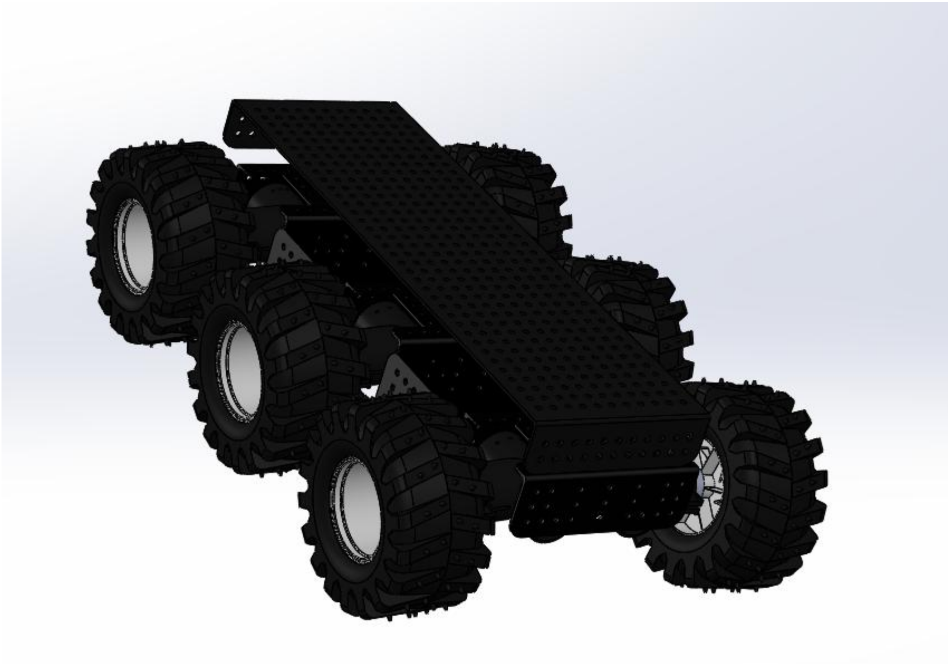
Pathfinder Preliminary Documentation



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Sensors, Actuators, and Power:	Hightower, Collin
PCB Design and Manufacturing:	Arbi, Ahmed

Project Description

The Pathfinder project is an autonomous wild thumper model rover that is capable of traversing mountainous terrain via GPS coordinates. Pathfinder will utilize Bluetooth and satellite communications as well as obstacle avoidance measures to achieve its objective of completing a quarter mile course in a self-sufficient manner. In addition, Pathfinder will have the ability to navigate any quarter mile course with no threat to the mission payload or the safety of the rover.

Pathfinder was created with the desire to mimic the conditions faced by the Curiosity rover on Mars as well as functionality. The hope was to create a self-sufficient rover capable of avoiding environment and geographical threats without direct intervention by a human being. Due to environmental limitations, the scope of the project was refocused to navigating a Mediterranean environment as opposed to a desert while keeping the original goal of producing an autonomous rover. This decision was made due to the close proximity of ideal Mediterranean environments and the ability to test in the actual conditions of the final test.

Project Purpose

Due to the increasing interest and research in automation of various industries such as the aerospace and automotive industry, it is imperative that The Robot Company remain at the forefront of technological advancement of autonomous and self-sufficient machines.

Pathfinder is being created as a response to this increased interest in automation with the goal to provide opportunities for research in harsh environments that are inaccessible to human beings due to safety and health risks. Similar to the Curiosity rover, Pathfinder will have to ability to explore alien environments in a safe and relatively inexpensive manner without having to have a physical human presence there in order to conduct research.

Pathfinder is The Robot Company's effort to remain on the forefront of technological innovation with hopes of furthering scientific exploration and research in a safe and reliable manner.

Project Objective

Pathfinder must successfully self-navigate a quarter mile course with a goal of a full mile (four laps of the quarter mile course) in a Mediterranean environment using GPS waypoints provided by Arxterra while utilizing obstacle avoidance measures.

Three quarter mile courses have been mapped out at Fairview Park in Costa Mesa, CA which can be seen below:

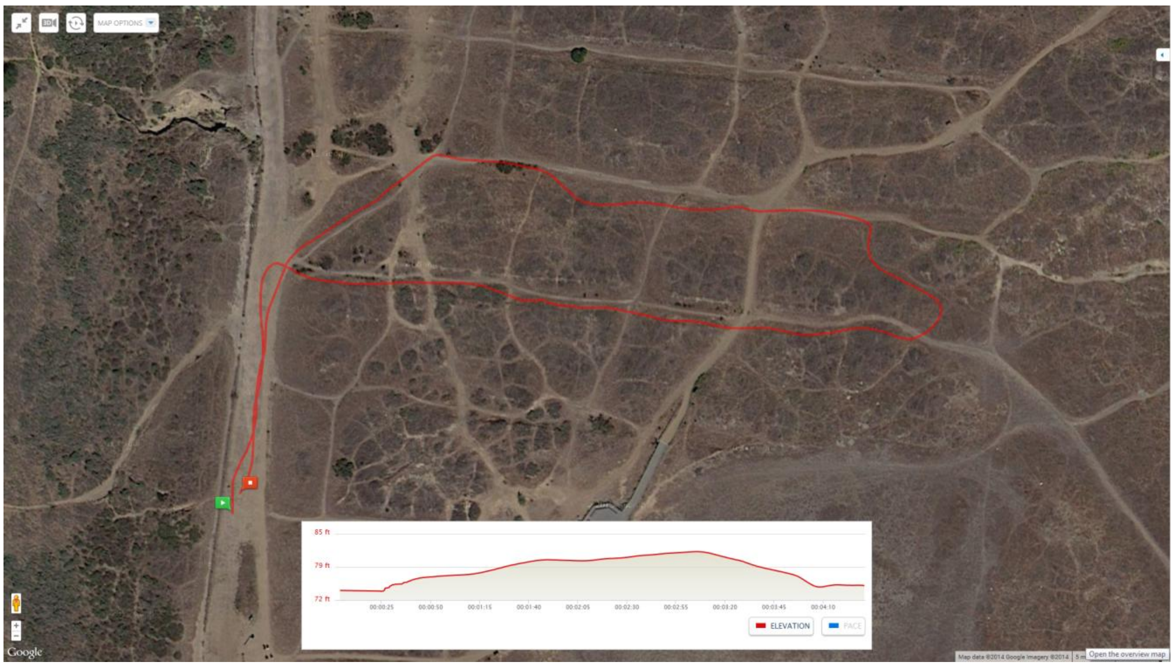


Figure One – Course One

Figure Two – Course Two

Figure Three – Course Three

Project Requirements

1. Sealed pan and tilt camera platform for an Android phone

a. Due to the dusty conditions of Fairview Park, a sealed environment for the Android phone is required in order to ensure uninterrupted visual communications back to the user

b. To verify this, we will place the pan and tilt system in a garbage bag and then fill it with baby powder and then introduce a blow dryer to simulate a sandstorm with the baby powder
    i. Baby powder was chosen because it is easily obtainable and is comparable to a fine, dry silt that contains particles that are 0.002 to 0.05 millimeters across. This is much finer than even the finest coarse soil particles found at Fairview park which measure 0.063 - 0.2 millimeters across[5][7]
    ii. If the pan and tilt system can withstand a finer soil grade than our testing location then it will pass the requirement of being sealed
        1. Results are TBD

2. Sealed environment for microprocessor and electronic components

a. Similar to the pan and tilt camera platform, dust has the potential to cause major interference with our electrical components. Due to this, all components must be housed in a sealed environment to avoid damage to the rover and its electrical components
    i. To verify this, we will place the sealed box in a tub of water and confirm that there is no air escaping from the box
        1. If the box can withstand both the pressure of the water and maintain a dry internal environment then it will pass the requirement of being sealed
        2. Results are TBD

b. An exception to this requirement are the motors as they come stock on the rover and are open to the environment and the elements
    i. We are requesting a waiver for this requirement because a comparable sealed DC motor is not easily available because the motors available are too small to drive the rover and any motor capable of driving the rover requires a higher voltage than 7.4V and has a beginning price of $65.00[1]

3. GPS navigation/waypoints using Arxterra

a. Pathfinder will maintain functionality similar to the Curiosity rover. As a result, direct user control is not the priority of this mission. Since Pathfinder will most likely be in very distant harsh environments, direct control will have too much lag time to safely navigate the rover. GPS coordinates will be used in conjunction with obstacle avoidance measures to achieve its objective. This way, all vital decisions are made on board the rover which will allow for a faster reaction time when avoiding obstacles
    i. To verify the functionality of the GPS navigation, we will define a home coordinate and a destination coordinate and have the Pathfinder travel from home to the destination coordinate
        1. From here we can determine the range of accuracy of the phone’s GPS which can be extrapolated from multiple tests so the margin of error is TBD

4. **Must travel a minimum of .25 miles with a goal of completing the quarter mile course four times to reach a mission distance of a mile**

    a. Pathfinder will need to have the ability to reliably cover large distances at a single time. Since it cannot directly receive any form a physical maintenance while on mission, it must demonstrate that it can handle lengthy missions in harsh environments without experiencing technical issues
        i. If the motors run at stall current for 30 minutes, the total consumption is 12000mAh (roughly 60% of capacity). The power consumption for other system components is 1500 mAh (roughly 45% of capacity)
        ii. For more information, please refer to the Power Budget section here

5. **Must be able to safely traverse mountainous terrain and avoid obstacles**

    a. The three courses we mapped out contain many terrain features that pose a threat to the rover's safety so Pathfinder must be able to navigate up and down various grades of slopes without compromising the rover's safety
        i. The steepest slope Pathfinder will encounter varies depending on the course
            1. For Course One, the steepest slope is approximately 12° and will be traversed once
            2. For Course Two, the steepest slope is approximately 29° and will be traversed twice; once going up the slope and once going down the slope
            3. For Course Three, the steepest slope is approximately 30° and will be traversed once
        ii. If Pathfinder can handle the worse-case slope of 30° then it will pass verification

    b. Additionally, Pathfinder will have the ability to pass over various objects without bottoming out
        i. To verify this, we went out to the course and measured the tallest objects the rover will encounter such as rocks and sticks and determined a general height range of 1.063 in. – 2.125 in.
            1. Using the measured height range for reference, the rover can handle approximately 7 lbs. of equipment which translates into a 2.2 in. ground clearance which is sufficient when avoiding the objects on course
            2. More information can be found on the Pathfinder Weight and Battery Test blog post by Ahmed Arbi and Colling Hightower here

6. **Must be able to withstand a Mediterranean environment**

    a. California, in terms of temperature ranges, is Mediterranean whereas rainfall would indicate a Desert environment [4][6]

i. The average temperature range for Costa Mesa, California was found to range from 46°F - 66°F for the month of December which was gathered from historic climate data for the month of December[4]

ii. Average rainfall for the month of December is approximately 2.5 inches[4] but due to the current drought, we are currently at 0.03 inches total (July 2014 – October 2014) when the average would indicate a total of 1.07 inches[6]

1. We are requesting a waiver for the water-proofing of the pan and tilt platform because evidence indicates minimal rainfall due to the drought and attempting to make the platform waterproof will over-complicate the design which may lead to a complete design change

b. Refer to the Project Assumption section here for a more in-depth discussion regarding Costa Mesa's environmental temperature and rainfall

System Block Diagram

The central system of the Pathfinder rover is the ATMega 2560 microprocessor, embedded on an Arduino Mega ADK. All Pathfinder subsystems will interface with the Arduino through either the Pololu Motor Shield, or the custom printed circuit board.

The Pololu Motor shield functionally interfaces the VHN 5019 motor drivers with the Arduino through 2 analog and 8 digital I/O pins (the shield physically connects to a total of 30 pins). Each motor channel (left and right) will be connected to MnA and MnB on the motor shield. One motor on each channel will equip shaft encoders. The motor batteries (Two 7.4V Li-Po) will be wired in parallel and connected to the motor shield as well as a voltage sensor.

The custom P.C.B. will functionally interface with the Arduino through 2 analog pins and 18 digital pins (the board physically connects to a total of 46 pins). The board will house a system temperature sensor (TMP35), voltage sensor (1135 - Precision Voltage Sensor), gyro (L3GD20), voltage regulator (designed by Ahmed Arbi), shaft encoders, and headers to interface the remaining subsystem components in a neat fashion. The system battery (11.1V Li-Po) will be connected to the onboard voltage regulator which will provide outputs of 8V for the Arduino, 5V for the pan and tilt servos, ultrasonic sensors and temperature sensor, and 3.3V for the Bluetooth shield (HC06) and gyroscope.

The Bluetooth shield will provide connection to an android phone (Samsung Galaxy S2) which will in turn connect to the Arxterra control panel through a wireless data connection. The phone's onboard GPS and compass will send coordinates and directions to the Arxterra control panel to be processed and communicated back to the Arduino.

For more information regarding the pin interface layout then please refer to the Pathfinder Pin Interface blog post by David Belanger here.

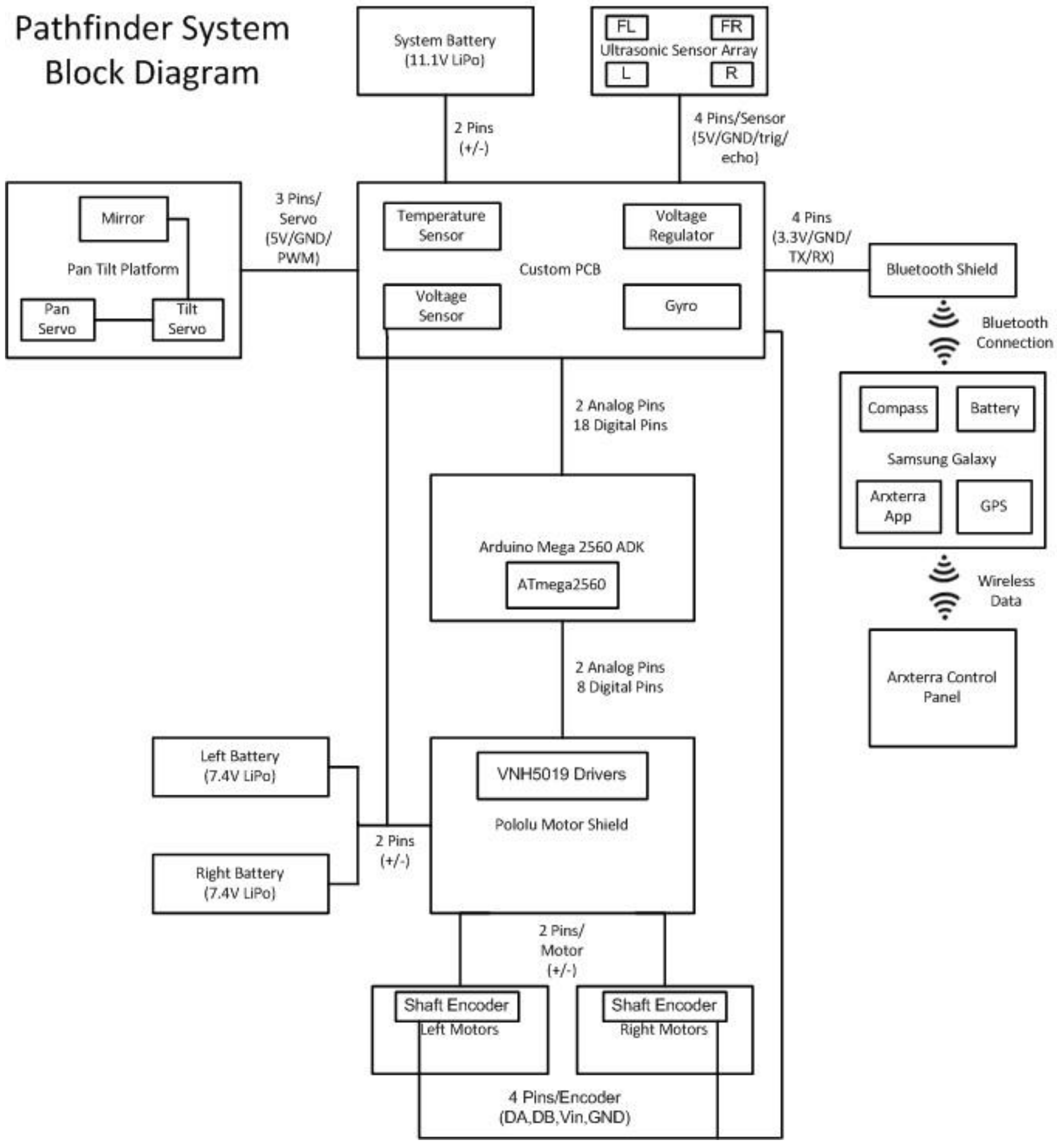


Figure Four – System Block Diagram with Interface Definition

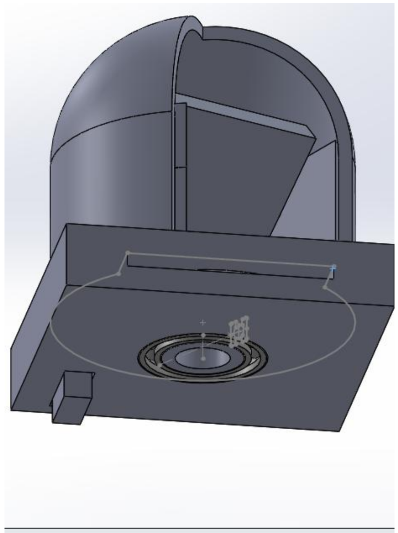
Major Project Elements

1. Sealed pan and tilt camera platform for an Android phone

a. A preliminary design for a sealed pan and tilt system has been designed to meet this requirement

b. The tilt system has been designed in a way that allows the dome to be sealed off from the rest of the system which protects the electronics from the elements

c. For a more in-depth discussion of this design, please refer to the Pathfinder Pan and Tilt Camera Platform blog post by James Henderson [here]



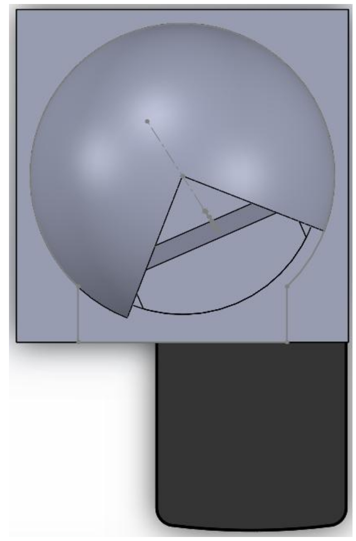


Figure Five – James Henderson's Sealed Pan and Tilt Camera Platform Design

2. **Sealed environment for microprocessor and electronic components**

    a. To meet this requirement, all components (similar to the pan and tilt system) will be housed in a box to protect the components from the elements.
        i. The dimensions and verification of this design are TBD
        ii. Initial design will be in SolidWorks and it will be 3D printed
            1. Design is TBD

3. **GPS navigation/waypoints using Arxterra**

    a. Pathfinder requires satellite communication with the Arxterra platform

    b. We will use an Samsung Galaxy S2 Smartphone with our rover as it has been verified by to work with Arxterra

    c. In order to get our microprocessor to communicate with the Android phone, we need to utilize a Baitaihem 4 Pin Serial Arduino Wireless Bluetooth Receiver Module HC-06 RS232 TTL UART Slave
        i. Commands have been defined specifically for Pathfinder to communicate to the Arxterra website
        ii. The explanation of these commands can be found here in the Pathfinder Arxterra Communication Commands blog post

4. **Must travel a minimum of .25 miles with an ideal distance of 1 mile**

    a. In order to execute a mission that requires the rover to travel a distance of a quarter mile, three batteries have been chosen to power the Pathfinder
        i. There will be a Gen Ace 11.1 V Li-Po Battery used to power the microprocessor and all electrical components on the Pathfinder
            1. This is a standalone power source that was measured to have an actual voltage value of 12.58V when fully charged
        ii. There will be two Gens Ace 7.4V Li-Po Battery that will be dedicated to powering the motors
            1. The two batteries have been measured to be 8.39V and 8.14V when fully charged
            2. The motors have been tested and verified to draw an average of 558.33 mA at no load
                a. More information can be found on the Pathfinder Weight and Battery Test blog post by Ahmed Arbi and Colling Hightower here
        iii. To monitor the voltage of the motor batteries, which will allow us to determine if the rover is able to sucessfully complete the mission before it runs out of power, we have chose to use a 1135 Phidgets Precision Voltage Sensor to monitor the voltage
            1. In order to verify this, we will drain the battery multiple times in order to obtain a rough transfer curve of the batteries voltage over time in order to determine the voltage drop off point
                a. For more information regarding this test, refer to the Battery Voltage and Slope Test in the Testing and Verification section here
                b. Results are TBD

    b. We will include shaft encoders to the motors in order to determine the distance we have gone which will assist in designing the controller
        i. This will also allow us to monitor speed of the rover which will allow us to regulate it and avoid any dangerous situations for the Pathfinder which falls under navigating the rover in a safe manner
            1. For more information on how we will verify the functionality of the shaft encoders, please refer to the Shaft Encoder Test in Testing and Verification here

    c. For a breakdown and description of Pathfinder's power budget, refer to the Power Budget section here

5. **Must be able to safely traverse mountainous terrain and avoid obstacles**

    a. The maximum equipment weight allowed on the Pathfinder was found to approximately 7 lbs. which will allow a 2.2 in. ground clearance

        i. Various obstacles were measured on out course that could cause the Pathfinder to bottom out
            1. A general height range was measured to be 1.063 in. – 2.125 in. which was used as a reference when determining the maximum weight the rover can support
            2. For more information regarding the ground clearance test and how we chose the maximum limit, please refer to the Pathfinder Weight and Battery Test blog post by Ahmed Arbi and Collin Hightower here

b. In order to avoid obstacles, four ultrasonic sensors have been chosen as the main method of detecting obstacles
    i. For more information regarding the obstacle avoidance test, please refer to the Obstacle Avoidance Test under Testing and Verification here
        1. Results are TBD

c. To keep the rover on its path during the mission, which will also factor into how will it navigates and avoids obstacles, we have chosen to utilize the L3GD20 3-Axis Gyroscope which can be used when designing the PID controller for regulating motor speed and direction
    i. To summarize, our verification will require Pathfinder to drive in a straight line without any significant drift as well as the ability to recover from an external disturbance and return to its original course
        1. For more information regarding this test, please refer to Arxterra Control Test under Testing and Verification here
        2. Results are TBD

d. The maximum slope the Pathfinder will face was measured to be a 30° over approximately 6 ft.
    i. To verify that the maximum slope the Pathfinder can handle, we will use a treadmill and tilt it while the rover is running to determine how steep of a slope it can handle
        1. For more information regarding this test, please refer to the Battery and Slope Test under Testing and Verification here

e. To power the motors, we have chosen to utilize the Pololu Dual VHN5019 Motor Shield which is rated to deliver a continuous 12A to the motors which is more than enough since our motors have been measured to draw 4A at stall

f. To handle the various sensors that are required, a custom PCB will be created which will interface all the sensors mentioned above to the Arduino
    i. This allows us to have all sensors on a separate board which will reduce clutter on our microcontroller
    ii. To verify that the PCB will work before we send it off to be manufactured, it will be bread boarded to ensure its functionality

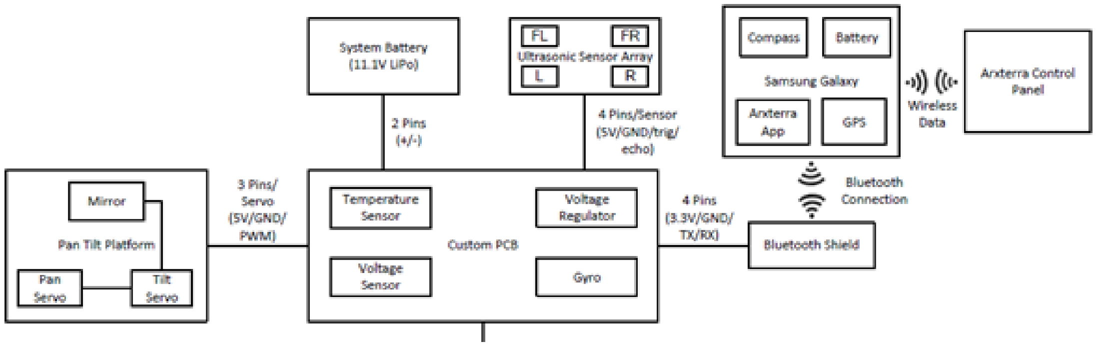


Figure Six – Ahmed Arbi's Custom PCB Block Diagram

g. Finally, the Arduino Mega ADK is chosen as our microprocessor as it features 54 digital I/O pins (15 PWM pins), 16 analog pins, and 4 UARTs ports[3]

h. Compared to the Uno which only has 14 digital I/O pins (6 PWM pins), 6 analog pins, and 1 UART port
   i. For more information on how we will utilize the pins on the Arduino Mega ADK, please refer to the system block diagram here and David Belanger's Pathfinder Pin Interface blog post here
   ii. Pins 22 through 49 will allow us to jump wires to the custom PCB which again, will lead to a more organized system and easier debugging and troubleshooting

6. Must be able to withstand the temperature ranges of a Mediterranean environment

a. In the case of Costa Mesa, CA, the temperature can range from 46˚F - 80˚F [4]
   i. In order to monitor the temperature of this requirement, we will add an TMP35 temperature sensor which will go on our custom PCB
   ii. The historic temperatures for the month of December (month of final demonstration) are 66°F while the historical averages for October and November are 75˚F and 71˚F so if the rover can perform testing during these months then it will be able to withstand the temperatures for the month of December[4]

Cost Breakdown

Item	Source	Cost	Quantity
L3GD20 3-Axis Gyroscope*	Pololu	$0.00	1
Parallax PING Ultrasonic Sensor	RobotShop	$59.98	2
Arduino Mega 2560 ADK Microcontroller R3*	RobotShop	$0.00	1
Pololu Dual VNH5019 Motor Driver Shield for Arduino*	Pololu	$0.00	1
Baitaihem 4 Pin Serial Arduino Wireless Bluetooth Receiver	Amazon	$9.49	1
TMP35 Temperature Sensor*	SparkFun	$0.00	1
Gens Ace 7.4 V Li-Po Battery 10000 mAh*	HobbyPartz	$0.00	2
Gens Ace 11.1 V Li-Po Battery 3300 mAh*	HobbyPartz	$0.00	1
Wild Thumper 75:1 Gear Ratio*	Pololu	$0.00	1
1135 Phidgets Precision Voltage Sensor	DigiKey	$42.00	1
*Already own	**Total w/o Tax and Shipping Estimation**	**$111.47**	
	Total w/ Tax and Shipping Estimation	**$136.50**	

Power Budget

Component	Quantity	I_{MIN} (mA)	I_{MAX} (mA)
Thumper DC Motors	6	558.33*	3850*
Arduino Mega ADK	1	-	750
SEN-10988 Temperature Sensor	1	10	-
L3GD20 3-Axis Gyroscope	1	7	-
1135 Phidgets Precision Voltage Sensor	1	3.2	-
Baitaihem 4 Pin Serial Arduino Wireless Bluetooth Receiver	1	10	-
Parallax PING Ultrasonic Sensor	4	15	-
Servos	2	150	1000
* Tested and measured - TBD	**TOTAL**	**3942.2**	**25870**

Assuming a speed of 1 mph, the quarter mile track takes 15 minutes. To account for obstacle avoidance, assume the time is doubled to 30 minutes. If the motors run at stall current for 30 minutes, the total consumption is 12000mAh (roughly 60% of capacity). Assuming maximum current draw from the servos and Arduino, the power consumption for other system components is 1500 mAh (roughly 45% of capacity).

Project Testing and Verification

1. Battery Voltage and Slope Test

a. A treadmill will be built in a similar fashion to a car dynamometer which allows us to measure the battery drain

b. We require this test because we need to determine the power budget of our rover which will allows us a rough run time estimate for the Pathfinder
    i. The purpose of this test is to determine the drop off point of our two motors batteries
    ii. With the knowledge of the drop off, we can pinpoint a general voltage range that will indicate if the rover is able to complete its assign mission or if it will die before completing the course
    iii. This will also allow us to measure the current draw by the motors at various inclines which will give us a general figure for current drain and will allow us to calculate a general run time for the Pathfinder
    iv. Results are TBD

c. Additionally, we will use the treadmill to test for the maximum slope the rover can handle
    i. We will incrementally incline the treadmill measuring the current from the motors
    ii. Once the motor hits the stall torque then we will set that as the maximum slope the rover can handle
    iii. Results are TBD

2. Obstacle Avoidance Test

a. It is a requirement to have obstacle avoidance measures for the Pathfinder so in order to being to have a working subroutine; we will have a tradeoff between environments in order to being building a working subroutine.

b. Collin will being writing an obstacle avoidance subroutine which will be executed on a flat, concrete/tile ground and will require that the Pathfinder must avoid any obstacles placed in front of it
    i. These obstacles can be anything such as a backpack or trashcan
    ii. Pathfinder will drive on a straight course and avoid any obstacles in its way
    iii. We will need to test the actual range of the ultrasonic sensors as well as the response time
    iv. Once the rover is built, a rough obstacle avoidance subroutine will be written and then we will measure the general reaction time of the rover at various speeds
    v. Results are TBD

c. Additionally, we will need to test for the reaction time of the sensors in order to determine the optimal distance for obstacle detection
    i. We will set the rover to drive at a wall and tell the motors to stop at a specified distance until we reach a distance where the rover cannot stop in time
        1. This value will be our limit when coding the obstacle avoidance and the results are TBD

3. Arxterra Communication Test

a. Once we receive the Bluetooth wireless module then we can begin testing communications with Arduino and Arxterra
   i. GPS coordinates and communication will be vital to the success of this mission so we must establish that we are able to communicate with Arxterra to and from the Arduino
      1. The commands used can be found here in the Pathfinder Arxterra Communication Commands blog post
   ii. We will begin by pinging Arxterra to see if a connection has been made and then follow up by sending dummy packets from the Arduino to Arxterra
   iii. This will ensure that we can communicate with Arxterra and will allow us an idea of what the response time is
      1. We can move the Android phone to achieve various levels of connectivity to determine a rough estimate of response time for each
      2. Results are TBD

4. Arxterra Control Test

a. Since it is not efficient to drive down to Costa Mesa every time we want to test the PID controller, we will trade off (similar to the obstacle avoidance test) environments in favor of convenience
   i. Since it can be overwhelming to code to such a terrain laden environment, we must focus on achieving some form of a PID controller than can function in a basic, flat environment
   ii. Once we have verified that our PID can successfully navigate in a straight without much straying then we can begin adapting the code for a harsher environment
   iii. The PID controller will have to accept disturbances so in a similar fashion to EE 444, we will allow the rover to drive straight and then "kick" it to disturb its course and see how it responds
      1. We will be attempting to find a critically damped system and avoiding an under damped or over damped system
         a. We can use this knowledge to tune our PID to the correct values
      2. Results are TBD

5. Temperature Sensor Test

a. Edwin Molina brought up an excellent point regarding having the temperature sensor on our custom PCB about how it will have interference from the voltage regulator

i. Having the sensor in such close proximity to heat producing components will compromise the reading of the sensor
ii. Once the rover is built, we will periodically compare the sensor reading to the actual reading of the environmental temperature
1. If there is too much interference then we will have that sensor read the internal environment of the electrical compartment and then add a separate sensor to the outside to have a clearer reading
iii. Results are TBD

6. Shaft Encoder Test

a. Since we will be monitoring speed and distance then we need to ensure the shaft encoders are functioning properly
i. Similar to the tests performed in EE 444, we will define a straight course using a tape measure then code the rover to drive the length of the tape measure
1. The rover shall stop at the defined range of 6 ft. to pass verification
ii. We must account for bouncing of the encoder signals which provided a lot of trouble in EE 444 so we will have to write a loop to delay the reading of the encoder so we don’t get false readings
1. We tell the rover to drive a distance that is equivalent of 200 ticks of the encoder and then add in a Serial.Print function to display how many ticks our code is actually detecting
a. We will modify until the number of defined ticks equals the number of ticks being detected
iii. Results TBD

7. Pan and Tilt Testing

a. We will place the pan and tilt system in a garbage bag with some baby powder and then introduce a hair dryer in order to simulate a sand storm, if it is found that there is no baby powder inside the sealed environment of the pan and tilt system then it will pass testing
i. Baby powder was chosen because it is easily obtainable and is comparable to a fine, dry silt which contains particles that are 0.002 to 0.05 millimeters across. This is much finer than even the finest coarse soil particles found at Fairview park which measure 0.063 - 0.2 millimeters across[5]
ii. If the pan and tilt system can withstand a finer soil grade than our testing location then it will pass the requirement of being sealed

b. Results TBD

8. **Gyro Testing**

    a. Another vital component of our system is the gyroscope as our PID has the potential to utilize this component
        i. In EE 444, it was known that the gyroscope has a slight drift and we must correct for that
        ii. We will calibrate the gyroscope and then command the rover to drive forward a defined distance and then tell it to stop and execute a 180˚ turn
            1. We will continue calibrating the gyro until Pathfinder can execute a perfect 180˚ degree without over or undershoot.
        iii. Results TBD

9. **GPS distance and speed calculations**

    a. We are already considering shaft encoders to determine distance travel and speed of the rover but it would be interesting to see how accurate a speed and distance calculation provided by the GPS coordinates would be
        i. We can achieve this by taking the difference between two GPS points and then determining how long it took the rover to reach the new GPS point
        ii. In order to test this, we will provide the rover will a few GPS points and while it is driving we will be pinging Arxterra
            1. We will have a past GPS coordinate variable and a current GPS variable and we will perform the distance and speed calculations and then compare them to the readings from the encoder
            2. If the readings show too much error then we can safely disregard having to calculate speed and distance from GPS
        iii. Results TBD

Project Assumptions

We must assume the weather at the testing location will be similar to what it has been in the past. According to U.S. climate data, Fairview Park will experience an average high of 66°F and an average low of 46°F with an average precipitation 2.09 inches. December features the third highest average precipitation by month behind January and February. To contrast these averages, OC Public Works have kept a year to date log of daily precipitation in Costa Mesa for the 2014 – 2015 year. The log shows that a mere 0.3 inches has fallen since July of 2014 while the expected total is supposed to be 1.07 inches according to the historical levels. These low precipitation levels are a result of the drought that California has been experiencing. Although the occurrence of rain is certainly possible, to say that it will rain on the date of Pathfinder's mission goes against all current evidence.[4][6]

Project Constraints

All documentation pertaining to the Pathfinder rover must be submitted by December 3rd, 2014 and demonstration of the rover must be completed within the week of December 3rd, 2014 to December 10th, 2014.

Project Boundaries

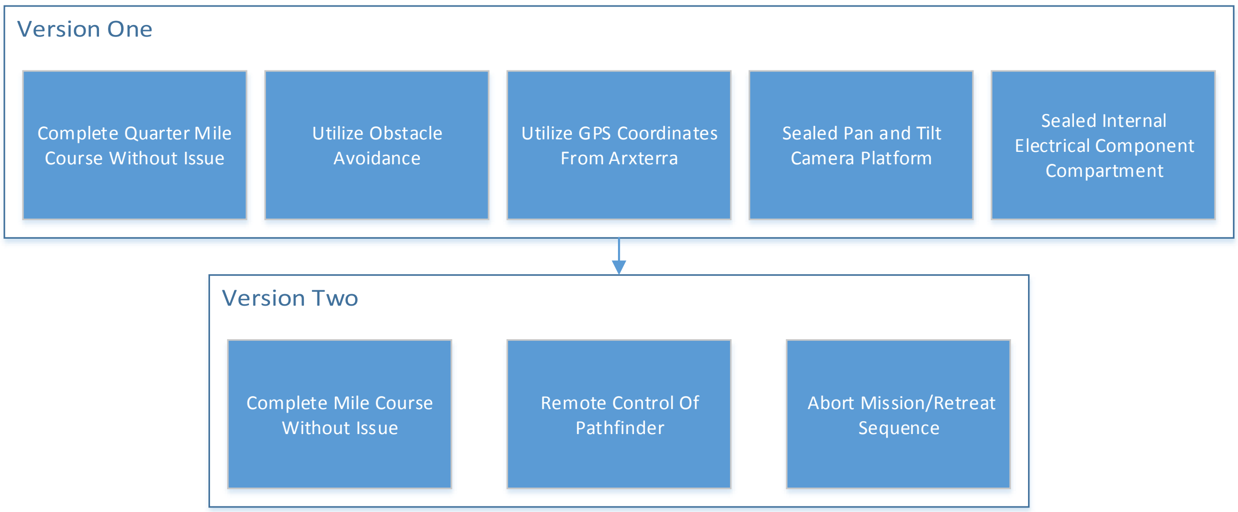


Figure Ten – Project Version Rollouts

The priority of this project is to have the rover autonomously navigate the aforementioned quarter mile courses. An ideal distance is one mile which would involve four laps of one of the course above. We must first ensure Pathfinder can complete at least one lap of the course before we proceed to the mile course.

GPS coordinates are required for demonstration so it will maintain priority until completed. Remote control will be implemented after we have verified that GPS navigation is reliable and ready for demonstration.

An abort mission/retreat sequence can be valuable if the voltage in the battery drops close to the point of no return. If the voltage drops too low to complete the initial course then the rover can enter into a retreat sequence using the previously received GPS coordinates and return to its home location. This can be a useful feature but it is not as important as getting the rover to actually navigate the initial course so it will be relegated to the second version of Pathfinder.

Project Deliverables

This project will yield a self-sufficient Wild Thumper model rover with the ability to communicate via satellite to receive GPS coordinates for navigation. Additionally, the rover will have safety and obstacle avoidance measures to ensure that the rover can complete the mission without taking any form of damage. Finally, rover will be able to successfully navigate one of the geographically mountainous courses defined above.

Project Schedule

Team Member	Task Name	Duration	Start	Finish
--	**Week Five**	6 days	Wed 10/1/14	Wed 10/8/14
--	Fifth Meeting	1.5 hrs?	Wed 10/1/14	Wed 10/1/14
--	**Preliminary Design Review (MILESTONE)**	**0 days**	**Mon 10/6/14**	**Mon 10/6/14**
--	Begin obtaining parts for Pathfinder	21 days	Wed 10/1/14	Wed 10/29/14
Collin Hightower	Continue improving obstacle avoidance flowchart	6 days?	Wed 10/1/14	Wed 10/8/14
James Henderson	Meet with team ROSCO to discuss mirror platform design	6 days?	Wed 10/1/14	Wed 10/8/14
Ahmed Arbi	Attend PCB design meeting	6 days?	Wed 10/1/14	Wed 10/8/14
David Belanger	Revise requirements and block diagram per group member input	6 days?	Wed 10/1/14	Wed 10/8/14
--	**Week Six**	6 days	Wed 10/8/14	Wed 10/15/14
--	Sixth Meeting	1.5 hrs?	Wed 10/8/14	Wed 10/8/14
--	Continue obtaining parts for Pathfinder	16 days	Wed 10/8/14	Wed 10/29/14
--	Begin assembling Pathfinder	21 days	Wed 10/8/14	Wed 11/5/14
Collin Hightower	Continue improving obstacle avoidance flowchart	6 days?	Wed 10/8/14	Wed 10/15/14
James Henderson	Begin design of PID	13 days?	Wed 10/8/14	Fri 10/24/14
Ahmed Arbi	Begin designing custom PCB board	13 days?	Wed 10/8/14	Fri 10/24/14
David Belanger	Revise requirements and block diagram per group member input	6 days?	Wed 10/8/14	Wed 10/15/14
--	**Week Seven**	6 days	Wed 10/15/14	Wed 10/22/14
--	Seventh Meeting	1.5 hrs?	Wed 10/15/14	Wed 10/15/14
--	Continue obtaining parts for Pathfinder	11 days	Wed 10/15/14	Wed 10/29/14
--	Continue assembling Pathfinder	16 days	Wed 10/15/14	Wed 11/5/14
--	**Preliminary Project Documentation (MILESTONE)**	**0 days**	**Mon 10/20/14**	**Mon 10/20/14**
Collin Hightower	Continue improving obstacle avoidance flowchart	6 days?	Wed 10/15/14	Wed 10/22/14
James Henderson	Continue design of PID	6 days?	Wed 10/15/14	Wed 10/22/14
Ahmed Arbi	Continue designing custom PCB board	6 days?	Wed 10/15/14	Wed 10/22/14
David Belanger	Turn in requirements and block diagram	6 days?	Wed 10/15/14	Wed 10/22/14
--	**Week Eight**	6 days	Wed 10/22/14	Wed 10/29/14
--	Eighth Meeting	1.5 hrs?	Wed 10/22/14	Wed 10/22/14
--	Finish obtaining parts for Pathfinder	6 days?	Wed 10/22/14	Wed 10/29/14
--	Continue assembling Pathfinder	11 days?	Wed 10/22/14	Wed 11/5/14
Collin Hightower	Present obstacle avoidance flowchart to group and begin coding	21 days?	Wed 10/22/14	Wed 11/19/14
James Henderson	Present design idea for PID controller and begin coding	21 days?	Wed 10/22/14	Wed 11/19/14
Ahmed Arbi	Present preliminary PCB design to group and begin implementing	21 days?	Wed 10/22/14	Wed 11/19/14
David Belanger	Begin Arxterra communications ideas and coding	21 days?	Wed 10/22/14	Wed 11/19/14
Daniel Givens	Begin Arxterra communications ideas and coding	21 days?	Wed 10/22/14	Wed 11/19/14
--	**Week Nine**	6 days	Wed 10/29/14	Wed 11/5/14
--	Ninth Meeting	1.5 hrs?	Wed 10/29/14	Wed 10/29/14
--	Continue assembling Pathfinder	6 days?	Wed 10/29/14	Wed 11/5/14
--	**Critical Design Review (MILESTONE)**	**0 days**	**Mon 11/3/14**	**Mon 11/3/14**
Collin Hightower	Continue obstacle avoidance coding	16 days	Wed 10/29/14	Wed 11/19/14

James Henderson	Continue PID coding	16 days	Wed 10/29/14	Wed 11/19/14
Ahmed Arbi	Continue PCB implementation	16 days	Wed 10/29/14	Wed 11/19/14
David Belanger	Continue Arxterra communications ideas and coding	16 days?	Wed 10/29/14	Wed 11/19/14
Daniel Givens	Continue Arxterra communications ideas and coding	16 days?	Wed 10/29/14	Wed 11/19/14
--	**Week Ten**	6 days	Wed 11/5/14	Wed 11/12/14
--	Tenth Meeting	1.5 hrs?	Wed 11/5/14	Wed 11/5/14
Collin Hightower	Continue obstacle avoidance coding	11 days?	Wed 11/5/14	Wed 11/19/14
James Henderson	Continue PID coding	11 days?	Wed 11/5/14	Wed 11/19/14
Ahmed Arbi	Continue PCB implementation	11 days?	Wed 11/5/14	Wed 11/19/14
David Belanger	Continue Arxterra communications ideas and coding	11 days?	Wed 11/5/14	Wed 11/19/14
Daniel Givens	Continue Arxterra communications ideas and coding	11 days?	Wed 11/5/14	Wed 11/19/14
--	**Week Eleven**	6 days	Wed 11/12/14	Wed 11/19/14
--	Eleventh Meeting	1.5 hrs?	Wed 11/12/14	Wed 11/12/14
Collin Hightower	Finish obstacle avoidance coding	6 days?	Wed 11/12/14	Wed 11/19/14
James Henderson	Finish PID coding	6 days?	Wed 11/12/14	Wed 11/19/14
Ahmed Arbi	Finish PCB implementation	6 days?	Wed 11/12/14	Wed 11/19/14
David Belanger	Finish Arxterra communications ideas and coding	6 days?	Wed 11/12/14	Wed 11/19/14
Daniel Givens	Finish Arxterra communications ideas and coding	6 days?	Wed 11/12/14	Wed 11/19/14
--	**Week Twelve**	6 days	Wed 11/19/14	Wed 11/26/14
--	Twelfth Meeting	1.5 hrs?	Wed 11/19/14	Wed 11/19/14
Collin Hightower	Begin obstacle avoidance debugging and trouble-shooting	16 days?	Wed 11/19/14	Wed 12/10/14
James Henderson	Begin PID code debugging and trouble-shooting	16 days?	Wed 11/19/14	Wed 12/10/14
Ahmed Arbi	Begin PCB implementation debugging and trouble-shooting	16 days?	Wed 11/19/14	Wed 12/10/14
David Belanger	Begin Arxterra communications code debugging and trouble-shooting	16 days?	Wed 11/19/14	Wed 12/10/14
Daniel Givens	Begin Arxterra communications code debugging and trouble-shooting	16 days?	Wed 11/19/14	Wed 12/10/14
--	**Week Thirteen**	6 days	Wed 11/26/14	Wed 12/3/14
--	Thirteenth Meeting	1.5 hrs?	Wed 11/26/14	Wed 11/26/14
--	**Project Documentation (MILESTONE)**	0 days	Mon 12/1/14	Mon 12/1/14
Collin Hightower	Continue obstacle avoidance debugging and trouble-shooting	11 days?	Wed 11/26/14	Wed 12/10/14
James Henderson	Continue PID code debugging and trouble-shooting	11 days?	Wed 11/26/14	Wed 12/10/14
Ahmed Arbi	Continue PCB implementation debugging and trouble-shooting	11 days?	Wed 11/26/14	Wed 12/10/14
David Belanger	Submit final documentation to Professor Hill	6 days	Wed 11/26/14	Wed 12/3/14
Daniel Givens	Submit final documentation to Professor Hill	6 days	Wed 11/26/14	Wed 12/3/14
--	**Week Fourteen**	6 days	Wed 12/3/14	Wed 12/10/14
--	Fourteenth Meeting	1.5 hrs?	Wed 12/3/14	Wed 12/3/14
--	**Project Demonstration (MILESTONE)**	0 days	Wed 12/10/14	Wed 12/10/14
Collin Hightower	Test Rover	6 days	Wed 12/3/14	Wed 12/10/14
James Henderson	Test Rover	6 days	Wed 12/3/14	Wed 12/10/14
Ahmed Arbi	Test Rover	6 days	Wed 12/3/14	Wed 12/10/14
David Belanger	Test Rover	6 days	Wed 12/3/14	Wed 12/10/14
Daniel Givens	Test Rover	6 days	Wed 12/3/14	Wed 12/10/14
--	**END**	0 days	Wed 12/10/14	Wed 12/10/14

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