FireBug Creations
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Dr. Andrew Rawicz,
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Dear Dr. Rawicz

The enclosed document, *FireBug Functional Specifications*, outlines the functional requirements surrounding our 370 project. The FireBug's primary goal is to extinguish fires and identify hazards. It will work in conjunction with SFU's airship to identify and, if possible, eliminate hazards. The FireBug will demonstrate the possibilities of machine assisted search and rescue operations, or indeed any application in a hazardous environment.

The project goal for ENSC 370 is to have a prototype capable of autonomous navigation between two points, including simple object avoidance. More extensive features will be added following the ENSC 370 deadlines.

Sincerely,

Julie Delisle

Julie Delisle
Media Relations Prime,
FireBug Creations

Enclosure: ENSC 370 FireBug Functional Specifications

FireBug Functional Specifications

FireBug Creations

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Executive Summary

In the past search and rescue missions have relied completely on the expertise of skilled professionals. These trained men and women regularly put themselves at risk to neutralize hazardous situations. With the rapid increases in processing power and improvements to artificial intelligence, automating these complex tasks can now be realized.

Our team of enthusiastic third year engineering science students plans to develop an autonomous land vehicle to work in conjunction with an aerial robot to identify and neutralize hazards, specifically fire, in a simulated disaster area. This land vehicle has been dubbed the FireBug.

FireBug Creations is currently developing a land vehicle that will be able to perform complicated tasks related to search and rescue. This vehicle will be entered in the International Aerial Robotics Competition in June 1999 as a slave to an existing aerial robot. The preliminary stage of the FireBug project is expected to be complete by April 1999, and will deliver a prototype capable of autonomous navigation directed by an external base station.

A successful mission will demonstrate the possibility of automating aspects of real search and rescue missions, saving lives and cost.

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1.0 Introduction

The unpredictable nature of search and rescue missions has made automating them impossible in the past. The reward of automating these missions would be enormous, as men and women would no longer be required to put themselves at risk to neutralize hazardous situations.

The purpose of the FireBug project is to demonstrate the feasibility of automating search and rescue missions. The FireBug, an autonomous land vehicle, will team up with an autonomous aerial robot in the 1999 International Aerial Robotics Competition. Together, these two vehicles will survey a simulated post natural disaster area and identify hazards. By carrying a payload of fire extinguishing equipment, the FireBug will attempt to put out fires identified by the aerial robot.

This document outlines the functional specifications of the FireBug system. Also included is simulation and testing information, required for the success of this project.

2.0 System Overview

The preliminary goal is to develop a system of autonomous vehicles to navigate in a 5 acre arena. An unknown number of obstacles and destinations are spread over this area. The responsibilities are divided between the vehicles. A Base Station acts as a relay between the various vehicles. There may be an arbitrary number of intermediary vehicles in the future. Currently, the design includes the main aerial robot, and the FireBug.

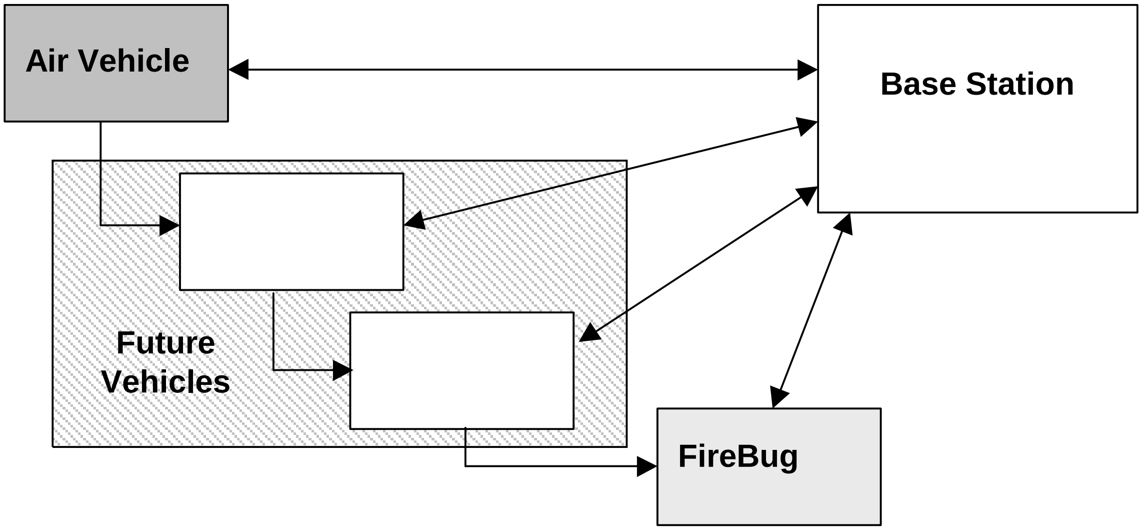

Figure 1: Overall System Diagram

The goal of the FireBug is to travel between supplied locations safely and autonomously. This task can be broken into several subtasks. The sensor array gathers information about the surrounding environment. The actuator array accepts desired setpoints for the steering, throttle and brakes, and supplies feedback about the current state of these controls. The vehicle controller block sets the controls based on their current state, information about the current destination, and the surrounding environment. The following block diagram describes the high level operation of the FireBug.

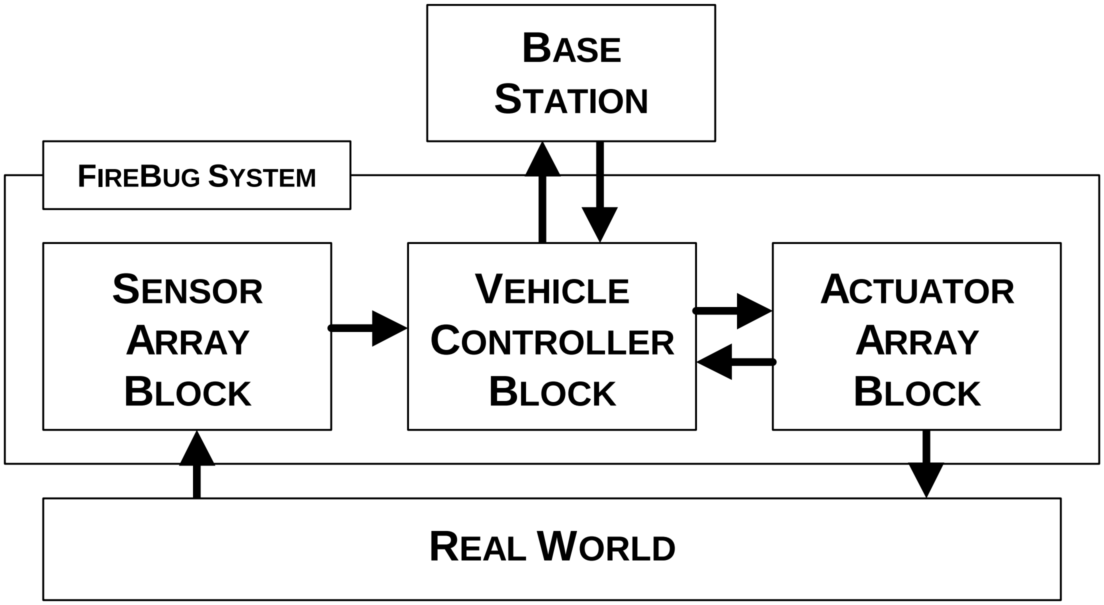

Figure 2: FireBug Block Diagram

3.0 Vehicle Specifictions

The following sections describe the operations of each system block.

3.1 Sensor Array

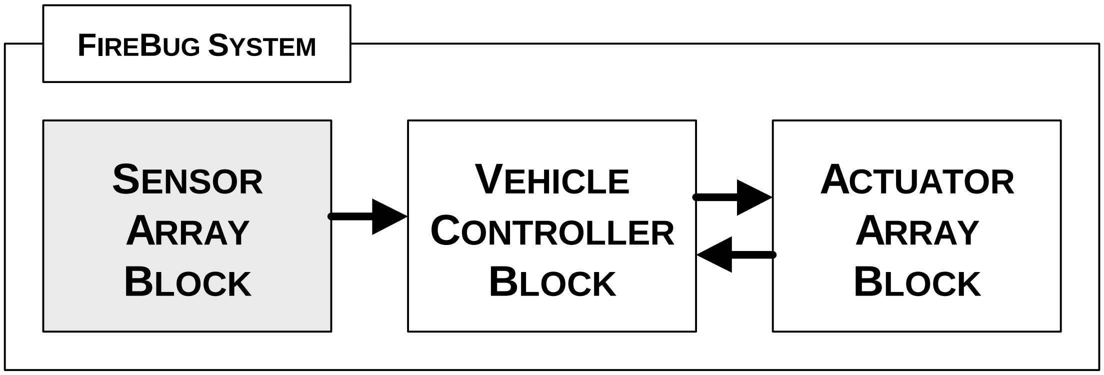

Figure 3: Sensor Array Context

The sensor array contains all sensors and algorithms that provide feedback to the vehicle controller from the environment. The properties that will be monitored by the sensor array are position, speed, acceleration, heading and the presence of and nature of local obstacles. Figure 4 shows the functional nature of the Sensor Array Block:

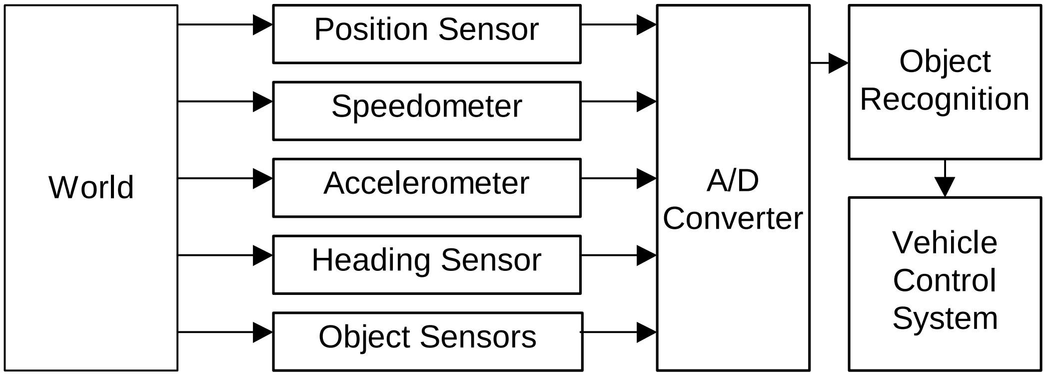

Figure 4: Sensor Array System

3.1.1 Position Sensor

The FireBug's position sensor must provide accurate and up to date position information to the Vehicle Control System (VCS). Since position is essential for locating objects and destination planning, the accuracy of the position sensor is important. The sensor must comply with the same coordinate system used by the base station.

3.1.2 Speedometer

The speedometer will provide accurate speed information while not inhibiting the motion of vehicle.

3.1.3 Accelerometer

The accelerometer will provide accurate acceleration information, while not inhibiting the FireBug's motion.

3.1.4 Heading Sensor

The FireBug's heading sensor will provide signal information in the form of an angle relative to North, or some other reference direction. This sensor will be fastened to the body of the vehicle and be used in conjunction with steering control.

3.1.5 Object recognition and Classification

To navigate smoothly over terrain, the FireBug will be able to recognize objects and estimate potential hazards associated with any given object. The FireBug must also detect objects at a great enough distance to keep at least a guard-band away from the obstacle. The guard-band is a safety distance, and is a function of the vehicle's speed and the response time of the VCS.

The sensors to be used for object recognition and classification will:

- be able to differentiate between oversized obstacles, and obstacles which can be driven over
- provide information about the approximate size of an obstacle
- distinguish between hot and cold objects
- distinguish fire from solid objects

In addition, the sensors must be able to function in several environmental conditions:

- heat/cold
- rain
- water hazard (splashing)

3.2 Vehicle Control System (VCS)

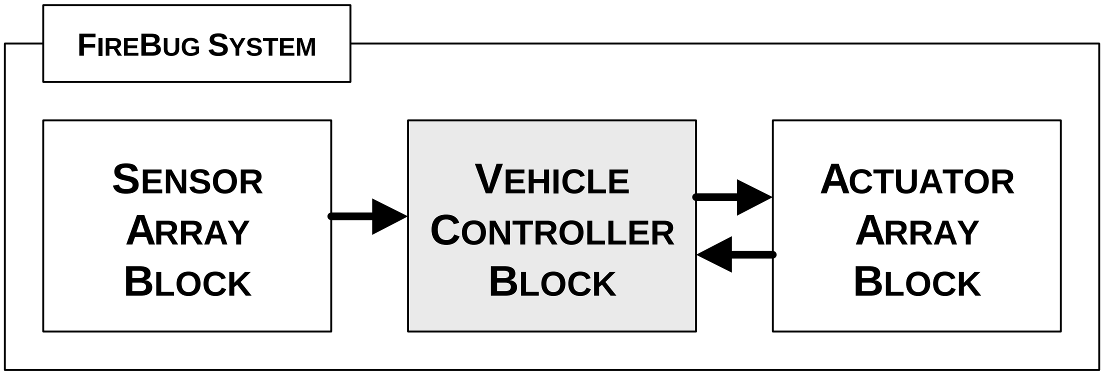

Figure 5: Vehicle Control System Context

3.2.1 Throttle Control

The speed and acceleration of the vehicle will be controlled through a throttle. By applying more force to the throttle, the acceleration of the vehicle, and thus speed, will increase.

Control of the vehicle speed raised the following questions:

- What speed is required, and under what circumstances?
- What is the maximum speed that the vehicle will run?
- How will the vehicle be made safe by control of its speed?

The FireBug must explore a five-acre field in less than one hour, which implies a certain minimum speed. However, due to safety reasons, the vehicle's top speed must also be limited to a maximum speed, determined by experiment. The top speed is based on the following factors:

- maximum speed
- distance from the destination
- objects encountered using sensors
- probability of encountering a new object
- time it takes to stop the vehicle
- steering position
- degree of turn being executed
- response time of the vehicle at its current speed

The throttle is tied to the current steering position. If the vehicle is turning, the vehicle's speed will be lowered, to avoid a loss of balance. Conversely, when the wheels straighten, the vehicle should accelerate to complete its mission more quickly.

In case of a vehicle malfunction or software error, a physical throttle limiter will prevent the vehicle from attaining uncontrollable speeds.

3.2.2 Steering Control

The position of the steering mechanism is determined by the following factors:

- error in the vehicle heading relative to the desired destination
- current speed and position of the vehicle

Error in the vehicle heading is given by the difference between the current heading and its desired heading. The steering compensation will be proportional to this error.

If a large error is introduced, the vehicle must first decrease its speed to a safe level in order that the turn be completed safely. The change in steering position must wait until the speed has reached a safe level.

3.2.3 Braking Control

The braking control system is one of several vehicle control subsystems. It can be used to manipulate the vehicle's speed directly.

3.2.3.1 Rapid Deceleration

A rapid decrease in speed will rarely be used. In such situations where the emergency kill switch is activated, the vehicle will come to an immediate stop, not coast to a gradual stop.

3.2.3.2 Parking Condition

When the vehicle is powered up, but not moving, the vehicle will assume a parked condition. This is to prevent rolling if situated on an incline.

3.2.4 Trajectory Planning Algorithms (TPA)

TPA includes all algorithms for navigation and object avoidance. All algorithms that are designed will first be simulated using the Simulator. Using the simulator, these algorithms will be tested for robustness, and effectiveness.

3.2.4.1 Overview of TPA Requirements

Destinations are supplied by the airship. Such destinations received from the airship can arrive at any time during the vehicles autonomous execution. A course needs to be planned based on:

- shortest route to destination
- level of importance
- known danger level, or risk

3.2.4.2 Trajectory Planning Considerations

To avoid obstacles, the VCS will choose a point near the obstacle, such that the destination can be reached from the sub-destination more easily than from the current position. To determine a sub-destination, the VCS requires the following information:

- current heading
- maximum turning radius
- guard-band

A complete trajectory from the current position to a destination may be composed of several sub-destinations. Each sub-destination will be chosen according to the previous algorithm. For any set of obstacles and destinations, there is more than one possible trajectory. Several possible trajectories will be evaluated, and the final trajectory chosen based on:

- shortest route
- danger level of obstacles
- destination priority

3.2.4.3 System Limitations Affecting TPA

Given the limitations of the system, there are several additional points that must be addressed:

- sensors have limited range
- response time of VCS
- response time of vehicle
- current speed and stopping distance

3.3 Actuator Array

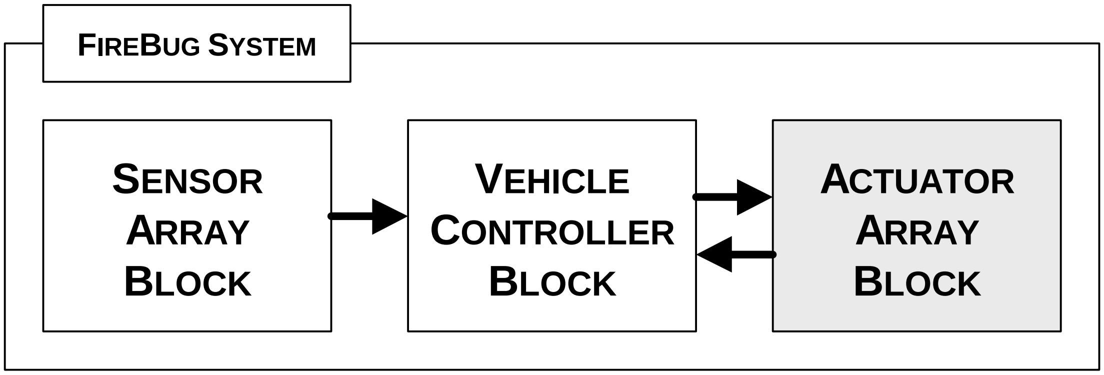

Figure 6: Actuator Array Context

The actuator array is responsible for controlling each of FireBug's actuators once provided digital input from the VCS. FireBug's actuator systems include steering, throttle, brakes, gearing and ignition. The following figure illustrates the functions of this block:

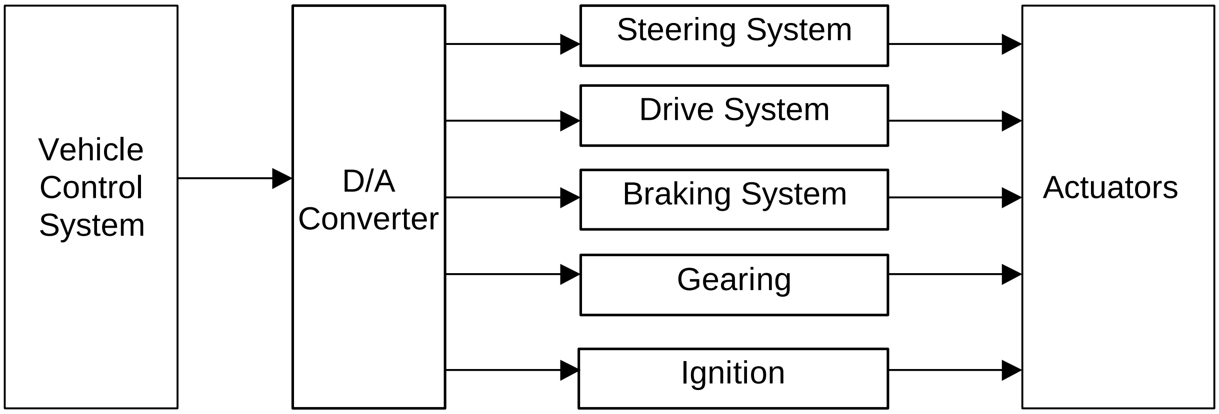

Figure 7: Actuator Array System

3.3.1 Throttle

The throttle system will provide thrust for the vehicle. The VCS will send a value between zero and the maximum throttle. A physical limitation will be attached to the throttle system for safety reasons.

3.3.2 Steering

The steering system will turn the wheels of the vehicle to the orientation specified by the VCS, given as an angle. When the angle supplied is zero, the wheels are straight.

3.3.3 Braking

The braking system is responsible for slowing the vehicle. For practical reasons we must ensure that the braking is used more or less as a switched element than an active element to reduce brake wear and increase the efficiency of the vehicle drive system.

3.3.4 Gearing

The FireBug will only have forward, neutral and reverse; therefore, the vehicle must be stationary when changing gears. All gearing required for higher speeds will be automatic.

3.3.5 Ignition

The FireBug will have electronic ignition, capable of starting up given an ignition signal from the VCS.

3.4 Base Station

The base station is responsible for providing the FireBug with destinations and external obstacle information. The base station operates using communication protocols transmitting over a wireless modem. Therefore, the FireBug must have the necessary hardware and software to communicate with the base station. To accurately respond to the destinations supplied, the FireBug will use the same coordinate system used by the base station.

The FireBug will also respond to the base station with information regarding map updates, vehicle status (e.g. position, speed, etc.), possible emergency situations and any permission requests. A permission request will occur if the FireBug identifies a local hazard that it could neutralize.

3.5 World

The purpose of the world block in our system is primarily for simulation reasons. The world, or environment, is governed by the laws of physics, and will take input from the actuator array and provide output to the sensor array. The world simulator is discussed in Section 7.0 – Testing and Modeling.

4.0 Physical Requirements

An all terrain vehicle (ATV) is well suited to our project. We will convert a recreational ATV into an autonomous land vehicle. An ATV has sufficient power and stability for our application and can carry a relatively large payload. All electronics must be contained onboard. The final vehicle will be able to hold a 50-kg payload.

Table 1: FireBug Vehicle Requirements

Dimensions (l × w × h)	~ 2m × 1m × 1m
Weight	140 kg
Payload	50 kg
Ground Clearance	15 cm
Engine	120 cc
Transmission	Automatic
Gears	Forward and Reverse

4.1 Environmental Requirements

The FireBug system will meet the following environmental requirements. The operating temperature will be between -20°C to 75°C, which allows the FireBug to operate in either winter or summer conditions, and near sources of extreme heat. The FireBug will function in wet and dry conditions.

4.2 Electrical Requirements

The FireBug system will meet the following electrical requirements.

Table 2: FireBug Electrical Requirements

Voltage Supply	12V
Peak Servo Current	100A
Average Total Current	15A
Peak Power Dissipation	1500W
Average Power Dissipation	180W

5.0 Safety Requirements

The FireBug system will meet the safety requirements outlined in the following sections.

5.1 Throttle Control

Both a software control (VCS) and a mechanical constraint will limit the vehicle speed. It is necessary to maintain the vehicle's guard-band to prevent the vehicle from colliding with obstacles. The range of the sensors will determine the maximum speed and the time required for one vehicle control loop iteration.

5.2 Emergency Kill

The vehicle will contain a remote kill switch accessible from the base station. It will also have an onboard secondary kill mechanism. The VCS will also contain algorithms to shut down in the event of an onboard emergency.

5.2.1 Software Kill Flag

The software kill flag will be used whenever the VCS detects an imminent emergency situation, such as a collision. In such a situation, the computer may issue a kill flag, which will kill the engine and stop the vehicle in a minimum number of seconds.

Table 3: Software Kill Flag Test	
Test 1: Stationary Test	
Setup	Turn on the FireBug. Allow the vehicle to stabilize.
Action	From the Base Station, send the software kill command.
Verify	Ensure that the engine stops within a reasonable time
Test 2: Moving Test	
Setup	Turn on the FireBug. Allow the vehicle to stabilize. Program a destination in front of the vehicle: 100m
Test	From the Base Station, send the software kill command
Verify	Ensure that the vehicle stops within a reasonable time Ensure that the engine stops within a reasonable time

5.2.2 Manual Kill Switch

The manual remote kill switch is an emergency stop measure engaged by a human operator from the Base Station. When the switch is engaged, the engine and the vehicle must stop as soon as possible. There is also a secondary kill switch on the vehicle itself, which must be activated by an operator on the vehicle. Following is a table of the tests.

Table 4: Manual Remote Kill Switch Test	
Test 1: Stationary Test	
Setup	Turn on the FireBug. Allow the vehicle to stabilize.
Action	Hit the manual kill switch
Verify	Ensure that the engine stops within a reasonable time
Test 2: Moving Test	
Setup	Turn on the FireBug. Allow the vehicle to stabilize. Program a destination in front of the vehicle: 100m
Test	Hit the manual kill switch
Verify	Ensure that the vehicle stops within a reasonable time Ensure that the engine stops within a reasonable time

5.3 Storage Considerations

The FireBug will satisfy university guidelines and the regulations put forth by the fire marshal. These regulations include issues surrounding gasoline and battery storage.

5.4 Standards Compliance

While we are currently not concerned with CSA or FCC standards, our immediate set of standards is given by the IARC Rules. Please see Appendix A and B for an extraction of the official IARC website.

6.0 Reliability Requirements

The FireBug will meet the following reliability requirements.

6.1 Accuracy

The error of the position equipment on board the vehicle will be well within the guard band of the vehicle. The accuracy will be largely determined by the precision of the position sensing equipment.

6.2 Durability

The FireBug system will be robust enough so that it can traverse all types of terrain for up to two hours per mission, depending on the fuel capacity. The expected lifetime of the vehicle under heavy use is five years. The system will be able to endure a noisy environment and vibrations characteristic of an off-road vehicle.

7.0 Testing

7.1 Simulation and Modelling

The FireBug must be thoroughly tested. However, testing a vehicle for the first time can lead to unexpected and expensive consequences. To avoid risk of damage to the vehicle, the FireBug Creations team is developing advanced simulation and modeling software to test the FireBug control algorithms before the FireBug is ever built.

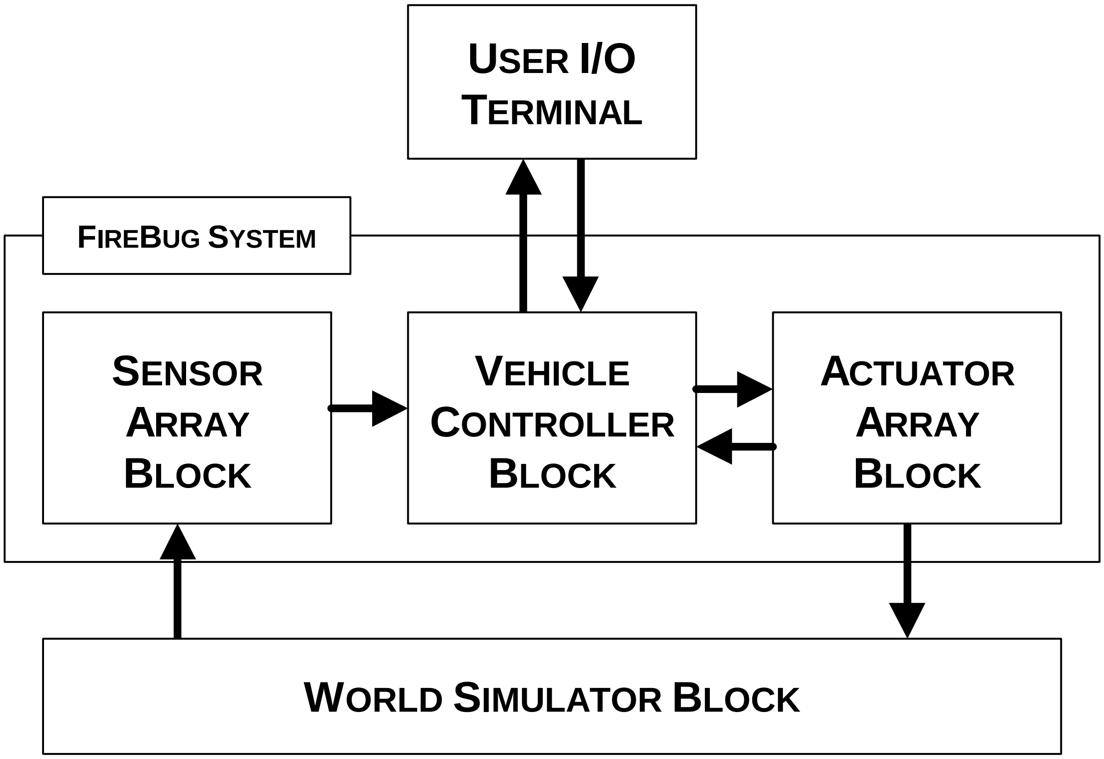

Figure 8: FireBug Simulation Diagram

When solid and reliable algorithms have been developed and simulated successfully, they will be tested in the physical FireBug under similar scenarios. The testing scenarios will be designed to stress the system, and to examine its performance.

7.1.1 Graphical Output Display (GOD)

To simplify the simulation results, the simulator will produce a graphical output format. The output display will:

- display a symbol of the FireBug at all times
- display a symbol of the Base Station when it is within the display boundaries
- display a symbol for each obstacle within the display boundaries

- display a symbol for each destination within the display boundaries
- display the coordinates of obstacles relative to the FireBug
- display the coordinates of destinations relative to the FireBug
- display the distance of obstacles relative to the FireBug
- display the distance of destinations relative to the FireBug

7.1.2 Textual Output Display (TOD)

In addition to the GOD, the simulator will offer a text output format. This display will offer information not available in the GOD, including:

- the current state of all the sensors
- the current state of all the actuators
- the current list of all destinations
- the current list of all obstacles
- the vehicle update interval (timeslice)
- the simulator update interval (timeslice)

7.1.3 Command-Line Prompt Input

The Command-Line Prompt will be used to request information to be displayed on the TOD (these are listed in Section 7.1.2). In addition, the prompt will be used to activate the GOD. The commands available at the prompt include:

- display all commands
- display timeslices of vehicle and simulator
- set timeslices of vehicle and simulator
- start simulation from current state
- add a new destination
- add a new obstacle
- enable the Graphical Output Display (GOD)
- kill the GOD

7.1.4 Accelerated Simulator

For fast verification of algorithmic changes, it is important that the simulator be able to speed up the simulation. Since the simulation scenarios may involve large distances, the actual time involved to complete a test run may be several hours. The Accelerated Simulator will:

- decrease the simulation timeslice to the smallest time possible
- enforce ratios of simulator timeslice to vehicle timeslice
- allow a pause at any time during its execution
- disable the GOD for the duration of the simulation

7.1.5 Real Time Simulator (RTS)

Since the software developed for the vehicle controller will be tested directly with the simulator, it is important that it be tested at real-time for final tests. In addition, the RTS is necessary if the user wishes to watch the GOD. The RTS will:

- execute at user-specified (or default) simulator timeslice and vehicle timeslice
- allow a pause at any time during its execution
- update the GOD (if active) during the simulation

7.1.6 FireBug Physical Model

For the simulation results to be reasonable, accurate physical models of the FireBug's control system (including servos, engine, brakes, etc) must be developed. Since the specifications of most part are available from the manufacturer's data books, this task will be aided. The FireBug Physical Model, used by the FireBug to control itself, will take into account these factors:

- response time of any servo motors used
- engine response time
- brake response time
- steering response time
- current state of all sensors
- current state of all actuators
- vehicle's guard-band
- list of current destinations
- list of current obstacles

7.1.7 Environmental Models

In addition to accurate models of the FireBug, a good Environmental Model is important. The Environmental Model is used by the Simulator to determine the next state of the vehicle's actuators (i.e. position, velocity, acceleration) and sensors (objects, their height etc.). The Environmental Model will take into account the following factors:

- coefficient of friction of the ground
- gravity
- the current state of the vehicle's actuators

7.2 Physical Test Plan

Obviously, no amount of simulation can entirely substitute field tests. Therefore, FireBug Creations has developed several important field tests.

7.2.1 Safety Requirements

Before any simulated scenarios are tested in the field, the Safety Requirements specified in Section 5.0 must be tested. Please refer to Table 4 and Table 5 in Section 5.2 – Emergency Kill.

7.2.2 Simulated Scenarios Confirmation

In addition to safety requirements, the FireBug's performance under simulated conditions must be tested. These tests are summarized below:

Table 5: Simulated Scenarios Test Expectations	
Test 1: Close or Crowded Quarters	
Setup	Arrange a series of obstacles in a closely packed arrangement
Action	Specify a destination in an area near in the centre of such an arrangement
Verify	Ensure that the FireBug's behaviour is close to its simulated behaviour. The desired response should include: • decreased speed • smaller (but still safe) guard-band • no collisions with obstacles • successful arrival at destination
Test 2: Destination is a Fire	
Setup	Build a small and controlled fire
Test	Specify a destination close to the fire
Verify	Ensure the FireBug's behaviour is close to its simulated behaviour. The desired response should include: • decreased speed near fire • confirmation of a fire found • activating fire extinguishing system
Test 3: Unexpected Obstacle Found	
Setup	Place an obstacle some distance in front of the FireBug
Action	Specify a destination beyond the obstacle, so that the obstacle will pass within the FireBug's guard-band if it does not alter its trajectory
Verify	Ensure the FireBug alters its trajectory appropriately. The response should include: • decreased speed upon recognition of object • altered course to avoid object • successful arrival at the destination

7.2.3 Un-simulated Scenarios Confirmation

As well as testing simulated scenarios, there are additional scenarios that should be tested that are difficult to simulate. These scenarios are summarized below:

Table 6: Un-simulated Scenarios Test Expectations	
Test 1: Foggy Environment	
Setup	Place an object some distance in front of the FireBug on a foggy day.
Action	Specify a destination beyond the object, so that the object will pass within the FireBug's guard-band if it does not alter its trajectory.
Verify	Ensure that the FireBug alters its direction in the same fashion as on a clear day.
Test 2: Extinguishing Fires	
Setup	Set up a small and controlled fire
Test	Specify a destination near the fire
Verify	Evaluate the success of the FireBug's attempts to extinguish the fire. A successful attempt should include: • activating the fire extinguishing system • a minimum time spent at the fire • a significantly quenched fire; if not completely extinguished, at least much smaller • no more than the FireBug's maximum time spent at the fire

8.0 Conclusion

The preceding document has illustrated the functional requirements of the FireBug project. The prototype will be constructed following the specifications outlined in this document. The FireBug project will demonstrate the long-term possibilities of machine assisted search and rescue operations.

9.0 References

More information regarding this project and related projects can be found on the following web locations.

SFU Aerial Robotics Group
http://www.ensc.sfu.ca/research/mirosot/ARG/

Association for Unmanned Vehicle Systems (AUVS),
International Aerial Robotics Competition
http://avdil.gtri.gatech.edu/AUVS/IARCLaunchPoint.html
Details on the Aerial Robotics Competition can be found on the AUVS web site.

Appendix A – General Rules Governing IARC Entries

1. Vehicles must be unmanned and autonomous. They must compete based on their ability to sense the semi-structured environment of the Competition Arena. They may be intelligent or preprogrammed, but they must not be flown by a remote human operator.

2. Computational power need not be carried by the air vehicle or subvehicle(s). Computers operating from standard commercial power may be set up outside the Competition Arena boundary and uni- or bi-directional data may be transmitted to/from the vehicles in the arena.

3. Data links will be by radio, infrared, acoustic, or other means so long as no tethers are employed.

4. The air vehicles must be free-flying, autonomous, and have no entangling encumbrances such as tethers.

5. Subsequent to 1998, subvehicles may be deployed within the arena to search for, and/or acquire information or objects. Subvehicle(s), must be fully autonomous, and must coordinate their actions and sensory inputs with all other components operating in the arena. Subvehicles may not act so independently that they could be considered separate, distinct entries to the competition. An autonomous air vehicle is mandatory whereas any number of cooperating autonomous subvehicles is optional. Subvehicles may be deployed from the primary vehicle or may be launched separately from the landing zone. Subvehicles may be ground-based or airborne. All vehicles must remain within the boundaries of the arena.

6. A Note About Ground-Based Subvehicles--

   Ground vehicles must be autonomous and subordinant to the aerial robotic component of the system in that it can be directed by the air vehicle or provide cues to direct the air vehicle, but all reporting is from the air vehicle's intelligence. What this means is that the air vehicle is not merely a relay for the ground vehicle transmissions. Rather, intelligent communication needs to be taking place wherein data from the air vehicle is updated and "more informed" based on the experiences of the ground vehicle.

   Example: The aerial robot detects a potential survivor at coordinates x,y, but due to obscuration of the potential target by smoke or the inability of the air vehicle to safely approach for a better look, the ground robot is instructed to inspect those coordinates while the aerial robot proceeds to search for other targets. Upon arrival to position (x,y) the ground robot reports that there is a survivor, but there are drums of potentially explosive material nearby at coordinates (x+4,y-1). This information is uplinked to the aerial robot which is now 100 meters away inspecting another target. The precise information from the ground robot is integrated into the map being compiled by the aerial robot and is transmitted back to the human team as a seamless report.

7. Air vehicles and air-deployed subvehicles may be of any size, but together may weigh no more than 90 kg/198 lbs (including fuel) when operational. Ground-based subvehicles proceeding under their own power from the landing zone have no weight restriction.

8. Any form of propulsion is acceptable if deemed safe in preliminary review by the judges.

Appendix B – Competition Details

The Arena:

A disaster scene will be replicated with highly unstructured and unpredictable events. Your autonomous robot(s) will have to be robust enough to operate in a realistic environment that contains wreckage, fire, smoke and aerosols, acoustic shock waves, motion on the ground and in the air, as well as unbriefed obstacles.

Your targets are injured humans on the ground that are simulated by animatronic synthetics capable of limited limb motion and sound. All survivors will be incapacitated and unable to move to safety under their own power. These synthetics will be programmed to expire at predetermined intervals unknown to the team. The number of injured humans and their location relative to the disaster scene is unknown.

Alternate targets of interest will represent potential hazards to rescue teams entering the area. These lower priority targets will include items such as drums of hazardous material, some potentially explosive, amid others which are inert.

Scoring:

An actual human search-and-rescue team will be given one chance to enter the area to rescue as many injured people as possible. Their time in the area will be limited due to the simulated radiation hazard. They will be encumbered with hazmat suits and respirators and will have to deal with fire threats and smoke obscuration. The human search-and-rescue team will set the baseline performance comparison to which the autonomous robots will be judged.

Teams will be able to field one or more fully autonomous robots which may work simultaneously and synergistically to identify and map targets of interest. Ground robots may be deployed from the aerial robots, or may be launched from the starting point to work in concert with the aerial robots.

Points will be accrued for successfully performing tasks that would normally have to be done by human search-and-rescue teams or fire fighters. These will include, but are not at this time limited to: identifying the location of survivors, identifying the location of dead bodies, identifying hazards to be avoided, and identifying potential hazards. Given enough time (less than one hour), all survivors will become dead bodies. More points will be allotted for identifying the living. In addition, actions taken by the autonomous robots to improve the situation will accrue points. This will include, but not at this time be limited to: extinguishing fires, extracting survivors, providing life-support equipment to survivors, laying down paths/markers/lines through wreckage to survivors or to other locations requiring the attention of emergency personnel.