Post-Mortem for Air Surveillance Drones

Project Team:

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Submitted to:

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Table of Content

List of Figures

List of Tables

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1. Introduction

Drones have many applications and the demand for them is increasing every day. In the United States, the FBI has used drones in several hostage situations, and some search and rescue teams and even hobbyists are considering using them for search and rescue efforts. Back in August, a Monmouth University poll showed that 88 percent of Americans support their use as a search and rescue platform. (Koebler, 2013)

While there are many different air surveillance solutions on the market, the cost of using a drone is significantly lower. The cost of search using regular helicopters is $1800 per hour, whereas using drones only cost a few hundred dollars per hour (Daflos, 2013). At ASD, we aim to bring the cost of search and rescue missions even lower while reducing the carbon footprint associated with such operations.

The ASD, Air Surveillance Drones, is a product that will be an inexpensive alternative to any competition while having little or no negative effect on the environment. ASD drones can be programed to cover an unlimited number of waypoints on the map and since it is solar power assisted it gives you an extended range. This is especially significant in case of search and rescue or forest fire when time is of an essence. The ASD drones reduce the concerns arising from current air surveillance solutions, such as environmental and economic requirements.

The objective of the ASD: Air Surveillance Drones is to enhance the quality of Air surveillance missions while keeping the cost of such operations affordable. Our drones allow the users to execute air surveillance missions with minimum man power. They will receive an input from the operator through our software application in order to determine the waypoints to be covered. Our software application communicates with the drone to determine the GPS coordinates of the desired destinations. The drone will travel through all the waypoints while providing live video streaming on the monitor in the ground station. The drone only needs to be operated manually for take-off and landing.

Moreover, using solar cells as an alternate source to recharge the batteries powering the engine makes ASD an inexpensive and environmentally friendly alternative to any other air surveillance solutions and also making it possible for longer flights without interruption.

2. System Specifications

2.1 High-level Description of Main Functions and Project Modules

The operation of the drone is separated into two different situations consisting of aircraft control and camera control, which need to be executed separately as is illustrated in Figure 2-1.

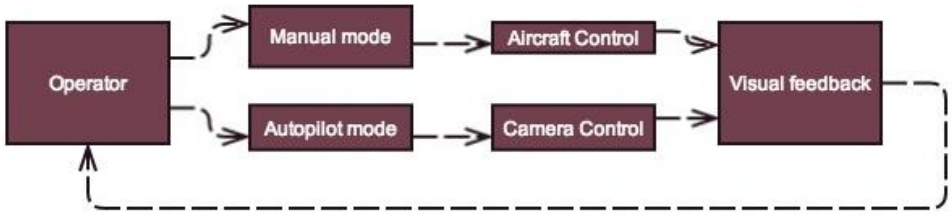

Figure 2-1: High-level Block Diagram

ASD's prototype drone is composed of four sub-systems: the radio system, the autopilot system, the video system and the power system. These systems need to work in conjunction with each other to achieve full functionality. The radio system and autopilot system are both able to command the airplane's servomotors and control surfaces and can individually be used as a backup in case one of them fails. The video system allows for visual navigation when the drone is in manual mode and air-surveillance when the drone is in autopilot mode allowing the operator to move the camera, which is mounted on a two-axis gimbal equipped with servomotors that allow movement. These systems are energized by the power system consisting of a high capacity lithium polymer battery connected in a parallel circuit with a solar cell array.

As a first step towards the development of the drone, extensive testing and modification of the aircraft's aerodynamics was conducted in order to maximize energy efficiency and range followed by individual system testing. Figure 2-2 shows a Solidworks model of the aircraft after the wingspan was increased to improve lift and allow for low-speed flying.

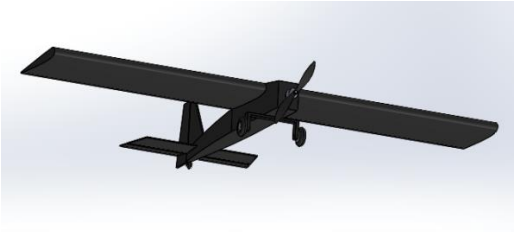

Figure 2-2: ASD's Mechanical Design

Using the on-board microcontroller's three-axis gyroscope, the drone is able to stabilize itself and allows for simplified operation. However, the operation of the drone does require the operator to have basic training for manual control of the aircraft. Figure 2-3 and Figure 2-4 further illustrate the control of the drone and the normal flying sequence procedure respectively.

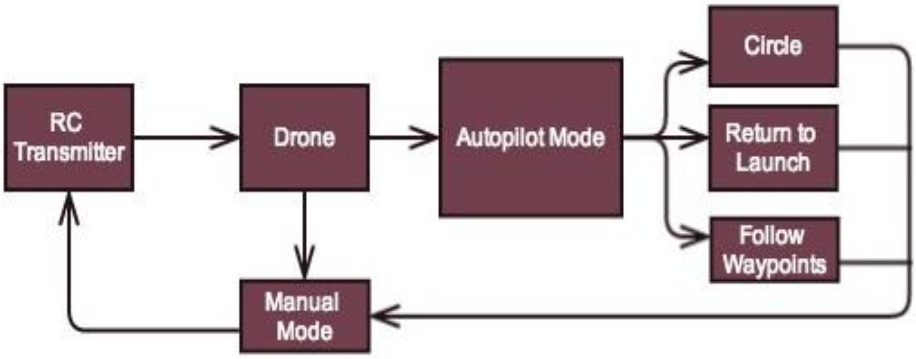

Figure 2-3: Drone control Block Diagram

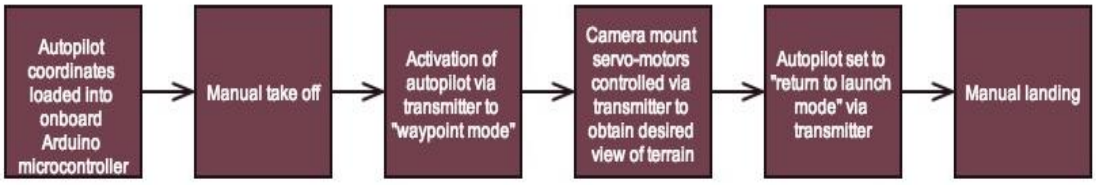

Figure 2-4: Mission operation Block Diagram

2.2 Cost and Materials

Table 1 shows the cost of the components required to build the Air Surveillance Drones (ADS).

Equipment List	Estimated Cost
Model Plane Building Materials	$350
1 x Boscam Video Receiver (RC 305 5.8 GHZ)	$50
1 x Boscam Video Transmitter (TS 353 5.8 GHZ 400mW)	$60
1 x Fat Shark FPV goggles	$200
1 x HD night vision FPV camera	$75
1 x 9CH FM Radio/Receiver	$275
2 x Batteries	$100
1 x Solar Cells	$130
1 x Engine (Turnigy G46 brushless outrunner 550kv)	$50
1 x Autopilot (F-TEK 31AP)	$140
1 x UBEK	$30
5 x Servos	$100
1 x Antennas	$40
1 x Cam mount (RC 5.8 GHZ FPV anti-vibration PTZ)	$50
Total Cost	$1650

Table 2.1- Initial Material and Cost Breakdown

The initial estimated cost for this project was estimated to be around $1650. The availability of funds was crucial for the completion of our project. We applied to the Engineering Science Student Society Endowment Fund (ESSSEF) but only received $350. That financially put a lot of constraints on the project and forced the team to adapt to the new budget by cutting down functionality with the way of the purchasing cheaper materials. By doing so we were able to cut our cost by $464 and that's considering the cost of new test plane we had to purchase after crashing our test plane. Table 2 shows the final breakdown of material used and its cost.

Equipment List	Estimated Cost
Model Plane Building Materials	$450
1 x Boscam Video Receiver (RC 305 5.8 GHZ)	$50
1 x Boscam Video Transmitter (TS 353 5.8 GHZ 400mW)	$60
1 x 7" LCD Monitor	$60
1 x HD night vision FPV camera	$75
2 x 6CH Radio/Receiver(Borrowed)	$0
2 x Batteries	$35
1 x Solar Cells	$130
1 x Engine (Turnigy G46 brushless outrunner 550kv)	$50
1 x Autopilot (F-TEK 31AP)	$96
1 x UBEK	$30
5 x Servos	$50
1 x Antennas	$40
1 x Cam mount (RC 5.8 GHZ FPV anti-vibration PTZ)	$50

Total Cost	**$1176**

Table 2.2- Final Material and Cost Breakdown

2.3 Schedule

Figure 2.1 shows the initial time line set for the completion of the project.

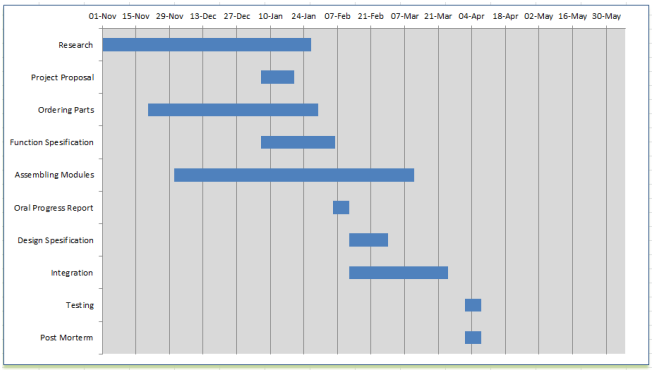

Figure 2.5- Gann Chart

Table 3 details the proposed and realized milestone dates for the ASD design. Striving to meet all deadlines we set for ourselves, and although during the course of this project number of unforeseen issues arose, we successfully met all the milestones we set for ourselves in the beginning of the term.

Milestone	Projected Milestone Date	Realized Milestone Date
Project Planning/Proposal	January 19	January 19
Design	March 1	March 1
Development, and Unit Test	April 3	March 23
Integration and Assembly Test	April 10	March 29
Project Closure	April 15	March 23

Table 2.3: Projected and Realized Milestones

4 Challenges

The risky nature of the project was one of the main concerns during the testing phase as any mistake could shatter the whole project. We lost two of the test planes during autopilot testing. Thanks to our contingency plans we were able to complete the drone despite these issues.

System integration was the most challenging part of the project. Complications coming from an ArduPilot faulty firmware delayed the project for nearly two weeks, as tracking down the problem was very challenging. Interference in the video system was another of the complications. It was caused due to a change in plans that resulted from budget concerns as the radio control frequency originally planned was 72 MHz but we used 2.4 GHz as we had the equipment from previous RC projects. As a team we decided that it would be more economical to change the video frequency and use the radio equipment we already had.

More complications arose when we started assembling the solar panel. The manufacturer's specifications did not match the requirements for our project. Moreover, the individual solar cells were quite fragile causing some of them to break when we tried to attach them to the wing. The problem was resolved by ordering a new batch of semi-flexible solar cells but unfortunately and due to budget concerns, it was impossible to completely satisfy the voltage required to recharge the plane's battery during flight as more cells are needed in the panel.
As a team, we sometimes had different opinions and ideas regarding many of the planes features which was a challenge but also an opportunity to learn how to work together in unity.

5 Group Dynamics

The ASD team worked well together throughout the semester and we are proud to say that we did not experience any conflict. The following chart describes how tasks and workload were distributed. Table 6.1 shows how the workload was distributed between members of the team. All the meeting agendas and minutes produced by the team over the course of the semester can be found I appendix 1.

6 Individual Learning/Work-load Distribution chart

High-Level Task	Armin	Carlos	Afshin
Plane Design and Building			XX
Solar Cells Circuits Design and Testing	XX	X	
Autopilot/GPS Module Assembly and testing	X	XX	
Camera System Assembly and Testing	X	XX	X
Autopilot programming	X	XX	X
System wiring	X	X	X
Research	X	X	X
Module and Systems Testing	XX	XX	X
Documentation	XX	X	X
Administrative	X		

Table 6.1: Workload Distribution

Armin Samadanian

Over the past several months, I have had the pleasure of working alongside three talented engineering students who share as much passion for the field as I do. We began collaborating as a group early before the course began as we pitched ideas back and forth. The project formally started when I pitched an idea regarding an Air Surveillance Drones to my colleagues. With approval from Dr. Andrew Rawicz, who headed the program, Air Surveillance Drones was born.

In my opinion, the team is most successful when we communicate our thought processes and ideas together while maintaining good time management. Even though we individually have our assigned parts in the project, we are able to work cohesively as a team because we all have a common goal. Not all members have similar time schedule, but we are able to accommodate each other when some are busier than others. I do not regret working with this team even though at times it can get frustrating. We all have different opinions and sometimes things get heated, but we are able to find a common ground on every decision. Sometimes it's best to listen and trust in their opinion even if the outcome is not as great.

While designing the hardware systems and components for the ASD, I believe that the most indispensable attribute I have acquired is an acute awareness of the importance of planning and time management. During the initial development stages of our project, I dedicated a great deal of time towards planning and researching datasheets as well as executing preliminary tests in order to ascertain that the subsystems were adequately designed to the utmost specifications. I believe that this helped ensure that there were no compatibility issues with the device overall. In the end, we did not encounter any major hardware issues. As such, the hardware prototype and implementation was carried out efficiently and thoroughly. As each hardware subsystem was designed modularly, it allowed for easy management of the project in terms of implementation and time management. If an issue arose, it was possible to remove that modular subsystem in order to do additional tests and execute any possible remediation without disrupting the development of the overall device. It is in my belief that this hardware modularity provided us with the ability to effectively tackle issues quickly and efficiently while retaining our composure.

Overall, I am very pleased with the success of our project and the team behind it. From the initial planning stages to a full-fledged prototype, it has been a pleasure to work with a group committed to bringing forth their skill sets. Personally, I feel that I have improved upon my hardware designs and my ability to work successfully in a team dynamic. I am confident that each and every member of ASD has acquired immeasurable experience and will excel at accomplishing any tasks set forth in the future.

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Juan Carlos Diaz

Capstone project was one of the greatest challenges I have had in my whole engineering studies, both interpersonally and technically. Working as a group in such a complex problem generated different points of views from all team members, I took this as an opportunity to allow myself to open to different suggestions and accept other methodologies to achieve a better end result. There were misunderstandings and lack of communication during some phases but we managed to fulfill our purpose and completed the project built and testing before our deadlines.

Furthermore, this project allowed me to expand my ability to interconnect different systems together as well as my general understanding of airplane aerodynamics. I feel that my overall mechanical and soldering skills were greatly increased while working on the project, as almost all components needed modifications to interconnect successfully. Working on the solar cells gave me a greater insight of power sources and their intrinsic IV characteristics as well as the importance of their internal resistance.

I previously worked on personal projects related to radio controlled models such as the construction and testing of RC helicopters, nonetheless working on the construction of an autonomous aircraft with so many capabilities and uses is something I am proud to have been part of and feel that if continued, could be a widely used product that could potentially save lives and protect our forests. Unfortunately, the characteristics of our drone were somewhat limited mainly due to budget concerns that forced us to employ some generic components, shortened the overall range of the aircraft due to a limited radio system and the lack of more solar panels to be able to recharge the batteries during flight.

Afshin Nikzat

Working on major projects can cause many difficulties. Complications faced can be caused by nature of the project, situation of group members or just simply how different members can work with each other. I learned a few new techniques with building planes. These can include the way wing was built and how to use simple tools to minimize uncertainties. For example first difficulty I faced was to increase the wingspan, keeping in mind aerodynamics cannot be affected and surface controls need to change accordingly. In this project having a stable plane is very basic and crucial. To increase the wingspan I needed to make extensions and make sure the whole wing at the end can handle the stress caused by the weight and the pressure of flowing air. To do so I had to add extra pieces to the wing and also put fiberglass on top of the wing, keeping in mind that aerodynamics should not change. Even if everything is tested, the last night when you try to test different parts, they start to fall apart. Slow and gradual changes that would not seem significant can cause many problems. Next difficulty faced was making the elevator stronger and exactly levelled. To solve this problem, after two attempts, I had to take several extra steps. First step was to put a heavy and flat item on elevators then glue. This step helped with making the elevator levelled. Next step was to add a piece of wood and glue it completely in order for the two parts of the elevator to have a support base. At this point it was possible to bend the shaft slightly and not damaging other parts. Afterwards could sand off the extra wood added. Another point learned during this project is that all subsystems need to be checked separately every time that system as a whole is going to be tested, especially if subsystems rely on each other.

Major projects can cause a lot of conflicts, even between best friends. Everyone has a really high expectation of other group members which can cause a conflict that postpones everyone's work. Different people could have a different view of what you want to do and would insist it is the right way. These discussions would lead to many conflicts inside groups. Aside from all points mentioned above, a person can be facing many problems in life that can cause distraction and lack of focus. Everyone should consider their personal problems and then make a schedule for their part accordingly.

7 Conclusion

All things considered, the Real-Time Air Surveillance Drones (ASD) project was a great success. The design of the product deviated very little from our initial design and most intended functionality was implemented. Our design choices were well supported and the results met all our expectations. We are still discussing the future of this product. Before the demo and reception of feedback from professors and teaching assistants, we do not intend to commercialize the device. If the project is to be commercialized, several aspects will be changed as we optimize the design for mass production and maximum usability.

We will also need to add some features such as thermal night vision camera and more enhanced solar power system which we originally intended to have but due to budget shortfalls we had to cut down.

8 References

[1] Koebler, J. (2013, November). "If drones are the future of search and rescue, why aren't they in the Philippines right now?" [Online].
Available: http://motherboard.vice.com/en_ca/blog/if-drones-are-the-future-of-search-and-rescue-why-arent-they-in-the-philippines-right-now

[2] Daflos, P. (2013, September 7). "Drones evaluated for use by BC search and rescue" [Online]
Available: http://bc.ctvnews.ca/drones-evaluated-for-use-by-b-c-search-and-rescue-1.1445059

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Appendix

Air Surveillance Drones

AGENDA

January 14, 2014
7:00pm-9:00pm

Purpose of Meeting: To discuss the initial start-up, exploration and basic design principles

Items for Discussion:

- Discussion on Company Name
- Discussion about the test plane
- Discussion of the ESSS funding request and funding exploratory findings

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Air Surveillance Drones

MINUTES

January 14, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To discuss the initial start-up, exploration and basic design principles

Minutes:

Armin Samadanian called the meeting to order at 7:00.

- **Discussion of name of company**

Discussion: Discussed various names. Air Surveillance Drones was decided upon. Afshin and Armin volunteered to develop the logo.

- **Discussion of results with buying the test plane**

Discussion: to purchase a Chipmonk plane. All the aspects of the plane and our plans were discussed.
Action: To purchase the test plane the next day
Discussion on the results of the funding exploratory findings
Discussion: Some rough figures were established.

Action: Carlos is creating and distributing a spreadsheet with the rough figures.

- **Discussion on handing in funding request to the ESSS**

Action: Armin will print and hand in the request. Others will create digital signatures.

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- **Other Business**

Engineering Notebooks to be obtained Proposal to be done at Carlos's house

Meeting was adjourned at 9:30pm.

Air Surveillance Drones

AGENDA

January 17, 2014
7:00pm-9:00pm

Purpose of Meeting: To discuss details of the functionality and achievable specifications

Items for Discussion:

- Re-routing
- Focus group
- Prototype functionality
- Storage Space for Materials

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Air Surveillance Drones

MINUTES

January 28, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To discuss details of the functionality and achievable specifications

Minutes:

Armin Samadanian called the meeting to order at 7:00.

A. **Logistics**

Discussion: Discussed the need for a place for the group to get together.

Action: Carlos house was chosen as a place for the team to gather and work on the project.

Focus Group

Discussion: Discussed the need for a focus group

Action: Questions to be forwarded to Carlos.

B. **Initial Functionality**

Discussion: Prototype initial functionality to be kept minimal

C. **Storage Space**

Discussion: Discussed the ability to obtain a locker in Lab1

Action: Another e-mail to be sent to Fred Heep by Afshin.

Meeting was adjourned at 9:30pm.

Air Surveillance Drones

AGENDA

January 28, 2014
10:00am-12:00pm

Purpose of Meeting: To discuss the presentation for the ESSEF
Items for Discussion:

- Development and discussion of the presentation

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Air Surveillance Drones

MINUTES

January 28, 2014
10:00am-12:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To discuss the presentation for the ESSEF

Minutes:

Armin Samadanian called the meeting to order at 7:00.

A. Development of the Presentation

Discussion: Re-discussed the costs involved for the presentation. Discussed roles and talking points.

Meeting was adjourned at 11:30am.

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Air Surveillance Drones

AGENDA

January 28, 2014
7:00pm-9:00pm

Purpose of Meeting: To discuss ordering of the parts

Items for Discussion:

- Discussion on what parts we are going to buy
- Discussion about the time we have for the items to arrive
- Discussion on our budget an our needs

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Air Surveillance Drones

MINUTES

January 31, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To discuss ordering of the parts

Minutes:

Armin Samadanian called the meeting to order at 7:00.

- **Discussion of ordering of the parts**
- **Discussion on how much we can afford to spend**
- **Discussion of the maximum time we can allocate for shipping**

Action: It was decided what items we were going to buy and it was decided to meet the next day to order the parts.

Meeting was adjourned at 9pm.

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Air Surveillance Drones

AGENDA

February 01, 2014
7:00pm-10:00pm

Purpose of Meeting: To order all the parts needed

Items for Discussion:

- Ordering parts for the project

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Air Surveillance Drones

MINUTES

February 01, 2014
7:00pm-10:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To order all the parts needed for the project

Minutes:

Armin Samadanian called the meeting to order at 7:00.

- **Do a thorough web search for all the parts we need**
- **To Finish ordering all the parts**

Action: Most of the material needed for the project was ordered

Meeting was adjourned at 12am.

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Air Surveillance Drones

AGENDA

February 19, 2014
7:00pm-10:00pm

Purpose of Meeting: To discuss and resolve implementation and issues with hardware and discuss the oral presentation

Items for Discussion:

- GPS Issues
- Oral Presentation

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Air Surveillance Drones

MINUTES

February 19, 2014
7:00pm-10:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To discuss and resolve implementation and issues with hardware and discuss the oral presentation

Minutes:

Armin Samadanian called the meeting to order at 7:00pm.

1 **GPS module**

Discussion: GPS Module does not work properly with ArduPilot

Action: Trying to switch to the older version software instead

2 **Oral Presentation**

Discussion: General talking points need to be assigned

Action: Roles assigned, meeting scheduled

Meeting was adjourned at 9:00pm.

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Air Surveillance Drones

AGENDA

February 28, 2014
7:00pm-9:00pm

Purpose of Meeting:
Items for Discussion:

- GPS Solution
- Testing plan for the plane

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Air Surveillance Drones

MINUTES

February 28, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Purpose of Meeting: To discuss and resolve implementation and issues with hardware and discuss the oral presentation

Minutes:

Armin Samadanian called the meeting to order at 7:00pm.

Purpose of Meeting: To discuss and resolve implementation and issues with hardware and discuss the oral presentation
Minutes:

Edwin Leong called the meeting to order at 9:10.

1 GPS Solution

Discussion: GPS communication has been solved
Action: Testing of GPS Code will commence
Action: Testing the setup of gps to make sure it works properly with ArduPilot

2 Testing of the Plane

Discussion: discussed a plan for testing the plane

Action: Armin and Carlos are going to do the first testing on March/02

Meeting was adjourned at 8:30pm.

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Air Surveillance Drones

AGENDA

March 12, 2014
7:00pm-9:00pm

Purpose of Meeting:
Items for Discussion:

- Current Progress
- Communications
- Design Specs and progress Report

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Air Surveillance Drones

MINUTES

March 12, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Minutes:

Armin Samadanian called the meeting to order at 7:00pm.

Purpose of Meeting: To discuss and resolve implementation and issues with hardware and discuss the reports.

- **Current Progress**

Discussion: Everyone's current progress. Status of GUI. Status of Ardupilot and Autopilot. Status of Plane and the hardware.
Action: Testing and Debugging of Communications and current completed architecture (considered core functionality)

- **Communications**

Discussion: Communications must be set and completed

Action: Armin and Carlos to work till the Sunday to complete to prepare for full functionality debugging. Sunday will be collaboration day

- **Design specs Progress Report**

Discussion: Design Specs Report coming up on Tuesday, also progress report coming up soon

after, Need to discuss sections and availability.

Action: Armin and Carlos will finish their sections before the Wednesday; Afshin will finish the rest of the report on the Tuesday.

Meeting was adjourned at 11:00pm.

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Air Surveillance Drones

AGENDA

March 20, 2014
7:00pm-9:00pm

Purpose of Meeting:
Items for Discussion:

- Status on the repairs on the plane crashed the day before
- Decision on how we are going to move forward with the tests
- Status with Solar cells and the circuitry

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Air Surveillance Drones

MINUTES

March 20, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Minutes:

Armin Samadanian called the meeting to order at 7:00pm.

Purpose of Meeting: To discuss repairs on the plane and decisions about retesting the plane and the plane and status of solar cells

- **Repairs on the plane**

Discussion: Discussed the status of the repairs on the plane

Action: Plane was completely fixed and restored

- **Retesting the Plane**

Discussion: When we can test the plane again

Action: Armin and Carlos to fly the plane the next day.

- **Solar Cells**

Discussion: Status with solar cells and circuitry

Action: Armin will finish soldering the solar cells and circuitry by March/24. Testing will be done right after.

Meeting was adjourned at 10:00pm.

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Air Surveillance Drones

AGENDA

March 25, 2014
7:00pm-9:00pm

Purpose of Meeting:
Items for Discussion:

- Solar cells Issues
- Demo Plan
- Testing
- Post-Mortem report

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Air Surveillance Drones

MINUTES

March 12, 2014
7:00pm-9:00pm

Present: Armin Samadanian, Juan Carlos Diaz, Afshin Nikzat

Minutes:

Armin Samadanian called the meeting to order at 7:00pm.

Purpose of Meeting: To discuss what to do about the issues with solar cells, Demo plans, finishing the testing, post-mortem report.

- **Issues with the solar cells**

Discussion: Discussed what to do with faulty and broken cells

Action: Armin will contact the distributor and will make sure to get the parts next day

- **Demo Plan**

Discussion: Demo must be prepared for.

Action: Afshin to work on initial demo and presentation materials until the 27th of April. Rest of team will begin working on the demo after the 27th.

- **Post-Mortem report**

Discussion: Design Specs Report coming up on Apr/01, need to discuss sections and availability.

Action: Armin and Carlos will finish their sections before the March/27; Afshin will finish the rest of the report after March/27.

Meeting was adjourned at 10:00pm.