FireBug Creations
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Dr. Andrew Rawicz,
School of Engineering Science
Department of Applied Science

Dear Dr. Rawicz

The enclosed document, *FireBug Process Report*, outlines the changes to design specifications and the experiences our project group encountered during our 370 project. Since the FireBug's primary goal is to work in conjunction with the SFU Aerial Robotics Group, a certain design strategy was implemented with early emphasis on getting the FireBug running.

Thank you for your time and consideration. All of us in FireBug Creations are very excited about continuing this project. Many of us are considering the implications of our research as possible thesis projects and marketable products.

Sincerely,

Julie Delisle
Media Relations Prime,
FireBug Creations

Enclosure: ENSC 370 FireBug Process Report

FireBug Process Report

FireBug Creations

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1.0 Introduction

This document summarizes the accomplishments and experiences of FireBug Creations during the last 4 months. FireBug Creations is a team of four Engineering Science students at Simon Fraser University. In January of 1999, FireBug Creations was formed to develop an autonomous vehicle for the International Aerial Robotics Competition in 1999, and continue through until the 2000 Millennial Event. This vehicle has been dubbed the FireBug.

After three months of development and research and one month of no sleep, the FireBug is ready to begin strenuous testing and software development. Currently, the FireBug's software is mainly remote-control based, to enable FireBug Creations to characterize the control system manually before attempting to develop reliable control algorithms to be used internally during the competition. FireBug Creations plans to begin applying real-time autonomous control features to the FireBug in early May.

For the purposes of this first milestone, the ENSC 370 project deadline, the FireBug is slightly behind schedule. Originally slated to be semi-autonomous, the FireBug is capable of running only simple autonomous routines, such as homing in on a specific GPS coordinate. Due to an incomplete sensor array, the FireBug cannot identify fires or directly measure its heading, two of its primary design features. In addition, the FireBug cannot change gears automatically. FireBug Creations has solutions to each of these problems, but will not be implementing them for ENSC 370.

Despite these issues, the FireBug has achieved a considerable goal – to develop a vehicle capable of automatic control, with no human operator on board. All control commands to the FireBug are issued through the onboard computer, which relays the commands through a wireless link to the remote control station. The complex task of expanding the FireBug to a fully autonomous vehicle can be more easily accomplished with valuable run-time data collected from the sensors and actuators while testing.

FireBug Creations fully expects to deliver a high-performance, fully autonomous land vehicle to the SFU ARG team in June 1999, capable of interacting with the air vehicle through the fixed base station. Both the SFU ARG and FireBug Creations feel that Simon Fraser University's team has an excellent chance to come in first place in this year's IARC.

2.0 Current Status of the FireBug

Except for the gear changing system, the actuator array is functional and has been fully tested. The main components of the actuator array are the throttle, steering, rear brakes, and front brakes. In addition to these control actuators, there are many less important actuators such as the headlights, taillights, and ignition.

The sensor array is less developed. The full sensor array includes ultrasound sensors, infrared sensors, ambient temperature sensor, GPS, compass, inclinometer, speedometer, wheel position sensor, computer temperature sensor, and CCD camera for vision.

Of these sensors, only the ultrasound sensors, GPS, and CCD camera have been developed and installed. The compass should have been in place, however it was damaged late in the semester. The other sensors are a lower priority, since they do not directly affect its controllability.

Using differential GPS feedback, generated by comparing mobile position with a fixed base position, we have the ability to accurately home in on a specific position. This will be the basis for more complex autonomous routines that will be implemented to satisfy requirements for the competition.

3.0 Deviation from Design Specificaitions

Figure 1 is an updated vehicle control system diagram highlighting the changes that have been/will be made to the FireBug's control system.

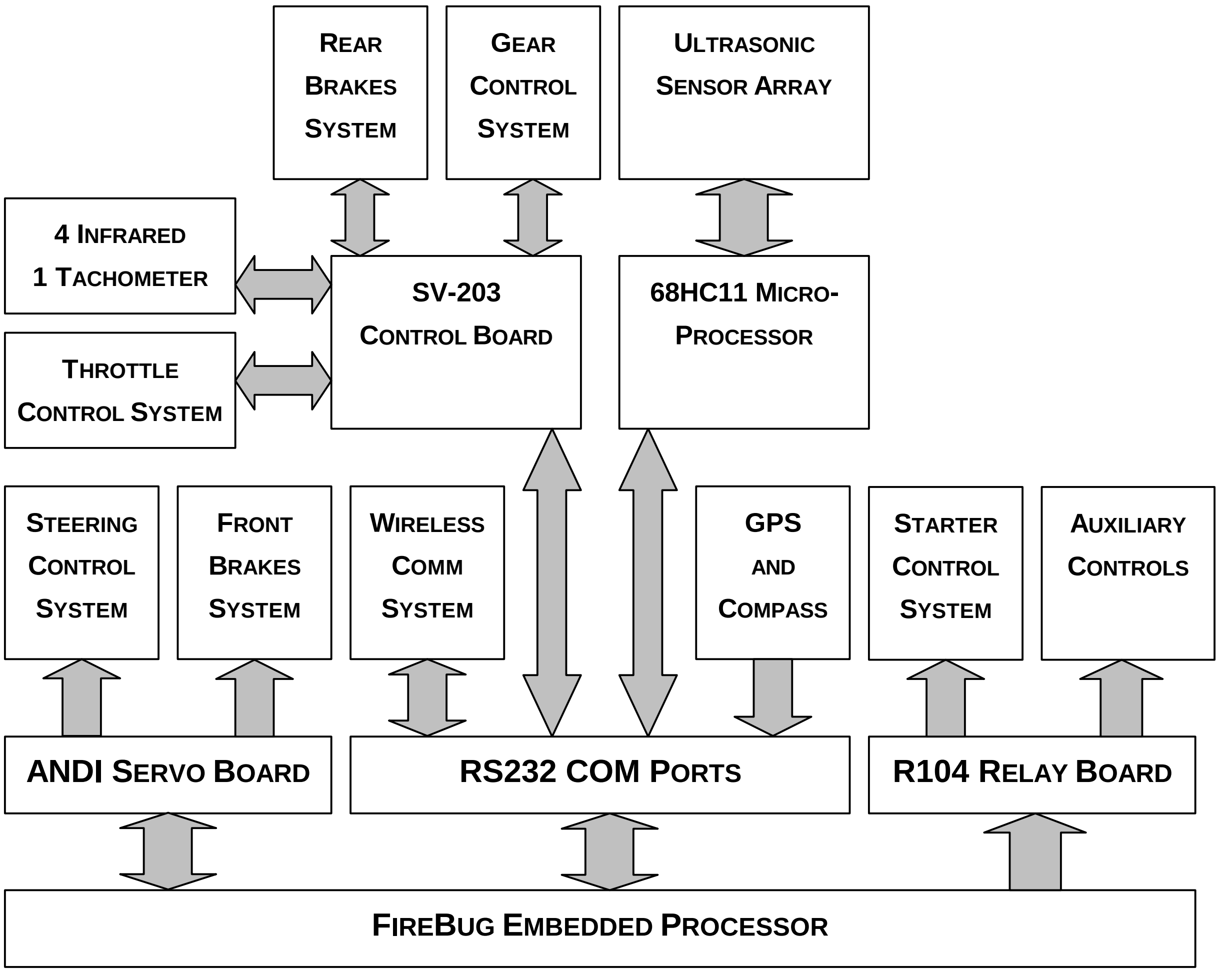

Figure 1: Vehicle Control System Block Overview

Note there are separate servo systems required for the front and rear brakes. Also, the throttle is now controlled by the SV-203 Servo Controller Board. The compass has been removed from the system temporarily while we investigate its characteristics. The auxiliary controls include headlights, brake lights, and software emergency kill.

3.1 Physical Control System

3.1.1 Throttle Control System

There has been no deviation from the FireBug Design Specifications in the Throttle Control System. Preliminary tests have shown that control of the throttle is difficult because of the nonlinearity associated with a combustion engine. Some proposals have been made to make the throttle more controllable, specifically a feedback loop on the RPM's of the engine to prevent stalls.

3.1.2 Steering Control System

There has been only minor deviation from the FireBug Design Specifications in the Steering Control System.

As a small deviation, however, the FireBug control software has imposed a requirement that before turning the wheels, the FireBug must begin moving either forward or backwards. This restriction is designed to reduce the strain on our H-bridge motor driver, which has failed at maximum rated load. Efforts are underway to locate new parts capable of handling this unexpected load.

3.1.3 Braking Control System

The Braking Control System has undergone a revision since the release of the FireBug Design Specifications document. Initially, the brakes were to have been controlled by solenoids, which would actuate the brakes in an on/off manner. This would have resulted in unpredictable behaviour of the FireBug at higher speeds. It also would have made complex maneuverability in small spaces difficult.

To overcome these difficulties, FireBug Creations installed servomotors to control the brakes, allowing more continuous braking. This modification imposes more complex software on the Braking Control System. Software feedback loops will soon be implemented to control speed and undesired roll using this braking system.

3.1.4 Control System Hardware Components

There have been minor changes to the Control System Hardware Components since the release of the FireBug Design Specifications.

3.1.4.1 ANDI-Servo Control Board

There has been no change to this section of the Control System Hardware. With increased current ratings for the H-Bridge we will be able to experiment with optimal PID characteristics of the servomotor feedback loop. The PID controller is currently set to minimize the current load on the H-Bridge.

3.1.4.2 SV-203 Servo Motor Controller Board

The SV-203 Servo Motor Controller has undergone no changes since the release of the FireBug Design Specifications. However, only two of the three proposed servomotors have been installed. In addition, no A/D ports are currently being used.

3.1.4.3 R104 Relay Board

There has been a small revision to the R104 board since the release of the FireBug Design Specifications. Rather than only having 16 relays, the board now has 20 relays.

3.2 Sensor Array

3.2.1 Position Sensor

There has been a minor change to the Position Sensor since the release of the FireBug Design Specifications.

Rather than using the NovaTel MiLLennium RT-2 DGPS system, FireBug Creations has opted to use the less expensive RT-20 DGPS, which has only 20 cm accuracy in differential mode, rather than 2 cm. FireBug Creations is confident that no one will notice this loss of accuracy. This new system will remain compatible with the other GPS systems in team.

3.2.2 Speedometer

The speedometer has not been implemented for the preliminary stage of the FireBug project. Crude velocity information can be supplied by the GPS for simple autonomous control. However, a small DC motor is in stock at FireBug Creations, and will be installed at the earliest convenience. A proposal has been made to implement accurate position and speed information using several magnets that pass a sensor as the vehicle moves. Such a system on all four wheels could give make it possible to recover control in skids and other such uncontrollable states.

3.2.3 Heading Sensor

The Precision Navigation TCMVR-20 electronic compass has been removed from the design for the preliminary stages of the project due to a failure late in the design phase. For unsophisticated autonomous navigation to be implemented for this year's competition, differential GPS heading information will be sufficient.

3.2.4 Object detection

3.2.4.1 Ultrasonic Sensors

There has been no deviation from the FireBug Design Specifications, however only one transceiver pair has been developed. The full complement of sensors will be manufactured within the next six weeks for use in this year's competition.

3.2.4.2 Infrared Sensors

This system has not yet been developed aside from initial designs, due to a backorder of parts. The IR sensors should have arrived in early March, but are back-ordered and expected to arrive in as little as four more weeks. FireBug Creations is investigating using a different vendor.

3.3 Actuator Array

3.3.1 Throttle

There has been only one minor deviation to the Throttle Actuator design since the FireBug Design Specifications Document was released.

Instead of using the HS805 servomotor, the throttle is actuated using the HS700 RC scale model. The torque necessary to pull the throttle cable can be provided by this much smaller servomotor, and it saves a considerable cost. Additionally, the HS700 can be controlled using the same power supply and controller (SV-203 controller board) as the HS805, which allows us to switch to the HS805 if the smaller servo's performance degrades in the long run.

3.3.2 Steering

There have been no changes to the Steering Actuator since the release of the FireBug Design Specifications.

3.3.3 Braking

The Braking Control System has undergone a revision since the release of the FireBug Design Specifications document. Initially, the brakes were to have been controlled by solenoids, which would actuate the brakes in an on/off manner. This would have resulted in unpredictable behaviour of the FireBug at higher speeds. It also would have made complex maneuverability in small spaces difficult.

To overcome this possibility, FireBug Creations revised the design to use servomotors to actuate the brake cables. While more expensive, this solution allows more control than on/off braking.

FireBug Creations decided to actuate the front and rear brakes separately. A large Pittman servomotor, being controlled by the ANDI servo controller, is used for the front disk brakes, and an HS805 RC Servo is used for the rear drum brakes.

3.3.4 Gearing

While not yet installed, this component has undergone a revision since the FireBug Design Specification was released.

Rather than using solenoidal actuators on the gear changing stick, FireBug Creations has revised the design to use a small servomotor to push the gear lever between forward, neutral, and reverse.

3.3.5 Ignition

There have been no changes to the Ignition Actuator since the release of the FireBug Design Specifications. During tests it was discovered engine problems occur rather frequently. A manual start switch will be added to make it possible to start the vehicle with out the main computer. This will simplify debugging of engine difficulties in the field.

3.3.6 Additional Actuators

There have been no changes to the Additional Actuators since the release of the FireBug Design Specifications. However, FireBug Creations did add the option of turning on the headlights and taillight using three extra relays on the R104 relay board.

3.4 Embedded Processor

3.4.1 Processor Hardware

There have been no changes to the Processor Hardware since the release of the FireBug Design Specifications.

3.5 Base Station

There have been no changes to the Base Station Specifications since the release of the FireBug Design Specifications.

Currently the Base communicates with the vehicle using raw serial data over the modem line. For the competition, we will be converting our code to use a TCP/IP SLIP connection over the wireless modems.

4.0 Physical Specifications

The FireBug's control hardware is contained in a Pelican case, and was designed with modularity in mind. Each component is attached to a piece of Plexiglas that slides into a slot inside the case. This allows the hardware in the FireBug to be quickly swapped with replacements should the need arise. It also prevents vibrations, since each Plexiglas mount is cut exactly to fit the Pelican case.

Since the computer container is environmentally sealed to allow the FireBug to travel in rain and snow, heat cannot escape easily from the case. At its average power of 48W, the box heats up quickly without ventilation. For the competition, we have designed an ice-box which will sit inside the computer container and absorb heat for the short amount of time required to drive autonomously. A more robust cooling system needs to be developed to allow the FireBug to operate in any environment without the electronics becoming damaged.

5.0 Safety Specifications

5.1 Throttle Limiter

The FireBug has minimum and maximum allowed throttle positions programmed into the control software. In addition, a simple mechanical constraint prevents accidentally increasing the throttle to such a level as to make the FireBug uncontrollable. The position of this mechanical constraint can be set by a trained FireBug technician, and is calibrated to limit the FireBug to approximately 10km/h.

5.2 Emergency Kill

There are four manual kill switches and one software-controlled kill switch in the FireBug system:

- Software engine shutoff relay
- FireBug master key shutoff
- Onboard emergency kill switch
- Remote emergency kill relay
- Link timeout kill relay

Together, these five switches make it easy and fast to shut down the FireBug in the case of an emergency, such as a software fault or miscalculation.

6.0 Reliability Specifications

6.1 Accuracy

FireBug Creations has logged several minutes worth of real GPS data gathered from tests. This data is not used during remote control, however it is transferred to the base station every 5 seconds to be logged and displayed on screen. GPS documentation claims a worldwide resolution of 2 metres, and down to 20 cm resolution using differential GPS.

FireBug Creations expects the accuracy of our DGPS system be approximately half as accurate as the documentation claims, based on our current worst-case tests. Even in the worst case, however, FireBug Creations expects to have a resolution of 1 m with differential GPS. Given that the FireBug will be equipped with ultrasound and infrared sensors, a resolution of 1 m will suffice.

6.2 Durability

There have been no changes to the Durability Requirements since the release of the FireBug Design Specifications.

Currently the FireBug does not meet its environmental requirements – specifically, its vibration resistance and waterproof requirements. The ultrasound sensors, for example, are mounted on a prototype board directly to the front of the FireBug. In the short term, the vibration requirements are less important than achieving a working design. When the wiring is complete and tested, waterproofing and vibration testing will begin. FireBug Creations is confident that these requirements will be met for the competition in June.

7.0 Time

The following Gantt chart illustrates the differences in proposed time required and actual time required for various tasks in the preliminary stages of the FireBug project.

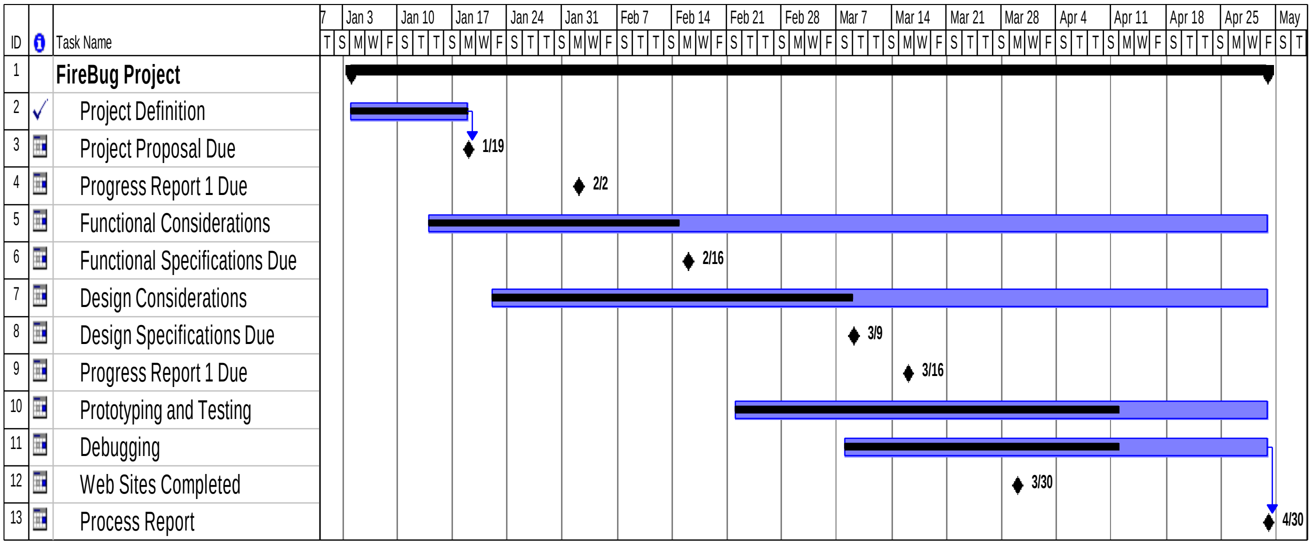

Figure 2: FireBug Project Gantt Chart

The thin black bar represents the proposed time schedule and the thick shaded bar represents the actual time required for each task.

As you can see the functional considerations are an ongoing process in this project as we have no specific, clearly defined problem to solve. The SFU ARG's competition strategy for the International Aerial Robotics Competition is constantly changing as the June competition deadline approaches. Functional specifications of the FireBug are fluctuating as the SFU ARG reshuffles priorities and resources to try and maximize the possible points attained at the competition.

8.0 Budgetary Issues

Table 1 compares the proposed budget with the expenditures thus far in the FireBug project.

Table 1 : Actual VS Estimated Expenses

Item	Estimated Expense	Actual Expense
Vehicle body	$1000.00	$3500.00
Sensors	500.00	30.00
Camera	500.00	Property of SFU ARG
Embedded processor and Peripheral Cards	1200.00	300.00 + Donations From Tri-M
2-way Wireless Communications Device	1600.00	Loaned by OMNEX
Global Positioning System (GPS)	1000.00	Loaned by Novatel
Fire Detection/Extinguisher	200.00	Not Implemented
Servo Motors/Gears	Not Accounted For	800.00
H-Bridge Parts	Not Accounted For	60.00
ATV Maintenance Manual	Not Accounted For	35.00
Enclosure/Connectors/Metal	Not Accounted For	400.00
Total Cost	**6000.00**	**5125.00**

Donations and loaned items have significantly reduced the funding required for the project. Also, the SFU ARG has provided our project with countless miscellaneous items essential to prototype development.

We grossly underestimated the funding required in other areas of the project, namely the steering system (servo and gear system), the Pelican case enclosure, and the connectors.

9:0 Book of Revelations

For this section, FireBug Creations has decided to drop the formal engineering talk.

Okay, this semester was really awesome for all of us. The hardest part was not being able to get the ATV until March. All of us wanted to rush out and get it right away in January or February. Maybe that wouldn't have been a good idea as far as money goes (we got a really good deal for this thing), but it sure would have put us farther ahead than we are.

For almost the whole semester, we've been pushing the barriers of fast parts sourcing. Our add-on gear for the steering, for example, was finally found three days before W-Day – the Day of the Weld. The ultrasound and infrared sensors were ordered in plenty of time, and indeed, the ultrasounds arrived in due course. The infrareds, however, are still on backorder.

As far as group dynamics goes, all of us were friends before the group started, and we're even closer friends now. We definitely had arguments; sometimes they even got pretty heated. But the arguments were about something, and that's what the energy got focussed around. Disagreements about the best way to implement something usually came down to choosing between the most reliable, the fastest, the most upgradeable, or some other option. Arguments and counter arguments were logical and well posed, and didn't descend into useless personal attacks.

The problem with our approach this year was we talked our way into something really big and unfinishable, then talked our way back down. We set our goals really high, then fell short, although still achieving very significant milestones. A better approach in a course being graded subjectively is to aim lower and end up much higher than the goal.

Unfortunately, this isn't the life philosophy of anyone in FireBug Creations. We do have a mix of 'Look before you leap'-ers and 'JUMP'-ers, but basically we all jumped together. We didn't fall in too deep, but we got wet. And we didn't need to.

Yay for FireBug Creations!

