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February 13, 2014

Dr. Andrew Rawicz
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Burnaby, British Columbia
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Re: ENSC 440 Functional Specification for ASD: Air Surveillance Drones

Dear Dr. Rawicz,

Enclosed to this letter is a document containing our Functional Specification for ASD: Air Surveillance Drones, describing an autonomous radio controlled surveillance aircraft. Our goal is to bring easy to use affordable autonomous drones for search and rescue operations, fire watch and other applications to the market.

The various requirements the autonomous aircraft will fulfill are detailed in the attached functional specification. Compliance standards, test plan, safety considerations required for our product can also be found inside the document.

Our company ASD was created by three dedicated engineering science students namely: Armin Samadanian, Juan Carlos Diaz and Afshin Nikzat. We thank you for considering our proposal and look forward to hearing from you. If you have any further questions please do not hesitate to contact us at asa128@sfu.ca

Sincerely,

Armin Samadanian
CEO
Air Surveillance Drones

Functional specification for Air Surveillance Drones

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Submitted to:

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Executive Summary

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.

ASD will be developed in five stages. In the first stage of development, we will be focusing on the aircraft's aerodynamic design. At the end of the first stage, the system shall have the following core functionalities:

- The plane should be able to be controlled manually from the ground station
- The operator should be able to fly the plane for minimum of 20 minutes from the ground station
- The plane should be able to take off and land without any problems

For the second stage, the power system will be upgraded. It shall be able to provide continuous power to all the components while being assisted by a solar cell array.

For the third stage, the autopilot system will be implemented. It shall be able to precisely and timely obtain the longitude and latitude coordinates from the aircraft as well as provide autonomous flight capabilities.

For the fourth stage, the video feedback system will be implemented. It shall be able to capture and display real-time video.

For the last stage of ASD development, we will integrate all the components. Also, once the proof of concept model is finished, we will continue to improve the performance and the overall design of ASD. Furthermore, ASD will comply with correlative standards.

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Glossary

RC:
The use of radio signals to remotely control a device is called Radio-Controlled (RC). It is achieved by means of a handheld Radio transmitter to control the vehicle.

FPV:
First Person View is a technique to control RC devices from distance. This method gives the capability of controlling vehicles from farther distances by using a camera. The camera will provide a first person perspective view for pilot as if he were onboard. This is also known as Remote Person View (RPV).

RF:
Radio Frequency is a rate of oscillation that relates to frequency of the wave. RF is mainly used for wireless communications.

FM:
Frequency Modulation is a method used to encode and transmit information using signals. Then the modulated signal will be demodulated at destination and data will be extracted.

GPS:
Global Positioning System is a system to obtain location and time information anywhere on earth using satellite navigation system.

SAR:
Search And Rescue is when a person is in need of immediate aid with no awareness of their location. There are a few sub fields, such as mountain, ground, urban, combat and air/sea search and rescue.

ESC:
An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake.

LCD:
Liquid crystal display or LCD is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals.

C2C:
Cradle-to-cradle or C2C design is a biomimetic approach to the design of products and systems.

1. Introduction

The ASD, Air Surveillance Drones, are solar powered planes with GPS capability and autopilot system being developed for any situation for which you need air surveillance. ASD allows for inexpensive and environmentally friendly alternative to any other air surveillance solutions while making it possible for longer flights without interruption.

1.1 Scope

This document provides the necessary requirements for a functional ASD Drone. The requirements will be categorized according to its functional priority. The priority requirements relate to the proof-of-concept, prototype, and production design from highest to lowest, respectively.

1.2 Intended Audience

The functional specification will be used by all members at ASD. It will allow for a measure of the Design progress during the development phase. Furthermore, this document becomes a guideline for function implementation, which will ensure compliance between both design and implementation phases. The testing of the product will also follow the procedures listed below as a final evaluation.

1.3 Classification

Throughout this document, the following convention will be used to describe the functional specification requirements:

R[n - p] Functional requirements

where *n* represents the functional requirement number and *p* denotes the priority level of the functional requirement. The notation *p* is classified as follows:

A. High priority; important requirements that are critical and essential to all our designs, especially the proof-of-concept design.
B. Medium priority; requirements that enhance the functionalities of our design in the prototype design.
C. Low priority; additional requirements will be implemented for the production design if there is sufficient time.

2. System Requirements

2.1 System Overview

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.

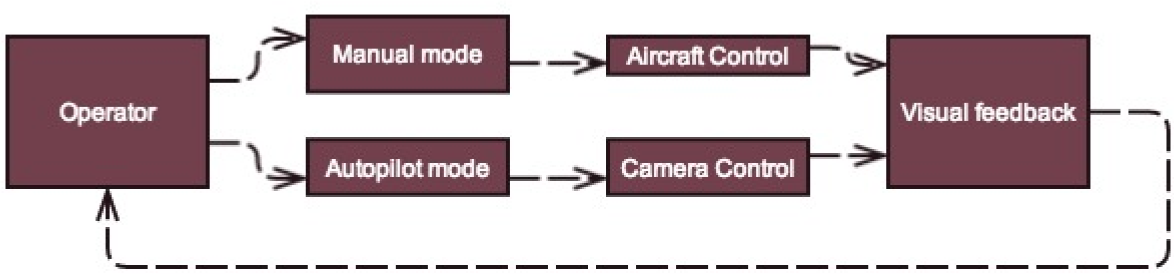

Figure 2-1: High-level Block Diagram

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.

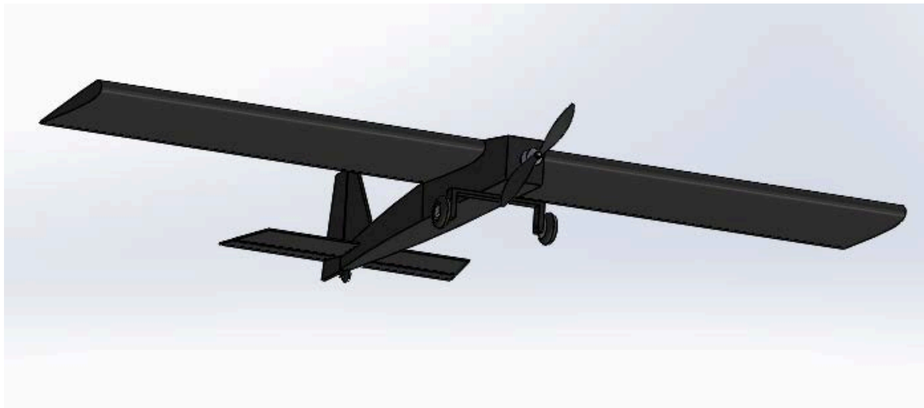

Figure 2-2: ASD's Mechanical Design

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.

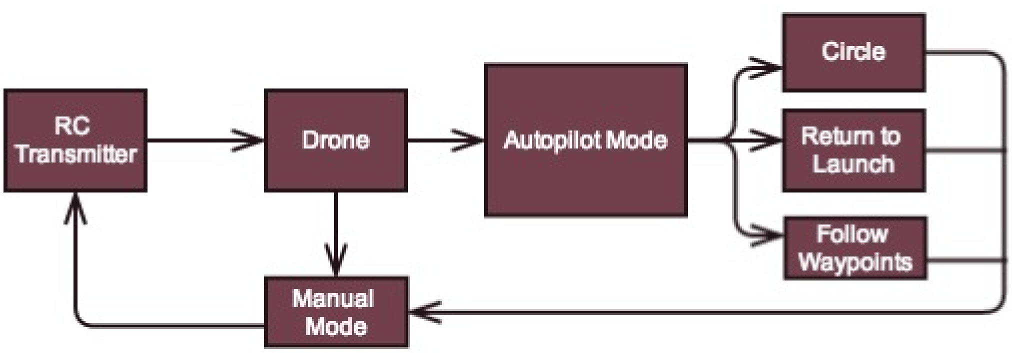

Figure 2-3: Drone control Block Diagram

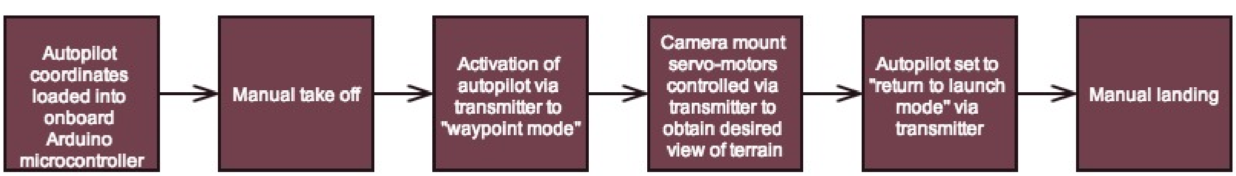

Figure 2-4: Mission operation Block Diagram

2.2 Safety Analysis

Care must be taken considering possibilities of causing harm to the others in case of any kind of malfunction. To address this concern, all applicable safety standards have been applied to the various components of our device and these standards are listed in the requirements for those components. Also, we must ensure that all the parts as a unit are also both within safety standards and incapable of causing harm to others.

2.3 Sustainability Analysis

A major production concern involves the C2C life-cycle of the product. A significant portion of the device is electronic and as a result we must ensure that such a portion can be recycled to be used elsewhere. Moreover, the plane itself is primarily made of wood and will be easily separable and recyclable. Solar power is the primary source of power for the plane and is used in conjunction with a battery to ensure continues power supply to the engine. For both the production stage and the prototype stage of the device, the motor, the battery, and the GPS unit will be also easily separable from the plane. Later modifications will be considered to simplify the design and cut down on the amount of material used in the process of creating it for the production stage.

2.4 General Requirements

[R1-A] The drone must be able to fly autonomously to preprogramed waypoints.
[R2-B] The drone shall have an autonomous return to launch feature.
[R3-B] The drone should be able to be controlled by a single person.
[R4-C] The retail price of the ASD Drone will remain between CDN$1200 to $1600

2.5 Physical Requirements

[R5-C] The drone shall not exceed 2.0 Kilograms in weight.
[R6-C] The wingspan must be at least 1.6 meters in length.

2.6 Electrical requirements

[R7-A] The lithium polymer battery must provide 14.9 V and have 5000 mAh capacity.
[R8-A] Solar cells must be able to provide 80 Watts of power output.
[R9-A] The power source for the ground station must be portable.

2.7 Mechanical Requirements

[R10-C] The drone can be disassembled for transportation.
[R11-C] The drone can easily be reassembled without any tools.
[R12-C] The battery shall be easily interchangeable

2.8 Environmental Requirements

[R13-A] The drone must be able to handle adverse weather conditions.
[R14-A] The drone operates normally at temperatures between 0°C and 40°C.
[R15-B] The drone can operate at night.

2.9 Standards

[R16-B] All electronics, connections and cables should be compliant with CSA Canadian electrical Code in regards to safety. [3]

[R17-B] The systems shall conform to OSHA-1910.269 standards [4].

[R18-B] The systems shall conform to ISO 9001 & ISO 14001 standards [5].

[R19-B] The systems shall conform to EN 60950 safety requirements [6].

[R20-B] The systems shall conform to EN 300-328standards [7].

[R21-B] The systems shall conform to conform to EN 301 489-1 and EN 301 489-17 [8][9].

2.10 Reliability and Durability

[R22-A] The drone will be waterproof.

[R23-B] The battery must be replaced every 250 cycles.

[R24-B] The solar cells must be regularly cleaned.

2.11 Safety Requirements

[R25-B] The drone will automatically return to launch site in case of a communication loss.

[R26-B] For operation of the autopilot, at least 6 GPS satellites must be locked before launch.

[R27-B] Automatic throttle control should only be used with a minimum of 9 GPS satellites.

[R28-B] The battery should be recharged in a fire resistant surface.

[R29-B] The battery must not be allowed to discharge more than 14V.

[R30-C] The operator will have exact GPS coordinates of the plane at all times.

[R31-C] The operator will fly the aircraft at a minimum height of 30m above the ground.

2.12 Performance Requirements

[R32-B] The drone must have minimum range of 7 kilometers.

[R33-B] The solar cells and battery must provide a flight time of at least 25 minutes.

[R34-C] The drone must be able to take off in maximum 10 meters.

2.13 Usability requirements

[R35-C] The operator must be trained to fly radio-controlled airplanes.

[R36-C] A single individual will operate the drone and camera.

[R37-C] The firmware in the microcontroller will be upgradeable by the operator.

3. Autopilot System

3.1 General Requirements

[R38-B] The integrated 3-axis gyroscope will provide control surface corrections for wind.
[R39-C] The autopilot will be conformed of an Ardupilot microcontroller and a GPS module.
[R40-C] The autopilot must be able to provide autonomous waypoint guided controls.
[R41-C] The autopilot must provide control commands to return to initial GPS coordinates.

3.2 Usability Requirements

[R42-C] The autopilot will be programmable during flight through the telemetry module.

[R43-C] Flight data will be transferred to and from the microcontroller with APM software.

3.3 Physical Requirements

[R44-C] The GPS module will be placed on top of the aircraft away from other signals.

[R45-C] Telemetry distance range should match video distance range.

3.3 Environmental Requirements

[R46-C] The GPS module works best in open areas and clear skies.

4. Video System

4.1 General Requirements

[R47-B] The video system will provide real-time visual feedback.
[R48-C] The distance range of the video system should be at least 7 kilometers.
[R49-C] The camera must provide light enhanced images for night flying.

4.2 Usability Requirements

[R50-C] The operator must be able to control the camera position.

[R51-C] The video received will be displayed on an LCD screen.

4.3 Electrical Requirements

[R52-C] The video transmitter must work with 5.5V DC.

[R53-C] The video receiver and LCD screen must work with 12V DC.

5. Radio System

5.1 General Requirements

[R54-B] The system will provide surface controls when drone is in manual mode.
[R55-C] The system must be able to engage and disengage the autopilot system.
[R56-C] The system will use FM at 72 MHz for an increased range.

5.2 Performance Requirements

[R57-C] The operator must be able to control the camera position.

[R58-C] The video received will be displayed on an LCD screen.

5.3 Safety Requirements

[R59-B] The system will work in conjunction with the autopilot to prevent control loss.

[R60-C] System's range will be at least 3 km greater than the operating range of the aircraft.

6. On-board Power System

6.1 General Requirements

[R61-B] Must provide at least 25 minutes of flight-time
[R62-C] The battery will be assisted by solar panels mounted on the wings.
[R63-C] The camera must provide light enhanced images for night flying.

6.2 Environmental Requirements

[R64-C] The solar panels require favourable sunny conditions to be effective.

[R65-C] The solar panels will be waterproofed.

6.3 Electrical Requirements

[R66-B] A voltage of at least 14V DC is needed at all times.

[R67-B] A maximum voltage of 18V DC can be supplied to the ESC.

[R68-C] The battery and solar panels will be connected in parallel and insulated by diodes.

7. User documentation

[R69-C] The user manual shall include a detailed setup guide for technicians and experienced users.
[R70-C] The user manual will be written in English, Spanish and Farsi
[R71-C] The user manual shall include the warranty, terms and condition, and contact information
[R72-C] The user manual shall include a company website which will include a FAQ help section
[**R73-C]** All documentation shall include the company's contact information

8. System test Plan

In order to provide products of the utmost quality, each component and subsystem will be rigorously tested to ensure that they meet functional specifications. We will be analyzing the hardware signals of each subsystem to ensure that they are up to specifications. Each element of the subsystems will be tested for its integrity, functionality, and power consumption. During the development of the prototype, we will test the implementation between the software and hardware systems. In addition, we will also validate the physical properties of the device such as its ability to handle different kinds of stress, temperature, and environmental conditions. The tests listed must be passed multiple times during different phases of the development cycle.

8.1 GPS Module Test

The GPS module will be tested to ensure that it is able to precisely and timely obtain the longitude and latitude coordinates of the Drone. The serial communication lines used to interface with the microcontroller will also be analyzed to ensure signal integrity. Testing of the GPS module includes, but is not limited to:

- Measuring the time it takes the GPS to acquire the satellite signals
- Measuring the accuracy of the Drone's coordinate
- Ensuring the GPS transmits the serial data accurately during processing
- Testing the strength of the signal in different weather conditions
- Ensuring that the GPS module does not have interference with other devices

8.2 Compass Module Test

The compass module (composing of the magnetometer) will be tested for its accuracy. The module's tilt compensation must also be tested for proper implementation. Testing of the compass module includes, but is not limited to:

- Measuring the accuracy of the compass
- Ensuring that the directional data is transmitted quickly to the microprocessor
- Testing for the potential disruptions caused by external magnetic forces

8.3 Solar Cells and Battery Test

The solar cells will be tested to ensure it meets safety standards while providing a reliable source of power. These solar cells will be implemented into the drone by placing them on the wings. The back-up battery will be tested to ensure that it provides 30 minutes of continuous usage as outlined in the requirements. Testing of the battery and the solar cells includes, but is not limited to:

- Measuring the device's power consumption to see how much of usage can be extracted from battery
- Testing the battery in conjunction with solar cells to ensure compatibility.
- Ensuring the back-up battery system will start powering the drone when there is no power provided by solar cells.
- Ensuring the solar cells and battery system are weather proof.
- Measuring the time required to fully recharge the battery.

8.4 Plane Engine Test

The engine will be tested to ensure it is powerful enough to operate the drone while being power efficient at the same time. Testing of the engine includes, but is not limited to:

- Ensuring the mechanical housing of the engine is strong enough to protect it from vibration shocks and from weather conditions.
- Testing of the amount of power the engine needs per unit time.
- Measuring the power the engine produces.

8.5 Video and Camera Test

The video and camera system will be tested to ensure the quality of the video it produces. It will also be tested for its performance in different weather and light conditions. Testing of the engine includes, but is not limited to:

- Camera testing
- Quality of Video tests
- Ensuring the weather and light conditions has minimal effect on the performance of our camera system
- Compatibility tests

8.6 Software (PC Interface/Microcontroller implementation) Test

All parts of the software will include tests to ensure proper functionality; ease of use and response to various mapping inputs. Testing of the software includes, but is not limited to:

- Autopilot testing
- Point of interest and path planning accuracy tests
- Usability tests and analysis of the GUI
- Platform testing
- Compatibility tests

9. Conclusion

The functional specifications illustrate the capabilities and requirements that will be held for this device and accompanied software. ASD Today is fully committed to implementing the core features of the device that we have elaborated upon in this document. If time permits, lower priority features will be implemented as well. Development is well underway and we expect to see a complete and functional working prototype by early April.

10. References

[1] Koebler, J. (2013, November). "If drones are the future of search and rescue, why aren't they in the Philippines right now?" Retrieved from: 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" retrieved from: http://bc.ctvnews.ca/drones-evaluated-for-use-by-b-c-search-and-rescue-1.1445059

[3] CAN/CSA-C22.2 No. 0-M91 (Reaffirmed 2001) General Requirements - Canadian Electrical Code, Part II, 2001, CSA Group.

[4] United States Department of labour, OSHA 1910.269 Electric Power Generation, Transmission, and Distribution, October 12, 1994. [online]. Available: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standar ds&p_id=9868 [Accessed: Feb 2, 2012].

[5] International Organization for Standardization, ISO 9001:2008 specifies requirements for a quality management system where an organization, August 25,2008. [Online]. Available: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber =46486. [Accessed: Feb 2, 2012].

[3]European Telecommunications Standards Institute. (2006). Electromagnetic compatibility and Radio spectrum Matters (ERM);Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive. Retrieved from: http://www.etsi.org/deliver/etsi_en/300300_300399/300328/01.07.01_40/en_300328v010701o.pdf

[4] CENELEC. (2000). Safety of information technology equipment. Retrieved from: http://www.itesafety.com/en_e3.pdf

[5] European Telecommunications Standards Institute. (2008).Electromagnetic compatibility and radio spectrum matters (erm); electromagnetic compatibility (emc) standard for radio equipment and services; part 1: Common technical requirements. Retrieved from: http://www.radiometrix.com/files/additional/pdf/regulatory/en_30148901v010801p.pdf

[6]European Telecommunications Standards Institute. (2012).Electromagnetic compatibility and radio spectrum matters (erm); electromagnetic compatibility (emc) standard for radio equipment; part 17: Specific conditions for broadband data transmission systems. Retrieved from: http://www.etsi.org/deliver/etsi_en/301400_301499/30148917/02.02.01_60/en_30148917v020201p.pdf