University of Alberta Aerial
Robotics Group

2009 AUVSI Student UAS Competition

Journal Paper Submission

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Abstract

The purpose of this paper is to describe the design, creation, and operation of the aircraft and support system entered in the AUVSI 2009 Student UAS Competition. This competition requires that the aircraft take off, navigate a predetermined search area, acquire target data, and return for landing, all autonomously. Key ranking criteria for its performance include the execution of the autonomous takeoff and landing, successful autonomous control, safe flight, accurate positioning, as well as acquisition and identification of target data. The entry described is based on an off-the-shelf airframe and gasoline engine combination, having a wingspan of 109”, a length of 76” and weighing about 22lbs gross. It is controlled with a Micropilot autopilot system and carries an imaging system composed of an onboard computer and DSLR camera. Onboard power is derived from lithium chemistry batteries, while communications are achieved with components using 900MHz and 2.4GHz ISM band frequencies.

Contents

1.0 Introduction

In the past months the University of Alberta Aerial Robotics Group (UAARG) has designed, prototyped, and began testing a small Unmanned Aerial System (UAS). The purpose of this project is to compete in the 2009 AUVSI Student Unmanned Aerial Systems Competition. It is the intention of the project team to use the knowledge gained from previous entries in the competition to improve their results this year.

The SUAS competition has provided the UAARG team with the opportunity to challenge themselves by designing, manufacturing, and demonstrating a complete unmanned aerial system. This system must be capable of supporting a company of Marines with intelligence, surveillance, and reconnaissance.

2.0 Methodology

The task of designing and implementing a complete unmanned aerial system is not trivial. As such, a structured methodology was utilized to ensure the project was completed successfully within time limits and financial budgets.

Upon acceptance of the task, a Plan of Action and Milestones (POA&M) was established by the team. This set of documents detailed the major tasks that required completion in order for the project to meet with success. In addition, a timeline in the form of a Gantt chart was prepared in order to determine the critical path, allotted time for different aspects of the project and to identify important milestones in the project. The plan included time allotments for a wide variety of tasks, including Problem Definition and System Specifications, Conceptual Design, Detailed Design, Critical Design Review, Procurement and Prototype Fabrication, Testing, and Additional Project Aspects.

2.1 Problem Definition and System Specifications

Initially, the project began with the problem definition and systems specifications, as outlined in the official competition rules. Specific attention was paid to any and all rules and regulations directly governing a legal solution. For example, key safety requirements such as the 55lbs maximum takeoff weight (Rule 4.1.1) must be prioritized to ensure entry disqualification at demonstration time does not occur. As part of the project definition process, key mission goals and objectives were identified, including both required and optional tasks. Required tasks, such as meeting safety expectations and the mission timeline (Rule 3.5.5), were automatically included in design considerations, whereas optional tasks, such as fully autonomous target identification, were included if deemed feasible. Other tasks were left as stretch objectives for the team. These stretch objectives were kept in mind to allow for the possibility of future expansion and improvements to the project. Please see Table 2.1.1 for a summary of system design objectives.

Table 2.1.1: Summary System Design Objectives

Objective	Priority
Takeoff/Landing	Critical
Autonomous takeoff/landing	Stretch
Waypoint/Altitude Navigation	Objective
Dynamic Waypoint Modification	Objective
Target Locating	Objective
Target Recognition	Objective
Autonomous Target Recognition	Stretch
Offset Target Location	Objective
Area Search	Objective
Mission Time (20-40min)	Critical
Actionable Intelligence	Objective
Safety Regulations	Critical

Besides the specifications derived from the official rules, a number of other specifications were decided upon by the team. One of the major design drivers was the need for the system to be modular. Modularity ensures that failure or problems in one portion of the system can be easily remedied by addressing only that part, with limited collateral in other portions of the system. This also aids in upgradeability, the other important aspect of the design. Modular subsystems allow future work to be completed on an incremental basis.

2.2 Conceptual Design

After the system specifications had been defined, work began on a conceptual design. During this stage, candidate options for the various subsystems were identified and evaluated. Identification included brainstorming and preliminary research on the variety of options and design paths possible. Each subsystem had different concepts and different evaluation parameters. Further detail is given in the design descriptions of individual subsystems. The entire UAS system as a whole was also considered, as some systems are at least partially, if not wholly dependent on each other. For example, the choice of a large and heavy camera system does not agree with the use of a small, lightweight electric airframe.

2.3 Detailed Design

Following the conceptual design was the detailed design. In this stage, systems were fully designed, with the preparation of detailed engineering documents where appropriate. Documents prepared include mechanical drawings, electrical schematics and PCB board layouts, and bills of materials (BOMs).

2.4 Critical Design Review

Before any major resource commitments were made, the team participated in a Critical Design Review (CDR), to ensure the system could be completed as designed within time and monetary budgets. Present at the review were team design leads and experienced professional engineers acting as technical advisors. The review enabled the team to catch mistakes and non-workable portions of solutions such as parts difficult or impossible to properly manufacture. Additionally, it also allowed for a professional review of important engineering drawings, which were later sent to a machine shop for part manufacture.

2.5 Procurement and Prototype Fabrication

Upon the completion and approval of the design, component procurement and prototype fabrication began. Manufacture was accomplished through team member construction, commercial off the shelf components, and parts produced by a machine shop. It was found that in the original Gantt chart, the time allotted for component procurement was not sufficient. This will be important to note for future years. Additional delays occurred due to international shipping difficulties and backordered or unavailable items.

2.6 Testing

During the prototype fabrication stage, individual subsystems were tested repeatedly to catch problems before they became difficult to resolve. This was followed by more complete testing as different subsystems were integrated into the final product. Critical portions were tested and integrated first, followed by systems of lesser importance. Finally, after the systems work together in a complete package, the testing stage will conclude with optimization to obtain better performance from the system.

2.7 Additional Project Aspects

While the design, fabrication and testing portions of the project are of utter importance to meet end goals, less technical aspects are important to maintaining a project team. Most importantly, a significant amount of capital is required. The UAARG team obtained funding from a variety of sources. Baseline funds were obtained through faculty grants contributed to student vehicle projects at the University of Alberta. This money is distributed between the six operational student vehicle projects housed within the Faculty of Engineering at the University. Distribution is based on need, membership, and performance in previous years. Donations were also solicited from a variety of companies and alumni to supplement what the Faculty provided. UAARG also participates in community outreach events throughout the year to educate youth and community members, as well as network with potential donors. This ensures the group is viewed favourably by entities being solicited for funding. Membership management and recruitment presents additional challenges. It is often difficult to find students interested in working on the project and having a suitable skill set to do. While most skills can be learned in a peer to peer manner on the team, at minimum members must be self motivated, willing to learn and able to promise some level of time commitment.

3.0 Overall System Design Description

The UAS system designed by UAARG consists of a variety of subsystems both in the air and on the ground. An overview of how these parts fit together into the overall system is illustrated in a block diagram, as seen in Figure 3.0.1. Subsystems within the UAS include the air vehicle, the autopilot system, the imaging system, the communications systems, the power systems and the safety systems. These systems are built from a combination of both custom and off-the-shelf components.

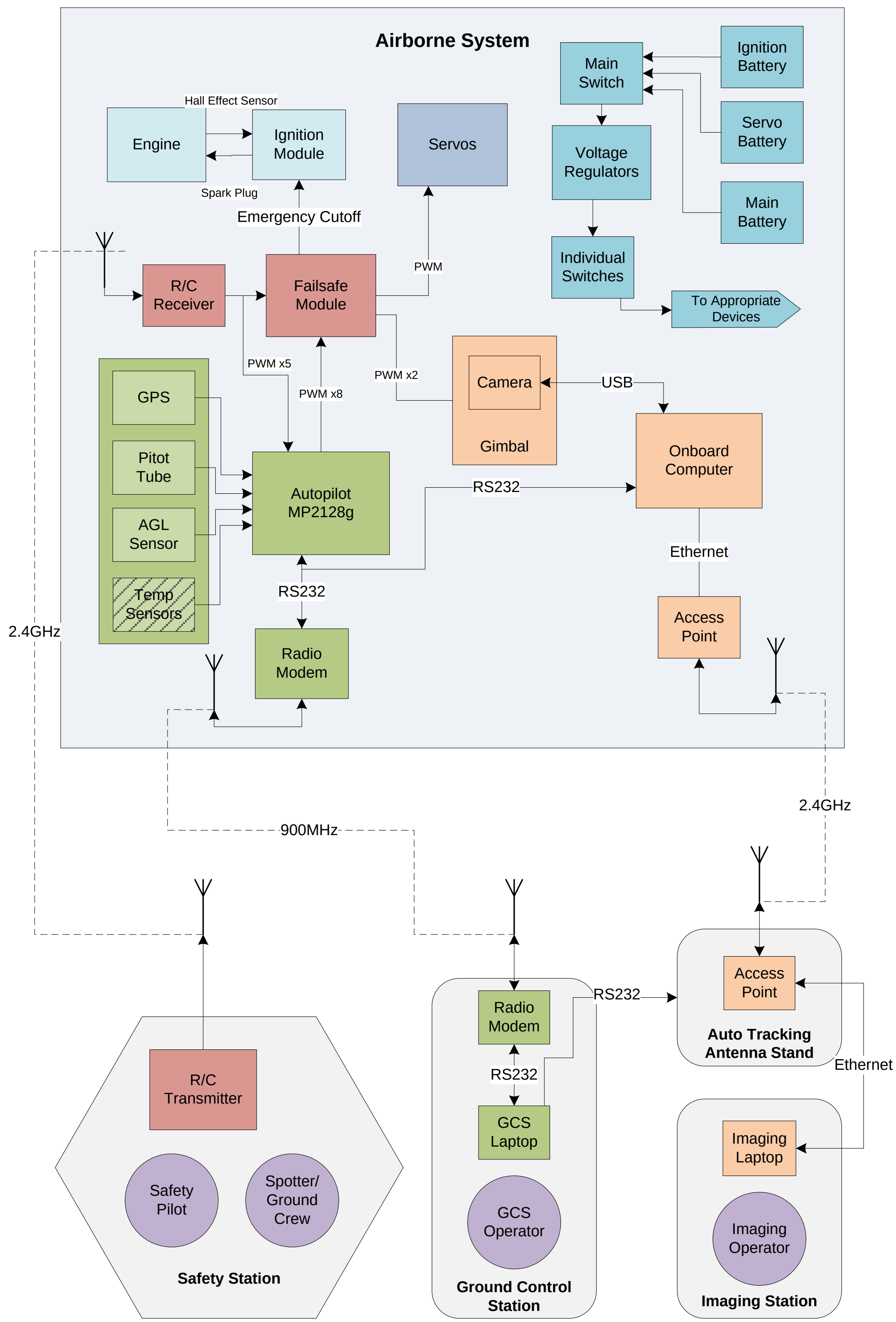

Figure 3.0.1: Overall System Block Diagram

3.1 Air Vehicle

The air vehicle must be capable of carrying the electronic payload in such a way that it can successfully complete the mission. Several alternatives were examined in order to reach a solution that had the best chance of success, as noted in Table 3.1.1 and Table 3.1.2.

Table 3.1.1: Airframe Selection Decision Matrix

Decision Parameter	Foam-Electric	Rascal 110	Telemaster	Custom Design	Helicopter
Cost	1	0	0	0	-1
Availability	1	1	1	-1	1
Experience	0	1	0	-1	-1
Payload Capability	-1	1	1	1	0
Flight Characteristics	1	1	1	0	-1
Manufacturing Time	1	1	-1	-1	1
Flight Endurance	0	1	1	0	-1
Total	**3**	**6**	**3**	**-2**	**-2**

Table 3.1.2: Propulsion Selection Decision Matrix

Decision Parameter	Electric	Glow	Gasoline
Cost	-1	1	0
Power	-1	0	1
Vibration	1	-1	-1
Endurance	-1	0	1
Weight	-1	0	0
Total	**-3**	**0**	**1**

Ultimately, the Rascal 110 ARF (Almost Ready to Fly) was chosen with an Evolution 26GX gas engine. Specifications are shown in Table 3.1.3 and Table 3.1.4.

The Rascal offers large volume and weight cargo capacity while the ARF kit greatly reduces assembly time. As for the engine, the Evolution engine was tested and proven in competition last year, and its power and fuel consumption are well suited to this design. Its onboard capacity of 24.5 oz of fuel allows for approximately 80 minutes of flight time. Ground testing resulted in a fuel consumption of 3.9 oz in 13 minutes at cruising throttle. Initial flight testing has confirmed that the Rascal airframe is capable of comfortably carrying payload while maintaining positive flight characteristics.

Table 3.1.3: Airframe Specs

Rascal 110 ARF	
Wingspan (in)	110
Fuselage Length (in)	76
Airfoil	E205
Wing Area (in^2)	1275
Weight (lbs)	22

Table 3.1.4: Engine Specs

Evolution 26GX	
Bore (mm)	33
Stroke (mm)	30.1
Displacement (in^3)	1.6
Weight (g)	936
RPM	1400-8700
Output	3.8HP@9000 rpm
Fuel	Oil:Gasoline mix 1:40

Several modifications were made to the Rascal airframe to prepare it as a UAV platform:

- The engine was mounted on a vibration isolation mount to reduce the vibration transmitted to the fuselage. This is critical to obtain high quality images of the ground and targets.
- The tail was modified to allow easy removal from the fuselage, which greatly improves the ease of transport of the vehicle and allows for quick re-assembly. This design is used extensively in model aircraft and has been proven to be safe and effective.
- The payload bay was modified to accept the camera and its gimbal. A hatch in the bottom of the fuselage was cut to provide the camera with a clear view in any orientation.
- Custom designed aluminum boxes were made to house all of the electronic components in the payload bay. This serves to protect the components from damage and shields each component from electromagnetic radiation. The modular design also allows for the easy removal of any board if repairs are required.

The air vehicle features a pitch-roll gimbal for mounting the camera to the fuselage. It is required to support the camera while correcting for the pitch and roll of the air vehicle. This ensures that the camera is always pointing straight down or at a selected target. A modified design, commissioned as part of an undergraduate student design project, was chosen for its simplicity and ease of installation in the Rascal fuselage.

The gimbal is actuated with servos driven by the autopilot. Using the built in camera control features in the autopilot, it allows for commanded camera movements while maintaining a vertical camera orientation.

3.2 Autopilot

The UAARG team decided to use an MP2128 autopilot from Micropilot, which is a powerful, widely available platform. It is a small, lightweight, fast, fully featured autopilot capable of meeting all the required objectives and parameters of this competition. It provides capabilities such as autonomous takeoff and landing, in-flight programmable way points, and sensory control, such automatic movement of the camera gimbal. Most importantly, this module integrates GPS and 3-axis accelerometers, as well as actuators, while providing the navigation information. Additionally, it is equipped with an air pressure sensor for measuring differential and absolute pressures, which estimate the altitude and air speed of the flight.

The ground control software/station (GCS) Horizon is also available from Micropilot, and offers a fully featured interface for communicating and monitoring the autopilot and any connected sensors. All of the data processed by the autopilot can be sent back to the ground station for close observation of the telemetry data. The telemetry data can be read as raw readings or through graphical representations, to ensure that all of the flight instrumentation, power systems are within flight specifications. Horizon (GCS) allows for near real-time viewing of the data.

3.3 Imaging System - Onboard

Based on past experience, the camera for the imaging system has been upgraded. The new model in use is a Nikon D60 DSLR camera with a fixed 50mm lens. A few key factors affected the decision to transition from a more primitive digital camera to this DSLR system.

First of all, DSLRs have better computer control abilities than do point and shoot camera. Previously, the Canon SX100 on the aircraft was able to remotely capture images under computer control, and was able to control some of the camera's functions, but was missing some key functions. Its autofocus was not software controllable, and there was no override to shut it off remotely. The autofocus would refocus on every picture, and because the field of view was moving, it never focused properly. This also wasted valuable time. Using the D60 with a fixed lens, the focus can be locked at infinity, eliminating one cause of poor quality images. Also, this model allows for real-time modifications of the settings on the camera to be made, such as changes to exposure time.

Compared to the previous model, the DSLR lens has a much wider aperture, enabling the use of faster shutter times. This leads to much clearer pictures, as the physical vibration of the camera has less of a blurring effect on the shot. Likewise, due to the increased size of the CCD sensor in the DSLR compared to a point and shoot camera, higher ISO settings produce pictures with less noise, further reducing the shutter speed without significantly reducing image quality.

Thirdly, the Nikon D60 has a better ability to handle multiple sets of images compared to the Canon SX100. With the SX100, only a limited number of images could be captured before the camera locked up, and required physical contact with the camera itself to reset. This situation was problematic towards the end goal of unmanned operation of the aircraft. After extensive testing, it has been determined that the Nikon D60 does not suffer from similar problems and can function for extended periods of time without manual operator interference.

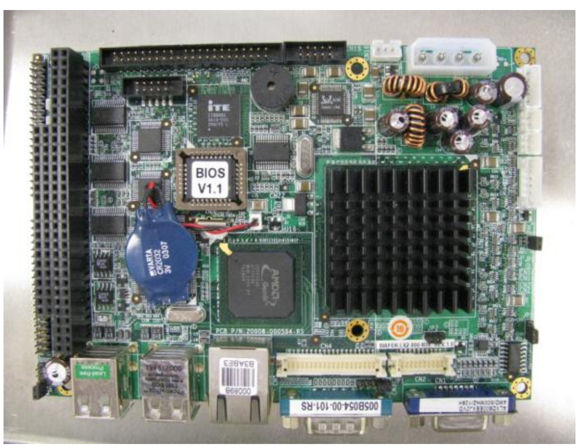

Figure 3.3.1: Wafer LX-2

The onboard computer is a Wafer LX-2 single board computer, as seen in Figure 3.3.1. It has an AMD Geode processor, which uses the x86 instruction set. This allows for easy development of the onboard software on normal desktop computers without the trouble of cross compiling for the single board computer.

The Wafer uses a 4GB CF card for persistent storage, as spinning magnetic media is not suitable for a high vibration application. There is also 1GB of RAM on the board as well. While running a stripped down version of Debian Linux, the board communicates with the camera through USB, with the wireless access point through an Ethernet connection, and with other devices through RS-232. This allows for a huge library of open source software and libraries to greatly simplify the development of the onboard software.

The onboard sensor data monitoring and camera control software is a custom designed and written application that listens to the autopilot data stream, a separate dedicated GPS, controls the capture of images with the camera, tags the images with the relevant telemetry data, and ensures images and data are transferred to the ground. A separate dedicated GPS with a faster update rate than the autopilot GPS was added to the system because the autopilot GPS is only updated once per second.

This is too slow of an update rate to accurately tag the photos taken by the plane, as the GPS update and the image capture must be synchronized as much as possible to maintain accurate target location identification. If an image is taken between GPS updates, because the plane flies quite quickly, images can be tagged with "stale" location data, leading to incorrect target locations. Based on the height of the aircraft, the airspeed, and the field of view of the camera lens, images are captured in sync with GPS updates. An image may not be captured at every GPS update, instead they are captured as necessary to ensure good visual coverage of the ground. The software also listens to the continuous stream of autopilot telemetry data, keeping a copy of the most recent data. Once an image is acquired from the camera, it is tagged with all of the autopilot telemetry data and the GPS data and sent over the Wi-Fi link to the ground computer.

The onboard software is multithreaded, with each thread managing one of the many concurrent tasks. There are separate threads for the dedicated GPS, the autopilot telemetry parsing, camera control, real-time camera settings control from the ground, and data transfer to the ground.

Since Linux itself uses very little memory, as does the onboard software, a large part of the memory can be allocated to a RAM drive to store the images captured from the camera and associated telemetry data. In this way, even if the communication link completely fails, the software can keep acquiring images and store them in the aircraft, and if necessary the images can be retrieved once the aircraft lands. Using a RAM drive is much quicker than writing to the CF card, and saves wear on the CF card, which can only be written to so many times before it becomes unreliable.

3.4 Imaging System – Ground Station

The ground station image viewer provides the operator with a larger view then the plane is capable of alone. Using a series of images the viewer reconstructs a view of the world that can be moved and zoomed, facilitating target recognition and positioning. Any targets found can then be marked, saving the position and other information. A block diagram is found in Figure 3.4.1.

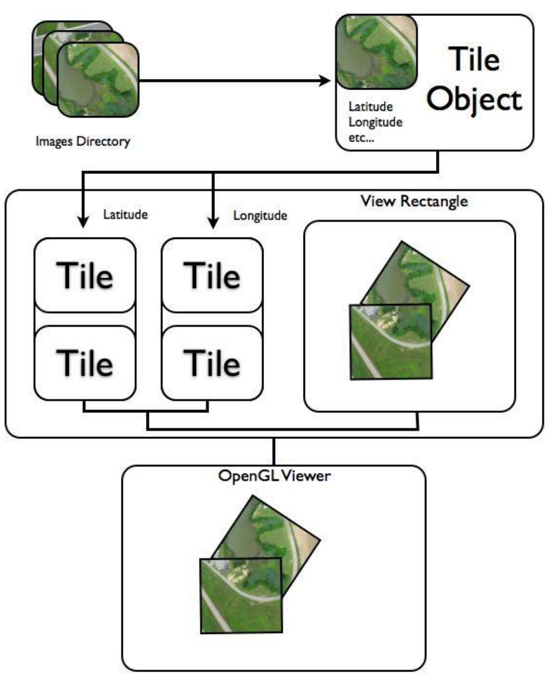

Figure 3.4.1: Imaging Ground Station Block Diagram

Two main problems arise when designing software such as this. Firstly is memory, images are large data objects consuming system memory quickly. Secondly in this system there are several coordinate systems to take into account: Mouse, Geographic, and graphics drawing coordinates.

To draw images quickly they must be in system memory. These images can be very large and consume memory quickly, the solution to this problem is to perform a Virtual Memory trick known as paging. The algorithm swaps images in and out of video memory on an as needed basis. The algorithm also takes into account load times so a look ahead is add to load images that might be visible soon. The algorithm works by separating the tile objects into two sorted list, one for latitude the other longitude. The View Rectangle, knowing its current location searches for images in that region.

There are three coordinate systems in use, Geographic (latitude, longitude), Mouse (Screen), and Drawing Coordinates. Choosing a drawing coordinate system, is a critical choice. Because OpenGL is used to display the images the coordinate system had to be a flat Cartesian system, latitude and longitude are not.

To convert to a flat system the Haversine formula is used:

$$a = \sin^2\left(\frac{\Delta lat}{2}\right) + \cos(lat1) * \cos(lat2) * \sin^2(\frac{\Delta long}{2})$$

$$2 * arctan2\left(\sqrt{}a\sqrt{}(1-a)\right)$$

$$Distance = EarthRadius * C$$

This formula does assume Earth is a perfect sphere but it still generally accurate to within 2 meters. Using this formula the conversion from Geographic to Drawing is simple using a known Geographic origin point.

Conversion from Drawing Coordinates to Geographic is done using a formula that given a bearing θ and a distance *d* calculates the endpoint location:

$$R = EarthRadius$$

$$lat_2 = \arcsin\left(\sin(lat_1) * \cos\left(\frac{d}{R}\right) + (\ \cos(lat_1) * \sin\left(\frac{d}{R}\right) * \cos(\theta)\right)$$

$$lon2 = lon1 + arctan2(\sin(\theta) * \sin\left(\frac{d}{R}\right) * \cos(lat1)\,, \cos\left(\frac{d}{R}\right) - \sin(lat1) * sing(lat2)$$

The mouse coordinates is a screen coordinate that must be converted into latitude and longitude based on where the viewer currently rests. The coordinates are first converted into drawing coordinates using OpenGL's gluUnProject. This function returns a vector corresponding to the drawing coordinates the mouse is currently over. From there Drawing to Geographic Coordinates is performed.

Images for systems processing are expected to be in a directory. This directory is watched by the Linux inotify or the BSD kevent system calls. These events allow a separate thread to sleep until an event occurs rather then continuously polling the directory, a time consuming and potentially cache thrashing operation. Because this watching can be done in a separate thread there is less impact on system performance, with only a slight increase in programming complexity.

3.5 Communications

All of the RF data links in the system are in ISM band unlicensed spectrum ranges. There is a plethora of hardware available for these frequencies (902-928Mhz, 2.400-2.483Ghz, and 5.8Ghz) that is fairly inexpensive as it has such a wide market. Using ISM frequencies also alleviates the need for costly licenses, or risking the consequences of using licensed spectrum without a license.

The main data link for the aircraft to move the digital images to the ground in near real time is provided by a 2.4 GHz Wi-Fi link. Both power and sensitivity are important to maintain a high bandwidth link in less than ideal conditions, such as this case, where the aircraft is continually moving. Consequently, this was the driving factor in the selection of radios for the project. On the plane, the stock 2.5dBi diversity "rubber duck" omnidirectional antennae are simply extended from the access point to the plane body. The two diversity antennae are also oriented to cover both polarities. Since the aircraft can fly in any direction in relation to the ground station, this arrangement is the ideal solution. This provides both spatial and polarity diversity, mitigating the effects of a continuously time varying fading channel, which is a consequence of having a moving node as part of the link. On the ground, a single high gain (24dBi) parabolic reflector is used. This reflector is mounted on an auto tracking antenna stand, which will be discussed further in its own section. Having the high gain antenna on the ground continuously pointing at the airplane allows for a very stable high bandwidth connection to be maintained at all times.

The radios selected also support the Super G standard, which uses channel bonding, frame bursting, and compression to achieve an even higher data rate using 802.11g modulation. It is not yet known how well this works in a long range outdoor situation, but theory suggests that with a good link margin, as is expected, the Super G mode will perform well. Based on literature, a real world TCP/IP throughput rate of 40 - 60 Mbps can be expected on Super G. This greatly improves over the real world throughput of 4 - 5 Mbps attainable using 802.11b, allowing for much more imagery to be acquired at significantly higher resolution, improving target acquisition.

The autopilot communicates with its ground station through a 900MHz XTend OEM RF long range serial radio modem. This radio is a FSK 900Mhz frequency hopping spread spectrum radios, chosen for its high output power (+30dBm) as well as extremely sensitive receive sections (-110dBm at 9600 bps). Consequently, this allows for the use of small 2.5dBi omnidirectional antennae on both the aircraft and the ground station, providing more than sufficient coverage for the allowed flight area of the competition. Additionally, the modules are very small and light, which are important factors for model aircraft use.

Safety pilot control override is accomplished using an off-the-shelf uni-directional radio control aircraft transmitter and receiver pair. There are multiple systems in use for the control of R/C aircraft, including analog 50MHz, analog and digital 72MHz, and digital 2.4GHz systems. Prior experience shows that 72MHz systems are prone to faults due to EMI from the variety of electrical and RF components onboard the airframe. For this reason, a digital spread spectrum 2.4GHz system was chosen to provide better immunity to interference. In testing thus far, no problems have been encountered using the Futaba FASST system, even with considerable traffic on 2.4GHz ISM bands both internal and external to the UAS.

3.6 Communications – Imaging System Antenna

The Automated Antenna Tracking System (AATS) was designed for the imaging system, to ensure reliable wireless communication between the ground station to the UAV. This is accomplished using the GPS coordinates of the ground station to direct the antennal. To provide an accurate and precise aim, the tracking control of the antenna was automated. In previous design architectures, this tracking was done manually, which provided inconsistent and unreliable results. Mission critical communication is not transmitted through this system, so temporary loss of communication does not compromise the success of the mission.

Figure 3.6.1: AATS

Robustness was the primary criterion in the design of the AATS, which was designed and manufactured in-house. It is pictured in Figure 3.6.1. The design consists of a self contained aluminum structure resting on top of a tri-pod support. This structure was designed to accommodate the control mechanism for the pan and tilt of the antenna. Altogether, the mechanism allows for a 360 degree azimuth traverse and a 100 degree elevation traverse. Two DC motors with encoders are used to execute and track the movements required to accurately point the antenna to the UAV. These motors were selected based on torque requirements and availability. For proper balance and safety, the design includes a counter weight and a chain guard protection plate.

The antenna pointer controller system is responsible for interpreting sensor signals controlling the pan and tilt motors of the antenna pointer. While the plane is in flight, it transmits telemetry data, independently from the AATS, to the Horizon GCS, through its radio modem. This data is transmitted to the AATS via serial port. After receiving the plane's location from the Horizon GCS, the AATS measures its own location and using a GPS receiver and an electronic compass. Then, based on the vector from the ground station to the plane, it calculates the heading and tilt angles required to align the antenna, and controls the pan/tilt motors to move to the appropriate location.

Due the number of serial ports required (2), the ATMega644P was chosen as the microprocessor for the controller system. The slave microcontrollers are ATMega32L, the compass module is HMC6343 and the GPS is Parallax28146 – the best choice in the accuracy/price tradeoff. The controller amplifiers are A3959, which supply up to 3A to the motors continuously.

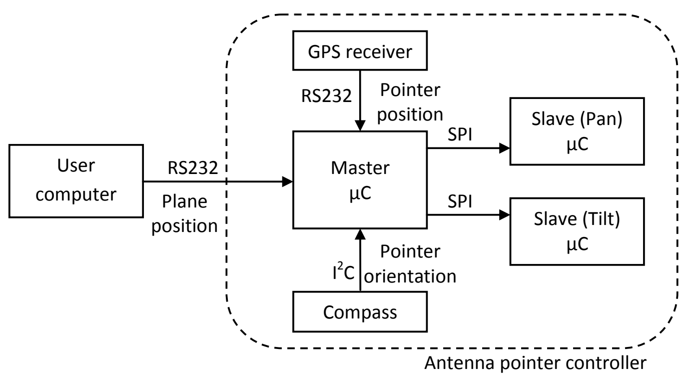

Figure 3.6.2: AATS Controller Block Diagram

To ensure accurate heading angle of the antenna pointer, the compass reading is compensated according to magnetic declination table – saved for different latitudes and longitudes in a look-up table. If the location does not exist in the table, the closest location is considered. Then, the plane data are received and the ground-to-plane vector is calculated. This calculation happens every second because of the plane's GPS sampling rate. Nonetheless, the time constant of the antenna pointer motors is smaller than one second. Appropriate sampling time for the motor controller is 100ms. In order to eliminate inter-sample behaviour or wait-and-move tracking, the plane velocity is combined with its position to predict its position in the next 9 samples. The local motor controllers are working on a PID controller with the coefficient tuned for an overdamped, smooth tracking of the plane.

3.7 Power Systems

Power is supplied to onboard systems from three separate batteries. The engine ignition module is powered by a dedicated 2400mAh 7.4V lithium ion battery to eliminate any electrical noise from propagating to the sensitive electronics. This provides more than enough capacity for multiple missions. The servos, failsafe module and R/C receiver are powered by another 2400mAh 7.4V lithium ion battery, with a 5V high efficiency switching voltage regulator. Again, this power system is isolated as servos can draw large currents, which can cause voltage sags that other systems are sensitive to. All other onboard systems are powered by a pair of 2170mAh 7.4V lithium polymer batteries with the aid of several additional switching voltage regulators to provide the correct voltages. The regulators provide built-in under-voltage protection to prevent the lithium batteries to an unrecoverable low voltage. There are both step-up and step-down switching voltage converters, as some things require less voltage than the battery voltage, and some require more. Using switching regulators ensures constant voltages to the various subsystems even as the battery voltages change.

3.8 EMI Shielding

Shielding of all the electronics is very important. There are many devices that are sensitive to electrical and RF noise, and just as many devices that produce the same kind of noise. An example of this is the onboard computer, which runs at 500MHz, the 3rd harmonic of which is 1500Mhz, very close to the GPS carrier frequency, which in the past was a large problem before the computer was shielded. Also, servos are very sensitive to RF noise on the signal line, and there are many high powered radios on the plane. From previous experience, careful EMI and RF shielding is essential for correct operation of all of the systems. Shielding is accomplished in several ways. The electronic system components are housed in aluminum enclosures that are connected to a common ground. All signal cables are shielded. Careful attention to the shielding system in the design process ensured there were no ground loops, and a single point of shield ground. Ferrite

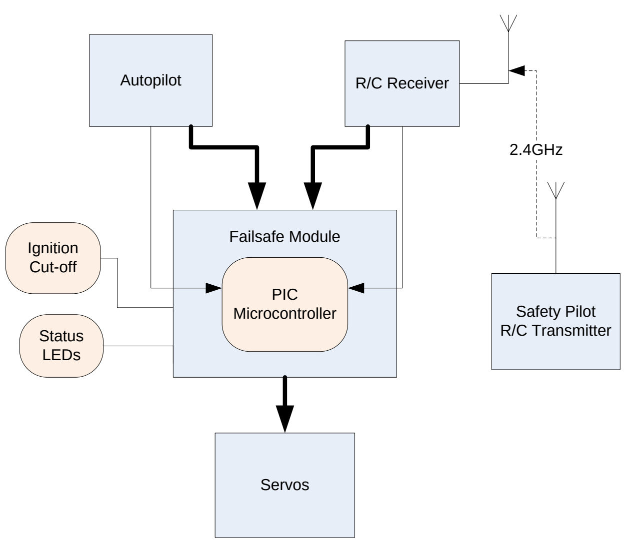

Figure 3.9.1: Failsafe Block Diagram

beads are placed on any cable that connects to anything that is sensitive to high frequency noise, namely the servos.

3.9 Failsafe System

Safety is an important aspect in the design of the UAS. The failsafe system is composed of several components. Figure 3.9.1 shows a block diagram of the system. The primary software for failsafe functionality lies in the autopilot. Built-in error handling threads monitor both the R/C and serial communications links. If loss of transmit signal occurs for 30 seconds, the autopilot executes a Return Home command. After a signal loss of three minutes, the autopilot commands the Failsafe Module to switch over to manual safety pilot control. Manual control is achieved through the use of the 2.4GHz R/C system. In addition to autopilot commanded control changes, the safety pilot can override the autopilot at any time the aircraft is within range of the R/C transmitter. The R/C receiver used in the system is equipped with a failsafe functionality. If the receiver does not have a valid signal from the transmitter, specific servo positions are commanded and held until the signal is re-acquired, at which point manual control is regained. The failsafe positions in the receiver are set to command a flight termination consisting of a gentle power-off spiral to the ground within 500ft of the termination command. Termination is achieved by commanding manual control and then turning off the R/C transmitter to invoke servo failsafe positions. After termination, manual control can be regained by turning the transmitter back on, but the engine cannot be restarted.

The Failsafe Module was designed and built in-house. It consists of a set of 2 to 1 data selectors that allow either the autopilot or the R/C receiver to provide signals to the servos. The input is enabled by a small PIC microcontroller that monitors servo lines from both the receiver and the autopilot to determine which control signals should be used. To ensure the engine can be completely shut down, the Failsafe Module also breaks the ignition circuit using a MOSFET switch. Additional features include Schmitt triggers on all servo signal inputs to eliminate noise and prevent servo glitches, and status LEDs to indicate correct operation and mode.

An additional level of redundancy exists in the servos themselves. The servos used in all parts of the aircraft are Hitec RCD programmable digital servos. A failsafe position can be directly programmed into the servo such that in case of total servo signal loss, the servo will assume a preset position if power is maintained. Again, these preset positions command a minimum energy flight termination.

A single point failure analysis was completed to identify unrecoverable failure modes. The two most severe problems were airframe structural failure and servo power failure. Both highly unlikely, each would result in erratic and unpredictable results, depending on the position of servos at failure or the point of structural failure. All other failure modes could be recovered via manual control, flight termination commands or will merely impair objective completion.

4.0 Conclusion

The UAARG team successfully produced a UAS designed to compete in the AUVSI SUAS Competition. A systems engineering methodology was used to produce a vehicle capable of meeting the desired objectives. The end product was fabricated with a combination of off-the-shelf and custom components and software.