Fire Extinguishing Autonomous Robot

F.E.A.R.

The Firefighting Robot

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Introduction

Abstract

The purpose of this project is to design an autonomous robot that will detect, verify and extinguish a lit candle that is randomly placed in the designated competition course. This will be achieved by utilizing sonar and infrared sensors coupled with brushed dc motor encoder feedback, to navigate the course and find the flame. Once the flame is found, it will be verified with specialized infrared sensors and extinguished with the onboard water pump system. This process will be realized with high quality, high speed parts coupled with powerful computing and algorithms that will ensure efficiency and speed.

Project Description

The goal of F.E.A.R. is to find and extinguish the candle flame as quickly as possible. In order to achieve the fastest time possible. It must actively map and memorize the course during each attempt to calculate the shortest distance to the candle in subsequent runs. With the proper sensors, programming, and hardware this can be achieved.

The competition consists of two challenges. In the first challenge, each team is allowed to have three attempts to complete the time trial course. Each team is then scored based on the inverse of the time needed to extinguish the flame. The best time from the three runs will be documented and chosen as the final time. The candle and decoy locations will not be changed during the first three run attempts. Once the robot has been deployed on the playing field, reprogramming or sending any scripts to the robot is prohibited. However, repairs and general maintenance can be performed. This includes repairing a broken component, charging batteries, and refilling the 100 mL reservoir between runs.

In the second challenge, all the teams will compete at once. During this time, a new course will be set up and reconstructed so that the robots do not know the location of the flame or decoys. Once the start command is given, each robot will enter the playing field and attempt to find and extinguish the flame before the other competitors. The robots are not disqualified for spraying a decoy in this event. This challenge is a race to extinguish the flame. The robots are allowed to interact with each other to gain an advantage or use sabotage, such as spraying another robot with water or slamming them against a wall; but offensive weapons are not allowed. After the contest, the team that wins will gain a multiplier coefficient that will be applied to their challenge one score.

There are particular sensors being utilized to help with mobility, tracking, detection, and avoidance. Each set of sensors work together to allow the robot to function properly. These include IR distance sensors, ultrasonic range finders, IR flame detection sensors, and distance tracking.

Advanced programming is crucial to allow the robot to operate properly. F.E.A.R. must be able to read and store each sensor's data as quickly as it is available and utilize this data to allow it to move quickly through the course. Algorithms must be employed to ensure that any garbage data is thrown out and not used. F.E.A.R. will log data from previous runs and utilize dead reckoning estimates to accurately guess the location of crucial landmarks and improve the time taken to find the flame.

It is essential for the chassis design to be maneuverable and able to achieve high rates of speed. By implementing a differential steering design and having a powerful motor mounted to each wheel, F.E.A.R. is able to achieve this goal. The majority of the weight is located at the bottom of the robot to ensure a low center of gravity to aid with stability and maneuverability. This includes the water storage and an electric water deployment pump. A complete full independent suspension system is also utilized for constant traction to the tires and for overcoming possible rough terrain, as well as stabilization.

By implementing these designs into F.E.A.R., it ensures the best possible chance to perform as fast as possible to accomplish its goals.

Design

Block Diagram

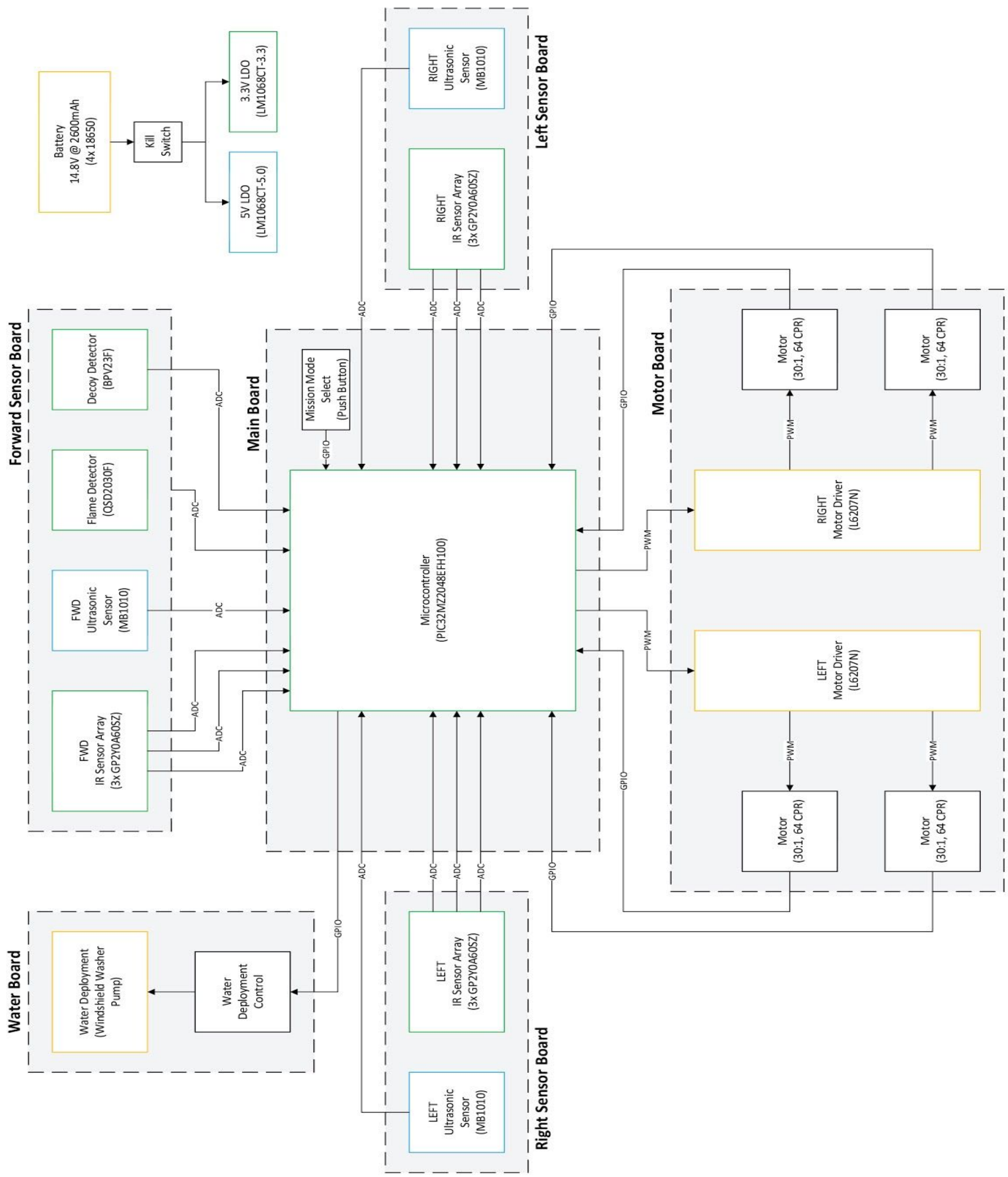

Figure 1: F.E.A.R. Block Diagram

Block Diagram Design

Water Board

The water board is comprised of a switching circuit that will turn on the 12V water pump and allow for water to be dispensed out of the fire extinguishing nozzle.

Sensor Boards

The sensor boards are made up of various sensors used for movement, flame detection, and avoidance. An IR sensor (GP2Y0A60SZLF) is used to detect short range distances. An Ultrasonic sensor (MB1010) is used to detect long range distances. Two different photodiodes (QSD2030F and BPV23F) are used to measure the specific wavelength of the flame and the decoy. The layout of the sensor board is designed to optimize the vision cone of IR sensors.

Motor Board

The motor board consists of two motor controllers (L6207N) which have two dual full H-bridges that control the speed and direction of the motors. There are four brushed DC motors that have a 30:1 gear ratio which provides a large amount of torque without sacrificing speed. Embedded into the motors are encoders which have 64 cycles per revolution. The encoder feedback will allow F.E.A.R. to be able accurately monitor the speed of each motor.

Main Board

The main board is what controls all functions of the robot, all programming code is executed here and distributed through the various input and output pins. The microcontroller used is PIC32MZ2048EFH100. A push button switch is used to toggle between missions, mapping mode or solving mode.

Power Distribution

F.E.A.R.'s power distribution will take place on the main board. The battery will be comprised of 4x 18650 Lithium Ion cells in series. The two low dropout voltage regulators (LM1068CT-5.0 and LM1068CT-3.3) will step 14.8V down to 5V and 3.3V. The kill switch will be a single-pole, single-throw rocker switch which will control the flow of power to F.E.A.R.'s circuitry. When switched to the "On" position, power will be applied to all the circuitry and when switched to the "Kill" position, power will be cut off from all of the circuitry.

Mockup Illustrations

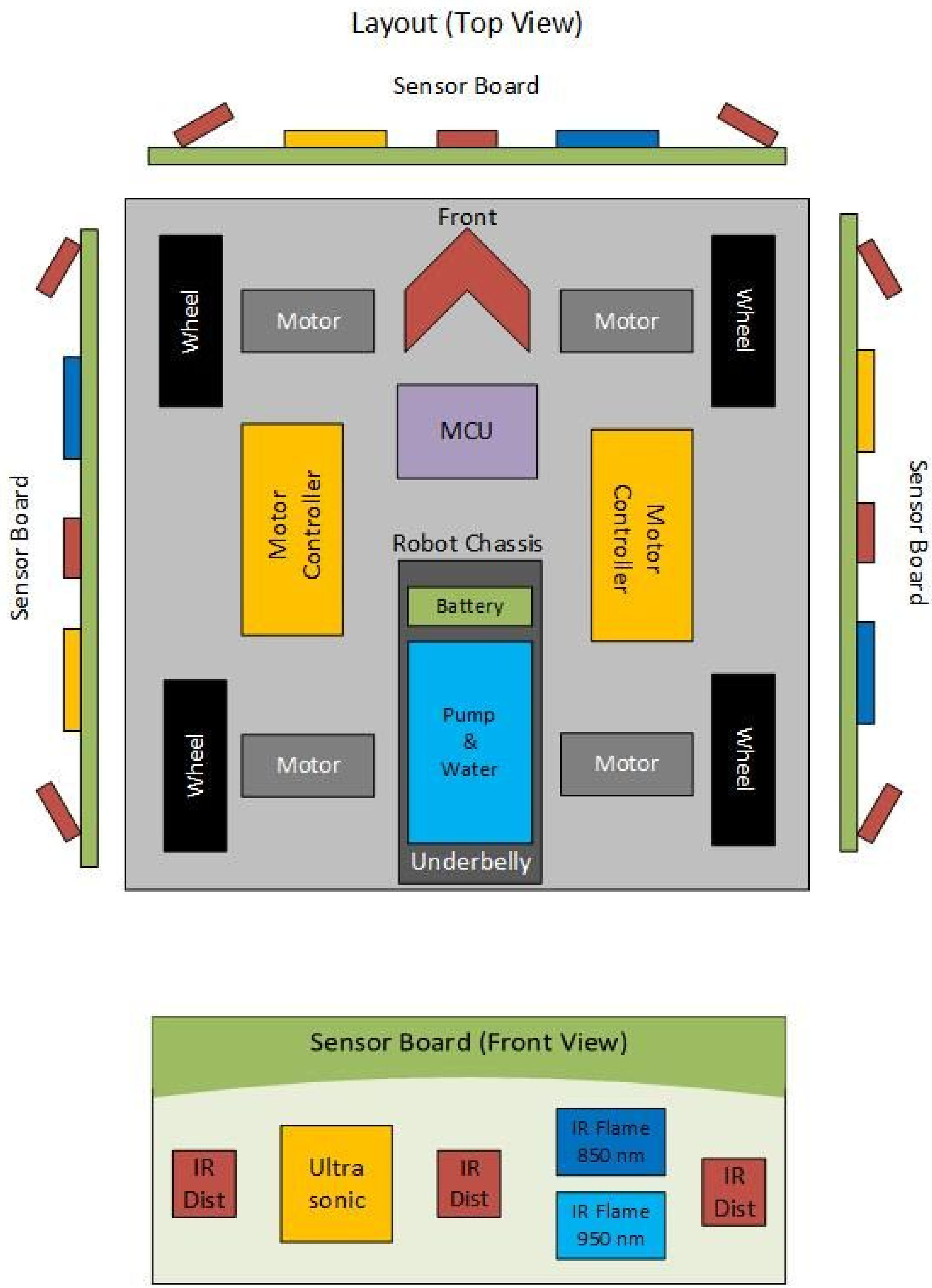

Figure 2: Block Mockup

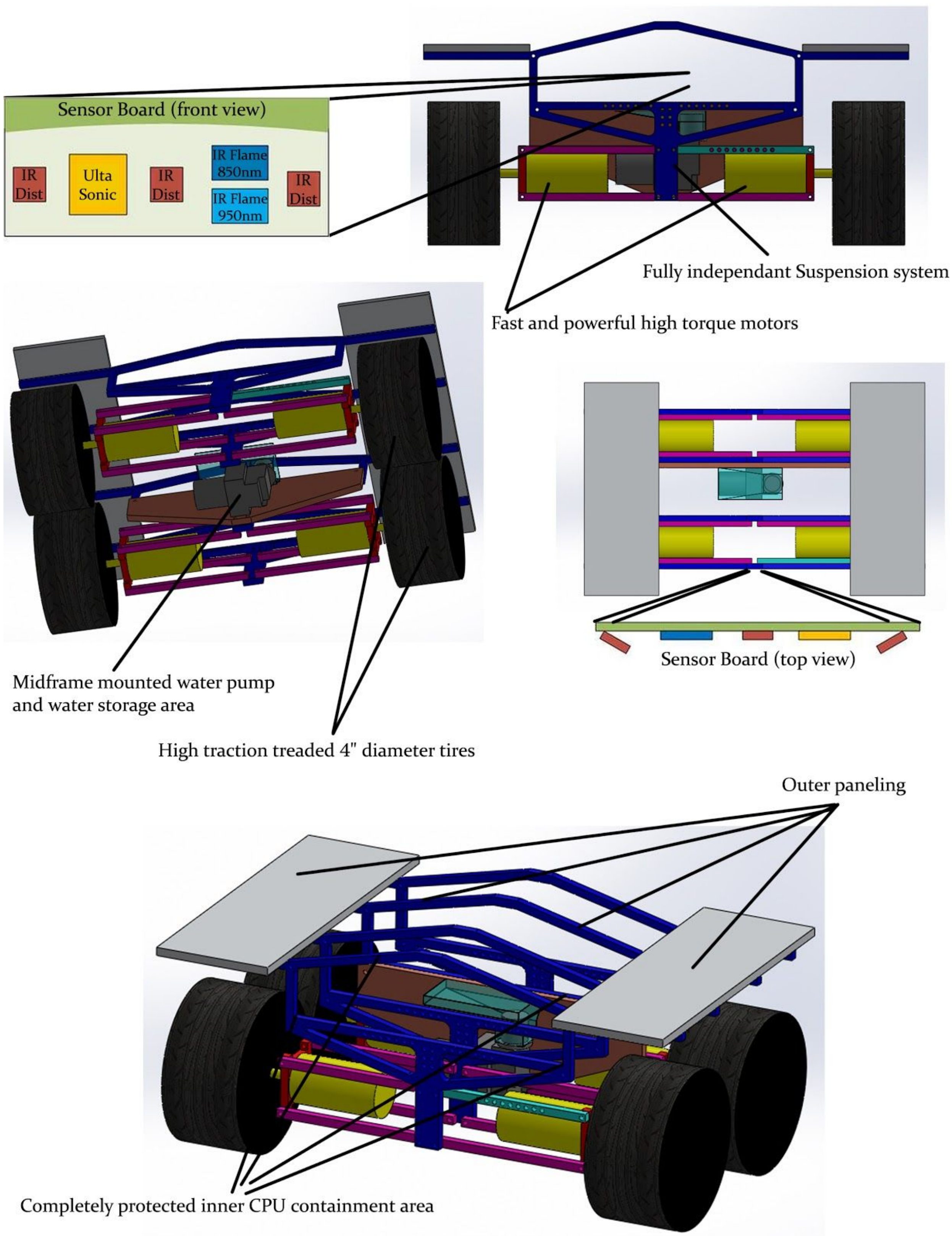

Figure 3: Chassis

Hardware Test Adapter

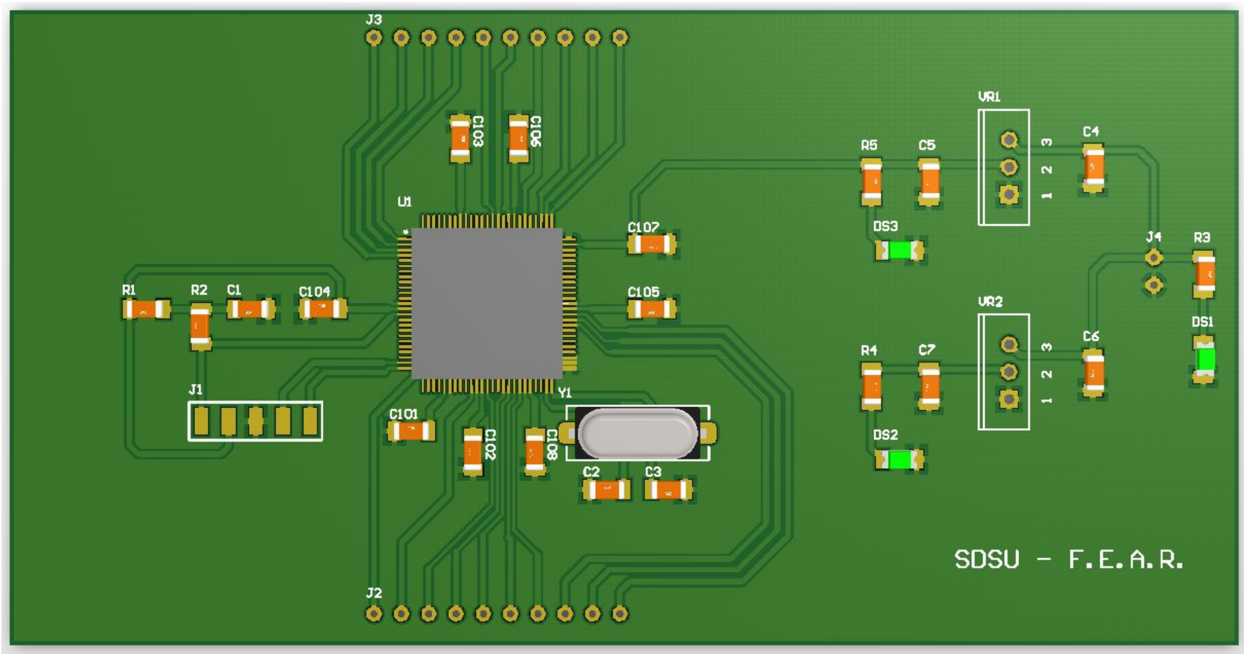

Figure 4: PIC32 Development Board

The PIC32 Development Board, will allow the software team to test code relating to the different subsystems of F.E.A.R. such as, the Motor Board, the Sensor Boards and the Water Board. It was designed to be capable of providing all of the necessary signals to each of the boards at the same time while maintaining a space saving form factor. The on board 3.3V and 5V voltage regulators allow for the board to be operated off of a single battery source. The signals include, 18 analog inputs capable of ADC for sensor and encoder feedback, 2 digital outputs capable of simultaneous PWM for motor control and 2 GPIO pins for mission select and water pump control.

Performance Requirements

Requirement	Plan	Measurable Goals
Quick Response	Complete the entire course in less than three minutes	• F.E.A.R. shall move at at a maximum speed of 4MPH
Accurate Detection	F.E.A.R. shall use multiple sensor types for flame detection and verification	• Distinguish between a real flame and IR decoy • Detect a flame at three feet • Sensor coverage is at least a 180 degree frontal cone
Autonomous Navigation	F.E.A.R. shall employ an array of distance, heading, speed and position sensors to navigate	• Navigate autonomously • Maneuver around obstacles
Flame Suppression	F.E.A.R. shall carry an on board water suppression device that will automatically be deployed when a flame is detected	• Spray water a distance of one foot • Extinguish a small, floor level flame

Table 1: F.E.A.R. Performance Requirements

Testing and Verification

Hardware Test Procedures

Chassis

- Visual Verification Testing
    - Assembly Check: Prior to the chassis being assembled it will be visually inspected for manufacturing errors such as, misaligned holes, incorrect hole sizes, etc. After the chassis is assembled it will be visually inspected for assembly defects such as, incorrect hardware, etc.
- Alignment Testing
    - Suspension Test: When placed on a flat surface, verify that all four wheel make contact with the surface and frame sits level.

Circuit Boards

- Visual Verification Testing
    - Assembly Check: Prior to the circuit board being assembled it will be visually inspected for manufacturing errors such as, missing or broken traces, incorrect pad size, etc. After the circuit board is assembled it will be visually inspected for assembly defects such as, solder bridges, incorrect component polarities, etc.
- In Circuit Testing
    - Board Functionality Test: First, using a Digital Multi-Meter, the circuit board will be checked for short circuits. Next, power will be applied to the circuit board to verify that it turns on. Finally, the circuit board will be loaded with a simple “Blink LED” program to verify its functionality.
- Integration Testing
    - Motor Control Test: The main board will be connected to the motor board and then tested to verify that the microcontroller can control the motor controller via PWM.
    - Analog Sampling Test: The main board will be connected to the each of the sensor boards and then tested to verify that the microcontroller can sample the analog data via ADC.

- Water Deployment Test: The main board will connected to the Water Board to verify that the water deployment mechanism can be controlled and the exact range of the water pump.

Sensors

- IR Sensor Testing
  - The vision cone of the IR sensor will be tested by placing a flat object in front of the sensor and measuring the analog voltages that are outputted as the object is moved in and out of the field of view. The small analog voltages will first be amplified to a range of 0 to 5V for increased resolution and then fed into the ADC on the microcontroller. Once the signals are sampled and the digital values are calculated, they will then be converted into a distance. The expected operating range of the sensor is 10 cm to 150 cm.
- Ultrasonic Sensor Testing
  - The vision cone of the ultrasonic sensor will be tested by placing a flat object in front of the sensor and measuring the analog voltages that are outputted as the object is moved in and out of the field of view. The small analog voltages will first be amplified to a range of 0 to 5V for increased resolution and then fed into the ADC on the microcontroller. Once the signals are sampled and the digital values are calculated, they will then be converted into a distance. The expected operating range of the sensor is 0 to 6.45 m.
- Flame Sensor Testing
  - The vision cone of the flame sensor will be tested by placing a flame in front of the sensor and measuring the analog voltages that are outputted as the flame is moved in and out of the field of view. The small analog voltages will first be amplified to a range of 0 to 5V for increased resolution and then fed into the ADC on the microcontroller. Once the signals are sampled and the digital values are calculated, they will then be converted into a distance. Next, the same test will be repeated with the decoy flame to verify that flame is seen while the decoy flame is filtered out.

Motors

- Encoder Feedback Testing
  - To characterize the encoder feedback the motor will be connected to a DC power supply while the voltage is varied from 0V to 15V in 3V steps. The output waveform will be measured on the oscilloscope for further analysis.

Software Test Procedures

Low-Level Testing

Facilitate a test to confirm the microcontroller's basic operations and functions.

- Check to make sure all internal logic is operational; including Timers, Interrupts, ADC, PWM, and UART.
- Test the input and output ports by executing a simple code that takes an input from a pin and triggers an output pin using an LED for verification.

High-Level Testing

Facilitate a test to confirm if the robot can self-coordinate by mapping, localization, path planning, and navigation. Further improvements to the robot will be made by updating the code that determines the angles of the wheels for each turn and adjusting the sensors displacement from the obstacle.

- Map Test
    - Preload the measured course and construct the environment with obstacles such as walls, doors, and objects in the 2-D array. Each object will occupy a section of the grid and be confirmed as F.E.A.R. advances by comparing the 2-D array to the actual 3-dimensional grid course.

- Localization Test
    - Test the accuracy of the robot's position by checking the coordinates of the robot from the 2-D array to the actual location on the course after a desired distance has been traveled.

- Path planning Test
    - Ensure the programmed algorithm is able to avoid obstacles within the map environment.
        - Test how well the robot avoids obstacles by measuring the accuracy of the turns, the distance from the object, and compare the results to the code.
    - Moving from the starting point to the hallway doors.
        - Test the first path by measuring the performance of the robot's movement to the door and compare the results to the code.
    - Moving within the room

- Test the second path by measuring the performance of the robot's movement in the room and compare the results to the code.

- Navigation Test
    - Check to see if F.E.A.R. can autonomously travel through the given course from the starting position avoiding decoys until it detects the candle and extinguishes the fire.
        - Test the duration it takes for the robot to detect fire by placing multiple decoy candles in the course.
        - Test to see if F.E.A.R. can extinguish the flame without misfiring water on a decoy.

Benchmarks

Benchmark	**Description**
Drive Straight	Can drive in a straight line for eight feet
Precise Turning	Can precisely make any turn (90 degree left, 45 degree right, etc)
Obstacle Avoidance	Can detect and maneuver around an obstacle
Full Speed	Can run at full speed without overheating
Decoy Detection	Can differentiate a decoy from a flame
Flame Suppression	Can extinguish a flame from at least one foot
No Program Defects	The MCU will not lock up or freeze during operation
Mode Switching	F.E.A.R. will behave differently when in mapping or quick extinguish mode

Table 2: F.E.A.R. Benchmarks

Project Management

Project Plan

In order to accomplish the final project in the desired time frame, effective planning and management must be implemented. A detailed block diagram is crucial to outline the needed components and help to form a prioritization of tasks. A Gantt chart can then be effectively formed to ensure all team members have a date oriented map of the progress that needs to be done at specific deadlines throughout production. By allowing each team member to contribute to the formation and maintenance of the Gantt chart, the goals will remain realistic and more achievable. Every member has an assignment to help finish the project on time. The best way to achieve the greatest results is to allow fluidity. If at any time a member struggles or advances before a deadline is set to be completed, all the members of the team will come together to ensure the goals of the project are met. Effective communication in this case is also needed from every member to achieve a productive team pace.

Milestones

Milestone	Description	Date
Block Diagram	A block diagram has been made showing the relationship between all components	9/29/2016
Component Characterization	All components have been characterized for all relevant datums and compared against given datasheet values	10/4/2016
Chassis Assembly	A chassis has been cut from solid ¼” plate aluminum and assembled using machine bolts and nuts. Outer and inner paneling are installed and made from plastic sheeting.	10/11/2016
Powered Chassis	The on board battery will supply power to the H-bridge that will control the speed and direction. At this time the chassis has had wheels, motors, battery and basic circuitry attached, but does not have autonomous functionality.	10/13/2016

Milestone	Description	Date
Unassisted Straight Line	Using only onboard sensors (IR and ultrasonic rangefinders, motor encoders) the robot will modulate the controls on the motor controller to adjust the rotational speed of each wheel such that F.E.A.R. will drive in a straight line	10/20/2016
Autonomous Locomotion	F.E.A.R. can navigate throughout the course by making turns and adjusting its speed, using encoder feedback, IR and ultrasonic distance sensors, and high level programming.	10/27/2016
Flame Detection	When a flame is within the range of the IR flame sensors, the navigation process will be interrupted and F.E.A.R. will proceed to verify the source of the flame	10/27/2016
Flame Extinguishing	Once F.E.A.R. has verified that a flame is present, it will maneuver to the flame and extinguish it by supplying power to the onboard 12v pump that sprays water through a dispersion nozzle.	10/27/2016
1st Testing Cycle	The completed robot will attempt the course before the competition day, any defects that are found at this time will be addressed and set for retesting.	11/3/2016
2nd Testing Cycle	Adjustments made after the first testing cycle will be retested and F.E.A.R. will attempt to complete the course again, any defects that are found at this time will be addressed and finalized.	11/17/2016
Final Assembly	F.E.A.R. has been assembled with all of its final parts, including exterior panels and miscellaneous items not needed for testing.	12/1/2016
Final Testing Cycle	F.E.A.R. will attempt to complete the course fully assembled, any defects that are found at this time will be readdressed.	12/8/2016

Table 3: F.E.A.R. Milestones

Gantt Chart

Chart Tasks and Dates

Task Mode	Task Name	Duration	Start	Finish
Manually Scheduled	Fall 2016 Semester	78 days	Mon 8/29/16	Wed 12/14/16
Auto Scheduled	Design Team Meeting	71 days	Thu 9/1/16	Thu 12/8/16
Manually Scheduled	Preliminary Planning	21 days	Thu 9/1/16	Thu 9/29/16
Auto Scheduled	MCU	10 days	Fri 9/30/16	Thu 10/13/16
Auto Scheduled	PIC Initialization	5 days	Fri 9/30/16	Thu 10/6/16
Auto Scheduled	Digital I/O	1 day	Fri 10/7/16	Fri 10/7/16
Auto Scheduled	Analog I/O	2 days	Fri 10/7/16	Mon 10/10/16
Auto Scheduled	PWM	2 days	Fri 10/7/16	Mon 10/10/16
Auto Scheduled	Timer	1 day	Fri 10/7/16	Fri 10/7/16
Auto Scheduled	Interrupts	5 days	Fri 10/7/16	Thu 10/13/16
Auto Scheduled	Programming	10 days	Fri 10/14/16	Thu 10/27/16
Auto Scheduled	Drive Straight	5 days	Fri 10/14/16	Thu 10/20/16
Auto Scheduled	Turn to Face	3 days	Fri 10/14/16	Tue 10/18/16
Auto Scheduled	Read Sensors	1 day	Fri 10/14/16	Fri 10/14/16
Auto Scheduled	Navigation	5 days	Fri 10/21/16	Thu 10/27/16
Auto Scheduled	Flame Detection	3 days	Tue 10/25/16	Thu 10/27/16
Auto Scheduled	Flame Extinguish	2 days	Wed 10/26/16	Thu 10/27/16
Auto Scheduled	Power	3 days	Tue 10/18/16	Thu 10/20/16
Auto Scheduled	3.3V Rail	3 days	Tue 10/18/16	Thu 10/20/16
Auto Scheduled	5V Rail	3 days	Tue 10/18/16	Thu 10/20/16
Auto Scheduled	12V Rail	3 days	Tue 10/18/16	Thu 10/20/16
Auto Scheduled	Battery Rail	1 day	Thu 10/20/16	Thu 10/20/16
Auto Scheduled	Sensor	6 days	Fri 9/30/16	Fri 10/7/16
Auto Scheduled	IR Sensor Characterization	1 day	Fri 9/30/16	Fri 9/30/16

Auto Scheduled	**Sonar Sensor Characterization**	**2 days**	**Fri 9/30/16**	**Mon 10/3/16**
Auto Scheduled	**Flame Sensor Characterization**	**3 days**	**Fri 9/30/16**	**Tue 10/4/16**
Auto Scheduled	**IR Sensor Hookup**	**5 days**	**Mon 10/3/16**	**Fri 10/7/16**
Auto Scheduled	**Sonar Sensor Hookup**	**1 day**	**Tue 10/4/16**	**Tue 10/4/16**
Auto Scheduled	**Flame Sensor Hookup**	**3 days**	**Wed 10/5/16**	**Fri 10/7/16**
Auto Scheduled	**Locomotion**	**10 days**	**Fri 9/30/16**	**Thu 10/13/16**
Auto Scheduled	**Motor Driver Characterization**	**1 day**	**Fri 9/30/16**	**Fri 9/30/16**
Auto Scheduled	**Motor Driver Hookup**	**3 days**	**Mon 10/3/16**	**Wed 10/5/16**
Auto Scheduled	**Motor Characterization**	**2 days**	**Thu 10/6/16**	**Fri 10/7/16**
Auto Scheduled	**Motor Hookup**	**4 days**	**Mon 10/10/16**	**Thu 10/13/16**
Auto Scheduled	**Chassis**	**10 days**	**Fri 9/30/16**	**Thu 10/13/16**
Auto Scheduled	**CAD Mockup**	**7 days**	**Fri 9/30/16**	**Mon 10/10/16**
Auto Scheduled	**Cut Parts**	**1 day**	**Tue 10/11/16**	**Tue 10/11/16**
Auto Scheduled	**Assembly**	**2 days**	**Wed 10/12/16**	**Thu 10/13/16**
Auto Scheduled	**Pump**	**8 days**	**Tue 10/11/16**	**Thu 10/20/16**
Auto Scheduled	**Pump Characterization**	**3 days**	**Tue 10/11/16**	**Thu 10/13/16**
Auto Scheduled	**Pump Hookup**	**5 days**	**Fri 10/14/16**	**Thu 10/20/16**
Auto Scheduled	**PCB Design**	**14 days**	**Mon 10/24/16**	**Thu 11/10/16**
Auto Scheduled	**Sensor Board Design**	**14 days**	**Mon 10/24/16**	**Thu 11/10/16**
Auto Scheduled	**Motor Driver Design**	**7 days**	**Wed 11/2/16**	**Thu 11/10/16**
Auto Scheduled	**Mainboard Design**	**10 days**	**Fri 10/28/16**	**Thu 11/10/16**
Auto Scheduled	**Website**	**47 days**	**Fri 10/7/16**	**Mon 12/12/16**
Auto Scheduled	**Prototype**	**21 days**	**Fri 10/7/16**	**Fri 11/4/16**
Auto Scheduled	**Finalization**	**21 days**	**Mon 11/14/16**	**Mon 12/12/16**
Auto Scheduled	**Trial Testing**	**14 days**	**Fri 10/28/16**	**Wed 11/16/16**
Auto Scheduled	**Final Testing and**	**11 days**	**Thu 11/17/16**	**Thu 12/1/16**

	Assembly			
Auto Scheduled	Cosmetic and Troubleshooting	8 days	Fri 12/2/16	Tue 12/13/16
Manually Scheduled	Powered Chassis	0 days	Thu 10/13/16	Thu 10/13/16
Manually Scheduled	Oral Presentation	0 days	Tue 10/18/16	Tue 10/18/16
Manually Scheduled	Unassisted Straight Line	0 days	Thu 10/20/16	Thu 10/20/16
Manually Scheduled	Autonomous Locomotion	0 days	Thu 10/27/16	Thu 10/27/16
Manually Scheduled	Flame Detection	0 days	Thu 10/27/16	Thu 10/27/16
Manually Scheduled	Flame Extinguish	0 days	Thu 10/27/16	Thu 10/27/16
Manually Scheduled	1st Testing Cycle	0 days	Thu 11/3/16	Thu 11/3/16
Manually Scheduled	Website Prototype Online	0 days	Fri 11/4/16	Fri 11/4/16
Manually Scheduled	Oral Presentation	0 days	Tue 11/8/16	Tue 11/8/16
Manually Scheduled	Final PCB Ordered	0 days	Thu 11/10/16	Thu 11/10/16
Manually Scheduled	2nd Testing Cycle	0 days	Thu 11/17/16	Thu 11/17/16
Manually Scheduled	Final Assembly	0 days	Thu 12/1/16	Thu 12/1/16
Manually Scheduled	Final Testing Cycle	0 days	Thu 12/8/16	Thu 12/8/16
Manually Scheduled	Website Online	0 days	Mon 12/12/16	Mon 12/12/16
Manually Scheduled	Design Day	0 days	Tue 12/13/16	Tue 12/13/16
Manually Scheduled	Final Report	0 days	Tue 12/20/16	Tue 12/20/16

ID		Task Mode	Task Name	Duration	Start	Finish
1			Fall 2016 Semester	78 days	Mon 8/29/1	Wed 12/14/
2			**Design Team Meeting**	**71 days**	**Thu 9/1/16**	**Thu 12/8/16**
18			Preliminary Planning	21 days	Thu 9/1/16	Thu 9/29/1
19			**MCU**	**10 days**	**Fri 9/30/16**	**Thu 10/13/**
20			PIC Initialization	5 days	Fri 9/30/16	Thu 10/6/1
21			Digital I/O	1 day	Fri 10/7/16	Fri 10/7/16
22			Analog I/O	2 days	Fri 10/7/16	Mon 10/10/
23			PWM	2 days	Fri 10/7/16	Mon 10/10/
24			Timer	1 day	Fri 10/7/16	Fri 10/7/16
25			Interrupts	5 days	Fri 10/7/16	Thu 10/13/
26			**Programming**	**10 days**	**Fri 10/14/1**	**Thu 10/27/**
27			Drive Straight	5 days	Fri 10/14/1	Thu 10/20/
28			Turn to Face	3 days	Fri 10/14/1	Tue 10/18/
29			Read Sensors	1 day	Fri 10/14/1	Fri 10/14/1
30			Navigation	5 days	Fri 10/21/1	Thu 10/27/
31			Flame Detection	3 days	Tue 10/25/	Thu 10/27/
32			Flame Extinguish	2 days	Wed 10/26/	Thu 10/27/
33			**Power**	**3 days**	**Tue 10/18/**	**Thu 10/20/**
34			3.3V Rail	3 days	Tue 10/18/	Thu 10/20/
35			5V Rail	3 days	Tue 10/18/	Thu 10/20/
36			12V Rail	3 days	Tue 10/18/	Thu 10/20/
37			Battery Rail	1 day	Thu 10/20/	Thu 10/20/
38			**Sensor**	**6 days**	**Fri 9/30/16**	**Fri 10/7/16**
39			IR Sensor Characterization	1 day	Fri 9/30/16	Fri 9/30/16
40			Sonar Sensor Characterization	2 days	Fri 9/30/16	Mon 10/3/16
41			Flame Sensor Characterization	3 days	Fri 9/30/16	Tue 10/4/16
42			IR Sensor Hookup	5 days	Mon 10/3/1	Fri 10/7/16
43			Sonar Sensor Hookup	1 day	Tue 10/4/16	Tue 10/4/16
44			Flame Sensor Hookup	3 days	Wed 10/5/16	Fri 10/7/16
45			**Locomotion**	**10 days**	**Fri 9/30/16**	**Thu 10/13/**
46			Motor Driver Characterization	1 day	Fri 9/30/16	Fri 9/30/16
47			Motor Driver Hookup	3 days	Mon 10/3/16	Wed 10/5/16
48			Motor Characterization	2 days	Thu 10/6/16	Fri 10/7/16
49			Motor Hookup	4 days	Mon 10/10/	Thu 10/13/
50			**Chassis**	**10 days**	**Fri 9/30/16**	**Thu 10/13/**
51			CAD Mockup	7 days	Fri 9/30/16	Mon 10/10/
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63			Finalization	21 days	Mon 11/14/	Mon 12/12/
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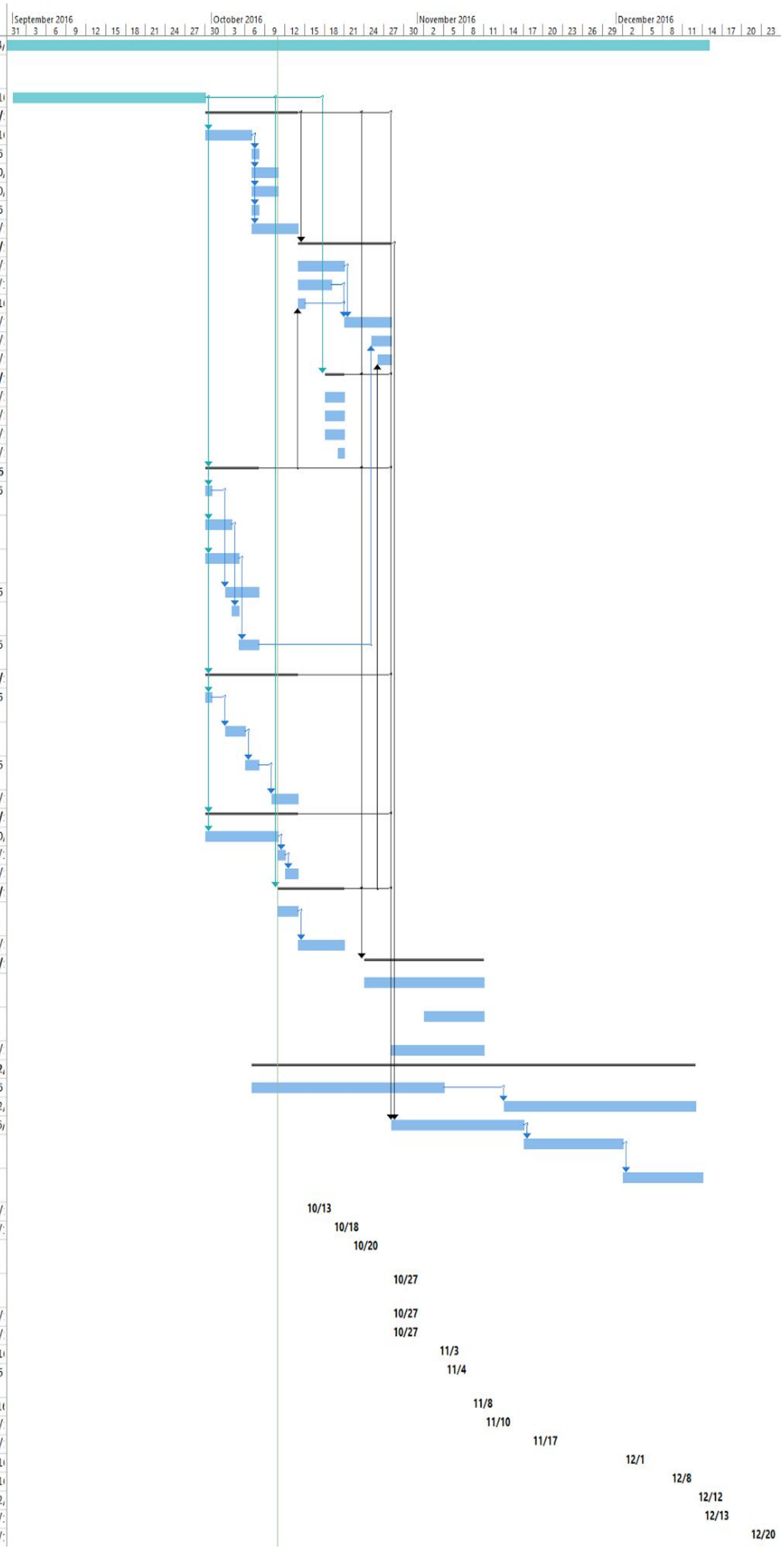
65			Final Testing and Assembly	11 days	Thu 11/17/16	Thu 12/1/16
66			Cosmetic and Troubleshooting	8 days	Fri 12/2/16	Tue 12/13/16
67			Powered Chassis	0 days	Thu 10/13/	Thu 10/13/
68			Oral Presentation	0 days	Tue 10/18/	Tue 10/18/
69			Unassisted Straight Line	0 days	Thu 10/20/16	Thu 10/20/16
70			Autonomous Locomotion	0 days	Thu 10/27/16	Thu 10/27/16
71			Flame Detection	0 days	Thu 10/27/	Thu 10/27/
72			Flame Extinguish	0 days	Thu 10/27/	Thu 10/27/
73			1st Testing Cycle	0 days	Thu 11/3/1	Thu 11/3/1
74			Website Prototype Online	0 days	Fri 11/4/16	Fri 11/4/16
75			Oral Presentation	0 days	Tue 11/8/1	Tue 11/8/1
76			Final PCB Ordered	0 days	Thu 11/10/	Thu 11/10/
77			2nd Testing Cycle	0 days	Thu 11/17/	Thu 11/17/
78			Final Assembly	0 days	Thu 12/1/1	Thu 12/1/1
79			Final Testing Cycle	0 days	Thu 12/8/1	Thu 12/8/1
80			Website Online	0 days	Mon 12/12/	Mon 12/12/
81			Design Day	0 days	Tue 12/13/	Tue 12/13/
82			Final Report	0 days	Tue 12/20/	Tue 12/20/



Budget

Proposed Budget

Item	Cost	Quantity	Total
Microcontroller and IC packages:			
Sampled Microcontroller	**$0.00**	**5.00**	**$0.00**
MCU Development Board	**$50.00**	**1.00**	**$50.00**
Motor Controller	**$10.00**	**4.00**	**$40.00**
Hardware:			
Motors	**$40.00**	**4.00**	**$160.00**
Wheels	**$15.00**	**4.00**	**$60.00**
Shock absorbers	**$4.00**	**10.00**	**$40.00**
Water Pump and Nozzles	**$50.00**	**1.00**	**$50.00**
Sensors:			
Ultrasonic Sensors	**$20.00**	**3.00**	**$60.00**
IR Sensors	**$10.00**	**9.00**	**$90.00**
Photodiodes	**$1.00**	**25.00**	**$25.00**
Electronic Hardware:			
Lithium Ion Batteries	**$30.00**	**2.00**	**$60.00**
Battery Charger	**$20.00**	**1.00**	**$20.00**
LDO Voltage Regulators	**$1.00**	**10.00**	**$10.00**
Passive Components	**$1.00**	**25.00**	**$25.00**
Manufacturing:			
Custom In-House Chassis	**$0.00**	**1.00**	**$0.00**
PCB	**$50.00**	**1.00**	**$50.00**
		Subtotal	**$740.00**
		Tax	**$59.20**
		Total	**$799.20**

Note: Quantities may include replacement parts

Proposed Budget Pie Chart