Titan – Walking Robot

Project Proposal

Submitted By:

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Submitted to:

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Sponsored by:San Diego State University

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1. INTRODUCTION

1.1. Abstract

Our team at Black Mesa is tasked with creating an autonomous walking robot that can navigate an obstacle course composed of walls and stairs. The robot must be untethered to a permanent power source (such as a power outlet) during execution of the task. Team Black Mesa will build the robot based on a small, stable, and relatively inexpensive design. The focus in terms of materials and components used will be lightweightness and small size. The hardware and intricate software will contribute to a four-legged robot that can traverse the given obstacle course.

1.2. Project Description

The problem that must be overcome is the traversal of a grid containing both walls and a set of stairs that must be climbed. The task must be completed by an autonomous walking robot whose dimensions must fall inside 7”x7”x7”. Our client did not make clear the ultimate purpose of the robot, but we have surmised it may be a small prototype for a futuristic war machine. Team Black Mesa will complete said task and will be certain of its completion when the robot is able to successfully reach the end of the obstacle course autonomously.

Black Mesa's sponsor for this project is San Diego State University. The university has provided a budget of $300 for the prototype. It is estimated that all of these resources will be used. Our design philosophy is to find the best parts within our financial constraints. Current estimations of production costs of a single unit - if mass distributed - indicate that it would most likely range between $100 and $150.

The design of the robot - dubbed Titan - will be similar to that of a spider, with the exception that only four legs will be used. Each leg will have 2 axis of rotations, being able to move forward/backward and left/right. The robot’s “feet” will be outfitted with piezoelectric sensors to calculate the proper pressure to be applied to the legs. In addition, Titan will utilize an accelerometer. This design will allow the robot to walk and turn while maintaining the stability necessary to climb and descend stairs without falling over. Servo motors will be used to facilitate the walking motion.

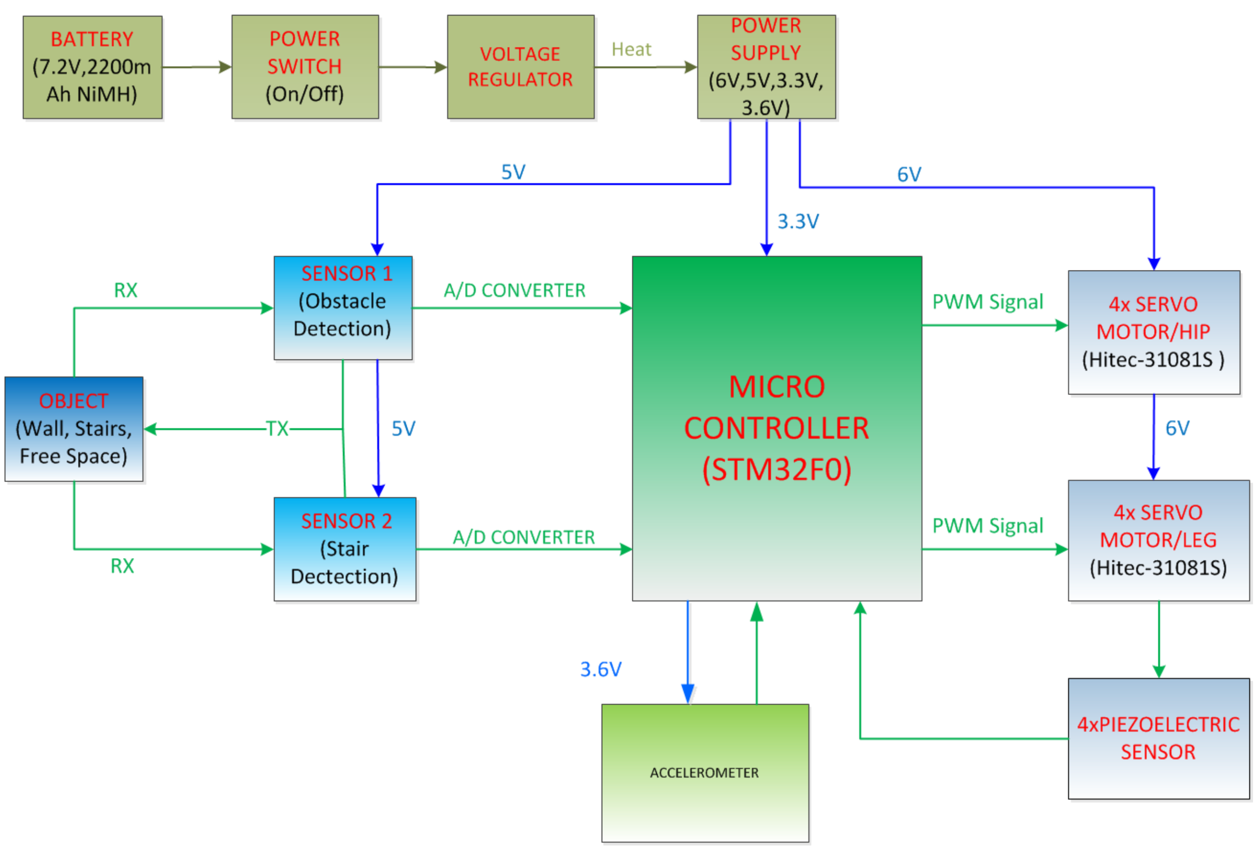
Two infrared sensors will be used to detect its surroundings, determining the distance and direction of potential obstacles. The two infrared sensors will be attached to a servo motor, allowing for visual “sweeps” of the road ahead.

2. SYSTEM DESIGN

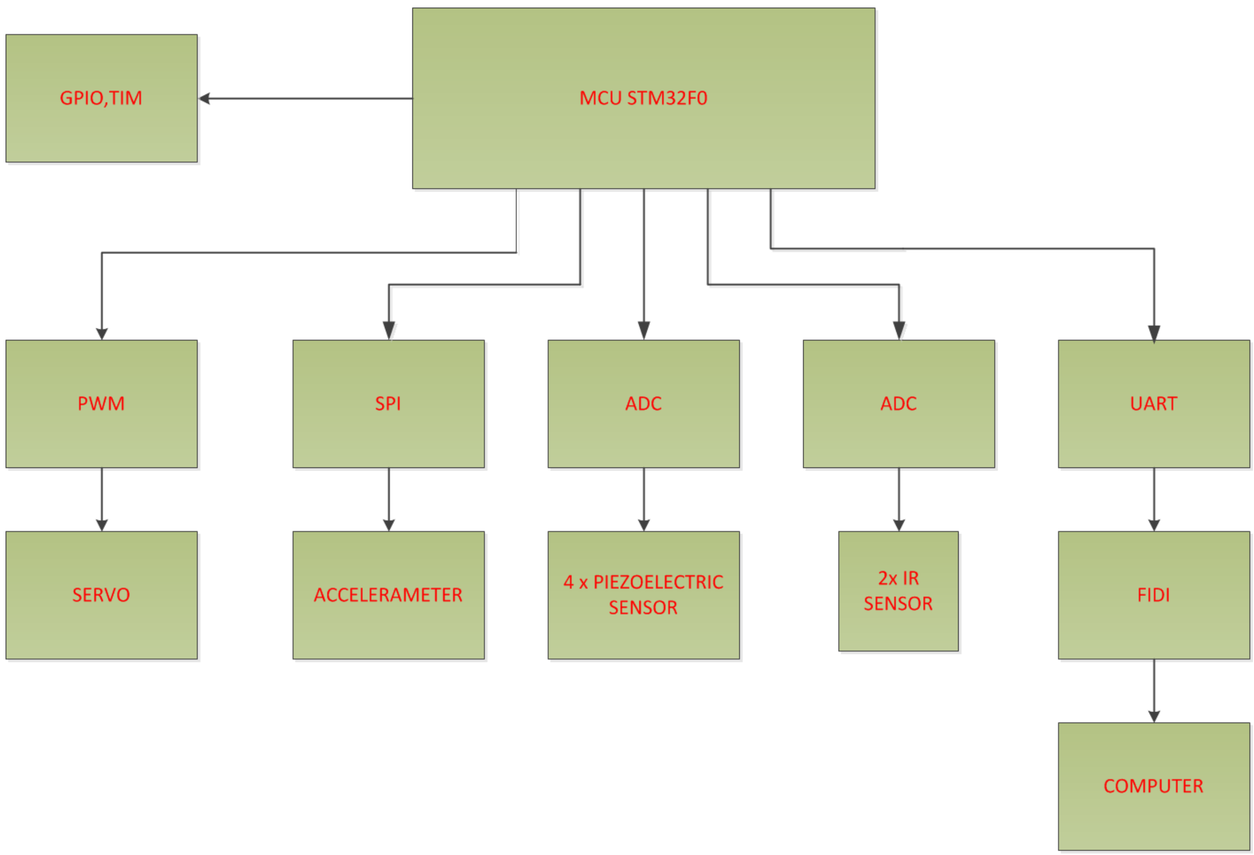
The walking robot consists of two significant parts: hardware and software. In order to achieve a walking robot, the hardware design process has many requirements dependent on the mechanical structure design and the electronic design. The mass of robot, the location of the center of mass, and the selection of the actuators have an important impact on the robot's performance. The electronic hardware is composed of the battery, the microcontroller, the servo motor, and sensors. The software portion is the brain of the system design it is responsible for all computations, decision making, and communications.

2.1.Block Diagram

a. System Block Diagram



b. Microcontroller Block Diagram



Battery

The battery we are using is a rechargeable 7.2 V 2200 mAh NiMH battery. It will be fed through a switch, and then through a voltage regulator. All together, the design will function as a power supply that can adequately provide the proper voltage to the various parts of the system.

Servos

We are using eight Hitec 31081S Micro Servos for the legs of our Titan robot. The same type of servo will be used to allow the infrared sensors to swivel. The servos will be controlled via PWM from the Microcontroller.

Sensors and Measurement Hardware

The “eyes” of our robot are the Sharp IR Distance Sensors. Upon detecting an object, the infrared sensors will send an analog signal back to the microcontroller, which process the signals through its built-in ADCs.

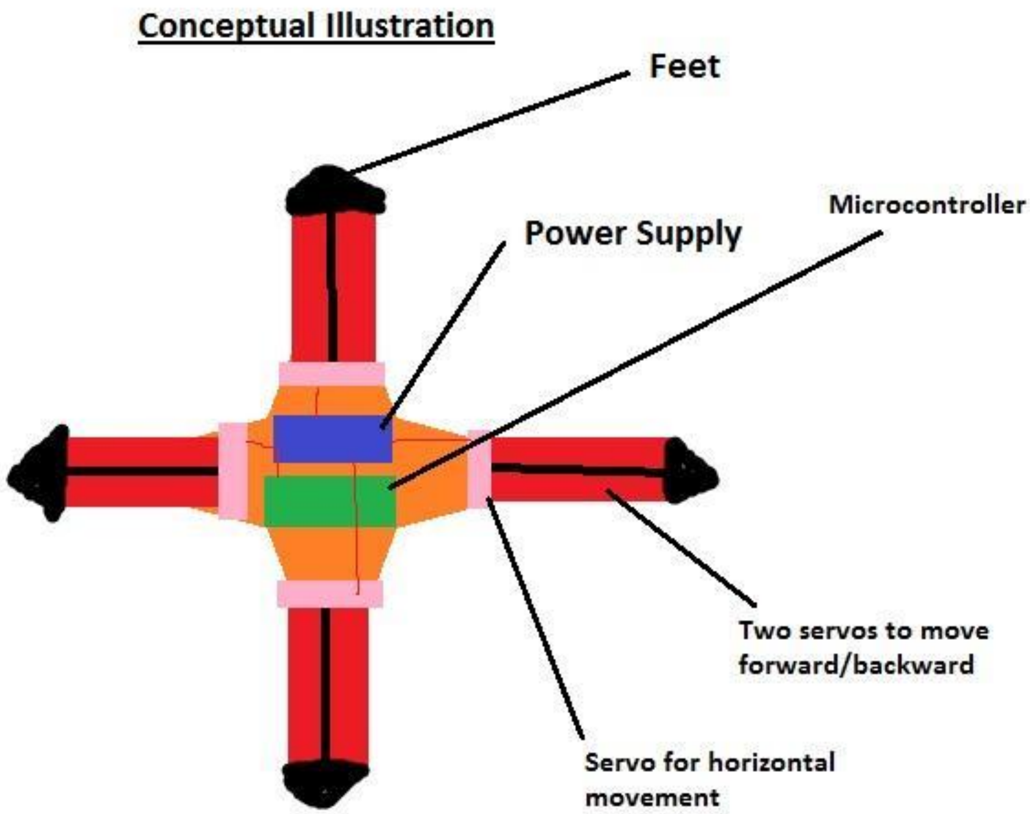
In addition, we will be using the Sparkfun Force Sensitive Resistor on each of the Titan’s “feet” to sense the amount of pressure being applied. The resistor will send generate a lower resistance when more pressure is applied. By running a current through the resistor and measuring the voltage, we can effectively measure the pressure. This will allow us to make sure that the robots’ “feet” reach the ground.

Also, we will be utilizing the SparkFun Triple Axis Accelerometer in order to keep the robot’s “body” level and balanced. The accelerometer will send back a digital 16-bit signal to the microcontroller that represents the acceleration detected. The data will then be used to detect the angle that the robot is oriented.

Microcontroller

The STM32F0 microcontroller, in the ARM Cortex family, is the “brain” of our robot. Chosen for its “jack-of-all-trades” nature, it will receive signals from the sensors and send out signals to the servo motors. Any analog signals received will be processed through the microcontroller’s built-in analog to digital converters.

2.2. Mock-Up Illustration



2.3. Performance Requirement:

The robot has to be able to traverse through a course with wall and stair obstacles to eventually reach a goal tile. To accomplish this, software for the robot will be based on several abstraction layers that rely heavily on each other. The requirements of operation for each layer is defined below:

- Obstacle Detection System (ODS)
  - Must be able to detect walls, stairs, and open space
  - Must be able to differentiate between detection of a wall, or stair
- Movement and Stability Controller (MSC)
  - Must be able to move robot reliably in all directions
  - Robot must be kept stable at all the times
  - The body of the robot must keep level, such that it is parallel to the ground
- Course Traversal Algorithm (CTA)
  - Keep the robot moving forward through obstacles
  - Reach the end goal
- Debug Mode and Operation Switching (DMOS)
  - Communicate back and forth between microcontroller and PC
  - Move the robot using a game controller connected to a PC
- Operation Mode Switching (OMS)
  - Switch between auto, manual, and reset modes
  - The robot should seek its goal in auto mode
  - Reset mode must reset the microcontroller, and effectively the code
  - Manual mode allows the user to control the robot through a tether

3. TESTING AND VERIFICATION

3.1. Testing Procedures

Before plugging everything into the microcontroller, and programming, the components must first be tested so that we may reduce the possibility of a part being broken as the reason for dysfunctional code during the debug stage.

First, the servos must be tested. One way to do this is to connect power to it, and then use a PWM signal from the microcontroller to make sure that it moves through the proper ranges. The IR LEDs can be tested by putting them in a circuit, and then hooking up a multimeter to them to monitor the voltage as an object is moved towards, and away from them. Similarly, the piezoelectric sensors can be put through a circuit, but instead their voltage will be monitored as pressure is applied to them. The accelerometer will be tougher to test, as it will require proper setup of the SPI bus on the microcontroller, however once values are received from the microcontroller, then they can be tested for accuracy as the accelerometer is tilted.

On a higher level, the code must also be tested. The first thing that must be set up is the UART peripheral on the microcontroller to the computer. Once that is done we have a way of communicating data to and from the devices. Now whenever there is an error with the microcontroller, we can have logs sent to the PC to help us find the problem, along with the use of a good debugger and use of breakpoints. Having these two tools under our belt will help as we look at the robot for signs of trouble during a trial and error phase. Through this methodology the movement, and stability system can be tuned. Movement can further be tested by hooking up a game controller to the PC in order to send movement commands through UART to the microcontroller, and observing its actions. In fact, these same methodologies will be used extensively to test most of the code, including the higher level algorithms that are controlling the autonomy of the robot.

3.2. Benchmarks

The benchmarks that will characterize the state when the project is considered "finished" are as follows:

- The ability to climb stairs without losing balance
- The ability to walk and turn without losing balance
- The ability to navigate any assortment of previously stated obstacles autonomously
- The ability to complete said obstacle course untethered to a permanent power source

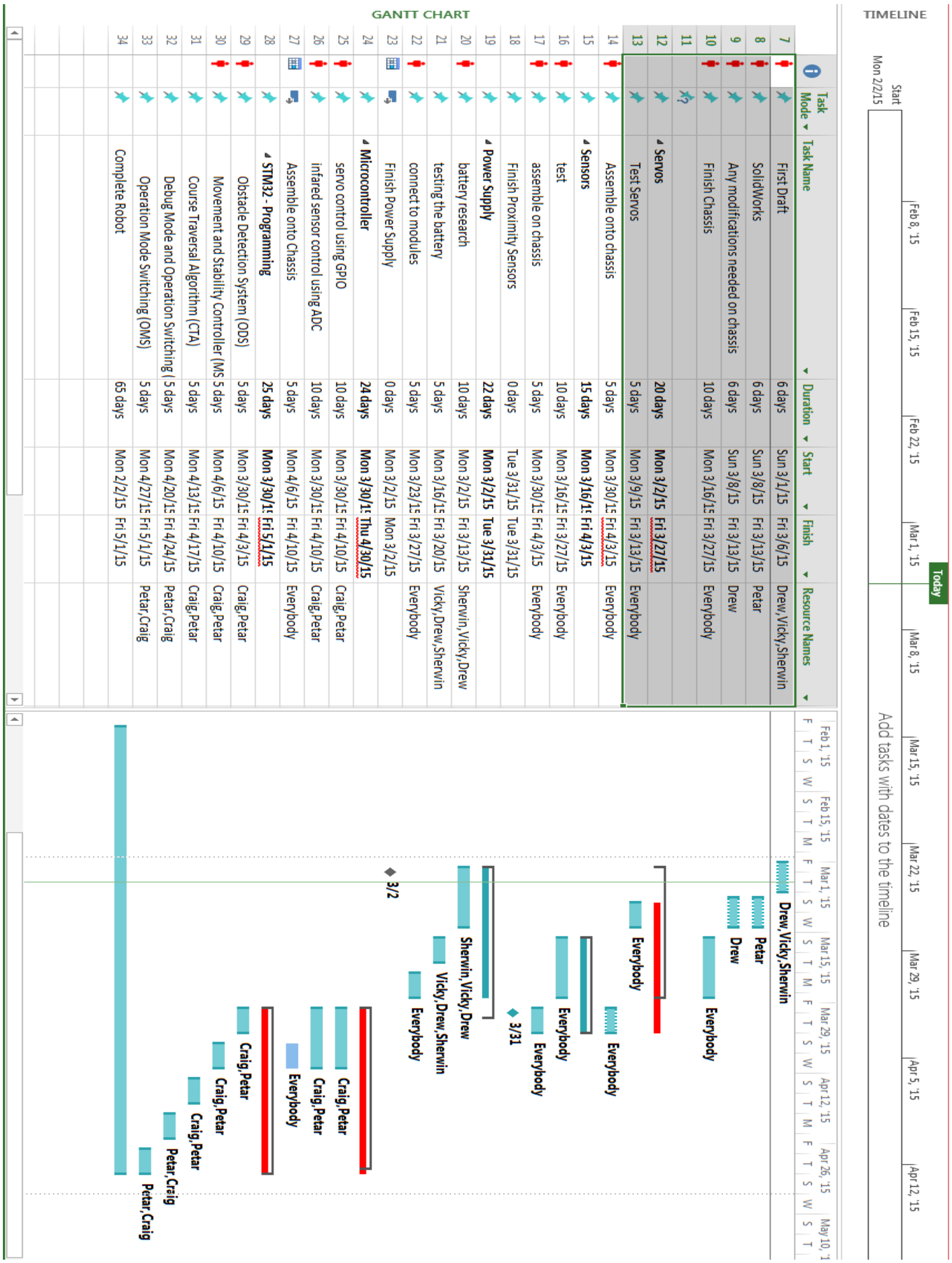
While there may be other features that our team wishes to install if the time constraints allow, the previously stated benchmarks are the core goals for the finished product.

4. PROJECT MANAGEMENT

4.1. Project Plan

Since this project only has three months to be finished, it is imperative that the schedule needs to be conformed in order to meet our goals. Following this paragraph, there will be a Gantt Chart that details essential tasks as well as people responsible for those tasks. The chart will also have a detailed schedule as well as milestones for the project.

4.2. Milestones



	Task Mode	Task Name	Duration	Start	Finish	Resource Names
7		First Draft	6 days	Sun 3/1/15	Fri 3/6/15	Drew,Vicky,Sherwin
8		SolidWorks	6 days	Sun 3/8/15	Fri 3/13/15	Petar
9		Any modifications needed on chassis	6 days	Sun 3/8/15	Fri 3/13/15	Drew
10		Finish Chassis	10 days	Mon 3/16/15	Fri 3/27/15	Everybody
11						
12		Servos	20 days	Mon 3/2/15	Fri 3/27/15	
13		Test Servos	5 days	Mon 3/9/15	Fri 3/13/15	Everybody
14		Assemble onto chassis	5 days	Mon 3/30/15	Fri 4/3/15	Everybody
15		Sensors	15 days	Mon 3/16/1!	Fri 4/3/15	
16		test	10 days	Mon 3/16/15	Fri 3/27/15	Everybody
17		assemble on chassis	5 days	Mon 3/30/15	Fri 4/3/15	Everybody
18		Finish Proximity Sensors	0 days	Tue 3/31/15	Tue 3/31/15	
19		Power Supply	22 days	Mon 3/2/15	Tue 3/31/15	
20		battery research	10 days	Mon 3/2/15	Fri 3/13/15	Sherwin,Vicky,Drew
21		testing the battery	5 days	Mon 3/16/15	Fri 3/20/15	Vicky,Drew,Sherwin
22		connect to modules	5 days	Mon 3/23/15	Fri 3/27/15	Everybody
23		Finish Power Supply	0 days	Mon 3/2/15	Mon 3/2/15	
24		Microcontroller	24 days	Mon 3/30/1!	Thu 4/30/15	
25		servo control using GPIO	10 days	Mon 3/30/15	Fri 4/10/15	Craig,Petar
26		infared sensor control using ADC	10 days	Mon 3/30/15	Fri 4/10/15	Craig,Petar
27		Assemble onto Chassis	5 days	Mon 4/6/15	Fri 4/10/15	Everybody
28		STM32 - Programming	25 days	Mon 3/30/1!	Fri 5/1/15	
29		Obstacle Detection System (ODS)	5 days	Mon 3/30/15	Fri 4/3/15	Craig,Petar
30		Movement and Stability Controller (MS	5 days	Mon 4/6/15	Fri 4/10/15	Craig,Petar
31		Course Traversal Algorithm (CTA)	5 days	Mon 4/13/15	Fri 4/17/15	Craig,Petar
32		Debug Mode and Operation Switching (	5 days	Mon 4/20/15	Fri 4/24/15	Petar,Craig
33		Operation Mode Switching (OMS)	5 days	Mon 4/27/15	Fri 5/1/15	Petar,Craig
34		Complete Robot	65 days	Mon 2/2/15	Fri 5/1/15	

5. BUDGET

SDSU Allocated Funds: $300

ITEM	DESCRIPTION	UNIT PRICE	QTY	TAX/SHIPPING	TOTAL
Battery	7.2 V 2200 mAh NiMH	$17.29	2	$5.6/$4.01	$44.30
Sensor	Sharp IR Distance Sensor	$9.95	2	$1.59/$3.95	$25.44
	Piezo Vibration Sensor	$2.95	4	$0.8/$2.01	$17.00
Accelerometer	SparkFun Triple Axis	$17.95	1	$3/$4.01	$24.96
Chassis	Parts Fabrication	$100.00	1	0	$100.00
Accessories	Connectors, brackets…	$50.00	1	0	$50.00
Unforeseen Cost		$38.30	1	0	$38.30
SUBTOTAL					$300.00

Personal Funds:

12xServos: Hitec 31081S Micro Servo: $160

6. PROMOTIONALFLYER

SAN DIEGO STATE UNIVERSITY

BLACK MESA INDUSTRIES

AUTONOMOUS WALKING ROBOT

Description:

The design of the robot will be similar to that of a spider, however only four legs will be used. Each leg will have 2 axis of rotations, being able to move forward/backward and left/right. This design will allow it to turn and walk, and most importantly, have a stable balance to climb and descend stairs without falling over. Currently, the robot must also be no larger than a 7" cube for practicality purposes. Infrared sensors will be used to detect it's surroundings, and give it a 'laster eye'.

Abstract:

The problem that must be conquered is that of autonomous traversing of a grid which contains both walls and a set of stairs that must be climbed over. This problems exists because there is a high demand to the customer for confidential purposes, possibly a futuristic war machine that can be scaled exponentially larger. Team Black Mesa will complete said task and will be certain of it's completion when the robot will be able to comepletly satisy the task of traversing the grid and obstacles autonomously.

Grid:

←	FINISHING BOXES	→
7	8	9
4	5	6
1	2	3
←	STARTING BOXES	→

The Team:

Sherwin Edquiban – Project Manager

Nguyet "Vicky" Vo – Hardware Lead

Drew San Vicente – Parts Manager

Petar Tasel – Software Lead

Craig Lewis – Website Developer

***NOTE: Obstacles in the form of walls and stairs are to be placed in the gird.**