GEOSURV II UNMANNED AERIAL VEHICLE

FINAL REPORT

PART C AVIONICS

Group Members:	**Lead Engineers:**
Ryan Mitchell	John Bauer
Stefan Radacina Rusu	Brian Wattie
Matthew Holmes	Fred Forbes
Kevin Ainsworth	
Chong Jin	
Guannan Wang	

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ABSTRACT

In the 2008-2009 school year the Avionics Team continued flight tests of the MP2028 autopilot with Avionics Test Bed 4 (ATB-4); designed the flight and instrumentation avionics systems for the GeoSurv II prototype; tested a critical subset of the flight avionics in ATB-5; prepared the avionics hardware and wiring for installation in the GeoSurv II prototype; and prepared documentation necessary for the first flight of the GeoSuv II prototype. The team designed the avionics systems for the GeoSurv II Prototype, which included the control system, independent flight termination system and the instruments for data acquisition. ATB-5 was designed, built and tested to replicate the GeoSurv II Prototype design and flown to demonstrate its viability and functionality. Avionics block diagrams were developed for different stages of the ATB-5 and GeoSurv II Prototype. Hardware was selected for all avionic components on the aircrafts. Wire cable runs were manufactured for installation on the prototype. Mounting supports for avionic components were created for installation in the fuselage. Horizon Ground Control Station software was calibrated to display the flight parameters of the prototype. A remaining task list with the work to be done in order to achieve first flight with the GeoSurv II Prototype was also compiled.

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NOMENCLATURE

AER	Aerodynamics and propulsion
AGL	Above Ground Level
ATB	Avionics Test Bed
AVI	Avionics and flight testing
BLOS	Beyond Line of Sight
BPS	Bits Per Second
CAD	Computer Aided Design
CHT	Cylinder Head Temperature
CIC	Computer In Command
DAS	Data Acquisition System
DR	Design Report
DSP	Digital Signal Processing
EDM	Electronic Distance Measuring
EMI	Electromagnetic Interference
FT	Fuselage Temperature
GCS	Ground Control Station
GPS	Global Positioning System
HP	Horsepower
IC	Integrated Circuit
IFR	Instrument Flight Rules
IFTS	Independent Flight Termination System
INT	Integration
KEAS	Knots Equivalent Airspeed
knots	Nautical Miles per hour
lbs	Pounds weight
LED	Light Emitting Diode
MP2028	MicroPilot 2028 Autopilot
MPADCs	MicroPilot Analog to Digital
NAV	Navigation
OAT	Outside Air Temperature
ODA	Obstacle Detection and Avoidance
OS	Operating System
PDR	Preliminary Design Review
PIC	Pilot In Command
PID	Proportional Integral Derivative
Pro/E	Professional Engineer CAD program
R/C	Radio Control
RPV	Remote Piloted Vehicle
SAF	System Safety and Certification
SGL	Sander Geophysics Ltd.
SRD	System Requirements Document
STR	Structures and Mechanical Systems
UAS	Unmanned Air System
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rules

1. INTRODUCTION

The following part of this report summarizes the work accomplished by the Avionics Group for the 2008-2009 project year. The duties of the group included testing and analysis of system designs, autopilot software modifications, design and manufacturing of sensor instruments, a final overall avionics systems design for the prototype, and continued performance testing and analysis of the MP2028 autopilot. Many documents were created to verify manufacturing and safety of the aircraft such as the ground test plans for the GeoSurv II Prototype.

The team's first task of the year was to integrate the MP2028 autopilot as the main control system in the ATB-4. Test flights where conducted to verify functionality and provide flight data. The major tasks of the team were the design and manufacturing of the avionic components for the GeoSurv II Prototype. This manufacturing included all additional required instruments for flight data acquisition. The next major task was to design, manufacture and test fly the ATB-5. The purpose of the ATB-5 was to replicate and verify the avionic systems designed for the GeoSurv II Prototype. This progress has led to a number of recommendations for future work, which are presented at the end of this part of the report.

2. AVIONICS DESIGN METHODOLOGY

A major task for the 2008-2009 avionics design team was to design the avionics configurations for the ATB-5 and the GeoSurv II prototype. This was accomplished through block diagrams which present the avionics physical architecture. The diagrams also show how these components are integrated to provide the overall required functionality. In addition, wiring diagrams were created for all systems in order to present the exact installation and configuration of the electrical components of all systems.

3. GEOSURV II PROTOTYPE

3.1 Prototype vs. Geosurv II Equipment

The GeoSurv II Prototype will only be used for testing and there are many capabilities not required as compared to the full GeoSurv II as outlined in the SRD. Some of these capabilities affect the avionics. Initially, the GeoSurv II Prototype will not contain the following equipment but the wiring conduits for them were built into the structure of the aircraft as specified in

DR94-08 in order to facilitate the installation and upgrade of the on-board avionics system. Cables and connections for these will not be installed or provided for at this time:

- magnetometer at the wing tip and pre-amplifier in the lower fuselage bay
- navigation (position) lights
- anti-collision light
- Iridium antenna

3.2 Wing Conduits

The wing will eventually contain the following equipment:

- magnetometer at the wing tip and pre-amplifier at the wing root
- navigation (position) lights
- servos

Wiring conduits are used to contain the cables and protect them from damage. The wiring conduits are of non conductive material to prevent short circuits of any exposed wire, and smooth on the inside, as any sharp edge can catch on a cable and strip the shield/insulation.

The wing has two conduits, one for the magnetometer cable, position lights and empennage servo cables and a second conduit for the aileron servo cables.

Servo cables need a conduit with a minimum inner diameter of 0.75in. The desired minimum bending radius for the conduit is 2.5in but the absolute minimum bending radius is 1.5in.

The intended GPS antenna location will be on top of the fuselage hatch while the Freewave transceiver antenna will be located on the lower payload bay hatch.

3.3 Empennage Conduits

The empennage will contain two servos on each elevator half and on each rudder. The empennage does not have any conduit but passages have been created in the foam core in order to allow servo cables to run through.

3.4 Fuselage Connection Points

The GeoSurv II is designed as a modular aircraft which can be disassembled for shipping. The wings and empennage are detachable from the booms and fuselage and therefore all of the wiring must disconnect at multiple points. The wiring from the empennage will be disconnected from the fuselage at the boom-to-wing interface. All wiring contained in the wing will be disconnected at the wing root from the fuselage. These cables will be disconnected and connected via the access panel in the bottom of the fuselage.

3.5 GeoSurv II Prototype RC Control

The UAV Prototype will be initially flown using an R/C system by an experienced pilot. The purpose of these early flights is to establish the flight performance of the GeoSurv II Prototype prior to eventual full integration of the MP2028 autopilot.

3.6 Remote Control Systems using 72MHz versus 2.4GHz

R/C aircraft radios are currently in a period of transition from older, frequency designated units in 72 MHz (50 channels designated 11 to 60, one channel per aircraft) to new 2.4 GHz systems that use more sophisticated techniques to lock receivers to transmitters which allow anywhere from 20 to 40 simultaneous connections. The 72MHz systems have other advantages as discussed below.

3.6.1 UAV Prototype Limiting Factors

The UAV Prototype is a custom aerial vehicle and several factors have to be taken into consideration for the remote control system used with it:

- The structure of the aircraft is a carbon fiber composite. This will have a shielding effect on radio signals, especially for 2.4GHz signals
- The engine of the aircraft is located behind the fuselage. When the aircraft is flying away from the pilot, the engine may block the radio control signals, especially 2.4GHz.
- The engine of the aircraft may create interference with the 72MHz receiver even though the engine ignition module is shielded.
- The airfield where the UAV prototype will fly is relatively free from other 72MHz noise interference
- A 2.4GHz receiver's antenna may need to be extended in order to be positioned for line-of-sight with the transmitter on the ground. This may create additional problems with matching the impedance of the antenna to the receiver. In addition, to ensure continuous reception at 2.4 GHz, an array of up to 6 antenna modules would have to be mounted with fairings outside of the Carbon Fiber fuselage. Such a solution would require additional design, fabrication and testing that would have jeopardized the Prototype schedule

The 72MHz R/C systems are a proven and tested technology but they may suffer from interference. 2.4 GHz systems offer the latest technology but they may suffer from loss of signal due to objects blocking direct line of sight. Both options were analyzed in DR94-09 and the 72MHz RC equipment was found to be more suitable for the GeoSurv II Prototype. It was concluded that:

a. the 72 MHz RC system offers the most reliable means of control
b. the 2.4 GHz while attractive would require considerable antenna module construction to avoid the carbon fiber problem and this would also require extensive testing before acceptance which would impact the prototype flight test schedule
c. A frequency monitor must be used to ensure free channel operation at the GeoSurv II Prototype's frequency

3.6.2 Dual Receivers for 72 MHz

In order to increase reliability and redundancy different setups can be created using two 72MHz receivers:

- One option is to use two separate standard receivers on the same frequency with one receiver controlling the port side of the aircraft and the other the starboard side. This setup allows the aircraft to still be controllable in case of a receiver failure or loss of signal to one receiver.
- Another option is to use an integrated on-board electronic system with two completely separated input circuits and two antennas which is available from Weatronic. Weatronic Dual Receivers are highly complex electronic devices

featuring an enormous variety of performance characteristics due to their sophisticated firmware and due to their powerful microprocessor. They are however new products and in-field performance information is non existent.

- Customs setups can be created with dual receivers, provided time and money is invested in developing the protocols, failure modes analysis and hardware to achieve the desired results.
- The susceptibility for radio frequency interference on 72MHz RC frequencies is usually avoided by frequency control at designated flying sites. To further ensure a free channel of operation a 72 MHz frequency spectrum monitor should be used to ensure that the UAV prototype's control channel is free from interference

3.6.3 Smart-Fly Power System

The GeoSurv II Prototype is a large aircraft and 2 servos will be installed on each control surface. Because of the large number of servos on the aircraft, peak power load is expected to be high. The servos on each control surface also need to be carefully setup to work synchronously. Normal commercial radio control systems cannot handle such electric current demands without significant wiring changes. However there are available add-on power distribution systems that can be used to overcome this deficiency. One of the most popular systems is the Smart-Fly Power System Eq6Turbo. The Smart-Fly Power System offers several important features:

- Weighs 128g and measures 6.0" x 3.0"
- Can be used with 2 Li-ion or Li-poly batteries
- Has 2 battery inputs that are protected against battery faults, lost cell or short circuit
- Has an adjustable servo regulator, with a range of 5.5V-6.5V, continuous 17.5Amp output current with a 35Amp peak. The servo regulator has a cooling fan that must not be obstructed.
- Has 8 channel inputs from the receiver. 6 of the channels outputs can have 3 servos independently connected to each, with individual servo matching and reversing. The other 2 output channels have 2 servo outputs each.
- Filtered and regulated 5.0V power to receiver
- Receivers can be end-loading or top-loading
- Fully buffered and RF filtered signal line for each servo. The RF filter helps prevent noise from getting to the servos. The buffer protects the other servos if one servo signal wire gets shorted.
- Long servo lead line matching
- Built-in Ignition Cutoff. This can be connected using a fiber optic cable to a module placed in series with the engine ignition module power.

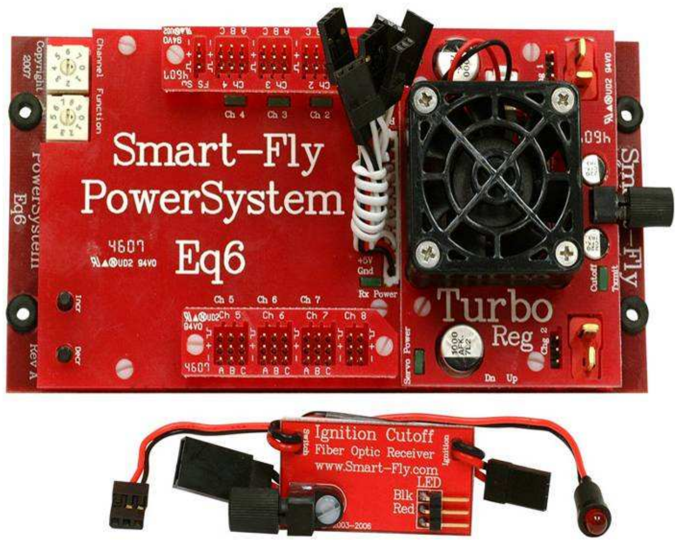


Figure 1: Smart-Fly Power System Eq6

It was concluded that the Smart-Fly Power System offers many features that will increase the reliability and controllability of the GeoSurv II Prototype. The Smart Fly system also offers a reliable solution to power demands and voltage regulation while also providing for redundancy and EMI shielding from the engine ignition module.

3.7 GeoSurv II Prototype Avionics Systems Design

The purpose of the GeoSurv II Prototype early flights is to establish the flight performance of the aircraft prior to eventual full integration of the MP2028 autopilot. The avionics system for the GeoSurv II prototype is composed of four different parts. These systems are the flight avionics, the data acquisition system, IFTS and the engine ignition module.

- The purpose of the flight avionics is to control the aircraft's flight. The initial flights will be controlled using an R/C system to verify proper behaviour and controls of the aircraft. This system will be phased out with the aircraft eventually being controlled by the autopilot. The radio control system consists of the JR transmitter which relays control signals to two JR receivers. Each one of these receivers is responsible for control of one side of the aircrafts control surfaces. The purpose of this is that in the event of a malfunction or loss of signal to one receiver the pilot will maintain control of the other side of the aircraft while the other servos will go to a specified neutral position. The two receivers are connected to the Smart-Fly PowerSystem Eq-6 Turbo. The Smart-Fly board will relay the signal to the servos on the control surfaces. Also the Smart-Fly board has a built in ignition cut-off signal that will be sent optically to the engine ignition module. The flight avionic system is depicted in Figure 2.

- The flight data acquisition system provides readings to monitor and evaluate flight parameters. This is accomplished by using the internal sensors of the MP2028 and its associated A/D converters to gather data. This data is then stored in the MP2028 data log and it is partially relayed to the Ground Control Station through telemetry. The data is displayed using MP2028 Horizon Software. The data acquisition system is depicted in Figure 3.

- The requirement for an Independent Flight Termination System (IFTS) was previously established in past ATB flight test programs. The IFTS is an independent safety feature that allows the pilot to kill the engine if required. This system is the backup for the main control system engine cut-off in the event of an emergency. The engine will be shut off by the IFTS in the following cases:

    - the switch on the transmitter is pressed
    - the IFTS receiver on the aircraft loses the signal from the transmitter
    - the IFTS battery on the aircraft fails

    The IFTS is depicted in Figure 4.

- The engine ignition module is powered by a battery and its purpose is to provide the spark voltage to the spark plugs at the proper time. If the connection from the engine battery is disconnected there will be no spark and consequently the engine will shut down. There are three switches connected in series between the battery and the ignition module. These are a manual safety switch, the ignition cut-off switch from the Smart-Fly PowerSystem, and finally the ignition cut-off switch from the IFTS. The engine ignition system is depicted in Figure 5.

More details on the GeoSurv II Prototype initial design choices can be found in DR94-09, DR104-01 and several other documents.

For more information on installation of the prototype including wiring diagrams refer to DR94-02.

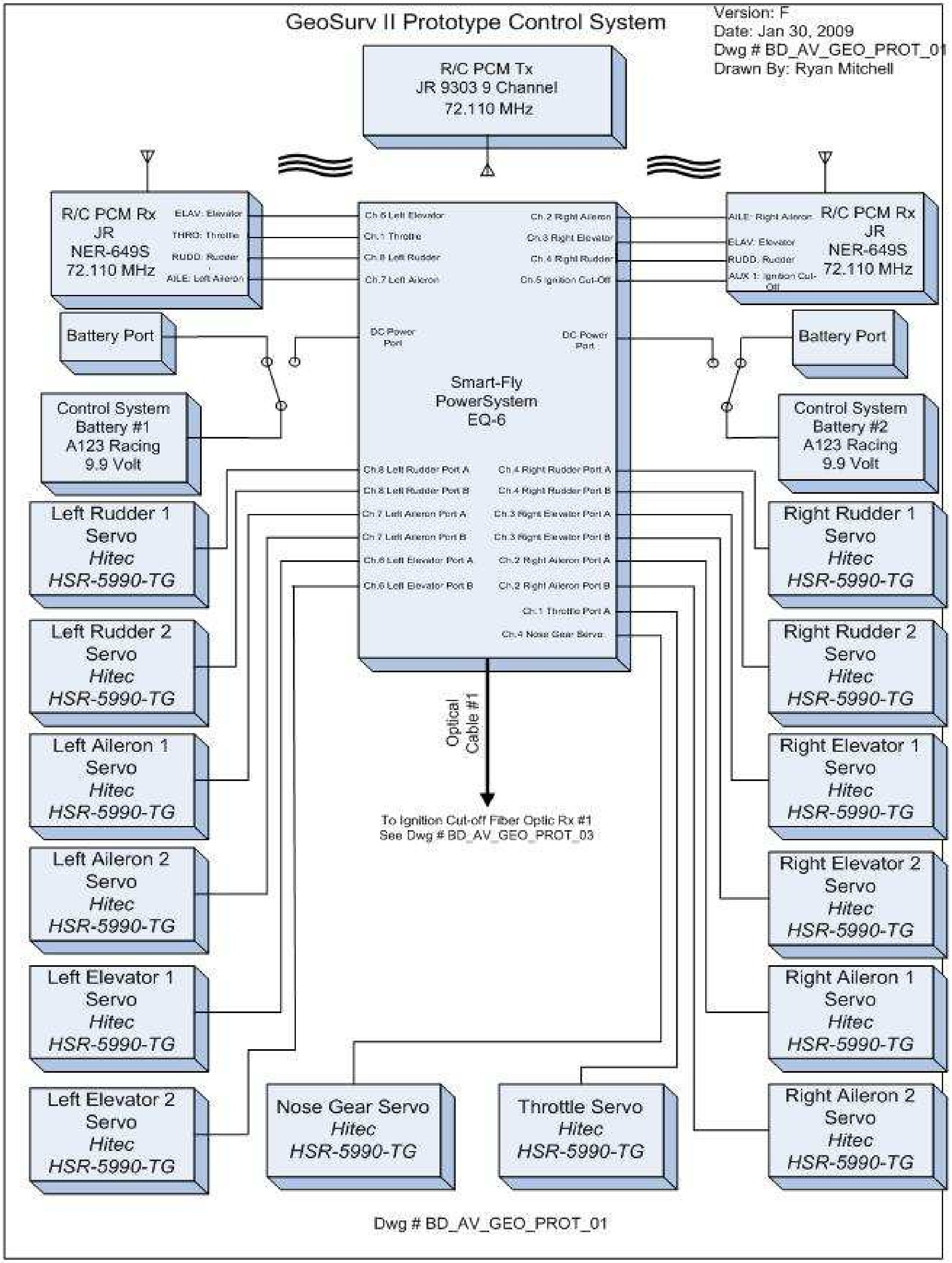


Figure 2: GeoSurv II Prototype Control System

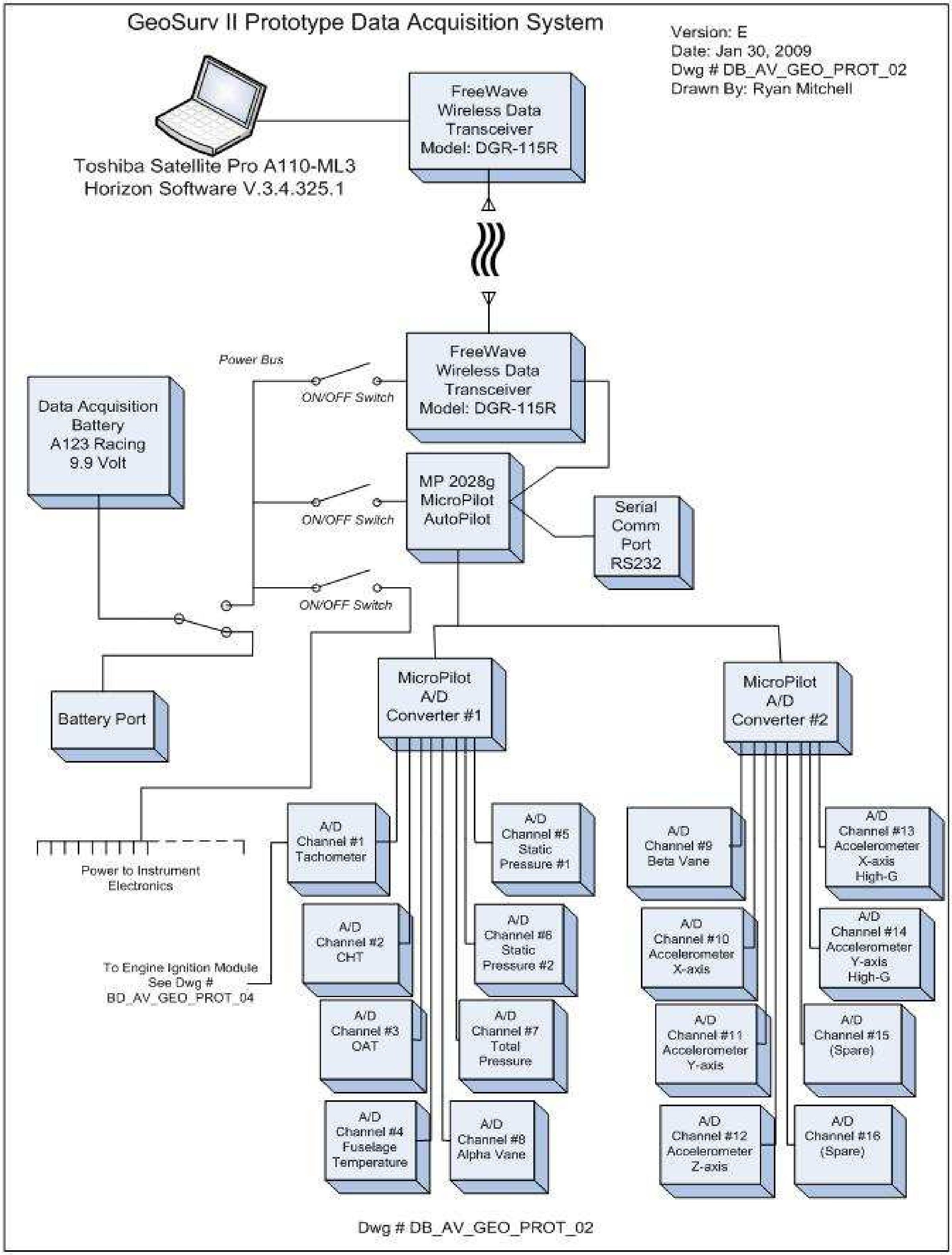


Figure 3: GeoSurv II Prototype Data Acquisition System

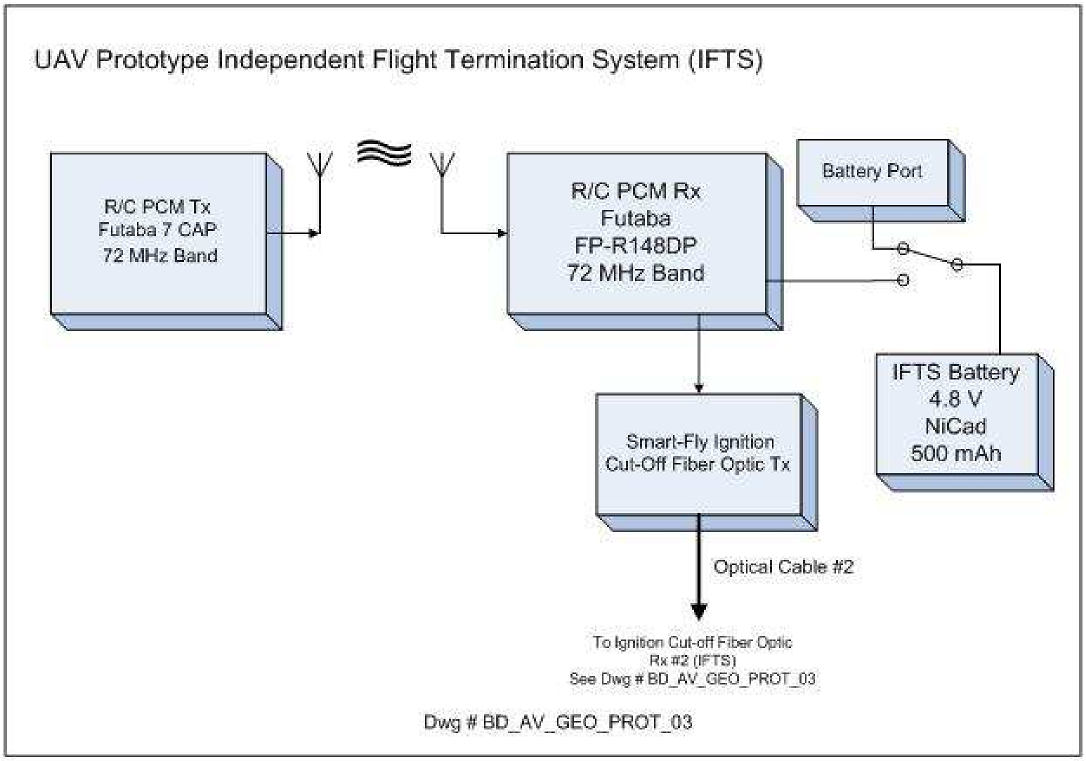


Figure 4: GeoSurv II Prototype Independent Flight Termination System

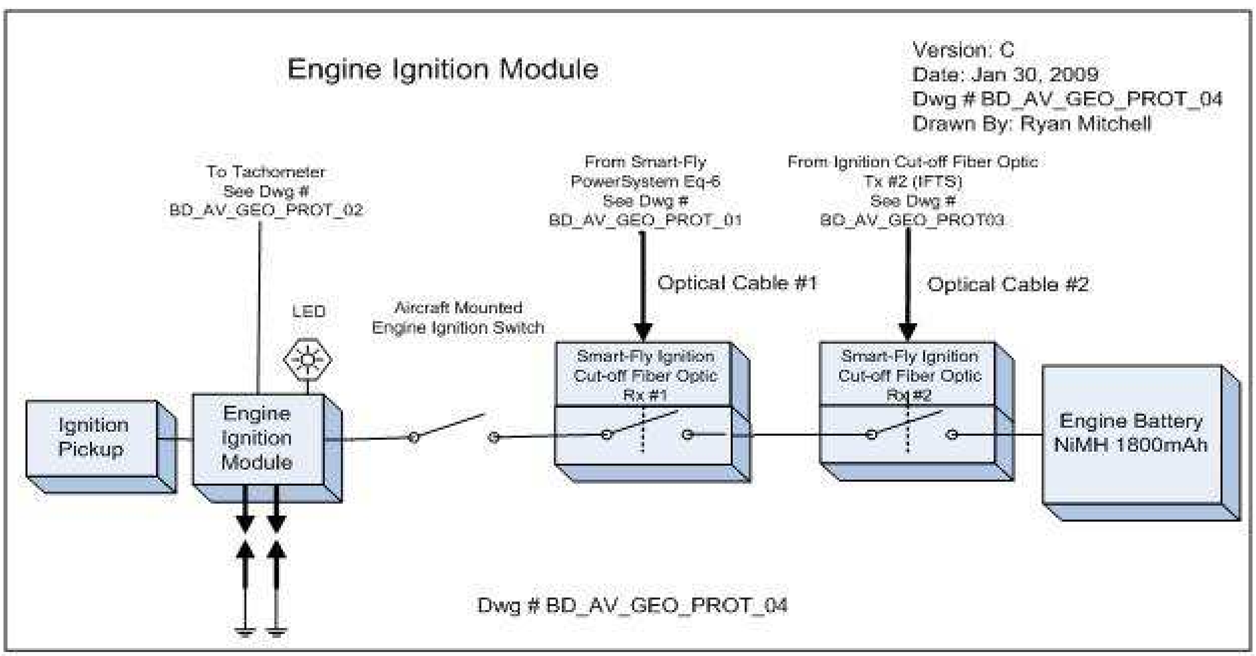


Figure 5: GeoSurv II Prototype Engine Ignition Module

3.8 GeoSurv II Prototype Wiring

The wiring cables required to implement the previous GeoSurv II Prototype diagrams needed to meet the following requirements:

- Minimum cost
- Small minimum bending radius
- Minimum temperature range of -20 to +60
- Small electrical resistance in each conductor
- 22 AWG conductors to match previously purchased wire crimper
- shielded with drain wire

An individual cable run is used for each servo on the aircraft. This increases the reliability and safety of the aircraft. If a disconnect point of an individual servo cable is damaged, only one servo will be lost instead of multiple.

If 2 servos shared the positive and ground power wires then the current load of the conductor would double and may exceed its manufacturer specified limit.

Multiple conductors in one cable also increase the minimum bending radius of the cable.

The shield of the cable will serve to protect the servo signal wires from interference and the drain wires of the cables will be connected to terminal blocks next to the Smart-Fly Power System Eq6. From there they can be connected to a ground.

Several cable types that had properties similar to the requirements have been investigated and they are presented below:

All cables are 3 conductors (22AWG) with overall shield and drain wire and the outer jacket material is PVC unless specified otherwise. The minimum bending radius is 10X the outside diameter of the cable.									
Only the shown lengths are available. Shipping costs are not shown									
Cable	Current Rating @ 25C (Amps)	Minimum bending radius (in)	Temperature Range (C)	Conductor DC Resistance (ohm/1000ft) @ 20C	Price (CAD $ / 100 ft)	Price (CAD $ / 250 ft)	Price (CAD $ / 500 ft)	Source	Note:
Belden 5501	2.8	1.25	-20 to +75	16.4	260			Digikey	
Belden 8771	2.9	2	-20 to +60	15	x	97	194	Newark	
Belden 9363	3.8	2	-30 to 105	15	x	x	292	Newark	
Belden 9770	3	1.5	-20 to +90	16	x	x	216	Newark	
Belden 9939*	3	2	-30 to +80	14.7	72	x	279		Has braid shield but no drain wire
Belden 9967*	2.8	2	-20 to +105	15.3	171	x	?		Has braid shield but no drain wire
Alphawire 3222*	~6.4*	1.84	-55 to +105	15.2	186	x	812	Newark	Has braid shield but no drain wire. Current rating is an estimate only.
Alphawire 5103C*	~6.4*	2.04	-20 to +105	16.4	430	x	?		Current rating is an estimate only
Alphawire 6339*	~6.4*	2.03	-20 to +80	16.3	77	x	308	Newark	Current rating is an estimate only

Figure 6: GeoSurv II Prototype Servo Cable Options

The Belden 9770 was the chosen cable for the GeoSurv II Prototype because of its low cost, small size, physical flexibility and availability. Its datasheet can be found in the Appendix and a sample is shown below.

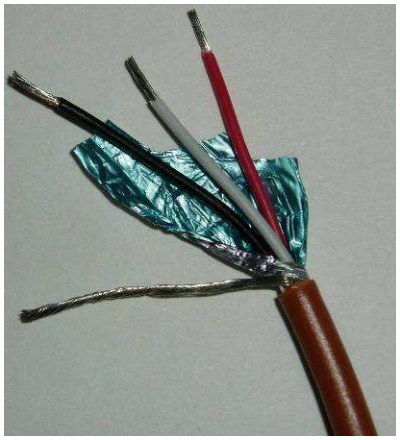
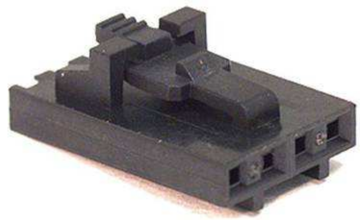


Figure 7: Belden 9770 Sample

3.9 Connectors

The GeoSurv II Prototype is a modular aircraft. It is designed to be disassembled at the wing-to-fuselage interface and at the tail boom ends. In order to meet this objective, the aircraft cable runs must also be disconnect able at those interfaces. In addition, a lightweight locking type connector is required to avoid inadvertent disconnection while in flight.

The chosen connectors for the GeoSurv II Prototype are the 4-pin Molex C-Grid SL .100. This is because of their small size, simple locking mechanism and low cost.



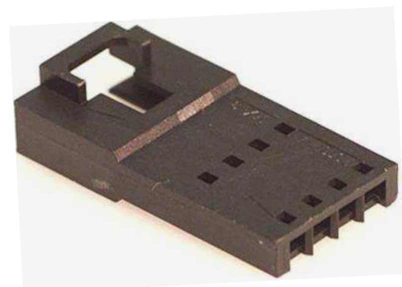


Figure 8: Molex C-Grid SL .100 Connector

The 4 pins are used for the positive and ground power wires, the servo signal wire and the shield drain wire.

In order to improve reliability and due to the fact that servo connectors will rarely be inspected, the standard Futaba connectors on all servos installed in the GeoSurv II Prototype have been replaced with 3-pin Molex C-Grid SL connectors.

3.10 Cable runs

There are 5 individual cable runs in the GeoSurv II Prototype and they all start at the Smart-Fly Power System Eq6 Turbo and end at a particular servo as shown below:

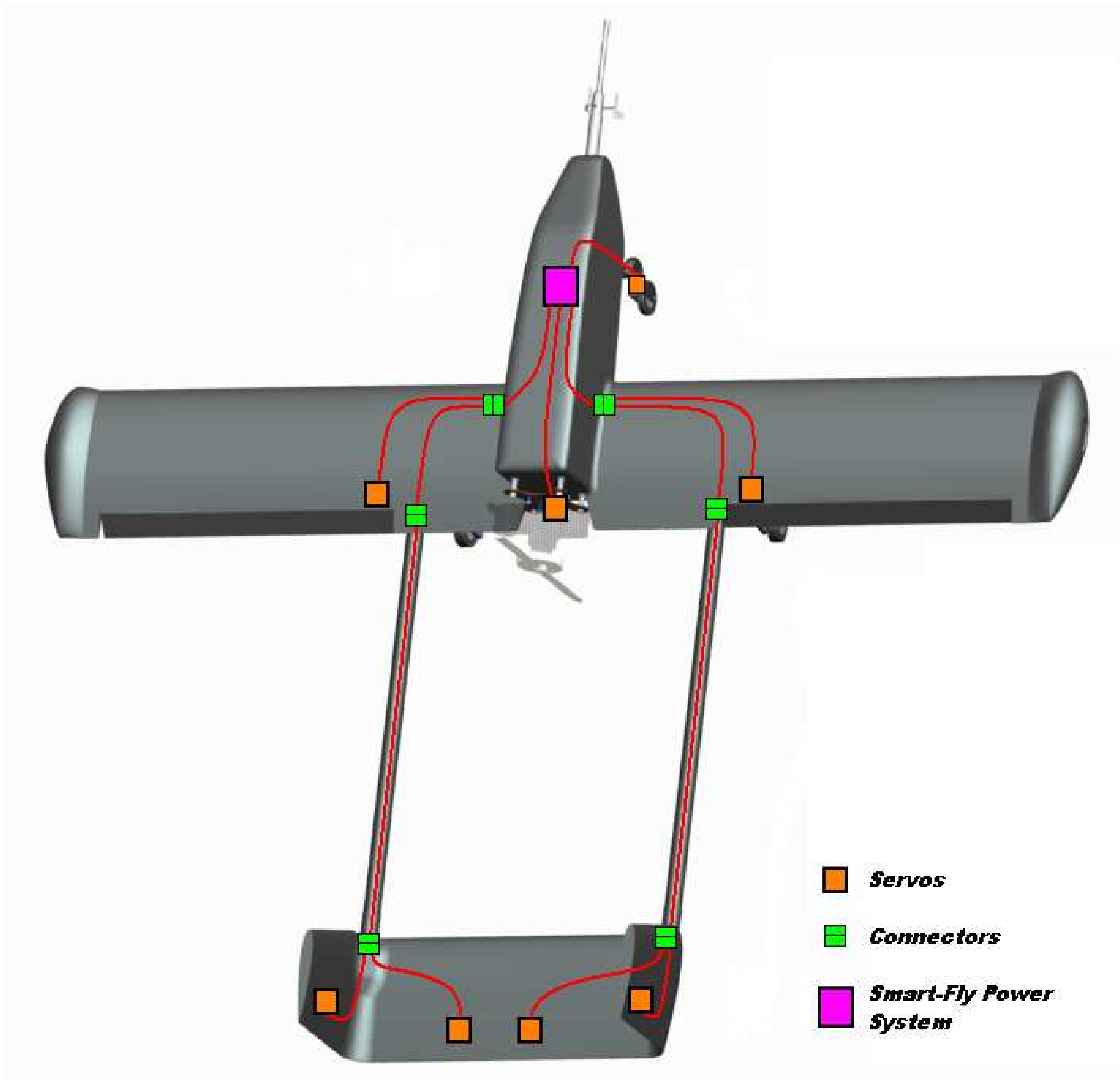


Figure 9: GeoSurv II Prototype Servo Runs

The cable runs consist of several individual segments and their breakdown is shown below:

Quantity	Length (in)	Start Interface	Start Interface Connector (male plug)	End Interface	End Interface Connector (female plug)
12	32	Smart-Fly Power System	3-pin Futaba	Fuselage/Wing	4-pin Molex
1	N/A	Smart-Fly Power System	3-pin Futaba	Throttle	3-pin Molex
1	N/A	Smart-Fly Power System	3-pin Futaba	Nose Landing gear	3-pin Molex
4	50	Fuselage/Wing	4-pin Molex	Aileron	3-pin Molex
8	50	Fuselage/Wing	4-pin Molex	Wing/Boom	4-pin Molex
8	110	Wing/Boom	4-pin Molex	Empennage/Boom	4-pin Molex
4	30	Empennage/Boom	4-pin Molex	Rudder	3-pin Molex
4	40	Empennage/Boom	4-pin Molex	Elevator	3-pin Molex

Figure 10: GeoSurv II Prototype Cable Runs Breakdown

More detailed information can be found in DR104-11.

3.11 Power Requirements

There are 14 servos on the GeoSurv II Prototype. There are 2 servos on each aircraft control surface, a throttle servo and a nose landing gear steering servo. The individual aircraft control surfaces are: 2 ailerons, 2 rudders, 2 elevators.

All servos on the GeoSurv II Prototype are HSR-5990TG. The Smart-Fly Power System Eq6 Turbo has a built-in adjustable voltage regulator. The voltage for the servos can be adjusted to 6.5V in order to maximize torque output from the servos.

The A123 batteries used on the GeoSurv II Prototype have a voltage of around 10.5V.
Using the information specified in DR104-11 it was found that the Smart-Fly Power System Eq6 Turbo can provide approximately 12Amps of continuous current to servos on the aircraft. The maximum transient current that the Smart-Fly Power System Eq6 Turbo can provide is estimated to be double, approximately 24 Amps.

The electrical demands of the aircraft will be examined during the ground tests.

3.12 Cable Testing

After each cable segment was created it was tested using a servo, a Servo Programmer in manual adjust mode and a patch cable. The patch cable had a Futaba connector on one end and a Molex

C-Grid SL on the other. The patch cable was connected between the cable segment under test and the Servo Programmer. The servo was connected to the other end of the cable segment under test. A responsive servo indicated proper electrical connections. The shield connection was tested using a multimeter.

3.13 Servo Programmer

Servo pairs on each control surface of the aircraft need to be synched and programmed in order to avoid mutual mechanical interference which could cause excessive current draw. The HSR-5990TG servos can be programmed using a PC and a program called “HMI Servo Programmer”. More information on the software can be found in DR104-12 and its interface can be seen below.

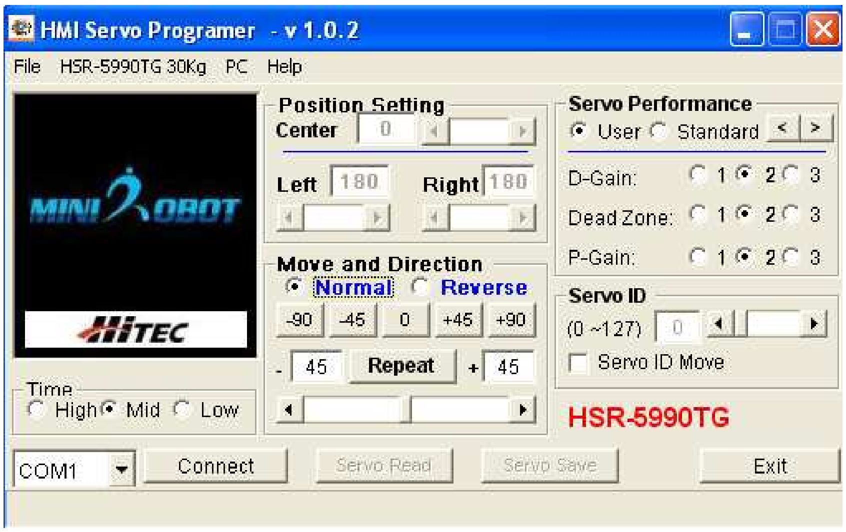


Figure 11: HMI Servo Programmer Interface

The parameters that can be programmed on the servos are the movement direction, D-Gain, Dead Zone and P-Gain.

The D-Gain setting adjusts how smoothly the servo stops.

The Dead Zone setting adjusts the inactive range of a stop point.

The P-Gain setting determines the speed and power of the servo.

On a tested servo all of the above settings were factory set to a level of 2 while on another the Dead Zone was set to 3. The manual for the servo programmer suggests avoiding the level 3 setting for all parameters as it may cause strong jittering or significant wear and tear.

3.14 Servo Travel

The servos installed on the flaperons of the aircraft need to have a travel of +/-45 degrees in order to achieve the desired movement of the control surface. The HSR-5990TG is capable of operating 180° by sending a pulse signal ranging from 0.6msec to 2.4msec.

Normal RC Transmitters send a pulse signal ranging from about 1.1msec to about 1.9msec. The newly acquired JR 9303 Transmitter can be set with 150% travel and the Smart-Fly Power System Eq6Turbo can also be adjusted to increase the servo travel up to a maximum of 0.8ms to 2.2ms. This will make the servo travel approximately -75° in one direction and +75°. Note that the angles are visual estimates.

More details can be found in DR104-12.

4. ATB-5

During the design and development it was paramount that the avionics system be tested in a flight environment in order to “prove” the design prior to implementation in the Prototype. The ATB 5 was selected to do this. The intent was to find and fix any problems with the design before the systems are installed in the GeoSurv II Prototype.

The ATB-5 is a Skyward 120 model aircraft. It has a wingspan of 108in and a weight of 32lb with avionics installed. The engine is 40 cc with 2 cycles and the propeller is 18 x 10 (diameter x pitch)

Figure 12: ATB-5 Before Flight

The main landing gear of ATB-5 can be changed between wheels and skis depending on seasonal conditions.

4.1 GeoSurv II Prototype vs. ATB-5

Several modifications had to be done to the GeoSurv II Prototype avionics design in order for it to be compatible with the ATB-5 aircraft and engine.

The GeoSurv II Prototype is a much larger aircraft than ATB-5 and has dual servos on each control surface instead of just one for ATB-5.

The GeoSurv II Prototype has dual rudders and a nose steering landing gear servo while ATB-5 is a tail dragger with the wheel mechanically connected to the rudder.

GeoSurv II Prototype engine has a battery powered ignition module while the ATB-5 engine has a magneto ignition. A magneto ignition is one where the spinning propeller shaft of the engine generates an electric current in a coil which then discharges at a specific position of the shaft to generate the spark that ignites the fuel in the engine.

In order to shut down the GeoSurv II Prototype engine a switch must be placed in series between the battery and the ignition module and opened. To shut down the ATB-5 engine a switch must be connected between the primary coil of the magneto and the engine ground and closed, effectively short-circuiting the charge for the spark.

4.2 ATB-5 Avionics Systems Design

The avionics system for the ATB-5 consists of three separate and independent systems. These systems are the flight avionics, the data acquisition system and the IFTS.

- The purpose of the flight avionics is to control the aircraft's flight and controls. The aircraft will be controlled using an R/C system. There will be a Futaba Transmitter relaying a signal to two Futaba receivers. Each receiver controls different surfaces on the aircraft through the Smart-Fly PowerSystem Eq-6. This system is depicted in Figure 13.

- The data acquisition system is installed to collect and report the in-flight and post-flight readings of certain flight parameters as described below. For initial test flights this system will be monitoring the built in sensors of the MP2028 a few additional sensors designed by the instrumentation group. This system saves the collected data on the MP2028 internal data log and also transmits select data to be displayed on the Ground Control Station during flight. The aircraft was designed and manufactured with the ability to record data from a laser altimeter. This system is depicted in Figure 14.

- Finally the IFTS is an independent system that provides the capability of shutting down the engine if required. This is the only option for terminating the engine during flight of the aircraft. This system consists of a separate Futaba transmitter which is operated by the pilot's assistant. The transmitter relays the signal to a separate Futaba receiver which is connected to a servo and switch that short circuits the engine ignition magneto coil to the aircraft's chassis ground, thus killing the ignition. This system is depicted in Figure 15.

For more information on the installation and functionality of the components including wiring diagrams refer to DR 94-10.

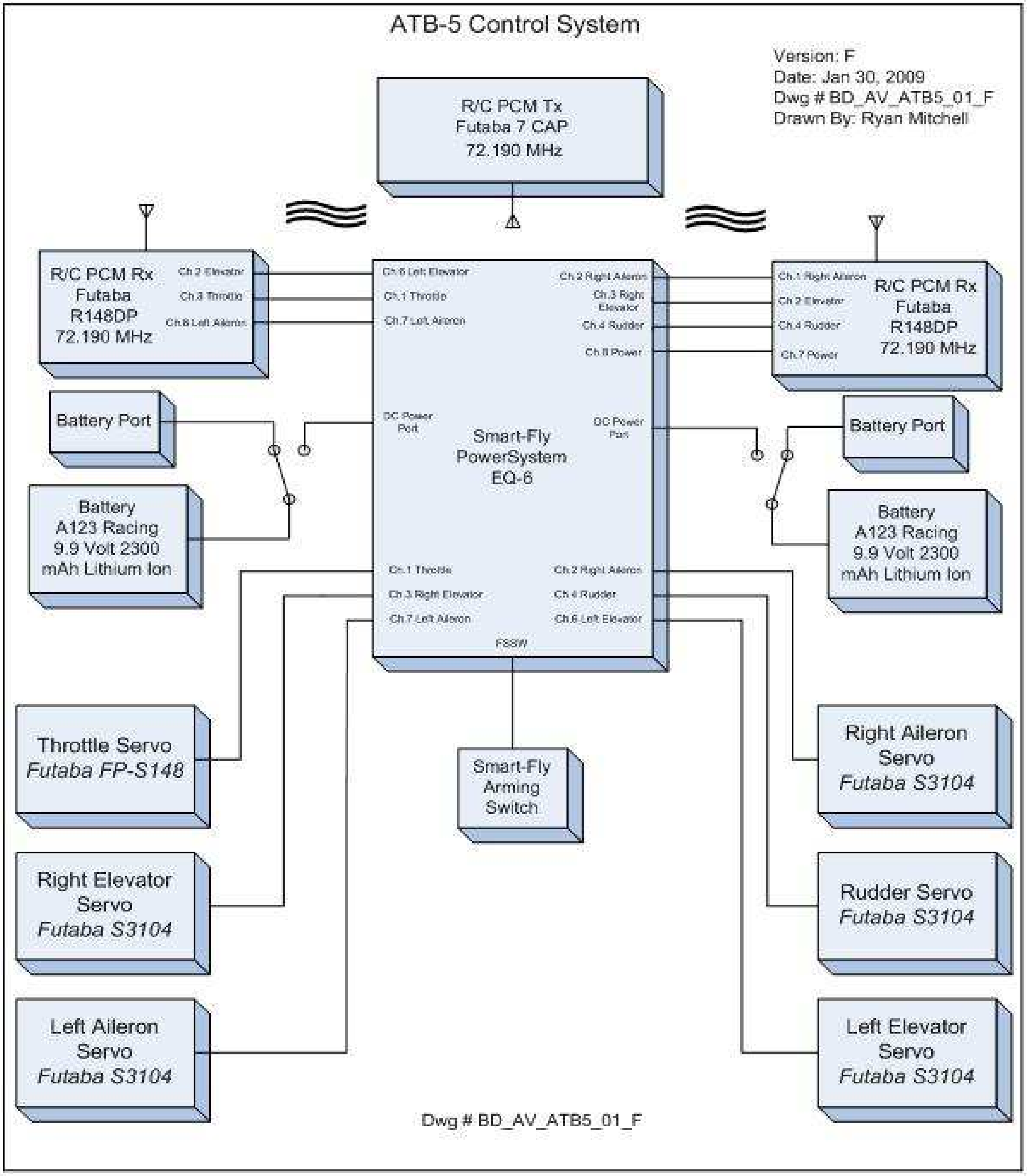


Figure 13: ATB-5 Control System

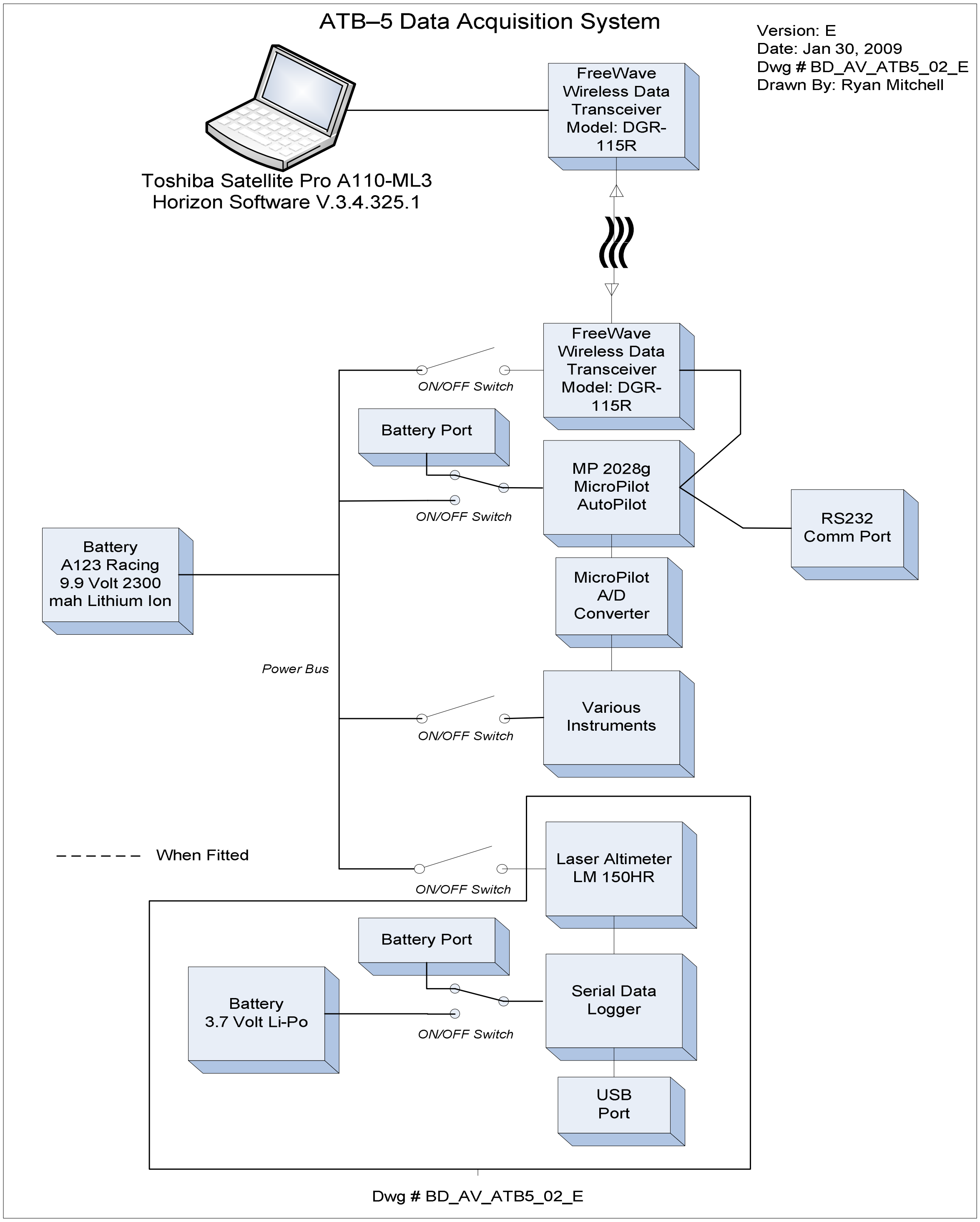


Figure 14: ATB-5 Data Acquisition System

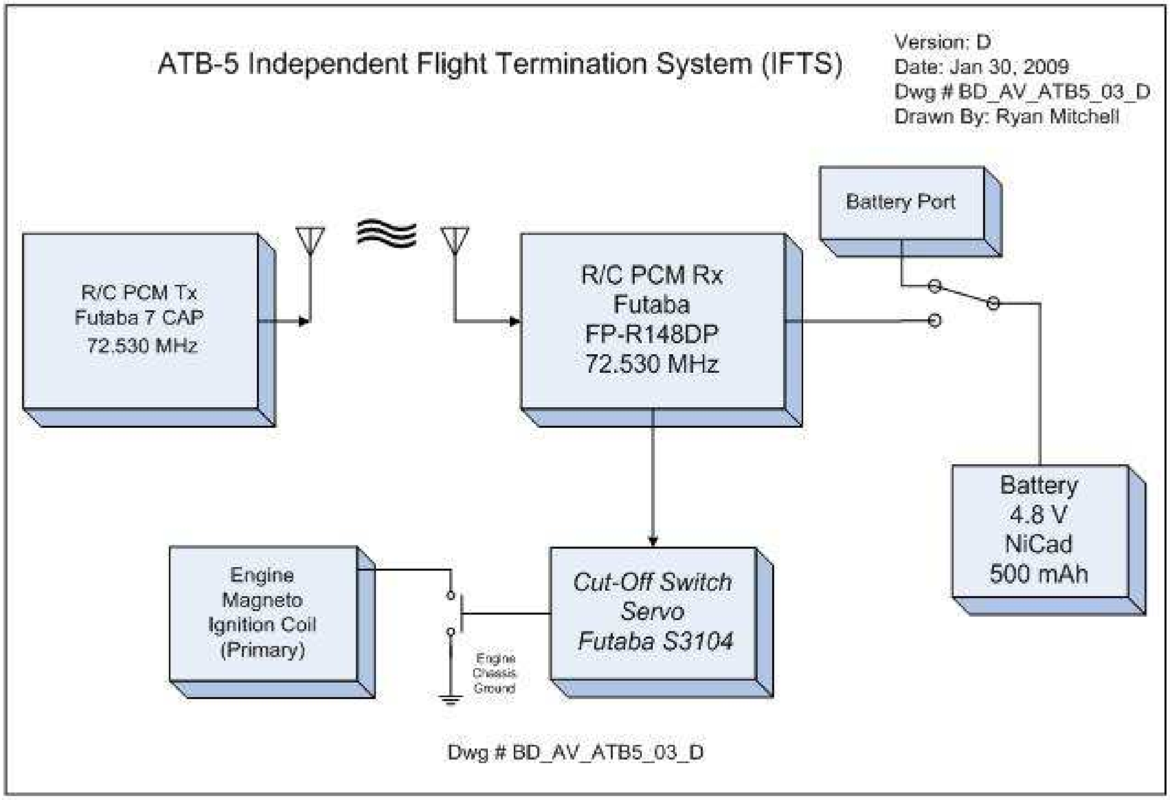


Figure 15: ATB-5 Independent Flight Termination System

4.3 Installation

Various parts of the ATB-5 installation are shown below. Details of the ATB-5 installation can be found in DR104-14.

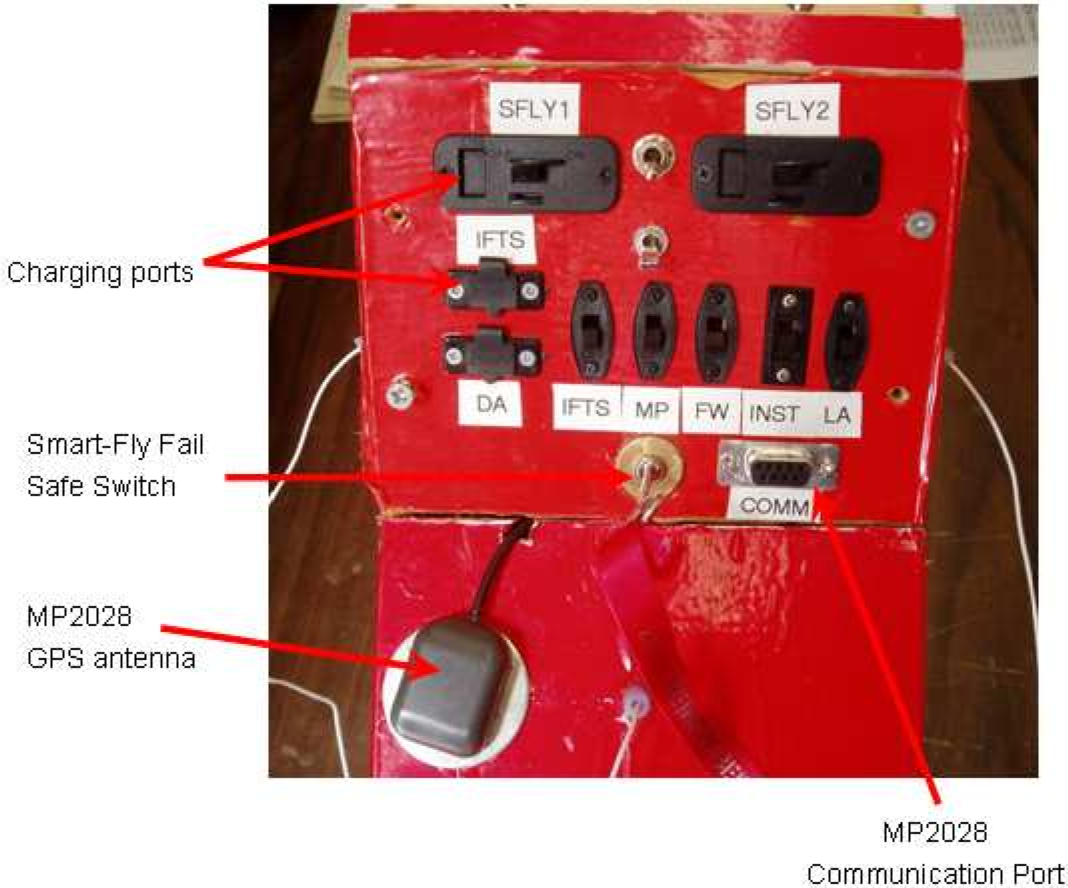


Figure 16: ATB-5 Switch Panel

All avionics systems on ATB-5 had a power-on switch on the Switch Panel. Several systems such as the MP2028, Freewave transceiver and instrumentation circuits had individual power-on switches but were all powered by a single battery. The above mentioned switches were connected to a small power bus board located below the Switch Panel. It had an input lead coming from the battery and several output leads that connected to each switch.

The Smart-Fly Fail Safe Switch connects to the Smart-Fly Power System Eq6 Turbo and prevents it from powering on until the metallic pin is pulled out.

The COMM port is used to download the MP2028 data log to a PC on the ground after each flight. The Freewave transceiver had to be powered off before connecting the PC to the COMM port. This is because the Freewave transceiver is also connected to the same communication wires and would drive one of them if powered on.

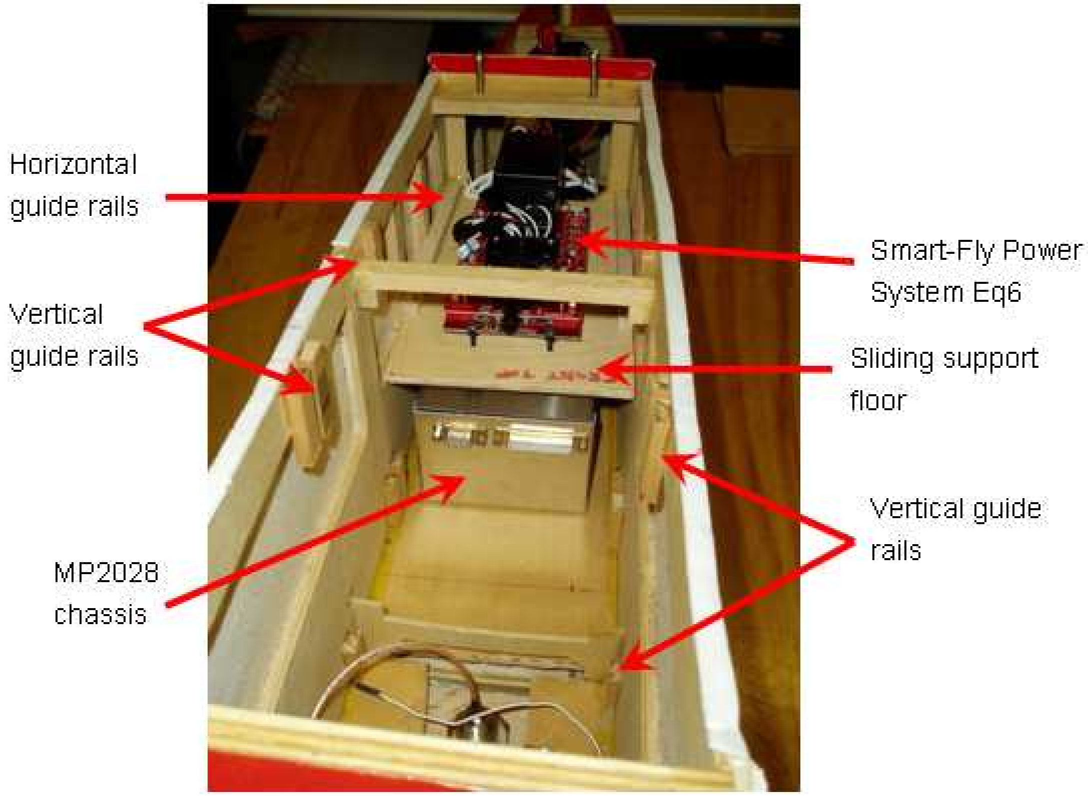


Figure 17: ATB-5 Fuselage

The ATB-5 fuselage has been divided into many compartments using sliding walls on guide rails. This is to allow the use of the fuselage compartment space in an economical way. The sliding walls allow full access to the entire fuselage space on the ground while isolating components and preventing damage during flight.

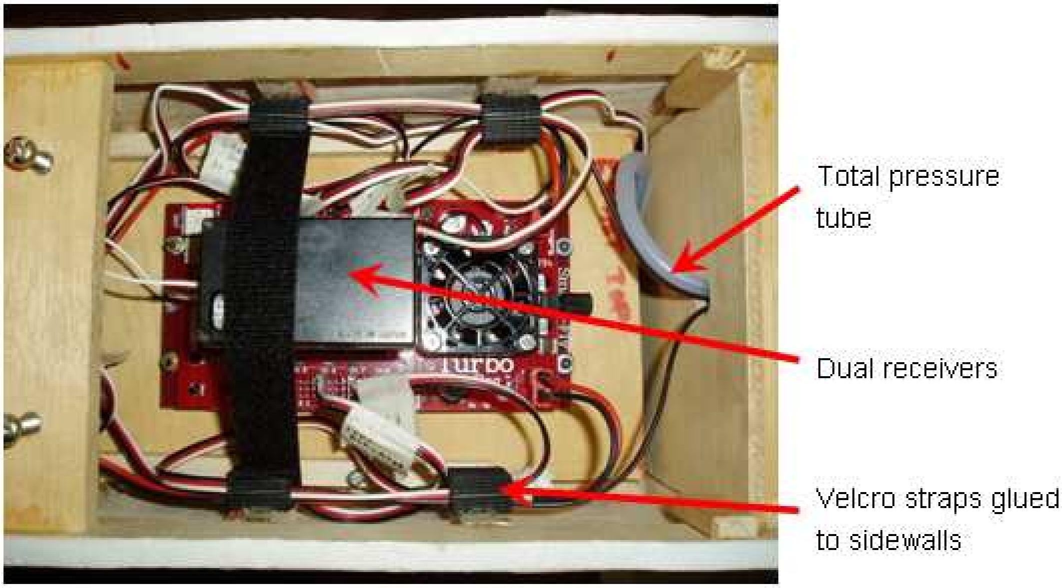


Figure 18: ATB-5 Smart-Fly

The Smart-Fly Power System Eq6 Turbo has been mounted on sorbothane pads in order to dampen the engine vibration. The MP2028 autopilot is susceptible to mechanical and acoustic vibration and therefore has its own enclosure mounted with sorbothane.

The batteries and fuel tank were also mounted in foam and secured with Velcro.

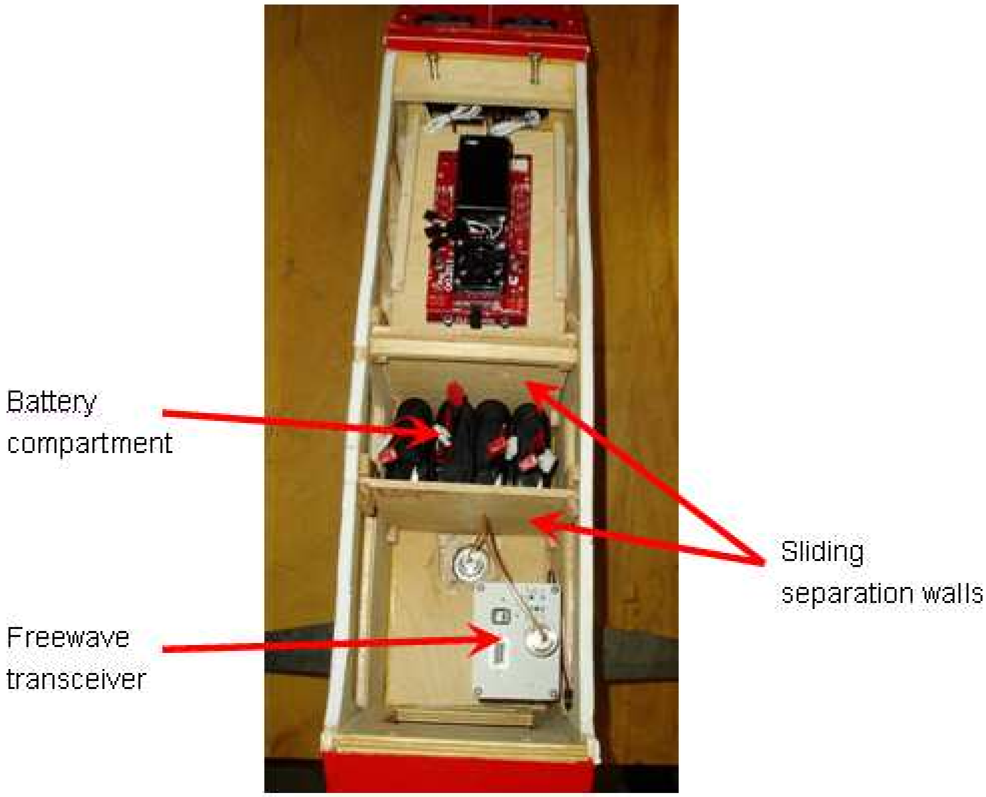


Figure 19: ATB-5 Avionics Bay

4.4 2.4 GHz Wireless Camera

Figure 20: 2.4GHz Wireless Camera

The wireless camera has a built-in transmitter, antenna and rechargeable lithium ion battery. The camera provided a "pilot's eye" view of the flight and thus provided an independent data source of visual flight manoeuvres with the horizon reference. The camera was mounted away from any interference in an area with clear view of the ground - on a wing tip. The adjustable focus lens of the camera was rotated to increase the clarity of the video.

The ground receiver can switch between 4 different frequencies indicated by Ch1 to Ch4. The receiver channel must match the wireless camera transmitter channel. In some circumstances interference may be present on a particular channel so another should be used for the wireless camera and receiver.

The EasyCAP video/audio analog to digital converter has been used to convert the outputs of the ground receiver to digital format. It connects to a PC USB 2.0 port such as the Ground Control Station PC. The EasyCAP was obtained “on loan” and has only been used for the ATB-5 flight.

Figure 21: Camera mounted on ATB-5

4.5 Wireless Camera Software

Various software can be used to record video from the EasyCAP video source. The software used for the ATB-5 flight was Ulead Video Studio SE. The video settings used were MPEG1 with a resolution of 720x480 and 2000kbit/sec recording rate.

4.6 ATB-5 Ground Tests

Prior to flight thorough ground tests were conducted on ATB-5 including:

- interference checks
- engine break in
- control system
- telemetry system
- IFTS tests

The official ATB-5 ground tests were successful.

4.7 ATB-5 First Flight

Figure 22: ATB-5 in flight

The AVI team obtained an SFOC and conducted the first ATB-5 flight at the Arnprior Radio Club field on February 18 2009. The ATB-5 first flight was recorded on the Ground Control Station with video being sent from the air by the wireless camera. The flight was also recorded from the ground with a camcorder. The two videos were later edited and time synchronized to produce a composite video. This video showed the wireless camera view on the top part of the screen and the ground camera in the bottom part as shown in Figure 23.

Figure 23: ATB-5 First Flight Video

ATB-5 Successful First Flight Highlights:

- ATB-5 avionics replicated the GeoSurv II Prototype avionics design as much as possible
- The dual receiver setup and IFTS worked without problems
- Data from MP2028 autopilot built in sensors, an air temperature sensor and a 3-axis accelerometer were logged
- The aircraft flew as desired by pilot
- No interference or signal loss to the receivers on the aircraft was observed
- The ATB5 flight confirmed that the GeoSurv II Prototype avionics can be approved and installed

5. GEOSURV II PROTOYPE INSTRUMENTATION

The prototype instrumentation system is designed to enable sensor add-ons specified through requirements by the various groups within the project team (i.e. aerodynamics, safety and certification, and structures), while providing the ability to ensure that sensor redundancy was included in the design to confirm separately the function of the integrated sensor of the autopilot. For these two purposes the data acquisition system (DAS) is fitted with 2 analog to digital converters (MPADCs) to expand the capabilities of the MicroPilot 2028 autopilot (MP2028) to monitor the performance and status of the aircraft.

In terms of the visual interface to the autopilot HORIZON, the ground control station (GCS) software, is used to monitor sensor parameters, log data accordingly, and provide post flight data logs for analysis. Additional features of the software included the ability to calibrate the MPADCs, create custom .vrs files, and the ability to adjust the sensor settings when monitoring sensors in meaningful units.

The autopilot and HORIZON are described in the following sections to highlight their ability to serve as a data acquisition system capable of monitoring necessary parameters on the aircraft, and does not examine the ability of the autopilot to act as an autonomous micro UAV controller. More specifically, the following section provides material which is further described in detail by the design reports that specify the function and design of the particular components of the DAS. When material is alluded to it is important that the documentation is reviewed in order to achieve the level of understanding necessary to make alterations to the system and operate it properly.

5.1 Data Acquisition System & Component Overview

The GeoSurv II Prototype aircraft is fitted with various components which constitute the on-board DAS system. Separately the GCS is described. The purpose of the system is to monitor the status and performance of the aircraft at the GCS, while accumulating a data log for post flight analysis. The block diagram included below provides an overview of the system layout and is included here again for clarity.

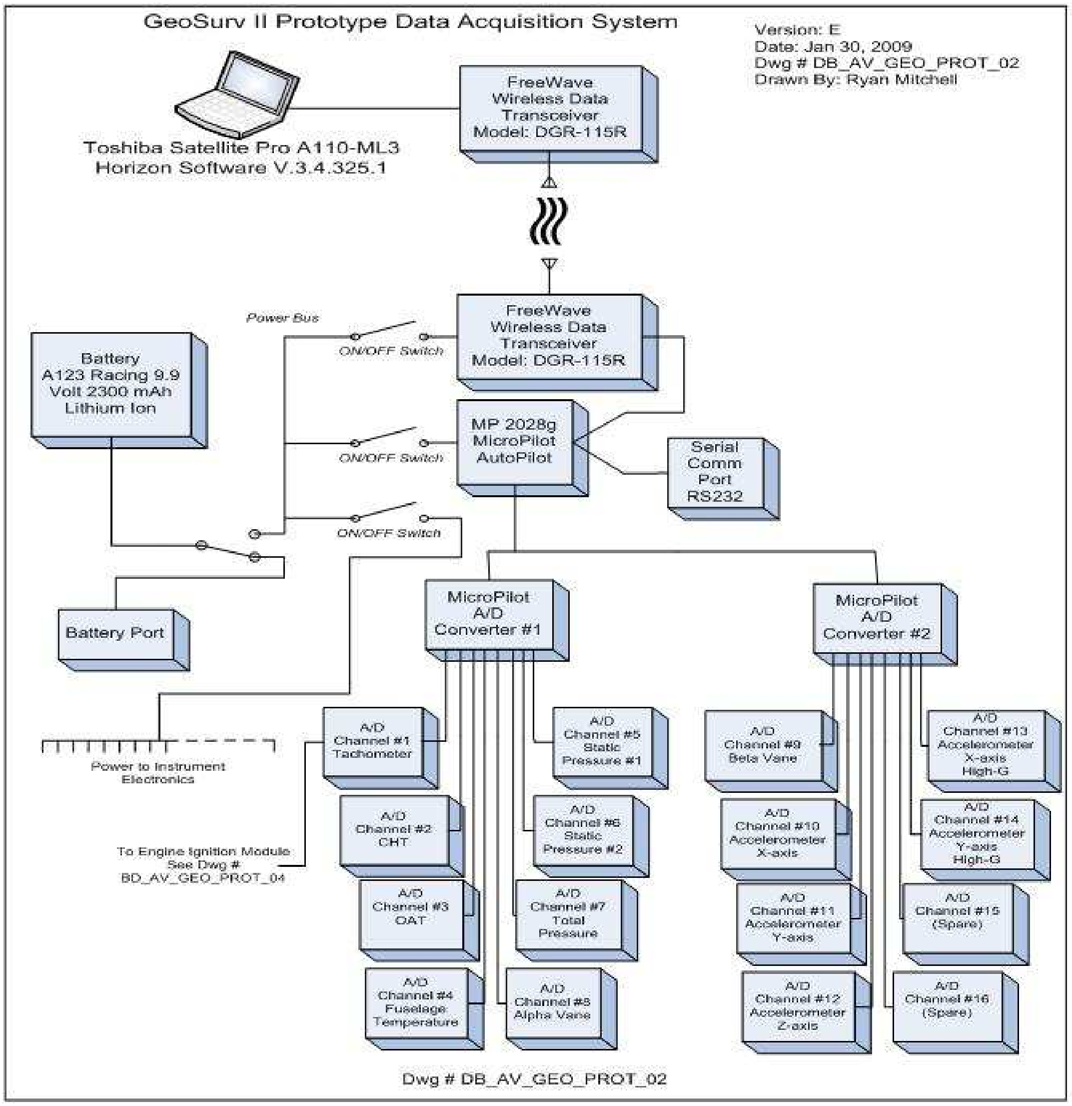


Figure 24: GeoSurv II Prototype Data Acquisition System

The GeoSurv II Prototype is fitted with instruments on the MP2028 and the custom instruments designed by AVI, interfaced through the MPADCs. A list of the custom instruments and the parameters monitored are as follows:

- Tachometer (RPM of the engine)
- Cylinder Head Temperature (CHT of the engine)
- Outside Air Temperature (OAT)
- Fuselage Temperature (FT)
- Alpha (angle of attack) & Beta (angle of sideslip) Vanes
- Total & Static Pressure (for indication of airspeed)
- 3 – Axis Acceleration +/- 6 g (redundancy for accelerometer function of the autopilot located at the CoG)

- 2 – Axis Acceleration +/- 18 g (for indication of landing g forces experienced by the landing gears at the CoG)

The integrated sensors of the autopilot which compliment the instrumentation system are as follows:

- 2 – Axis Accelerometers
- Total and static pressure sensors (indicate airspeed)
- Pitch, Roll, Yaw gyroscopes (attitude display)
- Above Ground Level ultrasonic altimeter

The GeoSurv II Prototype DAQ consists of the following components as shown in Figure 3 above with the addition of the designed custom instruments:

- 1 MP2028 2 MPADCs
- 2 Freewave Transceivers
- 1 GCS Laptop with HORIZON version 3.4.325.1

5.1.1 MicroPilot 2028 Autopilot & MicroPilot Analog to Digital Converters

The centre piece of the instrumentation system is the autopilot. The autopilot is a micro UAV controller designed for fully autonomous operation from launch to recovery. The purpose of the autopilot initially is to act as the device through which the GCS monitors the aircraft. The autopilot was used for the instrumentation system because of its ability to handle ADCs, to transmit data to the ground, to log data from the integrated sensors and the ADC sensors, and its ability to monitor aircraft attitude in flight. The capabilities of the autopilot are not limited to these features but for the purposes of the instrumentation system were seen as sufficient for real–time monitoring and data logging.

The features of the autopilot are extensive. This year's AVI team extended the autopilot system by adding 2 MPADCs for the addition of customized sensor designs. A design report is constructed to clarify the purpose of acquiring the converters, DR#94-03: Data Acquisition in the GeoSurv II Prototype. The design report details various features of the converters and the features of HORIZON in displaying custom sensor responses. It is particularly important that the manuals for the MP2028 [1] and the MPADCs [2] are reviewed before powering the equipment or adjusting the settings in HORIZON [3].

When the MPADCs were acquired an acceptance test was carried out to ensure that the converters were performing satisfactorily - DR#: MicroPilot ADC Acceptance Test details the results. Upon completion of the test it was found that one of the wiring harnesses was unacceptable and that all channels would require calibration for connection of customized sensors. Overall the MP2028 & the MPADC performs as expected with adhesion to the specifications laid out in the operating manuals.

5.2 Instrumentation Checklist & Design Details

An instrumentation checklist is constructed to ensure that the overall system is working properly after the assembly of the system is complete. The checklist is detailed in DR#104-04: Instrumentation Checklist.

In terms of ensuring the assemblage is carried out correctly and as designed, with particular attention to the details, DR#104-20: Instrumentation Design Details should be followed. When making design changes to the system this document details the important features of how one would make the changes.

It is extremely important that these documents are reviewed prior to powering up the instruments or making any alterations to the design.

5.3 Ground Control Station

The GCS is centered on the GCS HORIZON software. It is the user interface utilized to observe the autopilot, the integrated sensors and the sensors connected through the converters.

Overall, the GCS consists of a laptop with the current version of HORIZON, a transceiver, and an antenna. Additionally, the GCS must be supplied with power for the laptop and transceiver.

It is important that HORIZON functions properly before the aircraft takes off for flight. Essentially, the GCS provides the ability to view sensor response and aircraft status for assistance to the pilot, who is controlling the aircraft by radio control. It is critical that the GCS is operational when test flights are being performed so that the necessary data is observed and logged.

To better serve the pilot on the ground it is beneficial to have more than one observer of HORIZON on multiple laptops at the GCS for elimination of human factors. Also, when performing test flights, it is critical that shielding from glare is employed by those observing HORIZON. Of particular importance is that a GPS lock is achieved before the aircraft takes off so that the internal MP2028 data log begins recording before takeoff. These were issues when this year's team performed a test flight of ATB-5.

5.4 HORIZON Calibration & Settings

Calibration of the channels of the MPADCs is critical to ensure that the sensor responses observed through the ADCs are reasonably accurate. It is necessary that calibration of the channels is performed and the settings in HORIZON are as specified in DR#104-03: HORIZON Calibration Procedure & Settings.

HORIZON has a user friendly means of performing calibration, which is specified in DR#104-03. Of particular note is that calibration settings are saved along with the .vrs file. So as the scale and offset values are developed and flashed to the autopilot it is critical that the .vrs file saves the values. DR#104-03 details these findings and the necessary steps. It is absolutely necessary that the steps outlined are reviewed and followed closely.

It is important to note that the .vrs file uploaded to the autopilot is set appropriately because it determines MPADC voltage settings, telemetry and datalog settings, in addition to other features. For the purposes of the instrumentation settings, DR#104-03: HORIZON Calibration Procedure & Settings outlines the critical procedures for creating a useable .vrs file with the necessary calibration scale and offset.

The settings in HORIZON are very crucial to the user monitoring the GCS, who must interpret user friendly values which indicate the actual operation of the instruments in the air. DR#104-03: HORIZON Calibration Procedure & Settings further details the critical settings related to sensor settings for observation of user friendly values on the ground.

5.5 Custom Flight Instrumentation

The instrumentation system includes custom sensor designs which are assembled for installation in the prototype. The following section outlines the designs and provides some results. When a design report is referenced it is important that the document is reviewed in detail in order to discern the operation and features of the piece of equipment.

5.5.1 Tachometer

The implementation of a tachometer is derived from a timed pulse form the engine's ignition system. To achieve an RPM measurement the interface constructed involved the utilization of an electronic IC which performs frequency to voltage conversion. Essentially, the system converts the frequency of the input waveform from the engine's ignition system to a proportionate DC voltage level. The voltage at the converter indicates the RPM of the engine. The design of the interface is detailed in DR#94-14: Tachometer Interface to MicroPilot ADC.

5.5.2 Cylinder Head Temperature

To sense the CHT of the engine a type K thermocouple is used as the sensing element. The thermocouple is interfaced through a thermocouple IC that provides signal amplification for better voltage resolution and provides cold junction compensation to ensure that readings are referenced to 0ºC. The design of the CHT sensor is outlined in DR# 94-15: Temperature Sensor Interface to MicroPilot ADC.

5.5.3 Fuselage Temperature

Monitoring the temperature of the fuselage is implemented by utilizing a thermocouple IC which acts as a stand alone Celsius thermometer. This measurement will be taken from within the primary instrumentation enclosure within the fuselage. The IC itself is capable of discerning a temperature referenced to 0ºC. Again the details of this design are outlined in DR# 94-15: Temperature Sensor Interface to MicroPilot ADC.

5.5.4 2 Axis 18 g Accelerometer

The addition of an 18 g accelerometer is included in the prototype sensor suit for the purpose of measuring landing g forces experienced by the landing gear. An off the shelf accelerometer was purchased for this purpose. The design and signal conditioning characteristics of the assembled sensor are detailed in DR104-02: 2 Axis Accelerometer Design & Function.

5.5.5 Total and Static Pressure Instrumentation

The Aerodynamics Group requires the fuselage static pressure, and the static and total pressure at the air data boom. Three separate pressure transducers are used for this data acquisition. These pressure sensors will then have to be interfaced with the MicroPilot's analog to digital converter (ADC) in order for the data to be extracted. The results from the pressure sensors will be compared to the MicroPilot's integrated pressure sensors for redundant and to compare the pressure at different areas of the airplane.

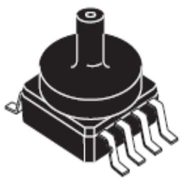


Figure 25: MPXA4115AC6U CASE 482A [1]

The pressure sensors instrumentation circuits used were the recommended circuit from the Motorola pressure sensor data sheet.

5.5.6 Pressure Sensor Wind Tunnel Results

Using the total and static pressure from the air data boom, the indicated speed of the wind tunnel is calculated. The results were compared to the manometers calculated speed and this comparison gives a good indication of how the pressure sensors are performing.

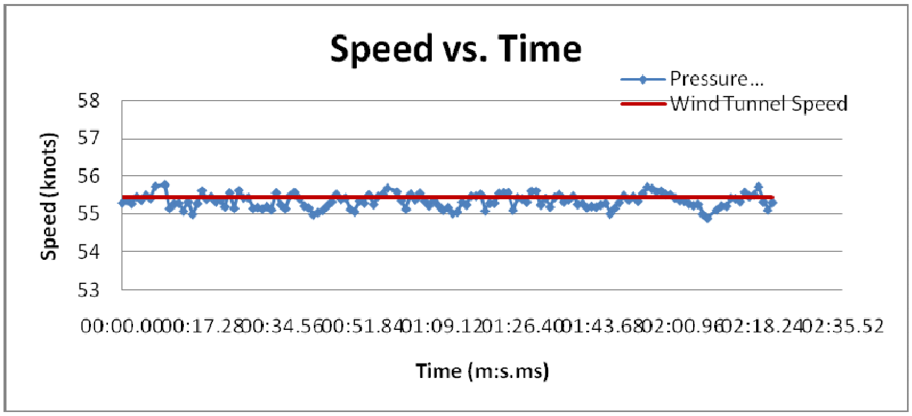


Figure 26: Pressure Sensors Wind Tunnel Results

The results from the wind tunnel indicated very consistent pressure readings. The pressure sensor calculations were indicating +/- 0.5 knots. This small error is acceptable for the GeoSurv II Prototype.

For further design details and test results the pressure sensors refer to DR94-12.

5.5.7 Alpha and Beta Position Instrumentation

The Aerodynamics Group requires angles from the alpha and beta vanes from the air data boom. A sensor will be used for each angle and therefore two sensors are required. The SP-12B high precision potentiometer will be used.

The potentiometers are used in junction with a variation of a bridge circuit. It allows the output of the alpha and beta vane instrumentation circuit to facilitate calibration for the zero angles.

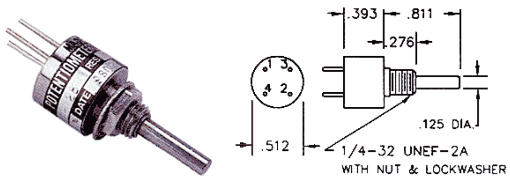


Figure 27: SP12B Potentiometer

5.5.8 Alpha Wind Tunnel Results

The results below show the alpha position in the wind tunnel. The air data boom was rotated from an angle of -20 degrees to +20 degree and in doing so the alpha vane output was logged simultaneously. The logged data was then taken and calculated to be an angle representation. The results showed that the potentiometers are very precise and the alpha and beta position instrumentation circuit will be adequate for the GeoSurv II Prototype.

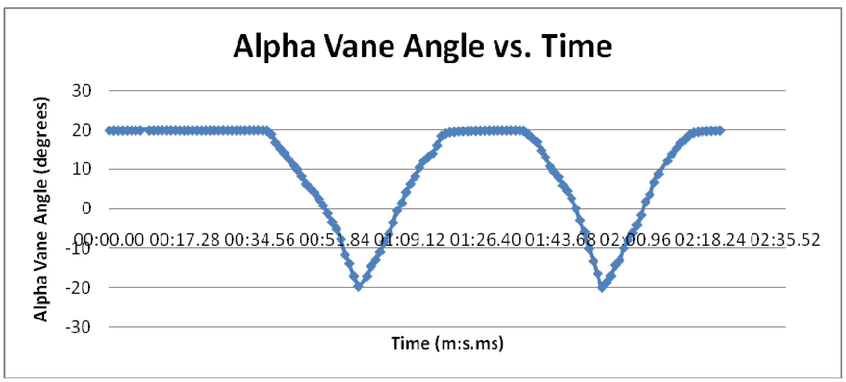


Figure 28: Alpha Position Sensor Results (-20C to +20C)

For further design details and test results for the alpha and beta vanes refer to DR94-11.

5.5.9 3-Axis 1.5g- 6g Accelerometer

An independent MMA7260Q 3-axis accelerometer was purchased from SparkFun and will be placed on the GeoSurv II prototype. It will be placed in the secondary instrumentation enclosure at the center of gravity of the GeoSurv II Prototype and will be used to compare the forces of acceleration with the MicroPilot autopilot accelerometer.

The accelerometer's output was signalled to have a sampling rate of 2.5 Hz. This will allow for filtering of the engine vibration and will cease any occurrence of aliasing.

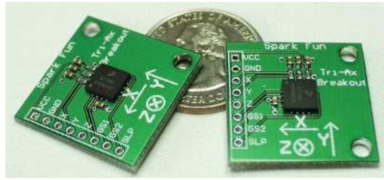


Figure 29: MMA7260Q Accelerometer

5.5.10 Independent Accelerometer Results

The 3-axis accelerometer was placed on the ATB-5 prototype. The output signalling configuration for these results was set to a sample rate of 60Hz. The sampling rate has to be taken in consideration when taking results since the MicroPilot Autopilot was sampling at 1Hz. The results compare the X-axis of the independent 3-axis accelerometer to the MicroPilot X-axis accelerometer.

For more information on 3-axis accelerometer refer to DR104-21.

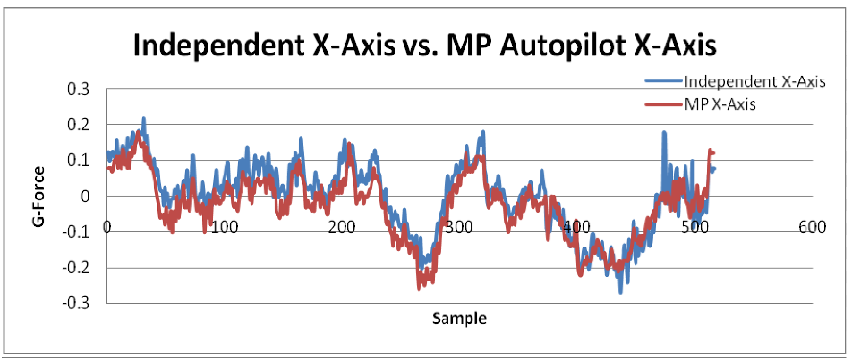


Figure 30: Independent X-Axis vs. MP Autopilot X-Axis

In comparing the results it can be observed that both accelerometers are not showing the exact same results. This difference could have been caused by the location of the accelerometers with respect to the center of gravity and the vibration caused by the GeoSurv II Prototype engine. The independent accelerometer was +- 0.03g's compared to the MicroPilot accelerometer and the independent accelerometer is adequate for the GeoSurv II Prototype.

5.5.11 Outside Air Temperature (OAT)

A negative temperature coefficient (NTC) thermistor is going to be placed on the outside of the GeoSurv II Prototypes fuselage to measure the OAT. It will be placed in series with a known resistor. The voltage output will be used to calculate the resistance of the thermistor. Knowing the resistance of the thermistor, the OAT can be calculated. Within the Horizon software a display can also be used and will show the current OAT.

Figure 31: NTC 10kΩ Thermistor

5.5.12 OAT Results

To test the accuracy of this thermistor circuit the temperature was taken from an infrared thermostat that reads temperature within +/- 1 ^{o}C. Those temperature readings were then compared to the calculated thermistor temperature. A NTC thermistor decreases its resistance with an inverse exponential relationship. This relationship makes the thermistor difficult to have a current display of the OAT and there for calculations must be performed from the raw data to find the thermistor temperature. The reason for the difficulty displaying the thermistor in Horizon is that Horizons display works on a linear relationship with an offset and not having this exponentially inverse relationship capability means that the display will have a significant error. The figure below shows the absolute difference between the infrared thermostat and the thermistor temperature. The results show that the thermistor was within +/- 1.6 ^{o}C. The results from thermistor are satisfactory for the GeoSurv II Prototype.

If a live display of the OAT needs to be takin a different sensor with linear voltage-to-temperature relationship should be used.

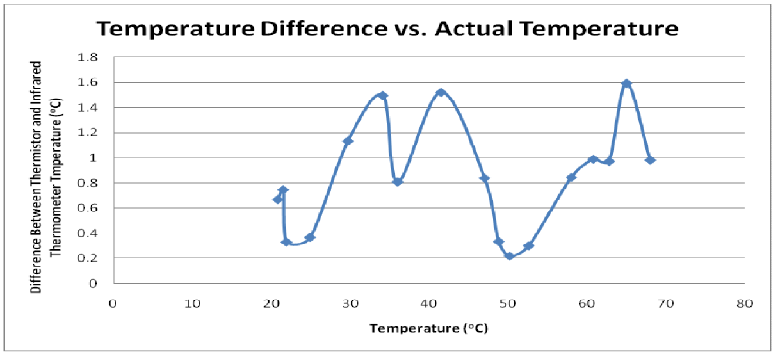


Figure 32: OAT Results

For more information on the OAT refer to DR104-21.

6. PRIMARY AND SECONDARY INSTRUMENTATION ENCLOSURES

This section presents the primary and the secondary instrumentation enclosure that are going to be placed in the GeoSurv II Prototypes fuselage and the different designs that were incorporated into the enclosures. The different designs include connectors used, vibration dampening inside and ouside of the encolsure, and placement of the internal ccircuitry.

6.1 Primary Instrumentation Enclosure

The primary instrumentation enclosure is used for the Micropilot Autopilot, the Micropilot Analog to Digital Converter (ADC), the 3 pressure sensor circuits, OAT circuit, and the alpha and beta vane circuits. The primary enclosure is an 8” x 6” x 3.5” aluminum chassis. It has a DB-9 and DB-25 connectors on the enclosure. It also has two port inlets to connect the air data boom’s static and total pressure ports to the the Micropilot autopilot pressure sensors and to the indepenent pressure sensors. The extra pressure sensor on the custom circuitry will be connected to the nose cone to evaluate the ram air pressure at that location. Sorbothane is placed on the bottom of the primary enclosure in 1.5” squares and is used to reduce the vibration caused by the engine and aircraft.

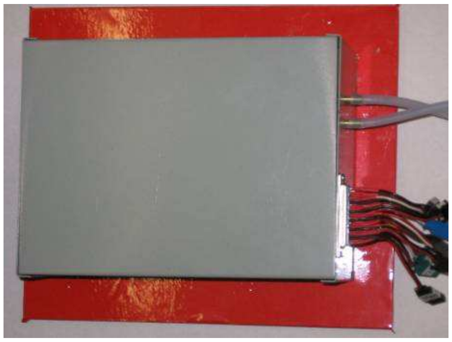


Figure 33: Primary Instrumentation Enclosure (8” x 6” x 3.5”)

6.1.1 DB-9 Connector

The DB-9 female connector that is mounted on the outside of the primary instrumentation enclosure is used to connect the MicroPilot to the Freewave tansciever and also the comm port on the switch panel. The cable that is being used is a custom made Y-splitter. When the comm port is being connected to the ground station the transiever switch on the GeoSurv II Protoype must be turned off to allow the MicroPilot and ground station laptop to send and receive. When the GeoSurv II Ptotype comm port is not connected to the ground station laptop, the transiever switch should be switched to the on position to allow for the transievers to send and receive data.

6.1.2 DB-25 Connector

The DB-25 female connector that is mounted on the outside of the enclosure will be used to connect the instrumentation and Micropilot to power, to connect the external sensors to the internal instrumentation circuits, and connect the external instrumentation circuits with the Micropilot ADC. The external sensors are connected with non-locking connectors. This allows each individual sensor and power to be disconnected seperately.

6.1.3 Futaba Non-Locking Connector

To connect the power and the sensors to the male DB-25 connector, Futaba non-locking male connectors were used. This connects external sensors to the primary and secondary enclosure and connects the sensors internal to the secondary enclosure.

External sensors to both enclosures include the OAT and alpha and beta potentiometers. These sensors will then be connected internally in the primary enclosure to their instrumentation circuit. The sensor signals that are sent from the secondary instrumentation box include the cylinder head temperature (CHT), the tachometer, and the 3-axis and 2-axis accelerometers.

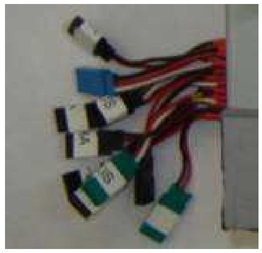


Figure 34: Futaba Non-Locking Connectors

6.1.4 Internal Power and ADC Connections

In order to connect the differnet internal wires in the primary encosure, terminal blocks were used. Terminal blocks connect the 13 sensor outputs from the female DB-25 to the ADC channels. This simplifies the wires internally and allows for the 16 ADC inputs to be changed or rearranged if needed.

Figure 35: Terminal Block

6.1.5 Vibration Dampening

The Micropilot Autopilot is susceptible to gyro failure caused by vibration from the range of 15Hz to 100Hz. This vibration is caused by the 30hp, two cylinder engine and must be dampened to eliminate the gyro failure.

A a visco-elastic polymer called Sorbothane that reduces vibration from 10-10000Hz was purchased. There are five, 1.5” square Sorbothane pads at ¼” thickness that will be placed at the 4 corners and at the center. This will equally displace the force on each individual pad and will maximize its dampening effects.

Gromets have been placed on the enclosure and the mounting bolts are placed through them . This eliminates any direct path for the vibration to travel from the instrumentation rack to the enclosure.

Internally to the enclosure foam will be placed around the instrumentation, MicroPilot and ADC’s. This will eliminate or minimize any internal vibration that is left.

6.2 Secondary Instrumenation Enclosure

The secondary instrumentation enclosure will contain instrumentation circuits. It will be placed at the center of gravity in the engine compartment of the fuselage. It will hold the tachometer circuit, the 3-axis and 2-axis accelerometer circuit, the CHT, and the FT. To power the secondary instrumentation enclosure and allow for the outputs to be wired to the primary instrumentation enclosure a DB-15 connector was put on the enclosure.

6.2.1 DB-15 Connector

Connected to the DB-15 is 9.9V power from the instumentation battery, 3 outputs from the 3-axis accelerometer, 2 ouput from the 2-axis accelerometer, tachometer output, CHT output, and FT.

6.2.2 Placement of Accelerometers

The accelerometers are hardmounted in the secondary instrumentation enclosure. The 3-axis accelerometer is placed with the x axis to the rear of the air vehicle, the y-axis parallel to the wings, and the z-axis direction towards the Earth.

The 2-axis accelerometer will have the y-axis towards the earth and the x-axis in the direction of the rear of the air vehicle.

For more information on instrumentation installation of the prototype refer to DR104-20.

7. SYSTEMS TEAM

The goal of 2008-2009 computer-system avionics team is to continue the autopilot flight testing, and to prepare for the flight test of GeoSurv II prototype. Two autopilot flight tests were done in order to study configurations of autopilot-controlled autonomous flight. A data acquisition system was designed for the laser altimeter. With the help of data-acquisition system, functionality tests for Laser Altimeter were accomplished successfully. Ground test plans and checklists were also made for avionics systems that will be applied on GeoSurv II prototype. VRS file settings that were applied for flight of ATB 5 had been documented for these settings will be applied onto MP2028 for the test flight of Prototype of GeoSurv II. Besides, area map of Arnprior, the area where first prototype flight is taken place, was acquired from GoogleEarth and then loaded into Horizon for monitoring the test flight of Prototype.

8. AUTOPILOT FLIGHT TESTING ON ATB-4

Investigation of the MP2028 autopilot was continued this year. It was fitted in ATB-4, a small radio-controlled aircraft, and two flights were made.

During the flight tests, the optimized PID (Proportional, Integral and Differentiate) loop settings from DR 64-01 were firstly used. But wing wobbling was still observed while ATB-4 was turning. Then, a new set of PID was chosen. It was proved to be better because wobbling was almost eliminated and ATB-4 flew stably. The improved PID setting is recorded in DR 104-09.

For both flight tests, the flight plan was also modified. Instead of flying around two designated point (Figure 36), the new flight plan required flying through those points (Figure 37).

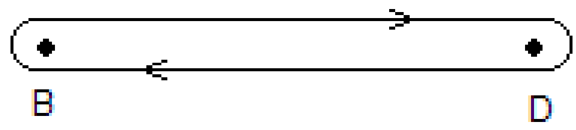


Figure 36: Original flight plan

Figure 37: New flight plan

A new FLY file was made to implement this change.

9. AUTOPILOT & HORIZON UPDATE

During this year, MicroPilot MP2028g has been upgraded with firmware version 3.4.325.1 loaded. The Horizon software on all GCS computers is upgraded to version 3.4.325.1 at the same time.

The new version of autopilot-Horizon combination gives many more useful features, such as the improved logging of user-defined data and a better datalog viewer.

10. LASER ALTIMETER LM150HR

Laser Altimeter LM150HR was chosen to provide precise altitude data to MP2028 in order to maintain stable low altitude flight. In 2008, research of feasibility of using LM150HR was done by testing the device and analyzing collected data.

11. FUNCTIONALITY TEST AND ANALYSIS

UAV flight can take place over various terrains and environments, so functionality tests were based on range testing on different materials such as wood, rock, and painted-wall. Tests were done on car-base and hand-base. Vibration test was also done on car-base test. Data analysis was done based on the data collected from the tests. Analysis focused on consistency of range data collected by LM150HR on various materials. The details of test refer to DR NO.94-16.

12. DATA DECODING

Data output of LM150HR is done by using data-logger with SD memory card. The SD card can then be plugged into computer and the logged file can be recognized as .txt file by computer. The data was recorded in ASCII format that cannot be shown as readable decimal numbers. A program that was able to load and decode the data easily was created.

Details of data collection/decoding can be referred to DR No. 94-07.

13. DATA ACQUISITION FOR LASER ALTIMETER

The LM150HR laser ranger was chosen as an altimeter candidate for GeoSurv II. During this year, flight tests with laser altimeter were proposed. In order to log altimetry data onboard, a data acquisition system was designed with a serial data logger.

The data acquisition system is connected to laser altimeter through standard RS-232 cable with DB9 connector. The altimetry data is recorded in a micro-SD card, and can be easily accessed on a computer. For detailed information about the data acquisition system, please refer to DR 94-05.

After working with the serial data logger, a modification of firmware was proposed to work with a GPS logger. This modification allows recorded altimetry data along with GPS timestamps, and to be synchronized with the other data sources, such as MP2028. The modification also decodes the altimetry data from raw format to human-readable format. For detailed information about the firmware modification, please refer to DR 94-07 and DR 104-10.

But, finally, the laser altimeter proposal was dropped for ATB-5 and GeoSurv II prototype. The laser altimeter flight test is postponed to next year.

14. ATB-5 DATA ANALYSIS

ATB-5 flight test was done on 18 February 2009 at Arnprior RC Club. The purpose of the test is to verify the entire avionics systems are working as designed.

After ATB-5 flight test, some portion of flight data was not present in either the autopilot internal log or the GCS standard telemetry log. After investigation, the reason was confirmed that the autopilot did not finish initialization at the time of take-off. DR 104-08 has detailed description about the data loss.

15. GEOSURV II PROTOTYPE AVIONICS DOCUMENTS

Three ground test plans and eight checklists are made for avionics systems on GeoSurv II prototype.

15.1 Avionics Ground Test Plan

The avionics ground test is divided into following three part

- IFTS
- Flight system
- Instrumentation

All test plans are made to verify the system functionalities and installation correctness. Every test plan contains normal operation scenario, failure scenarios and radio interference test. The test plans must be completed before GeoSurv II first flight, or after avionics hardware is modified. DR 104-05 gives detailed information about avionics ground test plans.

15.2 Avionics Checklist

The finally avionics checklists package will comprise the following eight forms.

- Avionics Physical Inspection Checklist
- Flight System and IFTS Functional Checklist
- Freewave Telemetry Setup
- GCS Assembly Checklist
- Instrumentation Functional Checklist
- Instrumentation Calibration Checklist
- IFTS R/C Transmitter Setup
- Flight System R/C Transmitter Setup

The last four checklists from above list remain to be accomplished.

These checklists ensure aircraft is serviceable after maintenance or assembly. Some of the checklists also provide guidelines to setup avionics systems. All checklists must be completed before flight.

DR 104-06 gives brief information about each checklist.

16. DOCUMENTING VRS FILE SETTINGS FOR INSTRUMENTATION SYSTEM

VRS file was used to control the behaviour of MP2028. To ensure the MP2028 collects data correctly from exterior sensors and telemetry connection successfully during flight of Prototype, the VRS file settings of ATB 5 test flight was recorded and documented for further use. Documentation including the entire user defined field and telemetry field. Details can be seen in DR 104-18, '.VRS file settings for instrumentation system for the prototype'.

17. AVIONICS BAY ARRANGEMENT

The avionics devices have to be loaded into avionics bay of prototype. The arrangement of locating avionics sub-system models was done and documented as formal design. The design also includes locating holes on fuselage, specifically on the interior deck, bulkhead, and bottom deck. Drilling holes in fuselage was for establishing the wired link between IFTS and engine, as well as Freewave antenna and receiver. Details of design can be referred to DR 104-17.

18. MAP ACQUIRING AND SETTING

A short DR was written to provide a decent tutorial to the users about how to correctly load maps into Horizon. For flight monitoring purpose, maps are loaded into Horizon to let the user know where the plane is. Loading map includes settings of Horizon software with GPS data. The detail of settings and map loading can be referred to DR104-15.

Maps were acquired from Google Earth, which provides global satellite pictures as well as precise GPS data of longitude and latitude. DR104-15 also contains the procedure of acquiring map from Google Earth.

19. MP2028 ONBOARD SENSOR DATA ANALYSIS

MP2028 has one static pressure sensor and dynamic pressure sensor integrated onboard. In test flights of ATB 4 and ATB 5, the data generated by these two sensors was recorded and filed. An analysis has been done in attempt to figure out if those sensors can provide consistent and reliable data. The result has shown that the consistency of pressure sensor data was good. For the static pressure sensor, it provided consisted altitude data, which means the altitude values were at a stable level without many glitches that have big difference from the average value. However, the reliability of static pressure sensor was not trustable because the altitude values were very different from the values given by GPS. Despite the GPS data was suggested not to be used due to the poor performance, the data provided by static pressure sensor was not matching up with the observation either. For dynamic pressure sensor, the data collected was of indicated airspeed, which was of good consistency. The indicated airspeed values detected by dynamic pressure sensor were also highly reliable for the data matches up with the ones calculated by GPS module. GPS was giving the ground speed values that were very close with the ones detected by dynamic pressure sensor while the plane was at cross wind position. Meanwhile, the ground speed became lower than indicated speed when the plane was flying against wind, and became higher than indicated speed when the plane was flying along the wind. More details can be seen in DR 104-16.

20. CONCLUSIONS

For the year of 2008-2009, one of the avionics team accomplishments was the design and integration of an avionics system for the GeoSurv II Prototype. This system was reproduced and flight tested successfully on ATB-5. Data from the flight was analyzed and recommendations for future designs were developed. During the design process avionics block diagrams and wiring diagrams were created for the ATB-5 and GeoSurv II Prototype. The team has also designed and built a suit of instruments and sensors that will gather flight data on the GeoSurv II Prototype. All avionic components for the GeoSurv II prototype have been completed and tested. This includes mounting supports and brackets. Once the aircraft is ready for installation, the avionics systems can be installed. Documentation and checklists have been created to verify the installation and perform ground tests in order to achieve first flight with the GeoSurv II Prototype.

21. RECOMMENDATIONS

The Avionics Group believes that the avionics system designed for the prototype is suitable for its purpose; hence at this stage it has no basic recommendations concerning the project. However, during the work described above certain practical points became apparent. They are to be found in various design reports or were noted by the group as work progressed. These points are summarized as recommendations below:

- Connectors should be inspected periodically and before every flight; this includes checking that the pins are fully inserted and locked in the connectors and that the wires are not damaged
- The power requirements of the GeoSurv II Prototype must be fully analyzed and understood. The power system must be able to provide sufficient power for all servos on the aircraft for continuous flight as well as for servo transient stalls. The voltage drop across the servo cables in continuous and stall situations must be accounted for, related to the mechanical output power of the servos and correlated to the aircraft design requirements.
- Cooling may be required for the power system and it should be addressed
- A frequency scanner should be used before flight tests to check that the 72MHz band is free from other interference
- The servo travel that can be obtained with our equipment should be accurately measured and translated into maximum aileron deflection. That information will enable the STR group to decide if the HSR-5990TG servos can meet their aileron specs.
- The servos installed on the GeoSurv II Prototype ailerons should be tested and the following information should be obtained:
  - power consumption of each servo when aileron is in neutral position
  - power consumption of each servo when aileron is under maximum expected flight load

  An estimate should also be made on the total power consumption of all the servos on the aircraft, static and peak.

  The above information will allow AVI group to identify if the power output from the servo voltage regulator is adequate and estimate the continuous “power-on” capacity of the batteries.
- The programmed parameters on all servos installed on the GeoSurv II Prototype should be verified.
- The wireless camera should be mounted with the lens horizontal angle parallel to the horizon so when the aircraft is flying level the video also appears level. The length of the camera should point down at a negative angle of about 30 degrees so that the ground can be seen from the air.
- An analog to digital video converter should be purchased by the AVI team.
- The focus of the wireless camera should be checked and adjusted before flight and the lens should be cleaned.

22. REFERENCES

1. “MicroPilot Autopilot Installation & Operation,” MicroPilot Inc., Version 10/OCT/08, © 1998 – 2008.

2. “Installing and Using the MP ADC Module,” MicroPilot Inc., © 2003 – 2008.

3. “HORIZONmp User’s Guide.” MicroPilot Inc., © 2004.

23. ACKNOWLEDGEMENTS

John Bauer, Lead Engineer – Avionics and Flight Testing

Fred Forbes, Lead Engineer – Avionics and Flight Testing

Brian Wattie, Lead Engineer – Avionics and Flight Testing

Prof. Paul Straznicky, Carleton University

24. DESIGN REPORT REFERENCE LIST

DR94-02 Avionics Installation Document for Prototype
Ryan Mitchell

DR94-03 Data Acquisition in the GeoSurv II Prototype
Matthew Holmes

DR94-04 MP2028 Chassis Design
Kevin Ainsworth

DR94-05 MP2028 Chassis Design
Guannan Wang

DR94-06 Communication Settings for Autopilot and GCS
Guannan Wang

DR94-07 Laser Altimeter Data Decryption
Chong Jin

DR94-08 UAV Prototype Conduits
Stefan Radacina Rusu

DR94-09 UAV Prototype Control System
Stefan Radacina Rusu

DR94-10	Avionics Installation Document for ATB-5 Ryan Mitchell
DR94-11	Alpha and Beta Position Sensors Kevin Ainsworth
DR94-12	Total and Static Pressure Sensors Kevin Ainsworth
DR94-13	MicroPilot ADC Acceptance Test Matthew Holmes
DR94-14	Tachometer Interface to MicroPilot ADC Matthew Holmes
DR94-15	Temperature Sensor Interface to Micropilot ADC Matthew Holmes
DR94-16	Laser Altimeter data analysis Chong Jin
DR104-01	Prototype Avionics Design Ryan Mitchell
DR104-02	2 Axis Accelerometer Function & Design Matthew Holmes
DR104-03	HORIZON Calibration Procedure & Settings Matthew Holmes
DR104-04	Instrumentation Checklist Matthew Holmes
DR104-05	GeoSurv II Prototype Avionics Ground Test Plans Guannan Wang
DR104-06	GeoSurv II Prototype Avionics Checklists Guannan Wang
DR104-07	GeoSurv II Prototype Avionics Interference Tests Guannan Wang
DR104-08	ATB-5 Flight Data Analysis: Data Loss Guannan Wang

DR104-09 ATB-4 PID Loop Corrections
Guannan Wang

DR104-10 Serial Data Logger Firmware Modification
Guannan Wang

DR104-11 GeoSurv II Prototype Wiring
Stefan Radacina Rusu

DR104-12 HSR-5990TG Servo Programming
Stefan Radacina Rusu

DR104-13 2.4GHz Wireless Camera
Stefan Radacina Rusu

DR104-14 ATB-5 Installation
Stefan Radacina Rusu