ROGUE AVIONICS
"Tomorrow's Innovations Today" ™
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February 16, 2009

Dr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, B.C. V5A 1S6

Re: ENSC 440 Functional Specification for a Virtual Piloting System

Dear Dr. Leung:

Attached is the functional specification for Rogue Avionics' Virtual Piloting System (VPS). Our project goal consists of the design and implementation of a wireless helicopter control system that avoids the use of a traditional on-board pilot. A pilot, instead, can operate the aircraft from the ground as if the pilot is physically in the cockpit.

The functional specification is written to provide users and developers a set of high-level requirements and descriptions for various system functions. This document is to be used as a guideline for Rogue Avionics' designers and engineers during the development stages of the VPS project.

Rogue Avionics consists of a team of four members: Jyh-Yuan Yeh, Isaac Chang, David Guo, and Xiaofeng Jin. Our company may be in its infant stage but the aspiration, innovation, and skill of its members are undeniable. If you have any questions or concerns about our proposal, please feel free to contact the team at *Rogue.Avionics@gmail.com*.

Sincerely,

JyhYuan Yeh

Jyh-Yuan Yeh
Chief Executive Officer
Rogue Avionics

Enclosed: Virtual Piloting System: The Functional Specification

VIRTUAL PILOTING SYSTEM

Source: NASA Image EL-1997-00111

THE FUNCTIONAL SPECIFICATION

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EXECUTIVE SUMMARY

Since 1903, when the Wright brothers first discovered flight, the age of aviation has become an integrated part of our daily lives. In 2007, close to 2.3 billion passengers and over 40% of all goods traded were transported by the world’s airlines. [1] Often overlooked in these statistics, however, are the pilots who fly the aircrafts carrying these people and goods. Often flying at high speeds and attitudes and through treacherous conditions, pilots put their own lives at risk to ensure that we get from point A to point B or that our Christmas presents arrive on time. Rogue Avionics’ Virtual Piloting System (VPS) is designed to be a safe, reliable, and cost-effective alternative for having an on-board pilot. Using an integrated system of camera, display, telemetry, and controls, a pilot is able to operate any aircraft from the safety of the ground as if the pilot was actually in the cockpit.

There are four key features included in the VPS:

1. *User-friendly control system that mimics actual on-board controls.*
2. *Expanded field of view that utilizes a moveable camera to shadow pilot head movements.*
3. *On-screen display that projects vital flight telemetry and information needed for proper flight.*
4. *Easy adaptability towards other aircrafts and applications by interchanging components.*

There are two phases in the development of the system. First, will be the initial proof-of-concept that will include the four main features mentioned. This concept will be implemented on our prototype helicopter with completion scheduled for April 2009. The second phase or production phase will expand on the adaptability of the concept to allow the VPS to be used on multiple platforms with minor modification. Our final product is to be operated by trained professionals in the airline, military, and aerospace industries.

The VPS functional specification is intended to act as a development roadmap for our designers and engineers. The requirements presented are to be evaluated and followed during the development phases to ensure that the final product conforms to our usability, functionality, and reliability standards. These specifications also represent Rogue Avionics’ desire to create a piloting system that will revolutionize aviation, as we know it.

TABLE OF CONTENTS

LIST OF FIGURES

1 INTRODUCTION

Since its discovery, air flight has become an integrated part of our lives whether it be going from point to point, transporting cargo, or fighting off enemies. With air flights’ rise in popularity, the numbers of pilots that need to risk their lives to fly these aircrafts have also increased. The VPS is meant to minimize the risk involved for pilots by allowing them to fly any aircraft from the safety of the ground. Using an integrated system of controls, displays, and telemetry, trained pilots will have the sensation of being actually inside the cockpit. Functional features and requirements will be described within this specification.

1.1 Scope

This document describes the specifications and requirements for a fully functioning VPS unit. The primary focus of the document is towards the proof-of-concept device features, however, partial description of the final production device will also be included. Possible modification and additional features that can be implemented on the unit will also be discussed. These additions are meant to address the specific needs for our different target markets.

1.2 Intended Audience

The functional specification is intended for use as a reference for Rogue Avionics’ VPS project team. Engineers and designers will use this document during the R&D, prototyping, and optimization stages of production to ensure that all components of the final unit meet all specifications and requirements. Project manager can also use this documents to plan development paths and milestones during the production process.

1.3 Classification

Each functional requirement listed in this document will be tracked using the convention:

[Rn-C] Functional Requirement…

Here, **n** is the functional requirement number and **c** is the corresponding development cycle the requirement applies to. For instance:

I The requirement applies to proof-of-concept stage only.
II The requirement applies to both proof-of-concept and production stages.
III The requirement applies to production stage only.

2 SYSTEM OVERVIEW

The VPS operates by constant interaction between the pilot and helicopter. *Figure 1* shows the input and output for both the pilot and helicopter and how they convey meaningful information to the destination object.

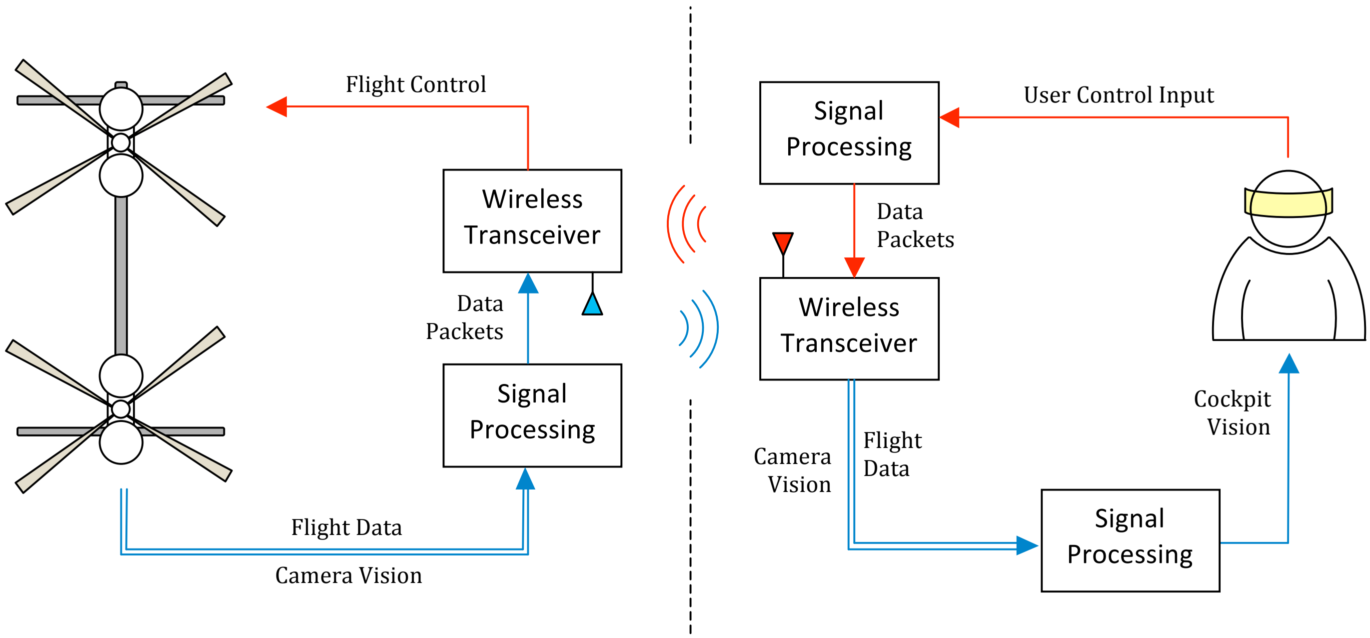

Figure 1: *System Overview of Virtual Piloting System*

Once the communication between the helicopter and the pilot is established, the video goggles will display the view from the camera. On the goggle display, flight information including acceleration, throttle, speed, flight time, and range is superimposed on the video feed. This data is meant to coincide with common cockpit dials to aid the pilot during flight. Flight control is accomplished using two joysticks similar to those found on a common helicopter. The layout of the joysticks allows the helicopter to be control with 4 degrees of freedom. Furthermore, head movements will be matched with changing camera angles to ensure the pilot gets a full video perception of the surroundings. Data, such as user input, video, and flight information, is transferred between the ground and helicopter wirelessly at near real-time rates, thus, promoting seamless flight.

3 SYSTEM REQUIREMENTS

The following subsections detail the specific requirements of different development phases of the VPS. Requirements are numbered following the previously defined classification and categorized, accordingly.

3.1 General Requirements

[R1-I] The helicopter must be easy to control by two joysticks with minimum Instructions.
[R2-I] The helicopter must be able to hover in the air by single action of a joystick at a fixed setting.
[R3-I] Helicopter flight must be contained within a 50m radius.
[R4-II] Operating the VPS will require two hands, and perfect or corrected vision.
[R5-II] There should be no pilot control constrain.
[R6-II] There should be no head movement constrain.
[R7-III] The retail price of the whole system should be no more than $1800.

3.2 Physical Requirements

[R8-I] The helicopter should be no bigger than 1/4 m^3.
[R9-I] The helicopter with electronics should be no heavier than 800g.
[R10-I] The helicopter must have some form of a crash prevention contraption.
[R11-I] The control station should weigh no heavier than 1kg.
[R12-I] The control station should be no bigger than 1/4 m^3.
[R13-II] The control station must have high mobility.
[R14-II] The visual glasses should be light and comfortable to wear.
[R15-II] The visual glasses should fit well for most people above the age of 16.
[R16-II] The visual glasses cannot slip when user turns his/her head.

3.3 Electrical Requirements

[R17-I] The helicopter should operate with a rechargeable 7.4V and 9V source.
[R18-I] 7.4V battery source must be capable of pushing at least 25 amps. [3]
[R19-I] All base station electronics must receive their power supply from a regulated 7.4V source.
[R20-II] All stepped voltages must be regulated and buffered properly.
[**R21-II]** All on-board helicopter electronics must be able to tolerate a fair degree of vibrations.

3.4 Mechanical Requirements

[R22-I] All motors should rotate at roughly the same speed when hovering.
[R23-I] Helicopter transmission and power train should be exposed for easy access and visual inspection.
[R24-I] Mechanically controllable swash plate assembly should be easily controlled using servo motors.

3.5 Environmental Requirements

[R25-I] Normal system operation must be guaranteed when within an elevation range from sea level to 350 m above sea level.
[R26-I] Normal system operation must be guaranteed when within the temperatures of 0 to 35°C.
[R27-I] System must not to be operated outside during rainy, snowy, or windy weather conditions.
[R28-I] System must not be operated near a radio tower, or area of high electromagnetic activity.

3.6 Reliability and Durability Requirements

[R29-I] An unloaded helicopter should be able to maintain flight for at least 7 minutes with fully charged battery.
[R30-I] The visual glasses should operate for at least 4 hours on a fully charged battery.
[R31-II] The helicopter must be easily flyable by instructed professional pilots.
[R32-II] The helicopter must be resistant to electronic and mechanical damage caused by light collision impact.
[R33-II] The camera's angular position should respond according to the speed and angle of the pilot's head movement.
[R34-II] The controllers must be able to withstand long-term and frequent usage and be resistant to breakage under normal operating conditions.
[R35-II] Microcontroller EEPROM life expectancy should be at least 100,000 flash cycles.

3.7 Safety Requirements

[R36-II] Visual inspection of helicopter must be done before each scheduled flight trial.
[R37-II] Maintenance check must be conducted every five flight trials.
[R38-II] The control and visual system must not cause any harm to the pilot.
[R39-II] Prolong viewing of visual glasses must not cause any strain on the eyes.

[R40-II] The control system must not interface with other devices unless it is desired.
[R41-II] The VPS must comply with all related safety regulatory and FCC standards.
[R42-III] The electronic and mechanical components and power connections must be fully enclosed to prevent injuries.

3.8 Performance Requirements

[R43-I] The helicopter must update flight control variables at a minimum of 75 times per second.
[R44-II] The helicopter must be able to detect operational failure of master controller.
[R45-II] The slave controller must immediately supersede flight control operations when master controller fails.
[R46-II] The control system should be able to detect volatile movement of the glasses and cease automatic adjustment for camera movement.
[**R47-II]** The height and speed of the helicopter must be readily available in near real-time on the visual display.

3.9 Usability Requirements

[R48-I] Helicopter should be powerful enough lift 125 g of equipment load.
[R49-I] Helicopter should be able to fly with the minimum velocity of 0.5 m/s with full equipment load.
[R50-I] Helicopter should be able to lift at speed of 0.25 m/s.
[R51-I] Helicopter must be capable of 4 degrees of aerial freedom.
[R52-I] Camera should have 2 degrees of rotation freedom, and an angular displacement of at least 80 degrees in each direction.
[R53-II] Visual output must be sharp enough to identify small objects.
[R54-III] Operation of the system must be simple and similar to that of a normal aircraft.
[R55-III] The system must be adaptable to be used on most aircrafts with minimal modification.

4 DOCUMENTATION REQUIREMENTS

[R56-II] All documentation must have an English version.
[R57-III] A user manual must be provided with the VPS outlining its functionality, operation, maintenance, and requirements.
[R58-III] The user manual must be written for an audience with minimal technical background.

5 SYSTEM TEST PLAN

5.1 Early Assessment

The VPS can be broken down into several different subcomponents. Each component can be represented by a process block in a flow chart, and will fall under one of the following categories of development listed below:

1. *Sampling Electronic Equipment*
2. *Inter-Circuit Communication*
3. *Wireless Communication*
4. *Motor Control*

Theoretically, these process blocks simply take inputs and create outputs. Therefore, these sub-systems can be developed in parallel and early testing can be done independent of each other. As algorithm scripting progresses, firmware testing can be conducted during flight. Details for the testing procedures will begin to unfold in the design specifications document once the VPS firmware platform starts to take shape. However, the four categories listed above have to pass certain tests outlined below.

The sampling of onboard electronics and the joystick will be done in a controlled environment. The key is to first simulate certain voltages and signals for our microcontroller to detect. Afterwards, the measured values will be compared with the known expected values. This will ensure that the microcontroller’s input channels were properly opened, and A-D conversion was successful.

Testing inter-circuit communication is not as complicated. Once IO channels have been opened to sample electronic equipment, the same IO channels will be re-used for communication between the microcontroller and other modules. Communication protocols will be established in later development stages. However, for early assessment purposes, all that needs to be verified is whether other system modules are responsive to serial commands. Wireless communication requires a more sophisticated protocol for transmission. Regardless of protocol, initial tests will focus on the quality of the received signal. A correlation needs to be drawn between an increase in data throughput rate and signal quality. A test to monitor the effects helicopter vibrations on the wireless transceiver also needs to be conducted.

Motor control plays a crucial role in the project’s development. Generating a motor control signal is relatively simple, but calibrating these signals to maintain flight stability is especially difficult. There really is no test procedure to quickly calibrate the motor signals. Calibration will most likely take the form of trial and error regression testing during test flights. Although, it would help to properly model the rudder, elevator, aileron, and throttle controls from the RC remote before conducting any regression tests.

5.2 Complete Integrated Solution

All individual sub-components may pass through early assessment testing, but may easily fail during final assembly without a clear roadmap for code integration. Members of Rogue Avionics' R&D team will deliver their code in March for complete systems integration. After this milestone, the first step is to dissolve all compiling errors. Next, the microcontroller must be able to access and command all subsystems. Guidelines will be devised in the design specifications for the time division of CPU time for each subsystem. For the time being, a check will be performed to ensure that there are no conflicts in memory allocation and interrupt servicing.

5.3 Benchmarks

Once we have successfully integrated each team member's code and execution is deemed stable, then the R&D team will proceed with performance testing. As a benchmark, the helicopter needs to be able to hover in the air and appear responsive to a pilot's joystick commands. At this point, data throughput rate will be tested to ensure that motor control variables are being updated quickly enough based on our defined requirements. If tests reveal a lag in flight control communication, then helicopter stability could be seriously compromised.

6 CONCLUSION

Rogue Avionics is committed to designing an alternative aircraft control system that will allow pilots to operate any aircraft without physically being inside the cockpit. The VPS will not only eliminate the entailed risks of being a pilot but should also revolutionize the current concept of aviation. This functional specification should have given readers a better understanding of the requirements involved in building such a system. Our development team is expecting completion of Phase I (Proof-of-Concept) by April 2009 with its success determining the continual development of future prototypes.

7 GLOSSARY

CCD: Charged-Coupled Device
EEPROM: Electrically Erasable Programmable Read-Only Memory
FCC: Federal Communications Commission
MCU: Microcontroller Unit
OOD: Object-Oriented Design
OSD: On Screen Display
PWM: Pulse Width Modulation
QA: Quality Assurance
UAV: Unmanned Aerial Vehicle
VOM: Video Overlay Module
VPS: Virtual Piloting System

8 REFERENCES

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[3] Walkera (2008). *Walkera #38 User Handbook* [Online]. Available from: http://www.walkera.com/cn/upload/explain/Z538-0104_expe.pdf. (Accessed: 16 Feb 2009).