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Autonomous Patrol and Surveillance System (APSS) – A Student Project to Help Aid the Campus Police

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Abstract

As part of this long term project, undergraduate students design, develop and test various components of the Autonomous Patrol and Surveillance System (APSS). APSS is intended to be an Unmanned Aerial Vehicle (UAV) system. The mission of APSS is to assist the campus police by patrolling the campus of Southern Polytechnic State University, capturing aerial imagery of the campus and relaying that information live to a ground station at the police department. In this paper, the goals and objectives of the project are discussed. Honors students are involved to help the faculty members conduct the research. Students not only learn the methods for conducting research, ways to seek funding, and ways to solve the complex multidisciplinary problem, but they also develop the interpersonal and communication skills, and learn lessons of time and resource management. This long term ongoing project requires several students to work collaboratively. Some of the challenges and lessons learned during the project are highlighted.

Keywords: UAV, Rotorcraft, Research Project, Honors Students,

Introduction

In this project, the students design, develop and build an unmanned rotorcraft based Autonomous Patrol and Surveillance System (APSS). The work in progress is presented in this paper. The purpose of the system is to patrol the Southern Polytechnic State University (SPSU) campus and provide live video surveillance to the campus police. Currently, the police department has a few dispatch officers. Their job is the patrol the campus during the school hours and often during the night. They maintain the security and safety of the campus. Over time, their job could become monotonous and tedious. They also serve to respond to emergency calls. Even though the campus is rather small, the average response time to an emergency call is 5-7 minutes. Because of this delay, by the time the officer gets to the location of interest, the emergency may escalate or may no longer be an issue. The timeliness of the first response may be crucial depending on the nature of the emergency. After analyzing the situation, the officer then takes the subsequent action, for example they call for backup, call the ambulance, fire brigade, or decide that the emergency is resolved and no further action is necessary. There is room for efficiency improvement in this entire process.

In this project, an autonomous aerial vehicle system is developed to fly along a set of predetermined waypoints. The rotorcraft is fitted with high definition cameras. The live footage is transmitted to the ground station located inside the police department building. The police officer, instead of having to patrol in their car, will now be able to sit in an office at the station and monitor the campus on a computer screen at a much faster pace. The GPS location of the

rotorcraft and live video of the corresponding location will be displayed on the computer screen. Additionally, the APSS will be used as the first responder in the case of an emergency. During the regular flight operation, when an emergency call comes in, the officer at the ground station will be able to point the vehicle to the location of interest. The vehicle will fly a direct path to the emergency location, which will help significantly reduce the response time. Since the vehicle is rotorcraft based, it has the capability to hover at geostationary points for extended periods of time. During its hover operation, the vehicle will continue to transmit the live video feedback to the ground station. This will help the campus police in their initial assessment of the situation. It will help them take the appropriate action in a timely manner. The APSS system is capable of being retrofitted with night vision and thermal imaging cameras for night operations. It is expected that the APSS will save the police department 50-60% of their operational cost. If proved robust and successful, similar systems can be deployed in the university and school campuses across the United States.

There are several examples of the use of UAVs for civilian purposes specifically for surveillance related missions. The Utah Department of Transportation is investigating the use of UAV aerial photography to improve UDOT Geological Information System (GIS) database with high resolution photographs of ongoing and recent highway construction[1]. The state of Washington has studied the capabilities of UAVs to use as an avalanche control tool [2], and the Florida Department of Transportation has research the feasibility of using surveillance video from UAVs for traffic control and management [3].

Project Goals

For a team of students working on a real life applied project, it is important to clearly define the long term goals. Following goals are laid out at the beginning of the project. All students that start the project are made familiar with these high level goals and objectives of the project. There are a number of features that the team wishes the APSS to have.

First, the system must be capable of fully autonomous flight. The goal is develop a system where an SPSU police officer is able to point to a location on a digital SPSU-campus map on a portable electronic device e.g. laptop or Ipad, and have the rotorcraft based vehicle travel to that physical location autonomously without further manual input. The system should also have the ability to be programmed to fly to predetermined patrol routes, freeing officers to perform other necessary tasks and services.

Second goal is for the APSS system to be equipped with both a live-video-feed wireless camera, as well as a standard mini high definition camera. The purpose of the first camera will be to provide visual information to police officers, so that they can quickly determine a proper course of action in the case of a crime or general disturbance of the peace on campus. The purpose of the second recording camera is for storing permanent flight footage, to be used for police records and aircraft troubleshooting and development.

Thirdly, the system should be programmable to be self-sustainable. For safety reasons, the system should automatically return to base or police station when it is low on fuel or its battery life is low. This will prevent accidental crashes and damage to both the aircraft and personnel or property on ground. Also, the system will be programmed for safe landing and automatic shut off in the case of a malfunction which could put the system and others at risk.

Fourth, the APSS should be capable of flying at night. To achieve this, the system will be equipped with night-vision and sonar camera. It could also use thermal imaging cameras, and more standard night vision cameras that take advantage of light outside of the visual spectrum.

Fifth, much of the APSS system should be modularized, so that its main components can be quickly moved to another airframe, or removed for service and maintenance, as required.

Honors Program

This ongoing research project is part of the honors class. Students from various disciplines take the honors class as an additional class beyond their regular semester load and as part of the class curriculum, they work on this research project. The research project is a long term multi-year continuous project started in 2011. The university honors program is designed to provide students with opportunities to develop as individuals and leaders during their academic journey at Southern Polytechnic State University. Honors coursework requires students to engage in acts of ethical, global, and civic inquiry with professors and fellow students. Such acts of inquiry require students to think critically and creatively as they solve problems related to technology, scientific discovery, and design. These thinking skills also aid students outside of classroom as they engage in experiential learning that fosters leadership skills necessary to serve communities on and off campus[4].

Honor students get involved with the faculty to help with the research project. Because of their involvement, students develop strong oral and written communication skills. They learn that in engineering fields, employers look for people who can communicate well. Landis[5] indicates that students rank communication skills as less important than problem solving, computer literacy, and math/science proficiency. Faculty members rank communication skills as less important than problem solving and math/science proficiency. Industry representatives rank communication skills second to problem solving skills. In addition to effective communication skills, in honors classes, students are taught to serve and help others. They are taught to develop leadership skills. Much of the education in the schools is about learning how to follow well. However, leadership skills are important to anyone who wishes to succeed at a high level. By getting students involved in the honors research courses, early in their education, students learn these leadership, management and governance skills. In this multi-semester project class, students help design, build and test the autonomous patrol and surveillance system.

Project Description

The research study is underway at SPSU to design, build, and fly an Autonomous Aerial Patrol and Surveillance System (APSS). New and former students get involved in this project at the beginning of each semester. The various disciplines involved in the project include aerospace, mechanical, mechatronics, electrical, computer, and systems engineering. Students build, assemble and test various components of the system depending on their area of interest. As the subsystems mature and are integrated, the overall system becomes more complex. For example, the onboard GPS will help the onboard computer to determine the current and the next location of the vehicle at all times. The current location will also be displayed, in addition to the live video feedback, on the monitor screens at the base station. The intention is to create a vehicle to have 120 minute endurance so it could be used for long operations without the need of breaks for refills or recharges. The system will also be used for every day surveillance, patrol, and safety operations. The use of the autonomous UAV is expected to save time and money for the campus police department.

In the past two semesters, students helped design and build several platforms for the UAV. The team started with a fixed wing platform and a fixed camera. Several flights tests were performed. The off the shelf fixed wing UAV without a flight computer and with a small video camera is shown in Figure 1.

Figure 1: Fixed Wing RC aircraft used for video capture capability

Some pictures of the flight tests performed, using the fixed wing platform, are shown in Figure 2. These pictures are taken at SPSU campus from the height of approximately 200 feet above the ground level. A view of the campus housing and a casual soccer game at a baseball field are shown in the pictures.

Figure 2: Aerial Photographs of SPSU campus using the fixed wing platform (manual flights)

From these results it was concluded that to be able to obtain better visual clarity, a hovering platform would be more desirable than a fixed wing platform due to the added stability of the former. This was decided based on the fact that in order to stay in the air, a fixed wing airplane must be in constant forward motion which is not ideal for a system which requires steady stable surveillance. A rotorcraft based platform comes with added challenges as the rotary components would be highly dangerous in the event of a malfunction and could possibly damage property or inflict injury on a person. Therefore, the group determined that safety features must be investigated to minimize potential risks. The features could include enclosing the rotors in a shroud or duct to protect objects and people from the blades and a manual shut-off feature that, in the case of a crash, would stop the spinning blades to minimize ensuing damage. Also, on-board components must be designed and selected to minimize the vehicle weight both to reduce the amount of power needed for loiter and the potential damage caused from the platform falling due to a malfunction. Additionally, alternatives are considered to maximize the flight endurance of the vehicle.

Flight Computer

An open source Arducopter APM 2.0 motherboard is used as the flight computer. The Xbee telemetry system is used as the link between the ground station and the aerial platform. The APM board is shown in Figure 3. It interfaces with the other components on the platform including the servo motors, onboard battery, sonar, GPS, and telemetry system. It translates the flight data from the onboard sensors to the corresponding control inputs to pilot the UAV.

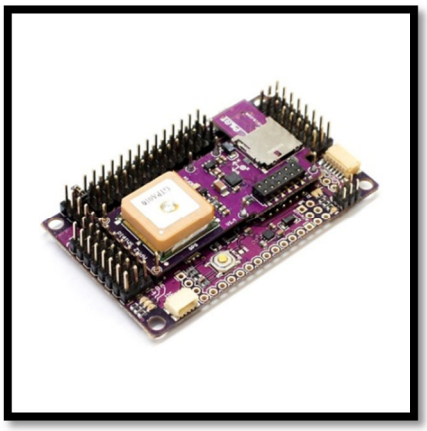

Figure 3: APM 2.0 Flight Computer

The Xbee telemetry system is shown in Figures 4 and 5. It is a wireless communications system to relay telemetry data from the APM 2.0 to the ground station and vice versa. The system makes use of both an airborne and ground antennas in order to establish a connection between the ground and airborne computers. The system can operate up to the line of sight range of 2 km.

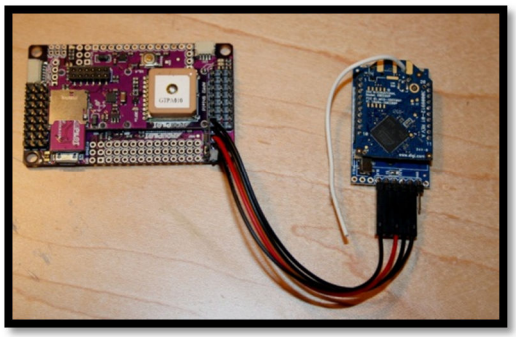

Figure 4: XBee – Airborne telemetry system

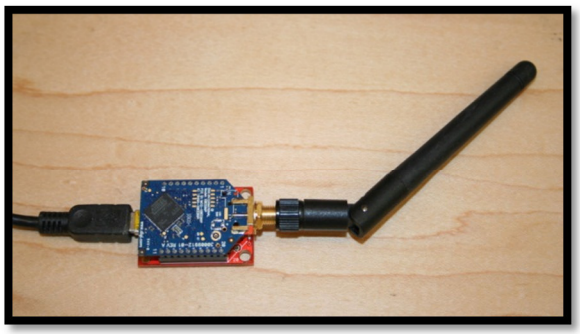

Figure 5: XBee – Ground telemetry system

Mission Planner

On the ground computer, user interface is referred to as the Mission Planner. Mission Planner is also open-source software. The APSS team tweaked the software and the firmware for the rotorcraft based platform. Mission planner is used to set waypoints for autonomous flight or take semi-manual control of the platform. It interfaces with the Google Maps. The onboard GPS on the APM helps locate the position, speed, altitude, and attitude of the aircraft. Mission planner shows the map view and the satellite view. User can select waypoints on the map and have the UAV fly between those waypoints. The speed and altitude can also be programmed using the Mission Planner. The user interface is shown in Figures 6 and 7.

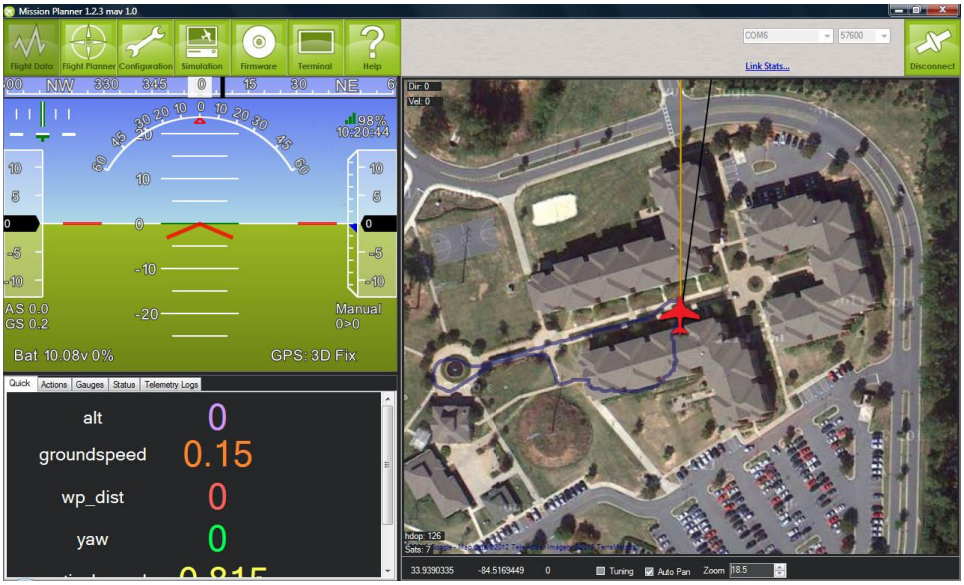

Figure 6: Mission Planner flight plan user interface

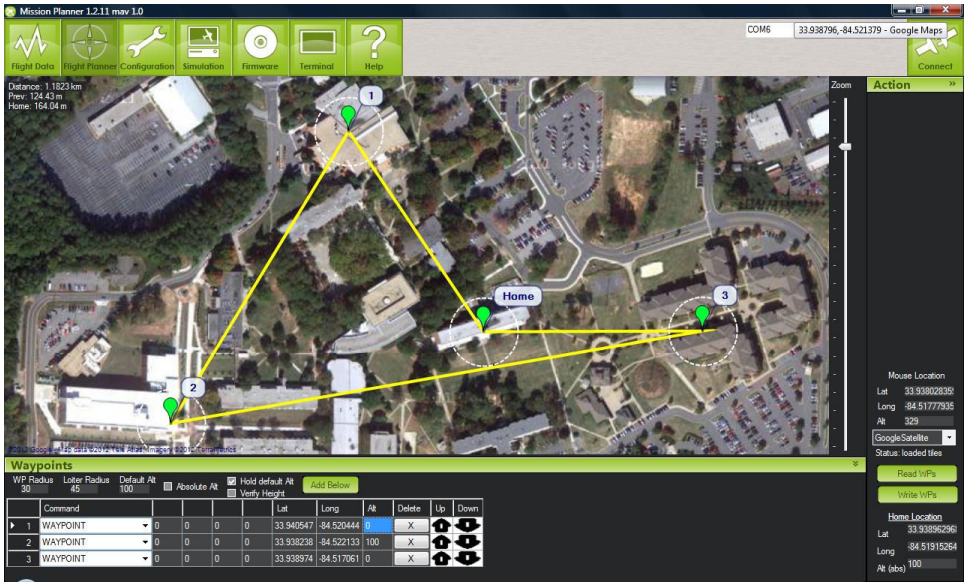

Figure 7: Mission Planner way point navigation mode

The flight computer and avionics circuit details are shown in Figure 8. The APM flight computer interfaces with the GPS, accelerometer, magnetometer, XBee, receiver, and pressure sensor. It also interfaces with all the control servo motors and the speed controller. The camera and its transmitter are controlled using a separate radio on a different frequency. The electric helicopter setup is shown in Figure 8. Although it has low noise signature, the biggest limitation of an electric rotorcraft based platform is the flight endurance. A flight time of 15 minutes is the best time that the team was able to achieve with the best lithium polymer batteries available in market. A similar electrical setup for gasoline powered rotorcraft is developed. It is expected that

the gasoline powered helicopter will have an endurance of approximately 1 hour, which can be increased by simple design modifications. The limitation comes from the high level of noise produced by the two stroke gasoline engine. The on-ground setup is shown in Figure 9.

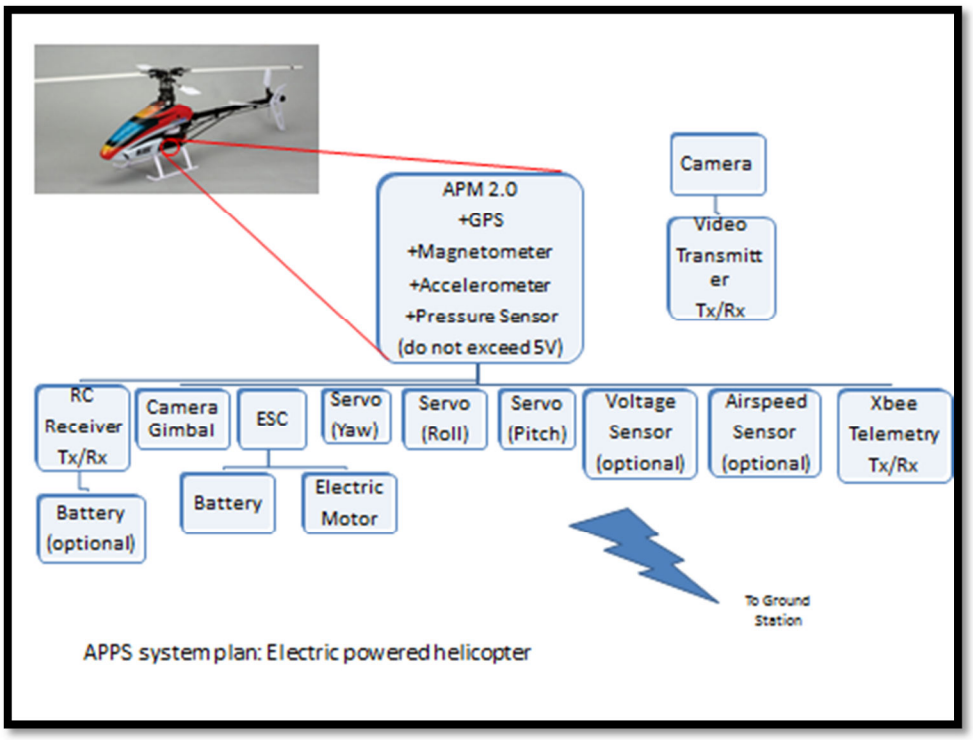

Figure 8: Electric onboard setup for the small electric rotorcraft

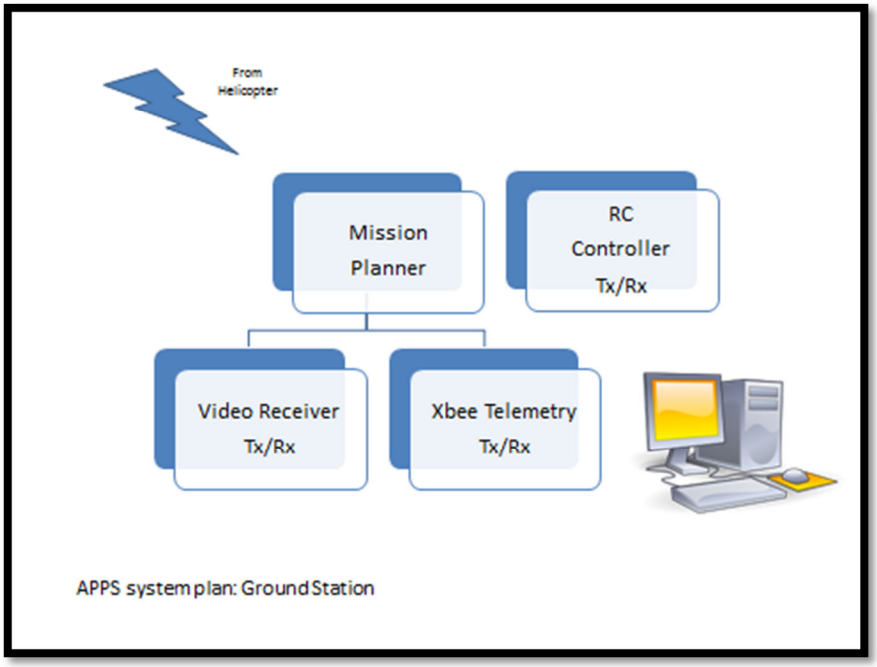

Figure 9: Electric on-ground setup interfaced with computer

Ground Tests

Before the flight computer is installed on the aerial vehicle, the team conducted tests of the autonomous system on a ground based rover. These tests are necessary to ensure a safe operation of the auto pilot and the flight computer. The rover is a modified radio control electric car shown in Figure 10.

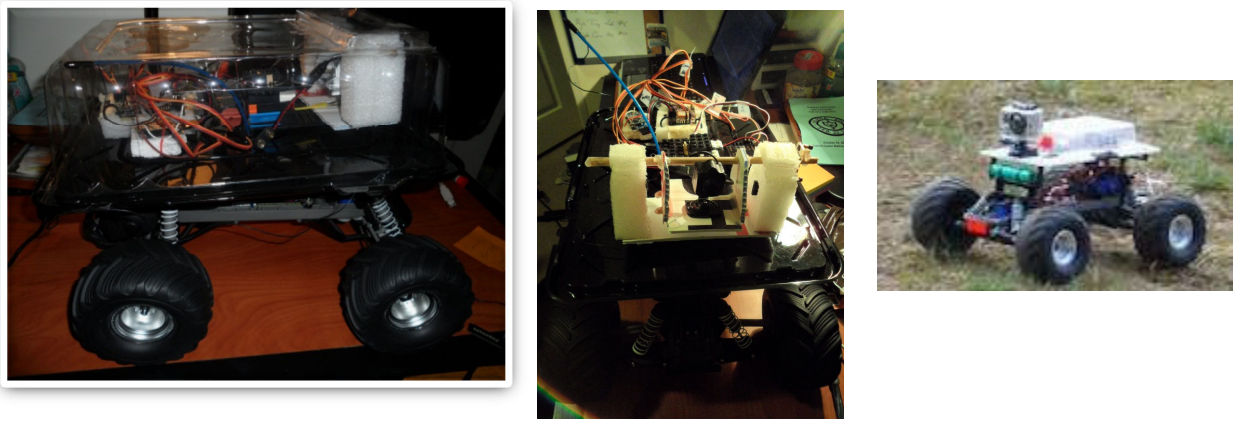

Figure 10: Ground based rover to test the autonomous operation of the flight computer

The GPS coordinate location and translation was successful with the rover based flight computer. The flight computer ground based tests are still in progress at the time of writing of this paper. Rigorous ground tests are needed to ensure that the system continues to operate and that the rover follows the pre-programmed route without failure. The team will introduce sudden expected errors like the loss of communication, low battery, closed route etc. to analyze how the rover reacts. Several iterations of design improvements are expected before a robust flight computer is ready for flight tests. It is expected that when the ground tests are complete and all the bugs have been fixed, the flight computer will be ready for installation on the aerial vehicle. Students get involved in this on-going project during the semester and contribute in the development and progress of the APSS system.

Students have identified other potential areas of concern including the environment the APSS will operate in. Due to the campus's proximity to Dobbins Reserve Air Force Base and Lockheed Martin, flight restrictions are enforced. The system must be programmed to fly above the highest obstacle on campus and stay below the restricted airspace. The presence of high tension power lines on campus presents a hazard to the UAV in the form of interference with the on-board electronics. In the worst case a potential crash into these high amperage lines could occur. A detailed campus map and a carefully pre-programmed route for the vehicle will help counter these hazards.

One final area demanding immediate investigation concerns the ethical implications of the APSS. Legal and ethical concerns arise from the APSS primary function i.e. surveillance, in the

fact that in specific circumstances this feature could be considered an invasion of privacy. Therefore, before introducing the APSS into the campus police's arsenal, steps must be taken in regard to public's reception to the system to quell any notion of ethical misuse.

After all considerations, the pictures obtained from the initial tests confirmed the belief that an aerial surveillance system would be beneficial for the campus police despite some constraints. As seen from Figures 1 and 2, large area can be visually covered in sections of the campus that are relatively cut-off from the rest of the school. Other possible platforms considered by the team are the large single main rotor UAV helicopter, and multi-copter concepts shown in Figure 11.

Figure 11: Potential other platforms under development by the APSS team

These platforms will provide stability and low levels of vibration needed for aerial photography. Further research will focus on the development of a new prototype to replace the fixed camera mount. In addition to the motion of the aircraft, the camera will have the pitch and yaw capability. This system will be modularized, the platform and the APSS components need to be developed independent of one another. Modularization will help with changeability, usability and serviceability of the system. This will help reduce delays in the system operation and will provide easy access to the module components in-case a malfunction occurs in the system.

Applications of APSS

Other aspects of the project include the identification of the uses of UAVs. UAVs are used for a variety of military and civilian applications. Students are motivated to work on the project when they learn about the various possible applications of the system. They are also encouraged to identify other possible applications of the system. The police patrol application focused in this project is civilian in nature. Other applications include but are not limited to aerial filmography, traffic monitoring, and emergency response management. UAVs have become smaller, more capable and less expensive because of the continuously improving technology and their growing use. Currently available UAVs are small enough to be transported in small vehicles and launched from a roadside without the need of a runway. At the same time they are capable enough to carry

sensors, flight computers, cameras and other equipment to provide aerial information at low cost. These aircraft are programmed to fly autonomously. The state of Georgia is interested in becoming one of the six Federal Aviation Administration (FAA) regional UAV test sites[6]. Following are some of the applications that student based research team has identified.

- Police operations – emergency response management
- Inspection of pavements, and highways for cracks
- Aerial Photography
- Accident report and management
- Inspection of bridge infrastructure and health
- Farming – surveying of crops, spraying
- Search and rescue operations – missing persons
- Advertisement & surveillance of small businesses (parking lots, garages, hangars, warehouses)
- Inspection of gas pipeline corridors
- Building, road, runway inspection – fly over roads to look for damage that needs to be repaired
- Traffic inspection
- News copters
- Bird control at the airports
- Delivery of payloads (documents, tools, supplies, newspaper)
- Roofing companies to look for damaged roofs
- Developing archives of aerial videos of historic sites, national parks, bike trails, hiking trails, parks, historic villages, national forests, camp grounds, amusement parks, tourist attractions, etc.
- Aerial views of games (football, baseball etc.)
- Aerial views of motor cross racing, NASCAR, horse racing, bicycle races, tour de France races, athletics etc.

After the APSS system is developed and tested for SPSU campus police, variants of the system can be used to accomplish the above listed missions and others.

Funding Opportunities

Seeking and securing funding is part of any research project. In this project, students are involved in the process of seeking funding opportunities. Students realize that there are many potential sources that could be explored. There are institutional internal funding opportunities. Students discover that within SPSU, there are several sources. The main source of funding within SPSU is the Alumni Board. Also, there is the possibility of receiving funding from the Student Government Association (SGA). Funding might also be available from the SPSU police department. However, it is expected that this would only be possible once the APSS project is

nearing completion, or is ready to be put to use by the police. To secure funding, students are encouraged to organize meetings and present their work in front campus officials. Through this exercise, students learn the lesson of marketing, defending, and promoting the work they have done. It also helps them answer the questions from skeptics and come up with other ideas to enhance the system.

Outside of, but close to, SPSU is Lockheed Martin Marietta facility and the Dobbins Air Force reserve base. An initial request for funding was turned down, but there is the hope of funding from Lockheed at a later time. It is expected that Lockheed will grant funding after the APSS system has been further developed, and is further legitimized in the view of the users and the public in general. In the meantime, Lockheed has offered to provide an engineering consultation with the team.

Another source of external funding is Gulfstream Aerospace Corporation. Gulfstream has a recent history of interacting with students at the collegiate level. Gulfstream has a large presence in Georgia, with corporate headquarters in Savannah, Georgia, and a large facility in Brunswick, Georgia. Boeing may also be willing to grant funding to the APSS research team. Delta Airlines and Northrop Grumman may be able to supply funding for the project. The team is in the process of applying for funds to these and other private and government organizations.

Challenges Faced and Lesson Learned

This research is part of a student based long term project. Students work on the project as part of their honors class. They start the project at the beginning of the semester and learn about the previous work done. They then contribute towards the project by either building new rotorcraft based prototypes, advancing the avionics, programming the mission planner, seeking funding sources, searching for existing work by other groups and documenting the work done. It is observed that since the honors class is not for credit, students often give it secondary importance. The students who enroll in this research project are honor students and are interested in working on this project. Despite that, some students spend most of the semester trying to understand the work that already has been done and end up contributing very little to the project. One of the lessons learned is to interview the students before they enroll in the class. During the interview, a brief summary of the progress made by the team could be explained and students could be asked to describe how they would help advance the project. Like any other research project, limited funding is another challenge that the team faces. It is observed that including students in the proposal writing process and project presentations helps increase the chances of getting funded.

Impact on Student Learning

The students involved in this research typically have little or no research background. Starting from fall 2011, an average of 2-3 students have participated in the project in every spring and fall semesters. Majority of these students are freshmen and sophomores and are not majoring in Aerospace Engineering and therefore have had no course background in the area. Some of these

students are returning students and others join the project for the first time every semester. The new students are brought up to speed in the first few meetings in the semester through lectures and discussions with the experienced students. They are fascinated by the project, its implications and want to become part of it because they believe that their efforts will help serve the society. The qualitative feedback received from the students has been positive and encouraging. Some of the comments received from the students at the end of semester evaluations are as follows:

"The most beneficial aspect of the class was being introduced to something new and something useful to society and being a part of it altogether"

"I was very interested in this course and really put out the effort to get things done week by week. Sometimes I was not able to get as much done as I would have liked, but I tried to keep up either way and gave it my all in trying to understand what was going on and to do my best in researching required/desired information"

"I got to work with my hands on building helicopters all semester. What could be more fun than that!"

"Not a lot of typical classwork – more research and brainstorming than anything – learned a lot about how all the components in a UAV communicate with one another and what they do"

On the Likert scale, this class has received an average of 5/5 score in all semesters from all students. Based on this feedback, the intent of the instructor is to continue to offer this class for new students. The long term goals of autonomous UAV will stay the same but the short term semester to semester goals may vary from constructing one type of equipment to another.

Future Work

After the ground tests are complete, the next iteration of this problem is to improve the platform design for the aerial vehicle, make the flight computer robust, program safe flight routes for the mission planner, and install high definition cameras. The cameras will include night vision and thermal vision capabilities. Team will also develop a gimbal system for the pitch and yaw motions of the camera. Integrated system tests will be performed to ensure the system capability, safety and effectiveness. A formal training process also needs to be devised for new students starting every semester. Students who acquire the skills over the semester can be asked to help

train the next generation of students. This project is expected to take 2-3 years to fully develop depending on the availability of funding. Further funding sources need to be explored.

Conclusions

In this research projects, undergraduate students are involved in design, development and testing of unmanned aerial vehicle to be used by the SPSU police department for patrol, surveillance and safety of the campus. This long term project includes the development of several sub systems and integration of the overall system. Students from various disciplines get involved in the hands on project. They contribute by putting together the system components, designing new platform, writing code, improving the mission planner, and programming the flight computer. They also help seek funding opportunities and present the project to groups inside and outside the campus. By taking this research course, the undergraduate honors students develop the leadership, independent research and communication skills. They learn to work in teams, address challenges and find solutions to a real world applied problem. While doing this research, early in their careers, they are expected to develop a system that will be useful for campus police at SPSU and beyond.

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