Palos Verdes Institute of Technology

AUVSI Student Unmanned Aerial Systems Competition 2013

Palos Verdes High School

Abstract:

The Palos Verdes High School Institute of Technology Aerospace team (PVIT) is proud to present Scout. Scout is a quadcopter weighing in at 1664g including the 3 cell 11.1 volt, 5,000 mAh Lithium Polymer battery. Scout has an autonomous and a manual flight mode which both communicate on the 2.4GHz radio while the video is on a 5.8GHz. Scout is the PVIT team's entry into the 2013 AUVSI Seafarer Chapter Student Unmanned Aerial System (SUAS). Scout is PVIT's first entry into the SUAS competition. Scout is a quadcopter capable of autonomous flight and the ability to identify targets and relay the live video back to the Ground Station.

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1. Introduction

1.1 PVIT team

This is the first competition that the current PVIT team is competing in and PVHS first entry into the AUVSI competition. The current PVIT team is comprised of three juniors, one sophomore, and one freshman. Inside the team we have two sub-teams working on Scout, one team focusing on hardware while the other group is focused on the software. Two team members are recurring from last year's group (which didn't compete) whom primarily worked on their understanding of autonomous flight and aircraft materials.

1.2 Competition requirements

Scout was designed to meet a very specific set of performance parameters set forth by the SUAS. The SUAS has two categories of requirements, the threshold and the objective requirements. The threshold is expected to be met and will be penalized if not reached; while bonus points are granted for achieving the objectives. The main categories of the thresholds and objectives are Autonomy, Imagery, Target Location, Mission Time, Operational Availability, and In-flight Re-tasking.

1.3 Expected results

At the point of the due date of this paper we have successfully tested each of the systems individually. On a later date we will test the Scouts systems as a whole to understand what to expect from Scout. Below is a chart of our expected performance during the competition.

Requirement Met	Testing Underway	Not Likely To Be Met
✔	◆	🚫
Parameter	**Threshold Requirement**	**Objective Requirement**
Autonomy	✔	✔
Imagery	✔	✔
Target Location	◆	◆
Mission Time	✔	🚫
Operational Availability	✔	◆
In-flight Re-tasking	✔	✔

2. Systems Engineering Approach

2.1 Aircraft design rational

Scout, our competition aircraft, is a quadcopter and was elected for the following main reasons. The first reason is the previous years' experience, inside the PVIT group. We had good experiences with building quadcopters and flying them manually. The second reason we decided to use the quadcopter is its ability to hover and be able to find the location of the targets without having to circle back costing us time and energy. The third and final reason we elected the quadcopter is its ability to compete against fixed wing aircraft on flight time. Scout's ability to hold a large charge through the Lithium Polymer battery and lightweight materials used to construct Scouts is superior.

2.2 Payload rational

The requirements set forth by AUVSI required a camera system that could stream high quality video over two miles and be able to read letters and see colors on the targets. These challenges lead us to narrow down to two main choices. Either use a smartphone to take pictures or video and send it back to the computer at our ground station or stick with the traditional FPV cameras. We decided on continuing to use the traditional FPV by using FoxTechFPV Horyzon 3 because of its ability to send HD video back to our ground center allowing us to see the targets much more clearly than SD with the bonus of longer ranges. In addition, we chose FPV because we had some experience with FPV from the previous year and felt that using a cellphone would add extra weight and require programing of an app or finding some other way to send the videos or photos back to the ground station.

2.3 Software rational

The requirements for the autonomous functions of the competition state that the vehicle should be able to take-off, land and navigate through GPS coordinates, and be able to add GPS coordinates in flight. In addition, the other major factors for our selection were cost (numerous autopilot systems available for under $1,000), familiarity with the system and whether it comes with a user interface and telemetry. At the end of our search we decided on using the DIYDrones ArduPilot system because it satisfied all our requirements (and cost only $150).

2.4 Frame rational

Last year's PVIT team was capable of flying Scout using a store bought kit from DIYDrones. Even though the team was capable of flying Scout manually this year we decided to upgrade to a full carbon fiber frame to decrease the overall weight. For the same reason, we also shortened the arms, and we shorted the wires to decrease the clutter. After decreasing the weight of Scout we also increased the amount of space in the center tower to house all of the required electronics.

3. UAS Design

3.1 Frame

Scouts frame is a custom built frame designed by the PVIT team to decrease as much weight as possible and thereby increasing flight time.

3.1.1 Arms

Scouts arms are made out of round 650mm length carbon fiber arms with machined aluminum motor mounts on the ends. The tubes are hollow allowing the wires from the motors to be fed back inside the center of the arms to connect with the speed controls.

3.1.2 Center tower

Scouts center tower is inverted with 4 main levels. The bottom level contains just the autopilot board. The second level contains the autopilot's transmitter, the camera mount, and the camera transmitter. The third level is the smallest level and contains the power distribution board and the last level contains the two batteries (one battery powers the motors while the other powers the camera system).

3.2 Power systems

Scout has 2 batteries; one for Scouts motors and the other for the camera system. Scouts motors are powered by a single 3 cell 11.1 volt, 5,000 mAh with a 20C-30C discharge rate, Lithium Polymer battery. The battery goes into our power distribution board which then goes to one of the four 20C motor controls which each one controls one 850 kV motors. The second smaller battery powers the camera system and the wireless transmitter. It is a 2 cell 7.4 volt, 2200mAh with a 25C-35C discharge rate, Lithium Polymer battery.

3.3 Payload and frame weight

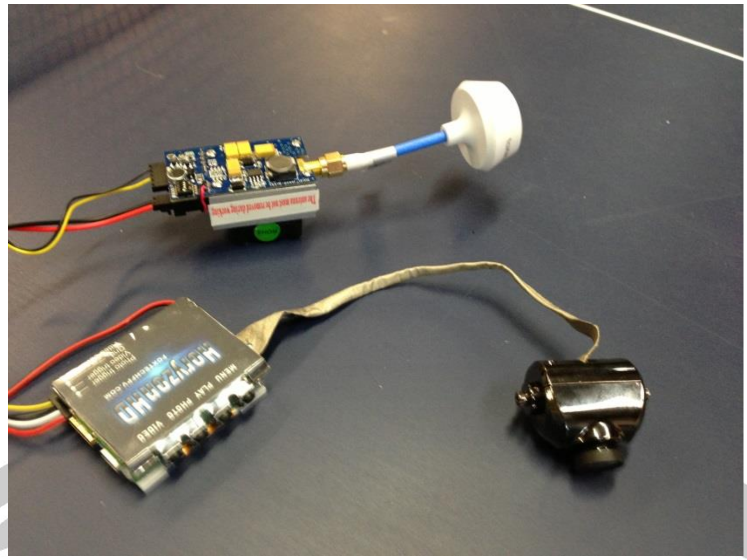
Part	Weight(grams)
Scout total	1664g
Frame	297g
Motors and ESC	408g
Camera system	181g
Both battery's	626g
Autopilot and R/C	152g

4. UAS Software

This is an image of the software that we use to tell Scout the course to fly

4.1 Camera system

Scout's camera system is a FoxTech's Horyzon 3 camera. The Horyzon 3 camera is capable of shooting 1280x720 video at 60 fps. The camera then sends the video on 5.8GHz back to the ground station for the PVIT team to identify the targets that Scout finds during the competition.

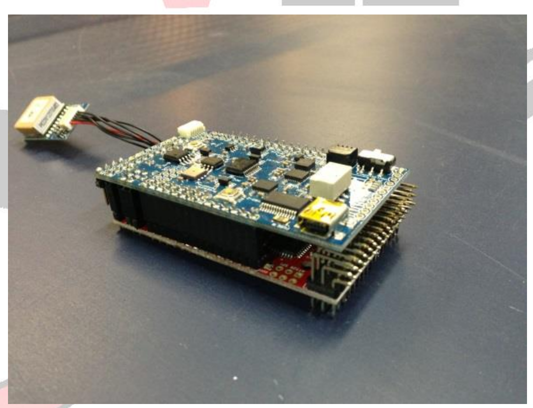


This is an image of the camera system and the 5.8GHz transmitter

4.2 Autopilot control

4.2.1 Autopilot board

Scout’s Autopilot board is the ArduPilotMega APM1-2560. The board itself contains 2 processors one atmega 2560 and one atmega 328. The onboard sensors include a 3-axis gyro, 3-axis accelerometer, barometer, and a GPS. The board is also capable of data logging 2 megabytes of memory.



Picture of the Autopilot Board without the telemetry attached

4.2.2 Autopilot software

The main flight software is APM Mission Planner some of its features are

- Point-and-click waypoint entry, using Google Maps.
- Full ground station for monitoring missions and sending in-flight commands.
- Select mission commands from drop-down menus
- See sensor output and test autopilot performance
- Download mission log files and analyze them
- Configure APM settings for the airframe
- See the output from APM's serial terminal

These features allow us to program Scout to go wherever we want Scout to go. This allows us to easily tell Scout to go to the GPS coordinates we want to identify and we are also able to add GPS points in flight. The final ability that will help us in the competition is to be able to do a search grid to find targets in certain areas.

4.3 Ground Station

On the ground station we receive two main blocks of information from Scout, the first is the telemetry from Scout while the second is the video from the camera on board Scout. The telemetry from Scout is received and displayed on the computer screen for us to track where Scout is during its flight. The video from the camera is displayed synchronously on a small television for our team to analyze and identify the targets.

5. Testing and Evaluation Results

5.1 Simulations

During testing we simulated both the cameras and the navigation of the autopilot systems. We tested the camera by making the smallest targets that we would see in the competition. We tested the camera by trying to recognize the targets by viewing them at different lengths to get an idea for what we would be capable of seeing. For navigation testing we programed a path into the board and then navigated the course by walking with the board to make sure that it was reading the GPS points and the altitude correctly.

5.2 Flight tests

As of the due date of this paper we have made approximately 15 flights and 2 of the flights were autonomous. The manual flights were mostly testing the flight time using different batteries and testing certain tweaks to Scouts frame. Our autonomous flight tests were simple takeoff and landings in the same location while the other one was to fly in a straight line and land successfully.

5.3 Full mission

At the point of this paper we have not done a full mission test, but we have individually tested each system to verify its functions for the mission.

6. Safety Considerations and Approach

6.1 General safety

Before each test flight to verify that the mechanical and the software are working. We complete a checklist to verify that each of the main systems and the subsystems are working properly. The PVIT team created the checklists for the vehicle to ensure the safety of the team and other people along with the protection of our vehicle. Before each flight we make sure that each team member knows what is expected to happen during the flight in order to be able to recognize and anticipate issues and alert the controller to abort or change the flight.

6.2 Checklists

We have 2 physical checklists to complete on Scout before each flight, one for the electronics systems and one for the frame.

Airworthiness checklist for the frame

1. All 4 arms screwed in place
2. Motors are set at 90 degrees
3. Center Tower is attached
4. Motors are spinning the right direction
5. Propellers are in the right orientation
6. Autopilot board is facing forward
7. Autopilot board is flat
8. Speed controls are attached to the battery
9. Battery(s) are attached to the Frame

Airworthiness checklist for the electronics

1. Current flight plan is loaded
2. The motors are attached in the correct order
3. The transmitter and receiver are connected
4. The Autopilot is connected to the computer
5. Ground station is receiving video from the camera

6.3 Test plans

Our testing of Scout began with individually testing the systems on the ground to verify that they are working properly before we tested them on Scout. We tested the systems interfaces as a whole on-board Scout before pushing and testing Scout on the full course.

6.4 Fail safe

Scouts autopilot comes equipped with a second processor that monitors the main processor for radio signal and if the main processor is functioning correctly. Depending on the situation that requires the fail safe to override the main board, Scout will do one of two functions; allow us to regain manual control if the processor fails or if there is loss of radio signal, Scout will return to the first programmed GPS coordinate.

7. Conclusions

At the point of this technical report we have fully tested each of Scouts systems individually and are looking towards testing Scout in a full mission after the report is due. Each of Scouts individual systems are capable of meeting each of the threshold requirements and meeting some of the objective requirements. Many of Scouts systems can be store bought however Scouts frame is custom built out of Carbon Fiber, designed by the PVIT team, which we believe will be one of the major asset in the AUVSI competition.