area.
 - **Waypoints** - GPS coordinates (ddd.mm.ssss) and altitudes will be announced the day prior to the flight competition. However, because of the dynamic nature of modern warfare, it is possible that additional waypoint(s) and/or search area adjustment(s) will be required.
 - **Enroute Search** – Air vehicles will be required to fly specific altitudes while identifying several targets along the predefined entry route. One of the targets will be directly along the route when the vehicle is required to be at 500 ft MSL (± 50 ft). Another target will be up to 250 ft from the center of the flight path while the vehicle is required to be at 200 ft MSL (± 50 ft). The team will be given the position of the off-center target. UAS shall not vary from the flight paths (± 100 ft tolerance) briefed during the mission planning in order to obtain an image of the target; flight path deviations shall not be permitted as to avoid being shot down by hostile or friendly forces. Enroute way points shall be achieved in order.
 - **Targets** - Targets will be constructed of plywood of a given size, basic geometric shape, and color. For an example, see figure 1. Each target will be a different shape and a unique color; a different color alphanumeric will be painted on each target. There are an unknown number of targets in the area. The additional target will be more reflective of a realistic surveillance target. The minimum dimension of the targets (length or width) will be 2 feet, and the maximum dimension will be 8 feet. Alpha-numerics will be sized to fit within the overall dimensions of the

target varying between 50-90% of the length/width of the target and between 2-6 inches in thickness, and will vary in color and contrast. The alphanumeric characters of the targets can be arranged to spell a “secret” message. Any team that can spell the message will receive bonus points and a cash prize.



Figure 1: Search and Rescue Targets

- **Area Search-** Once transitioning into the predefined search area via the entry/exit route, the air vehicle shall autonomously search for specific targets of interest. Air vehicles may search the area at any altitude between 100 and 750 ft MSL. Targets will be distributed throughout the search area. Competitors shall record the characteristics (location, shape, color, orientation, alpha, alpha color) of all observed targets on a target data sheet (and/or in electronic form) and provide this data to the judges at completion of the mission.
 - While executing the search mission, the team will be provided with a new search area (within the existing no fly zone boundaries) allowing you to locate “pop-up” targets. The “pop-up” target will be in the form of a human engaged in an activity of interest. There will be a minimum of 200 ft margin between the search area and the no fly zone boundary.
- **Landing-** Landing shall be performed completely within the designated takeoff/landing area. Transition to manual control is permitted for landing. Extra credit and a cash award will be provided for autonomous landing. Control in landing will be graded. Mission completion is when the air vehicle motion ceases, engine is shutdown, and the target data sheet and imagery have been provided to the judges.
- **Total Mission Time** - Total mission time is the time from declaration of mission start from the judges and permission to turn on transmitters until the vehicle has safely landed,

transmitters are shut off, and target data sheet (or spread sheet) is handed to the judges. Accuracy of results and time required to submit results will be measured. Missions completed between 20 and 40 minutes will receive some bonus points for each minute less than 40 minutes (must land vehicle, crashed and/or terminations do not earn bonus points); however, no additional points will be awarded for mission times less than 20 minutes. Significant points will be deducted for each minute over 40 minutes mission time, up to 60 minutes total where it is mandatory to turn in results. It should also be noted that each team will be given 40 minutes time to set up equipment prior to the beginning of the mission. After 40 minutes, the judges may declare mission start, regardless of the team's readiness to launch the mission. If 40 minutes has elapsed and the air vehicle has not achieved flight, the mission will be terminated.

- **Real Time Actionable Intelligence**-Extra credit will be given for providing complete and accurate information (actionable intelligence) during flight within the search area: once that information is provided, it cannot be modified later. Intelligence is actionable only if all six target characteristics (shape, background color, alphanumeric, alphanumeric color, orientation, and location) provided at that time and recorded on the target data sheet is correct. This will not be considered to be "real time" intelligence unless designated as such

Key Performance Parameters

While these measures will not disqualify a competitor, they are included in these constraints as failure to achieve the following thresholds will incur significant penalty.

- **Autonomy** - Maintain autonomy during way point navigation and area search.
- **Imagery** -Identify any two target characteristics (shape, background color, orientation, alphanumeric, and alphanumeric color).
- **Target Location** - Determine target location ddd.mmm.ssss within 250 ft.
- **Mission Time** - Less than 40 minutes total, imagery, location, identification provided at mission conclusion.
- **Operational Availability** - Complete 50% of missions within original tasking window.
- **In-Flight Re-Tasking** -Add a fly-to way point.

Safety Precautions

Flight operations of any type involve some level of risk to personnel and property. It is the responsibility of the individual teams to adhere to the safety guidelines beyond what ends up being stated in the rules and regulations. Before team six goes to the competition it will need to prove to sponsorship that it can operate, takeoff, fly and land within the boundaries of what is deemed as safe and efficient remote and autonomous flight. The list below contains some of the guidelines set forth by the Seafarer chapter for the 2013 competition

- The Maximum takeoff gross weight of the air vehicle shall be less than 55 lbs.
- The system shall provide sufficient information to the judges to ensure that it is operating within the no-fly/altitude boundaries on a continuous basis.
- The air vehicle shall be capable of manual override by the safety pilot during any phase of flight.
- The air vehicle shall automatically return home or terminate flight after loss of transmission signal for more than 30 sec.
- The air vehicle shall automatically terminate flight after loss of signal of more than 3 minutes.
- The return home system, if installed, should be capable of activation by the safety pilot.
- The flight termination system shall be capable of activation by the safety pilot.
- Flight termination for fixed wing aircraft without an alternate recovery system (like a parachute) shall select:
 - Throttle closed
 - Full up elevator
 - Full right rudder
 - Full right (or left) aileron
 - Full Flaps down (if so equipped)
 - The Fail-safe check will demonstrate flight termination on the ground by switching off the transmit radio for 30 seconds or 3 minutes (whichever applies) and observing activation of flight terminate commands.
 - The maximum airspeed of the air vehicle shall not exceed 100 KIAS.

RC Licensing and Regulations

Team six is currently in the process of obtaining local licensing and flight capabilities. There has been contact made with several different organizations in order to find out the appropriate steps to have the ability to fly the aircraft without the use of an outside source. This will save time and money as next semester begins, giving the team ample air time without relying on outside means to pilot the aircraft. Tallahassee law requires that a licensed RC pilot fly aircrafts within specific airfields designated for remote vehicles.

Model Aircraft Rules and Regulations

The following list of regulations comes from the FAA Modernization and Reform Act of 2012 set forth by the senate in an effort to govern the newly acclimated hobby(Senate). Minor regulations will vary from state to state, however being that the project competition is located in a different state, Team six will adhere to federal and state law and understands that federal law will take precedent in the event of any questions or misinterpretations.

- The aircraft is flown strictly for hobby or recreational use.
- The aircraft is operated in accordance with a community-based set of safety guidelines and within the programming of a nationwide community-based organization.
- The aircraft is limited to not more than 55 pounds unless otherwise certified through a design, construction, inspection, flight test, and operational safety program administered by a community-based organization.
- The aircraft is operated in a manner that does not interfere with and gives way to any manned aircraft.
- When flown within 5 miles of an airport, the operator of the aircraft provides the airport operator and the airport air traffic control tower (when an air traffic facility is located at the airport) with prior notice of the operation (model aircraft operators flying from a permanent location within 5 miles of an airport should establish a mutually-agreed upon operating procedure with the airport operator and the airport air traffic control tower (when an air traffic facility is located at the airport)).

- *Statutory Construction.*--Nothing in this section shall be construed to limit the authority of the Administrator to pursue enforcement action against persons operating model aircraft who endanger the safety of the national airspace system.
- *Model Aircraft Defined.*--In this section, the term "model aircraft" means an unmanned aircraft that is—
 - Capable of sustained flight in the atmosphere.
 - Flown within visual line of sight of the person operating the aircraft.
 - Flown for hobby or recreational purposes.

Major Components Overview

In order to successfully make it to the AUVSI competition, this year's autonomous aerial vehicle team is using a portion of last year's team's research and resources coupled with our own research and new objectives.

There are three major aspects of the competition that need to be addressed. First is flight. An aircraft platform that can support all of our needs and satisfy all of the requirements must be chosen. Second, is imaging and target recognition. A camera needs to be attached to the plane that can successfully and efficiently scan the ground for targets, as well as relay that information to a ground station. Finally, the third major component of the competition is that the first and second components have to be done autonomously. There needs to be an autopilot system integrated into the aircraft's controls such that once in the air, there are no corrections performed by the pilot.



Figure 2: Senior Telemaster - Acquired from last year's team

As previously stated, one of the first decision that needed to be made was to determine the aircraft that was to be used in the competition. Last year's team purchased a fixed wing aircraft which we had in our possession. The RC plane is called the Senior Telemaster and can be seen in Figure 2 above. Other common aircrafts used in the AUVSI competition are the helicopter, and the quadrotor seen in Figure 3 below.



Figure 3: (Left) Helicopter with mounted camera(Angelo, The Flying Eye Project)

(Right) Quadrotor with mounted camera(Jantzen, Final Design Package, Senior Design WebPage)

A decision matrix was used to determine what would be the most effective aircraft platform. The matrix can be seen below in Table 1. The criteria used in the decision matrix were determined and are as follows in order of importance: cost, lift to power capabilities, stability, ease of flight, and maneuverability.

Aircraft Decision Matrix		Senior Telemaster		Helicopter		Quadrotor	
Criteria	Max Weight	Grade	Weight	Grade	Weight	Grade	Weight
Cost	0.30	5	1.5	2	0.6	3	0.90
Lift to Power	0.25	4	1.0	3	0.75	2	0.50
Stability	0.20	3	0.6	2	0.40	3	0.60
Ease of Flight	0.15	3	0.45	2	0.30	4	0.60
Maneuverability	0.10	2	0.20	4	0.40	4	0.40
Total	1		3.75		2.45		3.0

Table 1: Aircraft Decision Matrix

As Table 1 shows, the Senior Telemaster is the best option. The reason for it being the best option is mainly due to the fact that we already had the plane on hand, which greatly reduces our cost. A large part of this project is to complete the tasks required while adhering to the given budget. Not having to take the cost of an aircraft out of our budget helps to accomplish that much easier. The airplane also has a higher lift to power (input power) ratio than both the helicopter and the quadrotor. This allows us to add components to the aircraft including but limited to a camera, GPS, autopilot, and not affect the characteristics of flight very much.

The imaging system was the next choice to be made. Last year’s group did some research and created a decision matrix in order to determine which camera would be best. They ended up deciding on the Sony FCB Block camera for the competition. The Sony camera has the capability of sending images as analog Video Blanking Syncs (VBS) and a high speed serial interface. In addition to having 18x optical zoom, the Sony camera also has the ability to customize the on-screen display. This customization will allow us to put information such as altitude, air speed, GPS location, and heading on the screen for easy viewing(Robotics, DIY Drones Amateur UAV Superstore). The decision matrix and camera selection can be seen in Table 2 and Figure 4 below.

Camera Decision Matrix		Nikon D300 DSLR		Sony KX-181 HQ		Sony FCB Block		Axis 212 PTZ	
Criteria	weight	Grade	Weighted G	Grade	Weighted G	Grade	Weighted G	Grade	Weighted G
Weight	0.2	2	0.4	5	1	4	0.8	3	0.6
Mounting	0.08	3	0.24	3	0.24	4	0.32	5	0.4
Resolution	0.15	5	0.75	3	0.45	3	0.45	3	0.45
Zoom	0.1	5	0.5	0	0	5	0.5	3	0.3
TX Ability	0.08	3	0.24	3	0.24	5	0.4	4	0.32
Price	0.15	1	0.15	5	0.75	3	0.45	2	0.3
Toughness	0.05	4	0.2	1	0.05	2	0.1	5	0.25
Power Req.	0.1	5	0.5	4	0.4	3	0.3	3	0.3
Dimensions	0.09	1	0.09	5	0.45	3	0.27	1	0.09
Total		29	3.07	29	3.58	32	3.59	29	3.01

Table 2: Imaging system decision matrix 2



Figure 4: Sony FCB Block Camera, (Shagieva, Singularity HUB)

Once the airplane is equipped with the camera, we will next need to install the autopilot system. As previously stated the autopilot system will control the aircraft throughout the entire mission. It is our goal to even have the plane takeoff and land via autopilot. The main autopilot systems

used by RC enthusiast are the ArduPilot Mega and the Paparazzi Tiny. Both systems were compared in a decision matrix that can be seen in Table 3 below.

Autopilot Decision Matrix		ArduPilot Mega 2.5		Paparazzi Tiny	
Criteria	Max Weight	Grade	Weight	Grade	Weight
Power Usage	0.35	3	1.05	3	0.6
Programming	0.30	4	1.20	2	0.75
Ground Station	0.20	4	0.80	4	0.40
Size/Weight	0.15	2	0.30	3	0.30
Total	1		3.35		2.90

Table 3: Autopilot decision matrix

The ArduPilot Mega 2.5 was chosen for our plane. The main factors in making this decision were that the ArduPilot can be more easily programmed by our team members and that the user interface on the ground station software that comes with the autopilot is more user friendly than that on the Paparazzi. An image of the ArduPilot Mega 2.5 can be seen below in Figure 5

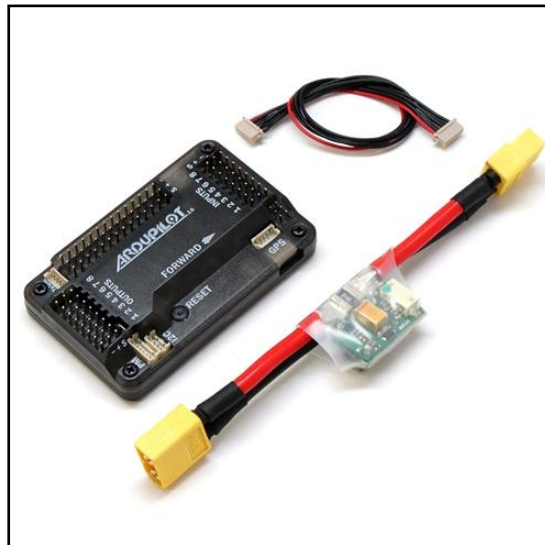


Figure 5: ArduPilot Mega 2.5 (fully assembled)(Technologies, HCLTech.com)

In addition to the ArduPilot Mega 2.5, we also purchased the 3DR Radio Telemetry Kit. The telemetry kit is made to be used with the ArduPilot Mega and allows the user at the ground station to communicate with the autopilot in real-time, allowing for the updating of waypoints, altitude corrections, as well as many other in flight changes.

Image Processing

Purpose & Top Level Design

The purpose for image processing within the scope of this project is to extrapolate six characteristics from each ground target using a ground computer in communication with the Sony FCB video camera attached to our air vehicle. The top level design for the image processing system that we have designed is shown below:

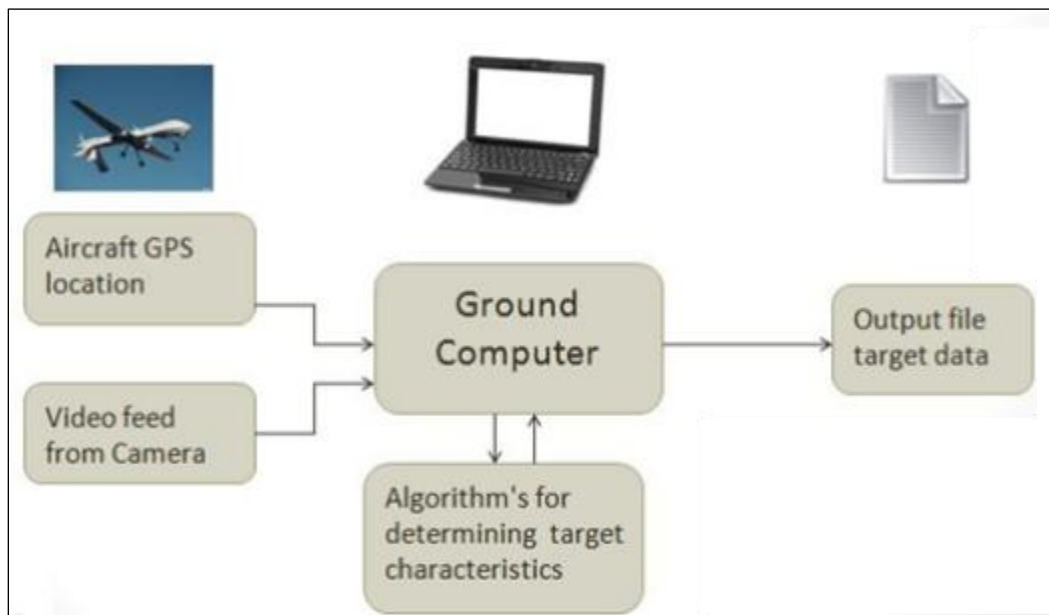


Figure 6-top level design for the image processing system

The process begins with inputs from Sony FCB video camera (the video feed) and the GPS location of the aircraft from the on-board receiver. Both these inputs are transmitted wirelessly from our air vehicle to our ground computer, and once received, the ground computer will match the video feed with its respective GPS location. The ground computer is programmed to continuously search each frame of the video feed for a target, and once a target is successfully recognized, it will capture that frame of the video for further image processing.

The captured video frame is then analyzed with image processing algorithms compiled using the open-source OpenCV computer vision library. The results of these algorithms are then outputted to a text document, while the video feed is still continuously being monitored for more targets.

Image Processing Algorithms

As previously stated, the general purpose of image processing within our competition is to extract relevant information from the ground targets using image processing algorithms. So before starting work on a solution it is important to define the constraints of the competition with respect to the target. The 2013 competition rules state:

"Targets will be constructed of plywood of a given size, basic geometric shape, and color."

From the perspective of a programmer, this statement is disheartening because “basic” is subjective in nature. Nonetheless, logical assumptions are made to define the possibilities of what a target can and cannot be. For a better understanding of the information needed to be determined from each target, an example target labeled with each characteristic is shown below.



Figure 7- Example Competition Target

To accomplish this information extraction, we have chosen to utilize the open-source computer vision library developed by Intel, OpenCV. OpenCV began in 1999 as an internal initiative within Intel to promote CPU intensive applications, and has since become the primary development tool for researchers and computer scientists in the field of computer vision(Bradski). The library itself consists of over 500 C and C++ algorithms, all optimized for efficiency by Intel, to be used for image and video analysis (Bradski). For use within our project, extensive time has been spent in researching to determine which OpenCV algorithms are best suited for determining each respective target characteristic. This process has resulted in the develop of a modular image processing system for determining target characteristics and is shown below:

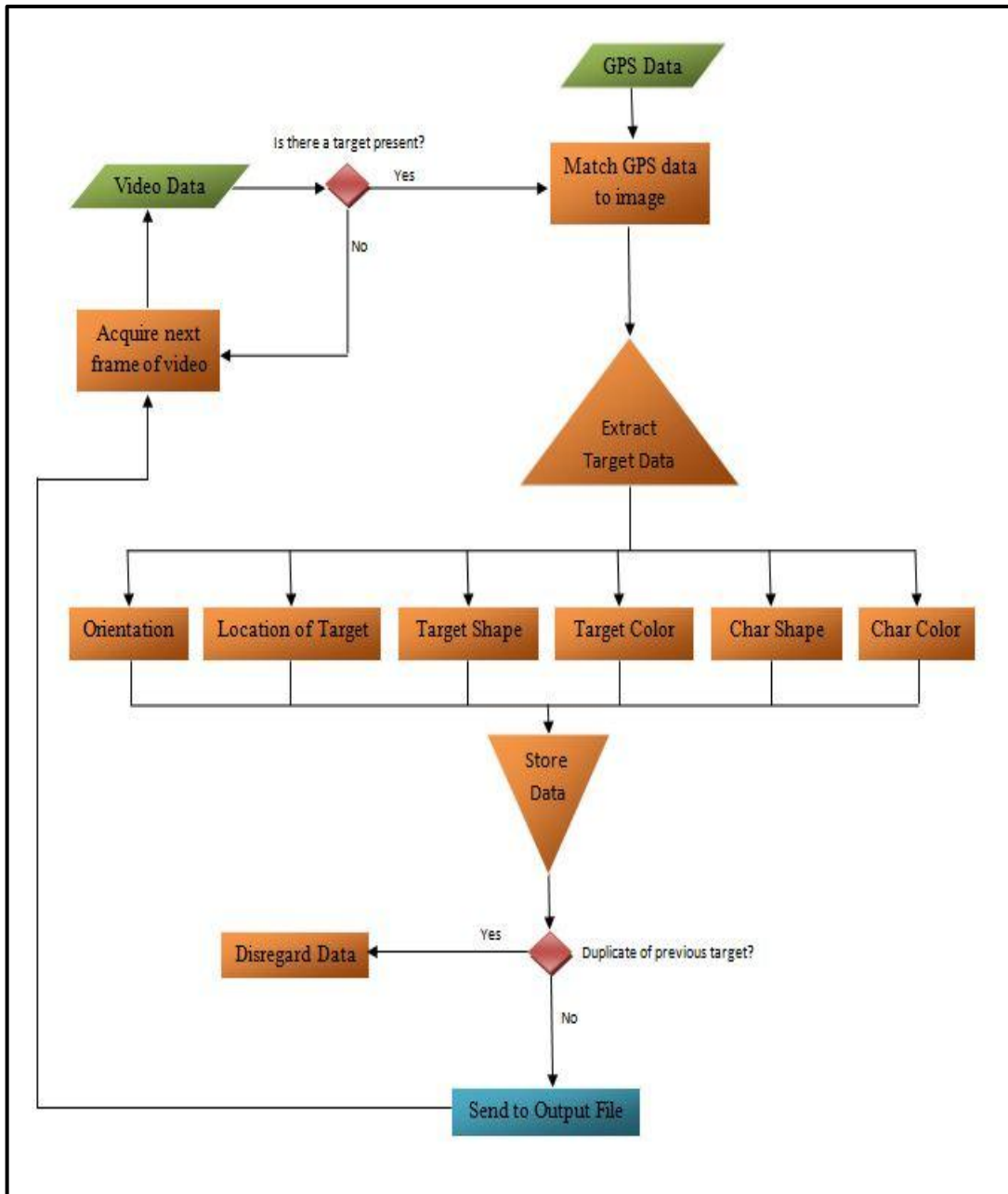


Figure 8- Modular image processing system

The first goal of our ground computer system, once successfully receiving the inputs from the air vehicle, will be to determine if, within that particular frame of video, a target is present. To do this, the frame of the video to be analyzed is first converted to a data type manipulatable in OpenCV. OpenCV provides the cvMAT matrix class which allows us to store images and video into an OpenCV defined matrix, and then manipulate them (Laganière).

After this is done, it is necessary to apply smoothing filters to the image (frame of the video feed). The logic we are using for identifying the target in the image is primarily focused on detecting edges in the image which result from the hue differences in color between the target and the background environment. So the desired filter for this logic is one that smoothes evenly throughout the image without smoothing the edges out. Many types of filtering algorithms exist in OpenCV, though for this application it has been found that a Gaussian filter is most appropriate and therefore the function `cvSmooth` was chosen. Now that the image has been smoothed, the edges of the target need to be detected, and for this OpenCV provides the function `cvCanny`. The Canny edge detection algorithm is essentially a refinement of a Laplacian edge detection method, but what makes the Canny algorithm more desirable in this application is that after finding an edge in the image, the method attempts to assemble the edges into contours (Laganière). The background environment has been filtered and is now just random noise within the image, so therefore if there is a contour present in the image, it can only be from a ground target. The final step in the process is to find the contours in the image and this is accomplished using the cleverly named OpenCV function `cvFindContours`. If there is a contour present, the image is sent to the next phase of analysis, and if not, the image is disregarded and the next frame of the video is assessed in the same manner.

The next step in the process, now that a target has been found within the image, is to match the original image to the corresponding GPS data. The competition provides a relatively large threshold for determining the target's ground location, and therefore assuming the determination of the target in the image will only take milliseconds to compute, the following successfully received GPS location will be utilized.

At this point, a target has been identified in the image, and the corresponding GPS location has been matched, i.e. all the inputs have been prepared, and the target characteristics are ready to be extracted. As shown in the flow chart above, a modular approach was pursued in the development of these algorithms. This was found necessary, because it allows our system to fail in certain modules (identifying certain characteristics) yet still produce a successful output. For testing, we were able to find the following targets, which we believe were most likely used in past years competitions:



Figure 9- Example targets

Target Color & Character Color Recognition

The first step in the process of identifying the color of the character and target is to convert the original image to the OpenCV manipulatable Mat data type. Once this is done, a filter is needed to reduce the noise from the background environment. When identifying the existence of a target we chose to apply a Gaussian smoothing filter in order to retain the edges of target within the image. For the process of color recognition, the retaining the colors is much more important and so through researching other filters in the OpenCV library, we found that the median blur filter is much more suitable for this application. This filter acts as a smudging agent, which works very well for determining the target color but at the consequence of completely eliminating information of the character in some cases.

After filtering the original image, the next step in the process of color detection is to convert the image from its current RGB (red, green, blue) color space to the HSV (hue, saturation, value). It is relatively common knowledge that combinations of the colors red, green, and blue can produce every other color in the visible spectrum. Using this additive property as a foundation, you can therefore visualize any color as just a point on a Cartesian coordinate system with axes of RGB instead of XYZ. The HSV color space arises as a cylindrical coordinate representation of the Cartesian RGB. It is valuable for our project to apply this conversion because it allows us to narrow our search of color in each image to just one variable, the hue (or H in HSV). Once the conversion to HSV is successful, we utilize another tool in image processing, the histogram, along with a logical assumption, to extract the color of each target.

A histogram is a table that is defined as a count of the number of pixels for a desired value (Laganière), and for our project that desired value is the hue. By creating a histogram of the hue values, we can then determine the most dominant hue in the image. We assume that because of the median blur filter applied earlier, along with the natural randomness of the background environment, the most dominant hue in the image must be that of the target. Once the dominant hue is found in the image, simple math can be used to see which color corresponds to that hue. Below is the output from the algorithm we have developed from this logic:

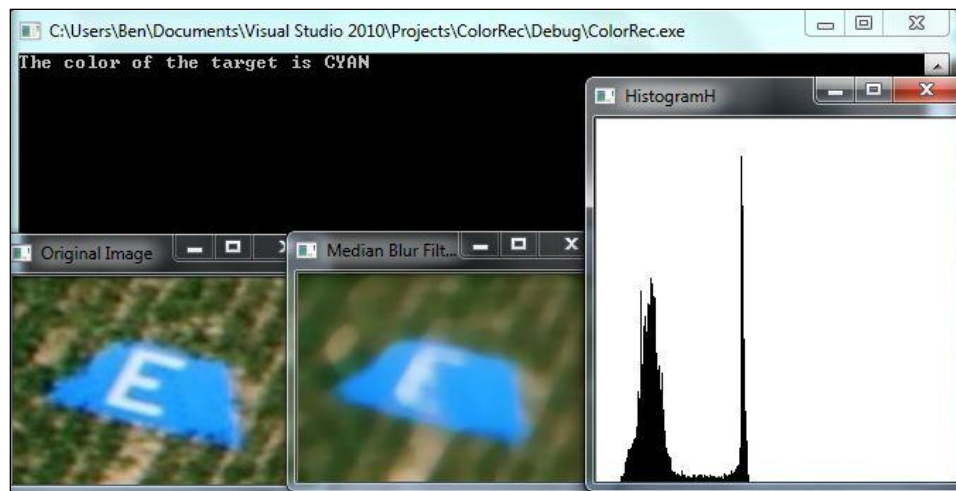


Figure 10- Algorithm output with blur filter

The figure shows the original target image, along with the image after the median blur filter is applied, as well as the histogram for the hue values of the filtered image. The histogram shows two significant peaks. The first peak from the left is the result of the background environment, and the much sharper second peak is the result of the target hue. The background in the image is non-uniform and therefore its resultant hue is more spread out when compared to the hand-painted target.

It is important to note that though this method works for all example targets used in testing, the logic is not flawless. By exclusively targeting the hue value, the algorithm will not successfully identify targets painted white or black. Also, because the character color will likely be the third most dominant hue in the image, it is required that another algorithm be developed for extracting that information.

Target Shape & Character Shape Recognition

The next module we developed was the algorithm for detecting the character and target shape. Similar to the algorithm developed for target color, the first step in this process is to convert the received image to the OpenCV Mat object type and then a smoothing filter is applied to reduce background noise.

After this is completed, the image is converted from a 3-Channel RGB image, to 3 single channel images (one channel for RGB respectively). This is done to improve efficiency and reduce computation time for the remaining processes in the algorithm. From here, a canny edge detector is applied to locate and connect the edges in each channel (keep in mind that depending on the color of the target, one of the channels will be much better for shape detection). The canny edge detector function requires the input of threshold values for the actual edge detection. The threshold set on the edge detection will determine whether the character is isolated, or the target shape. After the edges are detected, contours are extrapolated from the resulting images using the functions `cvFindContours` and `cvDrawContours`. Once the contours are found, it is logical to assume that intersecting contours implies a vertex of the target polygon (for extracting target shape) or a vertex of the alphanumeric character.

It is at this stage in the algorithm where the logic for extrapolating target shape and character differentiate. In the case of character identification, now that the alphanumeric has been completely isolated in the image, a computer learning algorithm can be applied to identify the character. On the other hand, shape identification relies more on mathematics and geometry to accomplish identification. Intersecting contour lines implies a vertex and the number of vertices gives the n value of an n -gon polygon, next is determining the angle between these intersections, this will help differentiate between a trapezoid (4-gon) and a square (also a 4-gon). Below is the output from the algorithm we have developed from this logic:

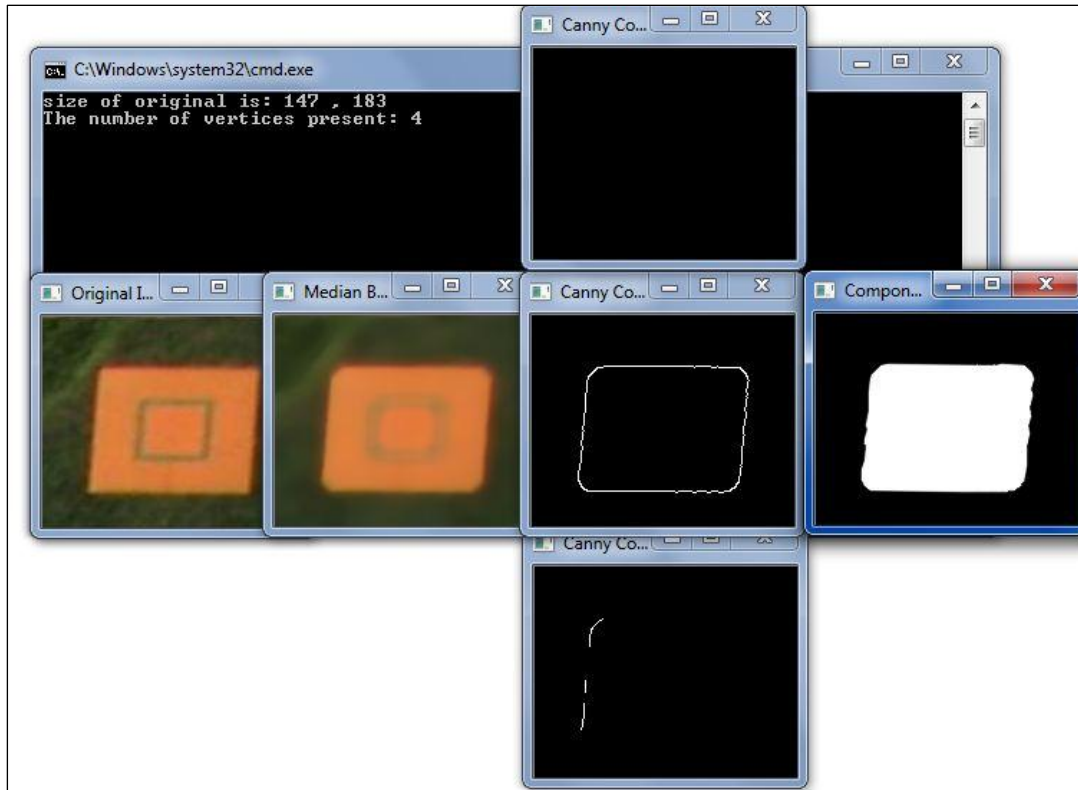


Figure 11- Example algorithm

Notice that the canny edge detection only works well for only one of the RGB channels, this is because the target is orange (red dominant), and therefore the red channel's edge detection is successful.

GPS Location Extraction

The next algorithm we have developed for our image processing system is determining the GPS location of the target. The logic for this module is dependent on the orientation of the camera on the air vehicle. For most of the mission, the camera will remain normal to the plane and ground. This means that the image can be treated as a two-dimensional plane, and therefore determining the targets location is just a matter of geometry (though it should be noted that the math changes relative to the air vehicle's altitude).

The other case is when we are attempting to find off-center targets and the camera is required to be tilted relative to the air vehicle. When this is occurring, perspective distortion becomes an issue on the camera and if left unresolved the output will have a significant probability of error. To correct for this distortion, we have researched different methods within OpenCV and decided

on the affine transformation to resolve this problem. The affine transformation allows for quick and efficient perspective distortion (and in this case correction).

Image Processing Output

Once the above algorithms have extracted the relevant target information, the next step in our image processing system is to output the results. First though, because we are using a video feed for input it is necessary to make sure that the target we have just processed is not a duplicate of a previously found target. This problem is to be expected when analyzing multiple frames per second. The solution to this problem is to cross-reference the extracted data with that of targets previously found, if a target does not possess an arbitrary number of unique characteristics it can safely be assumed to be a duplicate.

Now the extrapolated data is ready to be outputted and saved in the appropriate format. Our competition rules state that the output file for the target characteristics be a text file which has a new line for each discovered target. This is accomplished using a C++ script, each column in the file represents data for that target, and each row represents a new target.

Image Processing – The Final Semester

Next semester, our work on our image processing system will begin with primarily focusing on the implementation of algorithms presented above with the hardware we currently have. This implementation is crucial in the success of our system. Once this is accomplished, refining, debugging, and continuing the development of these algorithms will become the primary focus. This work will all hopefully culminate to a successful run this June at the competition.

Gimbal

A gimbal is a mechanism that is attached to a fixed surface and provides one or multiple degrees of rotational freedom. This is done by having a series of pivoting supports mounted onto each other, each providing an additional degree of freedom. Each support will pivot about a different normal axis and each of these axes will intersect the same point. This results in the innermost support being able to provide a platform whose orientation is completely independent of the orientation of the original fixed body. In our application, the fixed body will be the fuselage of the UAV and the camera will be mounted on the independent platform. Two degrees of freedom are needed for this purpose and an appropriate gimbal will be employed.

The gimbal will serve two separate functions for this project depending on the type of target to be identified. In the context of capturing images of the targets, the targets can be divided into three different types: search area targets, centerline targets, and off-centerline targets. The approach for capturing images of the search area and centerline targets will be similar in terms of the function of the gimbal, and the off-centerline targets will require a different method.

The gimbal will use two axes: the pitch and the lateral. As shown in Figure 12, the lateral axis is parallel to a line drawn longwise through the fuselage, and the pitch axis is parallel to a line drawn through the wingtips. These axes will pass through and intersect the center of mass of the UAV system. As the vehicle adjusts altitude, it will pitch, or rotate about the pitch axis. To correct heading, it may rotate about the yaw axis for minor corrections, which will have no meaningful impact on the camera, or roll for more significant corrections. This rotation will be compensated by adjusting the rotation about the lateral axis of the gimbal.

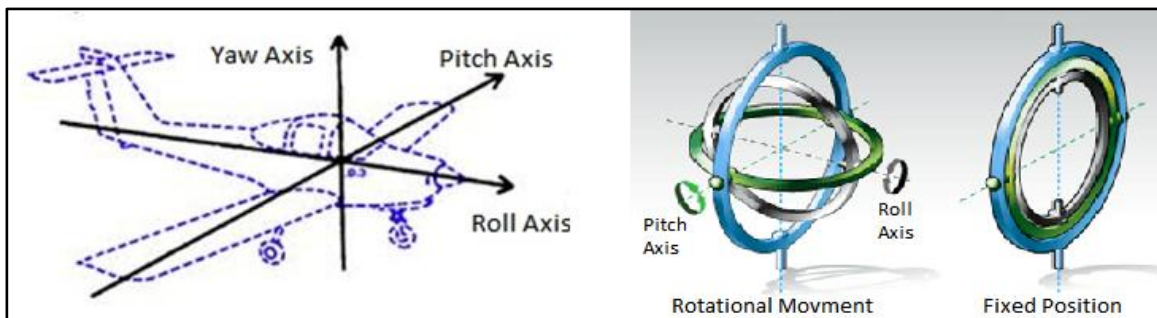


Figure 12-Axes of rotation (Carnegie) The Axes of an Airplane

To capture the search area and centerline targets, we have chosen to have the camera aimed normal to the ground. The idea is that the UAV will pass directly over these targets and the viewing angle of the camera will allow for minor tolerance in deviation from the flight path. For example, an altitude of 250 feet in the search area will allow the camera to capture the ground more than 100 feet lateral to the UAV. This is desired because it will provide a consistency in the images sent to be processed. The angles in this configuration are small and are more easily corrected by the algorithms used in the image processing. As the UAV is flying, it will constantly be correcting the altitude and heading, which will change the orientation of the aircraft. The roll of the gimbal in these cases is simply to correct for the rolling and pitching of the aircraft as the vehicle maneuvers itself to maintain its course.

The third and most challenging type of target to be identified is the off centerline targets. Two problems are immediately apparent. The first is that the scope of the ground to be covered is wider than that of the camera angle. Logically, the camera must be panned in some way to broaden the scope, which presents the second issue: perspective distortion. Perspective distortion will be discussed later in this report. An obstacle specified by the rules of the competition is that of the aforementioned example, a constant altitude of 200 feet must be maintained, and the target may be as far off of the centerline as 250 feet. Simple trigonometry tells us that the camera must be able to capture up to 55 degrees from a vertical line drawn from the ground to the UAV.

We've considered several different methods to achieve this needed viewing angle and as of yet have not tested our selection. We have chosen to have the camera cyclically pan laterally as the UAV covers ground. The frequency of this cycle is dependent on the groundspeed of the vehicle, and this cycle consists of four images taken as the camera pans left and right. Figure 13 visually depicts the cycle. Beginning with the camera panned full aircraft right, an image will be captured. The gimbal will rotate the camera normal to the ground where another image will be taken. The camera will continue sweeping toward the left until it reaches full left where the third image will be taken, and finally return to directly downward, where the final image of the cycle will be taken.

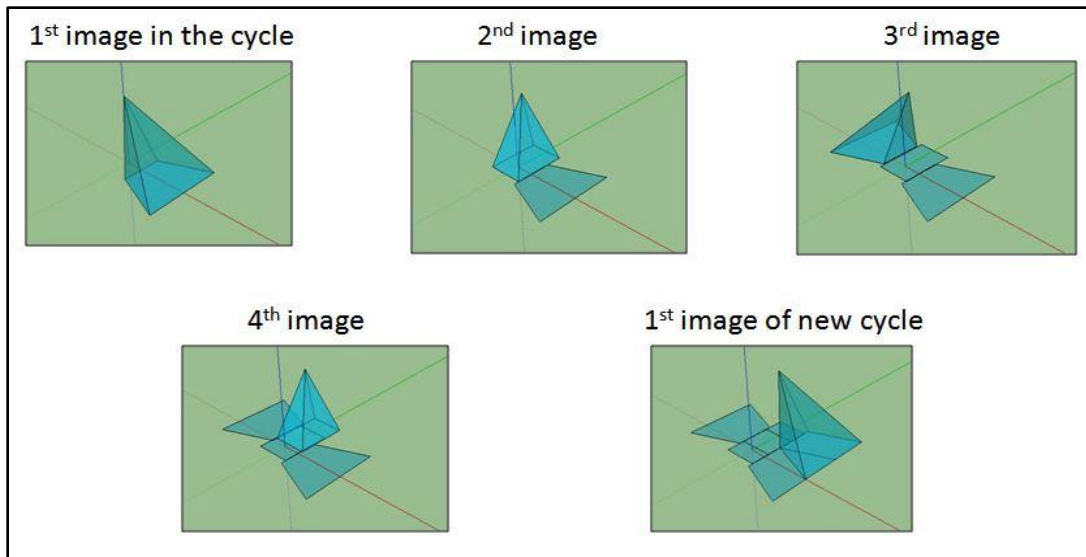


Figure 13- Image capture cycle

As mentioned, the frequency of this cycle is dependent on groundspeed. Simply put, if the camera is panning too slowly, the images will be too spread out and some ground will be missed. We have not yet flight tested our vehicle and an estimated ground speed of 55 miles per hour has been used to approximate the frequency of the cycle. A speed of 55 miles per hour is approximately 80 feet per second, and the viewing angle at the shortest longitudinal distance captures about 160 feet of ground. Therefore for every piece of ground to be captured, one cycle needs to be complete every two seconds, and an image taken every half-second. This is a high-end approximation intended to be most restrictive and the actual time required for a cycle will likely be much greater than two seconds.

Perspective distortion is the second challenge to be addressed with a panning camera. Essentially perspective distortion is the result of capturing an image at an angle between the standard axes. If the camera is pointed straight at the ground, a square target will appear as a square in the image because each part of the square is approximately the same distance from the lens. However, if this square is located at a large angle from the camera, this no longer holds true. Distant objects appear smaller, thus the furthest length of the square from the lens will appear smaller than the closest length as illustrated in Figure 14.

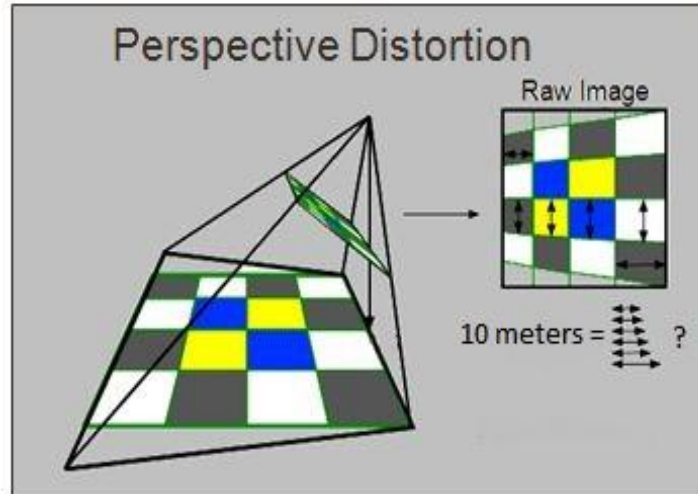


Figure 14- A square distorted due to perspective distortion (Logic-Orthorectification)

A means of correcting this is that of Affine transformation. The Affine transformation is a mathematical way to stretch images while preserving their proportions at the sacrifice of some angles and lengths(MathWorld. Weisstein). The transformation will be applied to the image processing algorithms to preserve the shapes of the potentially distorted images of the targets. We are currently in early development with this concept and will be further explored next semester.

Aerodynamic Characterizations

Airfoil analysis is very important when it comes to the capabilities of the lift and drag. When flying an aircraft, the best performance is when there is a high value for lift and a low value for drag. In order to find out the capabilities of the Senior Telemaster, an analysis of the airfoil was done to find an approximate value for the coefficient of lift at various angles of attack. These values were used to find the characteristics of the finite wing, which in turn allows us to find a value for a minimum air speed required for flight. This speed is needed in order to know what the minimum speed is that the plane can fly where the components implemented of the plane will not be affected in flight, such as the gimbal system.

The airfoil used in the design of the senior telemeter was the NACA 4409. Figure 15 below shows the curves for coefficient of lift, coefficient of drag and coefficient of moment with respect to various angles of attack. For the analysis on the finite wing, the only curve on the plot needed was the coefficient of lift with respect to the angle of attack. This curve was plotted in Figure 16 for clarity by taking data points from Figure 15 for the non-dimensional velocity $\frac{V}{V_0}$ of 0.4 and loading it into an excel file. Figure 16 allows for an approximate slope value from the curve shown which will lead to the discovery of the coefficient of lift for the finite wing.

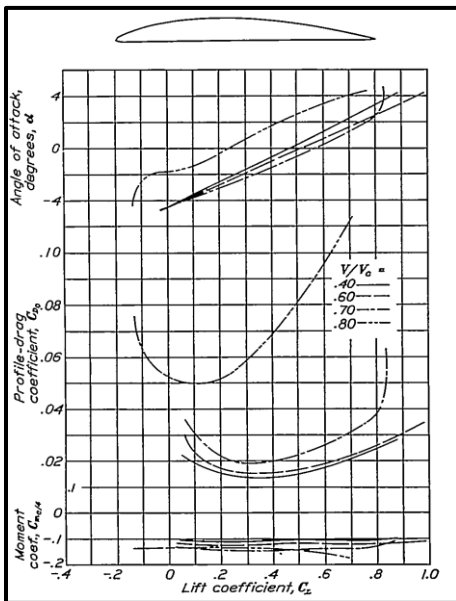


Figure 15: Lift, Drag and Moment Plots (Stack) (left)

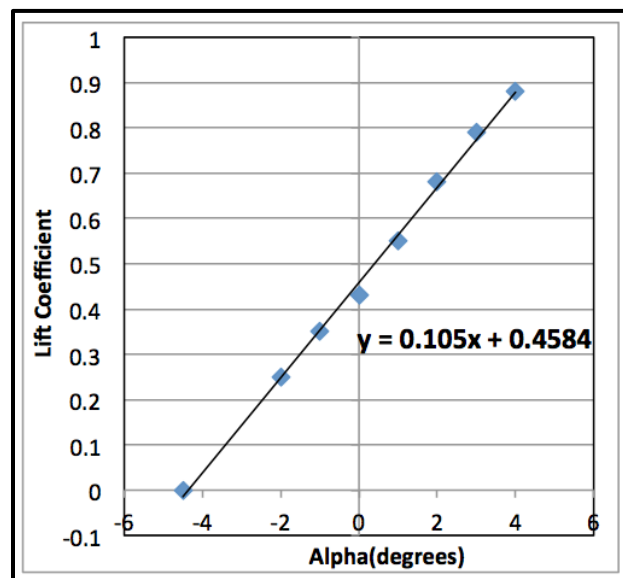


Figure 16: Lift Coefficient vs. Alpha (right)

In order to find the coefficient of lift for this wing, the assumption of elliptical lift distribution needs to be made. Elliptical wings have the best performance ratio out of all the different shaped wings, which lead to the assumption that the values will be based on the best performance. The equations used to find the lift coefficient are as followed:

$$a = \frac{a_0}{1 + \frac{a_0}{\pi * (AR)}} \qquad C_L = a(\alpha - \alpha_{L=0})$$

Equation 1: Lift slope for a finite wing

Equation 2: Lift Coefficient

The a_0 in Equation 1 is the initial slope found in the graph from Figure 16 as 0.105. The aspect ratio, AR , is known from the dimensions of the airplanes wing, which depends on the area and the span of the wing. An ideal aspect ratio is generally at a high number between the values of 6-8, because it is directly proportional to the slope, which is directly proportional to the lift. The aspect ratio for this wing came to a fairly good value at roughly 6.65. Also in Figure 16, the angle of attack when lift is equal to zero looks to be at about negative 4.5 degrees. Another assumption made was for α in Equation 2, the value of zero was chosen to represent “cruising” which is the aircraft maintaining a constant altitude and searching for targets. The lift coefficient had a value of 0.367. This value agrees with the graphs from Figure 15 and 16 because the lift coefficient occurs before the stall angle and is high enough to produce a reasonable amount of lift.

The next step would be to use Equation 3 to find the minimum velocity. One last assumption was made in the mathematical process of finding the velocity, which was that the lift is equal to the overall weight of the plane. The estimated weight of the plane is 15 pounds, which included the planes weight of 10.5 pounds and the added components weight of 4.5 pounds. In equation 3, S represents the area of the wings while the sea standard value of density was used for rho. With the values given and assumed, the minimum velocity came to approximately 13.5 mph.

$$C_L = \frac{L}{\frac{1}{2} \rho V^2 S}$$

Equation 3: Coefficient of Lift in terms of Velocity

This speed is suitable for the Senior Telemaster to cruise and search for the needed targets for the mission while maintaining the vision capabilities for the camera within the gimbal system. It

should be noted and restated that the minimum airspeed of 13.5 mph was obtain by using the elliptical lift distribution equation, therefore the actual demonstrated minimum airspeed is expected to be greater.

Budget

The budget for Team Six comes from the FIPSI coordinator and our sponsor, Dr. Shih. The team was given a \$2000 budget to be able to buy the needed items in assembling and operating the vehicle. As shown in Table 4 below, six items have been purchased thus far from two different companies, Tower Hobbies and UDrones. The Tower Hobbies purchase went a lot smoother than the second order because of the on schedule delivery. On the other hand, when it came to purchasing the items for the autonomous navigation, there was a longer delay than originally expected which ended up creating quite a setback. The purchase has since been re-ordered with priority shipping through a different website as of last week and should be received sometime before the winter break

Due to this project becoming a continuation of the senior design team from last year, majority of the more expensive items have already been purchased and are now being implemented into the aircraft. The total purchase for the fall semester of this project came up to a little over \$383, which is well under the total budget.

Company	Item	Item #	Quantity	Amount
Tower Hobbies	Battery	LXH348	1	\$37.99
	Plane Bands	LXJC77	1	\$2.59
UDrones	APM 2.5 ArduPilot Mega		1	\$179.99
	uBlox LEA-6H GPS Module		1	\$50.00
	3DR Radio Telemetry		1	\$85.00
	Airspeed Sensor		1	\$28.00
			Total	\$ 383.57
			Remaining Total	\$1616.43

Table 4: Budget

Autonomous Controls

The autopilot system that we chose to implement in our aircraft is the ArduPilot Mega 2.5. This autopilot system comes pre-soldered and tested, which reduces the possibility of errors when assembling the system and allows for more time to be spent integrating the autopilot with the other systems of the aircraft and completing the objectives of the project. The board comes equipped with a 3-axis gyro, to measure any change in the aircraft's axis of rotation (yaw, pitch, and roll), an accelerometer, to measure the static acceleration of gravity for tilt-sensing applications and the dynamic acceleration resulting from motion or shock, a magnetometer, to measure the strength and direction of the magnetic fields to act as a digital compass, and a barometer, to measure the atmospheric pressure to acquire altitude readings. The board also has a 4 MP Dataflash chip for automatic datalogging (Anderson). The ports of the board are highlighted in Figure 17 below, most notably the USB Port and the new wireless telemetry port.

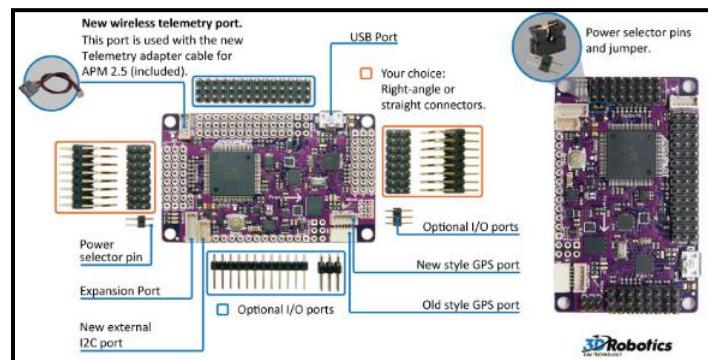


Figure 17- ArduPilot Mega 2.5 (Anderson)

The autopilot is completely open source and is Arduino compatible. We have downloaded the Arduino software in case any changes to the programming of the autopilot need to be made. The software uses the C/C++ programming language. A simple example program to blink one of the LED lights is shown below, in Figure 18. The screenshot also shows how we can connect our Arduino Mega board to the Arduino software by selecting the appropriate board under the tools tab.

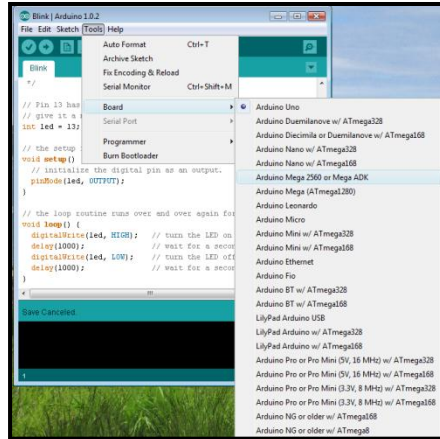


Figure 18- Arduino Software

The first upgrade we purchased was the 3DR GPS uBlock LEA-6. The 3DR GPS has a larger ceramic patch antenna, a rechargeable 3V lithium backup battery for warm starts, and I2C EEPROM for configuration storage (Anderson). This GPS boasts a lower power consumption, maximum sensitivity, and faster acquisition which lead to the decision to purchase the upgrade instead of using the standard Mediatek GPS. The 3DR GPS is shown below in Figure 19.



Figure 19- 3DR GPS uBlock LEA-6 (Anderson)

The second upgrade we purchased was the 3DR Radio Telemetry Kit. We will use the 915 MHz edition because this is the frequency that is legal in the United States and we would need to acquire the appropriate amateur radio license to operate at 433 MHz. This telemetry kit uses open source firmware, has a transmit power of up to 20dBm (100mW), air data rates up to 250 kbps, uses frequency hopping spread spectrum (FHSS), and adaptive time division multiplexing (TDM). It has a built in error correcting code that can correct up to 25% data bit errors and has adaptive flow control when used with the APM Mission Planner. Firmware upgrades and configuration are also fully supported in the APM Mission Planner(Anderson). This Telemetry

kit will ultimately allow the real time transfer of data from the aircraft to our station on the ground. The 3DR Radio Telemetry kit is smaller, cheaper, and has a larger range (about 1 mile compared to roughly 3/4ths of a mile) than the standard Xbee radio set. The telemetry kit is shown below in Figure 20. On the left side is the 3DR Radio 915 MHz “Air” module that will be connected to the IMU in the aircraft and on the right is the 3DR Radio USB-915 MHz “Ground” module that will be connected to the computer at our ground station.



Figure 20- 3DR Radio Telemetry Kit (1)

We have downloaded the APM Mission Planner software to complete the autonomous phases of the competition. A screenshot of the “Flight Planner” tab is shown on the bottom of the next page in Figure 21. The green balloons represent the waypoints and the red balloons represent a search area. Waypoints can be added by pointing and clicking on the screen and, once created, can be dragged to any desired location. When a waypoint is added it will be shown in the waypoint box below. The command at each waypoint can be set by clicking on the waypoint under the command column and choosing an option from the drop down box that appears. The options include: WAYPOINT, LAND, TAKEOFF, DO_SET_SPEED, DO_SET_HOME, etc.

When the TAKEOFF command is selected the plane will take off from the home position autonomously. The desired pitch angle of takeoff will also need to be set. In the example below the pitch angle is set to 25 degrees. The home position will be set from the position of the GPS when the autopilot is connected to the APM. The home position can also be altered by selecting the DO_SET_HOME command.

Next, for our project we will need to fly by certain waypoints at specific altitudes. This will be done by adding a waypoint at the desired position. As the screenshot shows, when a waypoint is added the longitude, latitude, and altitude of that waypoint are shown in the waypoint box. In order to alter the altitude we will simply enter the desired altitude in the altitude column for a

given waypoint. Also, we will be able to set the flight speed using the DO_SET_SPEED command. The speed and height of the aircraft are important when determining how many snapshots the camera will need to take to sufficiently scan the required area.

The LAND command will land the aircraft autonomously. The latitude, longitude, and altitude (usually 0) of the desired landing point will need to be entered in the waypoint box. How this command works is when the autopilot senses that it is within 2 seconds of touchdown or lower than 3 meters off the ground the APM will shut down the throttle and hold the correct heading, thus landing the aircraft autonomously.

Finally, a search area is created by right clicking on the screen and selecting “Draw Polygon”. Once all the necessary polygon points have been added, the polygon created can be saved as a search area. The polygon points can be moved, the same way as the waypoints, by clicking and dragging them to the desired location.

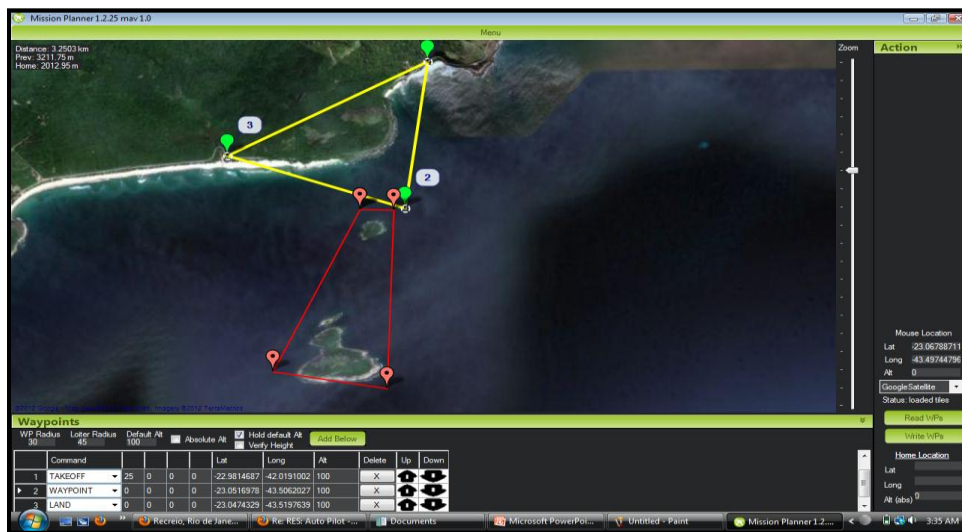


Figure 21- APM Flight Planner

A screenshot of the “Flight Data” tab of the APM Mission Planner is shown below in Figure 22. On the left is the data that will be streamed from the Telemetry Kit. In the “Quick” tab, shown in the screenshot, data such as the altitude, ground speed, distance to waypoint, etc. are illustrated. The “Gauges” tab includes gauges that display the speed, vertical speed indicator (VSI), altitude, and heading. The “Actions” tab allows us to select actions such as a preflight calibration, mission start, and setting changes to the current target waypoint. Changing a target waypoint can also be

executed by right clicking on the screen to the right. As the screenshot shows, a drop down box will appear where there is a “Fly to Here” option. This option will create a new waypoint at the location selected. The “Flight Data” tab also includes a “Status” tab with various reading such as roll, pitch, yaw, distance traveled, time in air, ground speed, vertical speed, latitude, longitude, altitude, etc. and a “Telemetry Logs” tab.

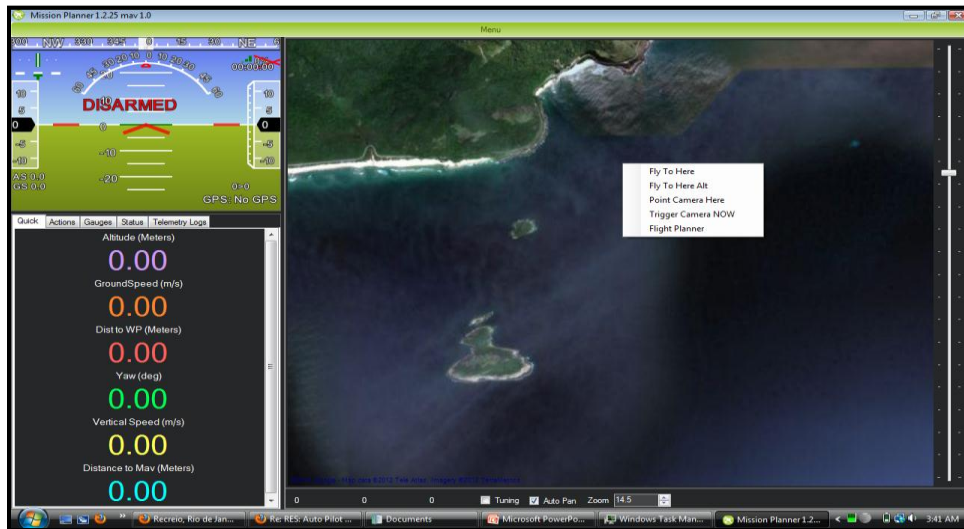


Figure 22- APM Flight Data

The threshold of the competition is to change the waypoint mid-flight. However, the objective is to change the search area mid-flight. We have already illustrated how a new waypoint can be added mid-flight, but we have not discussed how we will be changing the search area. It is unclear whether we will be able to access the “Flight Planner” mid-flight and upload new data to the flight. If so, we will be able to save a new search area and implement this new search area mid-flight. If not, we will need to find another method of altering the search area.

As of now, one idea is to set multiple waypoints in the path that the aircraft would travel to search a given search area. This would require several calculations to determine where the waypoints should be set in order to scan the search area completely and concisely. These calculations would need to be pre-determined so that the waypoints could be entered as quickly as possible, so that the aircraft would fly directly to the new search area without any delay.

Another possible option could be to alter the programming of the autopilot. The APM has a “Firmware” tab where we will be selecting the ArduPlane V2.68, which supplies the existing code to fly the plane. If the new waypoint cannot be entered into the “Flight Planner” and uploaded mid-flight it may be possible to alter the code, using the Arduino software, in order to allow for a new search area to be uploaded to a mission that is already being executed. We will have to wait until we test the autopilot system to see if this will actually be a problem that we will encounter.

The only other foreseeable problem(s) that we may encounter would come from integrating the autopilot/GPS/telemetry kit with the aircraft. Connecting the ArduPilot Mega 2.5 with the 3DR GPS uBlock LEA-6 and the 3DR Radio Telemetry Kit seems to be straight forward, but we may run into some difficulties when integrating this system with the aircraft itself, specifically, getting the rudders, elevators, ailerons, and throttle to work in sync with the autopilot system. The APM Mission Planner has a “Terminal” tab for manual set up of the APM and to run tests on the sensors, log reading, and other functions. Finally, the APM has a “Simulation” tab where we will be able to do hardware in the loop (HIL) testing as shown in the screenshot below in Figure 23. This test will give us readings on the GPS, the IMU, and on the autopilot output and status. By using the tests and simulations available and connecting the autopilot carefully and correctly we should be able to integrate the autopilot with the aircraft with minimal difficulty.

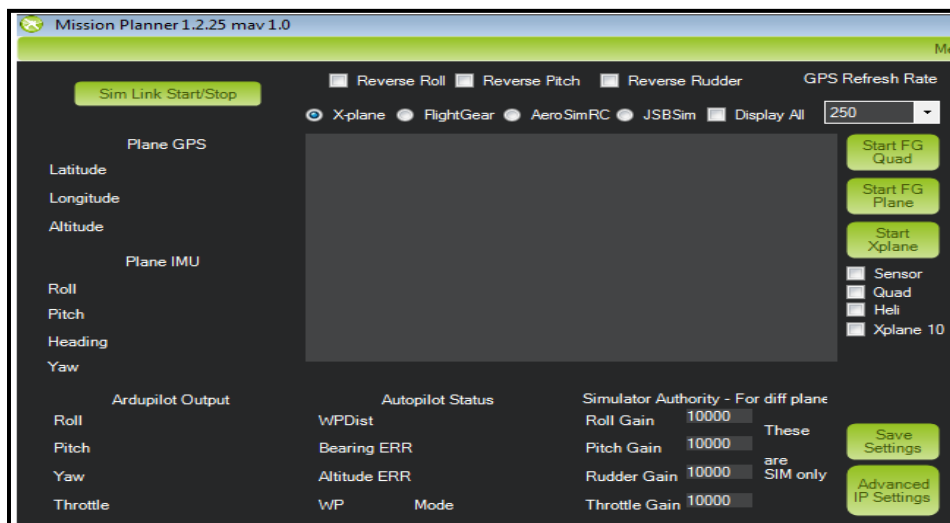


Figure 23- APM Simulation

A Futaba 7CAP 7-Channel transmitter and receiver, shown below in Figure 24, will be used for strictly backup and safety purposes. The unit uses 7 channels and operates at 72MHz(Jantzen, Blackmon and Carr). Since this year's project is a continuation of last year's project, where they flew the plane using this transmitter and receiver combination, the controller is already be connected and ready to control the plane.



Figure 24- Futaba 7CAP 7-Channel Transmitter and Receiver (Jantzen, Blackmon and Carr)

Environmental Concerns

As with any project there is always a concern with the environmental impact of your systems and design. The two most important areas for team six to be concerned with is utilizing the most environmentally friendly battery source and battery disposal should there be a crash and/or malfunction to the aircraft. One such battery we have explored is the Lithium-Ion phosphate battery pack which we are investigating the price points for. The manufacturer utilizes safe and eco-friendly practices and it also has a longer battery life. It is also important to maintain safe practices should we decide to use a nitro-methane/gas engine for our motor. This fuel is highly flammable and will need to be stored properly to avoid any accidents. We will also have to have spill kits available should there be a spill. Along with common sense and safe practices, team six is confident that we will have the smallest if not any blemish to our environment.

Looking Ahead

In the semester to come, we will be able to implement our research and methods to the hardware. The UAV will have its first flight early next semester and we may begin identifying practical problems that we have not yet foreseen. Some time has been lost due to the physical separation between the team members and the equipment. The most urgent issues at this time are mating the software with the hardware: the image processing programming with the camera, and the navigation software with the GPS system. These items are two of the fundamental obstacles of this project, the third being flight itself.

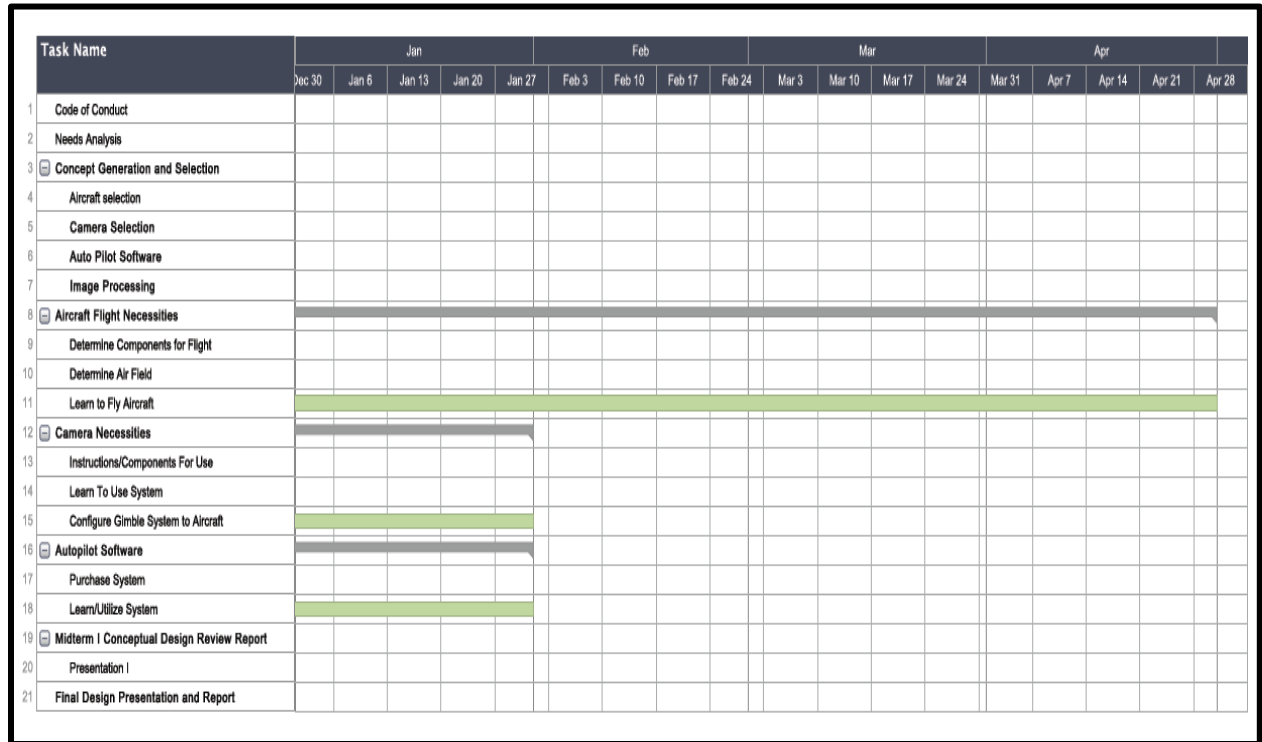
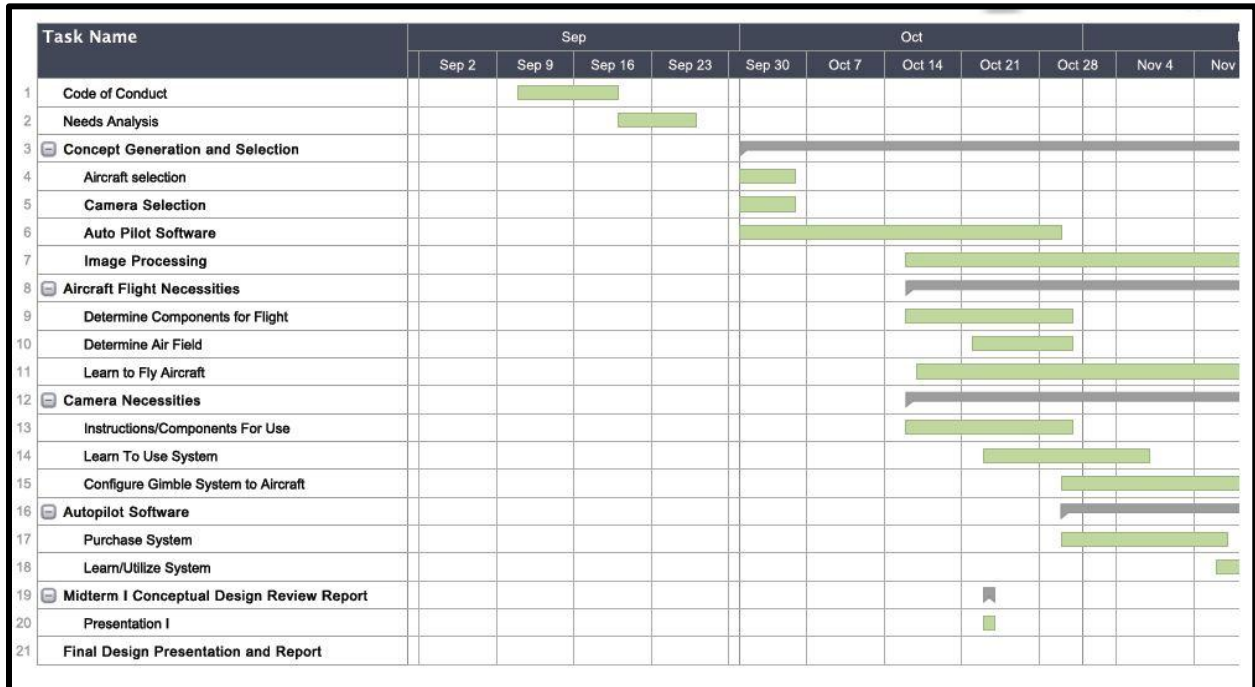
Team 6 has overcome some unusual challenges in a project of this scope this semester while maintaining significant forward progress. We have been working in international correspondence with great fluidity due to the responsibility of the individual team members and their contributions to the project. Communication has been and will be a key factor in our successes in this project, as well as the course.

Works Cited

- Anderson, Chris. "DIY Drones. 3D Robotics Inc." 10 December 2012. <http://www.diydrones.com/>>. Internet. 2012.
- Angelo. "The Flying Eye Project." december 2012. http://www.theflying-eyeprojectusa.com/rc_heli_camera_for_sale.htm. Internet. 10 december 2012.
- Bradski, Gary R., and Adrian Kaehler. *Learning OpenCV: Computer Vision with the OpenCV Library*. Sebastopol, CA: O'Reilly, 2008. Print.
- International, Association for Unmanned Vehicle Systems. *AUVSI Seafarer Chapter*. 31 October 2012. Internet. 20 November 2012.
- Jantzen, Ryan. "Final Design Package, Senior Design WebPage." 2011. *December 2012* <http://eng.fsu.edu/me/senior_design/2012/team14/deliverables/Final_Design_Package_VI.pdf> . Internet. 10 December 2012.
- Laganière, R. *OpenCV 2 Computer Vision Application Programming Cookbook: Over 50 Recipes to Master This Library of Programming Functions for Real-time Computer Vision*. Birmingham, UK: Packt Pub: Packt Pub, 2011. Print.
- Robotics, 3D. "DIY Drones Amateur UAV Superstore." December 2012. http://store.diydrones.com/APM_2_5_Assembled_p/br-apmpwrkt.htm>. Internet. 10 December 2012.
- Senate, United States. "http://www.modelaircraft.org/files/HR658_020112.pdf." 2012. *Model Aircraft-FAA*. Internet. 10 December 2012.
- Shagieva, Lena. "Singularity HUB." December 2012. <<http://singularityhub.com/2011/04/24/phenomenal-video-footage-of-extreme-sports-from-rc-helicopters/>>. 2012.
- Stack, John, and Albert E. Von Doehoff. "Test of 16 Related Airfoils at High Speeds." David, John. *Fundamentals of Aerodynamics*. New York: New York: McGraw-Hill, 1984. 492. Print.
- Technologies, HCL. *Enhanced Vision System*. 2012. December 2012. <<http://www.hcltech.com/aerospace-and-defense/enhanced-vision-system>>.

Appendix 1

Team 6 Gantt Chart



Appendix 2

Team 6 Code of Conduct

Philosophy:

In order to be a successful body it is necessary that each of its members collectively works together under specific expectations and clearly defined responsibilities. Team six has the added dilemma of having their team split between Brazil and Tallahassee. Therefore careful consideration will be put forth to address any and all concerns between the two countries. The next document will set the rules, standards, and responsibilities that Team 6 will implement during the design and construction of the Project: “Autonomous Aerial Vehicle- FIPSE Project”. The time frame will be from September 2012 to May 2013.

Responsibilities:

Team Leader - Ken Anderson M.E.

The team leader will be responsible for delegating the work equally and fairly to the members. It is the team leader's responsibility to make sure that everyone is aware of their tasks and has laid out specific deadlines and timelines for their completions. If something goes wrong the team leader, jointly with the coordinator/ instructor, will analyze the best solution based on project success and approval from all members. The team leader is also responsible for setting up group meetings among members.

Brazil Team Lead - Robert Woodruff E.E.

Because the UAV team has members in different countries there has been a Team Lead position added for the Brazil team. This position has the same duties as stated above for the purpose of having organized communication between the two teams.

Sponsor Liaison - Ken Anderson, Arielle Duen, Eric Milo

This role is responsible for delivering any project update, inquiry and piece of information to the sponsor (Dr.Shi). This role is being shared by the Tallahassee team since they attend class with Dr. Shih and will all have equal time in getting to speak with him.

Web Designer – Eric Milo M.E.

This role is responsible for the creation and upkeep of the team's web page. He is trusted with formatting the web page in the best interest of the team and will collaborate with the team for any major changes or additions.

Team Treasurer – Arielle Duen

The team treasurer will be responsible of keeping record of all financial transactions regarding the project. She must develop a plan that oversees all present and future expenses to ensure money security. Moreover she will provide any research of material, service, or part- cost and propose the best way to go. Before final decision on expenses is made, he must present his results to the other group members and receive approval from all.

Communication/Scheduling: All Members

There will be mandatory group meetings every week as determined by the coordinator. These meetings will be set according to discussed times which are convenient for the Brazil team and the Tallahassee team. Besides these personal meetings, communication will be made through phone interactions both verbal and written. All members are required to share contact information which includes: most convenient phone numbers, as well as email addresses.

An advanced schedule will be made within the first two weeks of the project and can be edited at any time but will be followed to the best of the group's ability. It will be laid out on Google calendar program so that all team members will have access and be responsible for dates. This is especially important for the UAV team because of the distance between the working members.

Decision Making

All decisions will be made unanimously by all group members and will be done in a professional manner. Anytime a problem or obstacle is encountered the group will do individual research to find solutions then have a team meeting to share results and discuss which solution is best. This will be done on top of a group brainstorming session to compound and improve existing ideas. If there is a disagreement, each member must come up with an argument for and against each idea and group must decide on which is best. If decision cannot be found, group will consult advisor.

If any problems arise they will be brought to the attention of the group as soon as possible in order to ensure swift reconciliation.

Terms of Agreement

By signing below I agree to follow these guidelines throughout the course of the project.

Team Member 1- Ken Anderson

Team Member 2- Arielle Duen

Team Member 3- Eric Milo

Team Member 4- Christopher Timmons

Team Member 5- Robert Woodruff

Team Member 6- Matthew Yasensky

Appendix 3

Acknowledgments

Team six would like to thank our sponsor and advisor Dr. Shih, our ECE advisor Dr. Frank, and our senior design professor Dr. Amin for all of their valuable input throughout this semester and we look forward to their advice during the spring semester. This project has been a valuable learning experience for all of us in Tallahassee and Brazil and we look forward to working as a single unified team here in Tallahassee for the remainder of the school year. Thank you for all who has assisted us in this design process.

