AUVSI Student UAS Competition

June 16

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Great Mills High School Engineering Club Team

Table of Contents

Abstract

This journal paper describes the Great Mills High School Team's unmanned aerial system (UAS) for entry into the 2010 AUVSI Student UAS Competition.

The UAS is composed of two technical subsystems, one unmanned aerial vehicle (UAV) that autonomously takes flight and the ground control station (GCS) which interacts with the UAV's internal Piccolo autopilot and directs flight parameters.

The UAV is a modified Senior Telemaster radio-controlled (R/C) aircraft designed to demonstrate the ability of autonomous takeoff, waypoint navigation, and autonomous landing.

Internally, the UAV is driven by a Piccolo *autopilot core, supported by a 3S 11.1 volt battery, manipulating control servo movements as well as the FS-120S III propulsion engine.*

The GCS is composed of a laptop and operated using Cloudcap's software. It is designed specifically for the Piccolo *system, allowing for waypoint navigation and instrument observation in a real-time feed.*

The UAV is configured with a single JVC Everio HD video camera within the belly of the fuselage, pointing directly along the negative z axis as well as an AVS-900-500-12V aerial video system (900 MHz).

Introduction

Last year, the Great Mills Unmanned Aerial System (UAS) team acquired resources, comprising a plane and an integrated MicroPilot autopilot avionics package that enabled them to compete at Patuxent River Naval Air Base in the 2009 AUVSI competition. This year's project is a continuation of the pioneer project the Great Mills UAS team set in motion in the previous year. The team purchased and built a kit plane, the Senior Telemaster. The Patuxent River Naval Air Base donated a second-hand Piccolo autopilot to the team, which required reconfiguration and modifications that would successfully allow full integration into the system. Over the course of one year, the team needed to construct the airframe, install the manual and automatic avionics control, and establish a communication link to the Ground Control Station (GCS). Throughout the course of the year, the Great Mills UAS team has been focusing on the ability to work synergically and effectively execute the assignment of particular tasks to specialized component divisions.

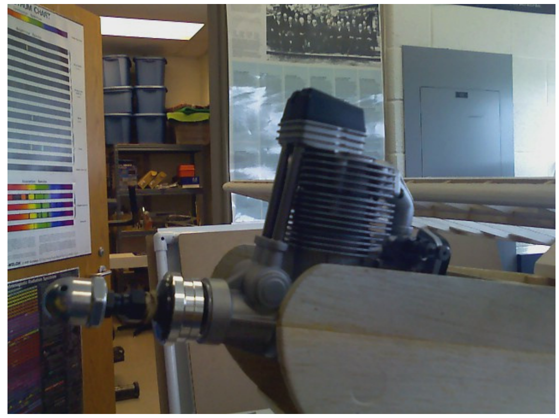
Mission

Our mission is to support a company of US Marines. We will launch our UAS to support this team by patrolling the near-by surroundings combining intelligence, surveillance and reconnaissance tactics. Our UAS is to comply with the air tasking order for departure and arrival procedures, and stay in our assigned airspace. Our UAS will search the area for targets and conduct resonance for convoy support.

We will be given 40 minutes before flight to set up equipment for the mission. Our UAS will take off under its own power. After takeoff, our UAS will fly between 100 and 750 feet. We will fly over the selected waypoints and stay in the assigned airspace. We will incorporate the waypoints given to us the day prior to the competition into our flight plan. We will fly at our specific altitude when identifying the targets. We will not deviate from our flight path when searching for targets. The targets we are searching for will have different shapes and colors. They will also have a letter on it and its overall shape will be no larger than 4 by 8 feet. While searching for the targets we will record the characteristics of all the observed targets on the target data sheet. The sheet will be shown to the judges at the end of our mission.

The UAS will land in the same area that it took off in. We will then kill the engine, stop the engine and make sure everything is off. Then we will give the data sheet and images to the judges. We will try to make our total mission time to be around 40 minutes from start to completion.

Mechanical Design Review



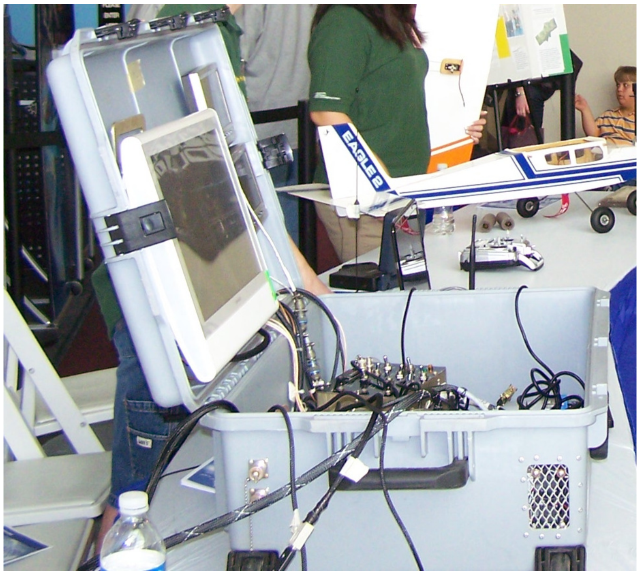
The aircraft is a Senior Telemaster aircraft that has been modified to hold an autopilot and camera in order to complete the tasks given to us. The plane has a wingspan of 95 in. and the fuselage is 60 in. The aircraft weighs 12.9 pounds without fuel. The UAV is propelled by a four stroke 120 Surpass III engine which uses a methyl, alcohol, and nitro-methane mix fuel. The propeller is a 14x6 which is manufactured by Master Airscrew.

The aircraft was bought in a kit, though serious design modification forced us to deviate from the defined construction plans. Two hatches were placed on top of the plane, one above the autopilot and the other above the camera for easier access. We modified the blueprints of the ailerons to install flaps. The wingspan of our vehicle is very large so the flaps would allow for easier landing. This required us to have a servo in the middle of the wings that would control the flaps. The servos controlling the ailerons are located six ribs in from the outside on both sides of the wing. The decision to have the servos so far out was due to the larger wingspan. It was agreed that there would be better control if the servos controlling the ailerons were located more towards the middle of their wing. Smaller hatches were put over these servos for easy access to the interior in case repair is needed. The servos that control the rudder and elevator are located towards the back of the fuselage where another hatch was put in place for access in case there is a need to refurbish equipment.

The fuel tank is located behind the engine. We then have the firewall followed by the autopilot. After the autopilot there is the servo that controls the throttle and batteries to the R/C and autopilot. These will be reached by the same hatch that opens to the autopilot. After the batteries, the camera sits in its wooden rig. In the bottom of the plane a modification was made so that the camera could see through. The bottom stringer was cut in two adjacent places. The piece was then taken out and used to create half cross braces perpendicular to each cut and on each side.

Autopilot & Avionics

Ground Control Station



The Piccolo Plus in the plane relays information to a Ground Control Station (GCS) using a transmitter and receiver of an Ultra-High Frequency (UHF). This GCS in turn sends that information to a PC. The information is displayed on the interface of the GCS software. Subsequently, the internal pilots have the ability to adjust the plane as necessary from that information. Both the User Interface and the Pilot Console communicate with the plane through the GCS.

STB Power Supply

The power supply is a portable circuit breaker which transfers the power from a standard 120V three pin connection, to a 45 pin serial connection. This functions to divide the power into our individual parts.

Piccolo Autopilot

The Piccolo Autopilot is located inside the fuselage of the plane. From its various components, software operators can discern the altitude, location, orientation, and velocity of the plane. The autopilot also uses a pitot tube to measure the air pressure outside of the plane, relaying the information of the outside air pressure to the Ground Control Station. The autopilot sends and receives information from the Ground Control Station and uses varying commands to fly the plane based on what the internal pilots dictate.

Autopilot Software Review

On the ground, the internal pilots use the Cloudcap Piccolo Command Center Software on the Ground Control Station. The software allows the internal pilots to communicate and adjust the settings of the plane as necessary to achieve the goals of the competition. The interface display consists of several components: map window, status lights window, aircraft window, layers window, primary flight window, and modes and actions bar. The map window is used by the internal pilots to see the path and location of their plane. The status lights window shows the internal pilots whether everything is working or not in the plane. The aircraft window keeps track of which aircraft are being used for respective simulation or flight. The layers window allows internal pilots to manage maps on the map window. The primary flight window is where most of the information from the Piccolo Plus (airspeed, altitude, orientation of the plane, etc.) is displayed on the interface. The modes and actions bar allows for termination of flight, takeoff, release of brakes, etc. with one button.

Autopilot Software Interface

Internal pilots use the interface to control the plane autonomously. After being calibrated with the plane, the User Interface can send the plane orders, and the plane can send back information, such as global position, orientation, altitude, attitude, and airspeed. The internal pilots can create a preplanned path for the plane to follow autonomously during flight through the use of waypoints, which are exact locations on the map that the plane must fly to, one after the other. This waypoint strategy is useful to the internal pilots during the waypoint section of the competition and also the search section. During the search section of the competition, a search pattern can be predetermined by the internal pilots to search for targets in the safest, most efficient method possible. The two search patterns that the internal pilots on the GMHS UAS team have considered are the square spiral pattern and the ladder pattern. Both patterns give ideal coverage of the search area in an efficient manner that best suits the camera. In order to capture the maximum area possible on video during the search portion of the competition, the camera must be parallel to the ground. Therefore, flying the plane level is the best option. These straight paths are the best choice in order to preserve the goal of level flight. However, the plane cannot perform the sharp turns needed for the patterns. In order to remain inside of the safety boundaries, the plane is forced to fly in relatively large circles, due to its inability to perform sharp turns. Therefore, the middle of the field is never seen by the plane. This issue must be solved through practice flights and real-time communication between the interface and the vehicle experience.

The internal pilots must be able to perform quick decision-making on the field of the competition. The internal pilots must remain vigilant in watching the information being sent back to the plane. Internal Pilots must be able to make adjustments in altitude, attitude, and heading quickly and accurately. They must also be able to adjust the flight path of the UAV in order to compensate for real world conditions.

Camera

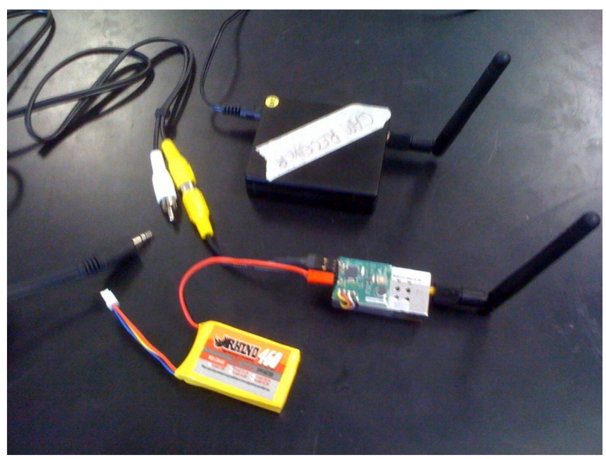
The video camera that we have selected is the JVC Everio. This camera adequately meets our needs to stream live video footage from the UAV to our ground station and allows the team to observe the live video stream.

The camera is the optimal choice for this operation because it has a composite video output jack which is compatible with our wireless video transmitter. It also has a durable battery which lasts about 2 hours, long enough to last multiple takeoffs. The Everio has the ability to zoom up to 40 times without hindering the video resolution, and is a useful feature during flight. The resolution on the Everio is 840x624, which allows the team at ground station to comfortably view the footage and easily spot the required targets for the mission.

The camera's size is also important to the mission because it is the appropriate size to fit inside the plane's inner fuselage. Its dimensions are 2.1" for width, 2.7" for height, and 4.5" for its depth. It weighs in at about 11 oz., which is roughly 70 of one pound. It is light enough to not impair the plane's flight, yet it is built out of sturdy material which offers a strong enough case to protect the important components.

Video Link

The video link is a standard audio/video (A/V) link, but only video is being transmitted because sound is not necessary in the role of the camera. There is a 900 MHz transmitter, a receiver, and a CCD camera. The receiver has an A/V link coming out of an RCA cable. The CCD camera has a cable connecting the camera to the transmitter. There are two batteries, Rhino 460, which are each 3-cell 11.1 Volt batteries.



Testing and Evaluation

Camera

To test our camera equipment, we were able to do the following: blur tests, distance/altitude tests and video quality tests. The blur testing consisted of the camera being passed along a track on a cart. As the camera was being passed, there was a series of colored letters on contrasting backgrounds. The video was recorded and then reviewed. As it was reviewed, we were watching to see if we were able to decipher which letter was which. Distance limits were much easier to find; the wireless system was set up with the camera and a target was placed at a set point and certain distances were marked off so that as the camera was moved, the limit was able to be accurately measured and recorded. We moved the camera until the video gave out.

Plane

In order for our plane to be flight worthy we determine its ability to turn, and its maximum and cruising speeds. Also, we ensure that the radio control range and airframe vibration are within acceptable ranges. In addition, we set the gains, thrust and throttle cap. Finally we ensure that the Center of Gravity is in the proper position to prevent catastrophic failure in flight.

Autopilot

We calibrate the ailerons, elevators, rudder, altitude and orientation in order to sync the autopilot's virtual world to our reality. After doing so, a program containing a short in-flight pattern is uploaded. The plane takes off manually and then switches over to the autopilot in the air. Other programs are created to test various vital flight dynamics including the act of flying straight, turning right, turning left and circling. If these are all successful, the full program resulting from our flight plan is uploaded and flown in test scenarios over several trials. If this is not successful we will begin the troubleshooting process in order to determine the error and correct it quickly and effectively.

Safety

Safety is a vital point of constant concern on the part of the GMHS team and daily checklists and procedures have been designed to prevent catastrophe. Initial concerns during construction included the required safety considerations associated with the construction of the plane such as wearing goggles while drilling, cutting away from their bodies to prevent injury, and careful attention to the re-measuring of vital aircraft components.

During flight, the team takes many precautions. During all flights the team members will keep their hands away from the propeller at all times. The team members will take care not to stand in the path of propellers or plane before launching. They will tie the plane to the ground while starting the engine. They will also charge all batteries before flying. Special designated team members will keep their eyes on the plane at ALL times. The team will also keep the fuel for the plane safely contained.

In order to prevent error, our team has created a checklist to follow before, during, and after flight. The checklist is attached in the Appendix.

FAIL SAFE MODE

There are three different fail-safe modes to ensure that everyone remains safe. The first precaution we took was to turn control over to the pilot in the case that autopilot fails, disconnects, or dies. The second fail-safe mode drives all flight controls to neutral or another setting of our choice (such as settings that will cause the plane to slowly descend) and retards the throttle. This mode is in place for if the receiver loses link or connection with the Ground Control Station. The third and final fail-safe mode is a backup battery in the case that the main battery dies.

Team Role Descriptions

Role Name	*Role Description*	*Members with Respective Roles*
Mission Commander	The Mission Commander is the leader of the entire team. He sets the agenda, decides where we should be, and makes sure that we are making good progress. The Mission Commander oversees activities, runs team meetings, and helps wherever work needs to be done. He will also be the designated liaison in-flight at the competition	Greg Lynn
First Officer	The First Officer is the second-in-command. She acts as Mission Commander when Greg is not present from meetings and aids Greg in everything that needs to be done. She also attends important events.	Jennifer Lyons
Exterior Pilot	The Exterior Pilots will act as Safety Pilots at the competition. They will be the pilots to fly the plane in RC mode when the team decides to fly the plane in that mode. They have been practicing flight all year on a simulator.	Dominic Rodriguez (Lead) Joe Hodkiewicz
Interior Pilot (GCS)	The Interior Pilots control the Ground Control Station (GCS). They will be the ones to fly the plane in PC mode when the team decides to fly it from the laptop. The GCS operators have to know the software inside and out, and have to be able to communicate with the autopilot (and therefore control the plane from the laptop) successfully.	Ryan Martin Joe Hodkiewicz Molly Tracy (Lead)
Autopilot Technician	The Interior Pilots deal with the software of the autopilot. The Autopilot Technicians deal with the hardware of the autopilot. They connect the wires, set up the computer, worry about all of the connections working, and make sure that all of the hardware is working in good order.	Ryan Martin Joe Hodkiewicz (Lead)
Imaging Engineer	The Imaging Engineer is the engineer dealing with the camera. The Imaging Engineer controls the camera in the plane and the video link.	Brendan Tomasic Carson Myers Christian Bridgette (Lead)
Mechanical Engineer	The Mechanical Engineers built the plane. They chose a plane, ordered the kit, built the plane from the parts, built a chamber for the autopilot to go in, and will ensure that the plane will fly.	Jackie "Skittles" Riggs Jackie "Ducky" Weber Carson Myers Saif Hassan Jennifer Lyons (Lead)

Acknowledgements

We would like to thank the following people for making our plane possible this year:

- Mr. Allen Skinner – *For allowing us to use his room over the course of the year to build our plane and program our software*
- Mr. Stansfield – *For oversight of our building processes and major donation of materials*
- Mr. Ing – *For oversight on the autopilot and donation of materials*
- Mr. Young – *For checking and troubleshooting our work*
- Brad Daniels – *For troubleshooting and advising*
- Mr. Hodkiewicz – *For advising and troubleshooting*
- Mr. Lent – *For allowing us to use his workspace to build the camera apparatus*

APPENDIX I

Procedural Checklist

Install the autopilot in the fuselage of the UAV.
Secure the control surface connections (ailerons, elevators, throttle, and rudder).
Secure the AGL, GPS, and radio modem cables and connections; do not connect any power cables.
Connect the AGL cable and Pitot tube to the autopilot.
Use nylon tear-away screws to attach the wings to the fuselage.
Perform the pre-flight checklist:

- Go through the equipment checklist to ensure that all parts are present.
- Examine the propeller to make sure that it is free of nicks and the propeller position at the compression point has not moved.
- Make sure that the engine mount and the firewall are secure.
- Make sure that the landing gear is securely attached to the fuselage.
- Make sure that the wheel collars are secure on the axle.
- Check to make sure that the wing is securely bolted to the fuselage.
- Tug on the ailerons, elevator, and rudder to ensure that the control hook-ups are secure from the servos to the control horns.
- Examine the fuselage covering to check for peeling away.
- Check the battery to see if it is charged.
- Set up communication with the autopilot.
- Check wiring, fuel, and servo connections.
- Check engine mount <u>with engine running</u> and systems under stress of vibration.
- Check the muffler to see that it is not loose or shifting when the engine is running.
- Perform a transmitter/Controller Range Check at 100 and 500 feet while the engine is running and under stress of vibration.
- Turn off the engine.

Fuel the air vehicle with the electric fuel pump in the field kit.
Turn the transmitter on and set it to PIC Mode.
Power up the servo board. Note the fact that the control surfaces twitch in response.
Power up the autopilot. Note the fact that the control surfaces shift to a neutral position after initialization of the autopilot.
Power up the camera system.
Run the Piccolo Command Center software on the User Interface.
Turn the radio modem receiver on.
Turn the camera receiver on.
Connect the UAV autopilot to the software.
Start the engine.
Tune the engine as necessary.
Commence flight.

Post-flight

Cut the engine power.
Download the flight information from the software.
Disconnect the software and the UAV.
Power off the autopilot, software, camera, radio modem, and UAV.