EML 4905 Senior Design Project

A B.S. THESIS
PREPARED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

ASME Student Design Competition:
Remote Inspection Device
25% Report

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November 2012

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Juan Sebastian Fajardo, Marybel Hernandez, and Ryan Manalo and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

The purpose of this project is to design, manufacture, and build a remote inspection vehicle to compete at the annual 2013 American Society of Mechanical Engineering (ASME) student design competition. The vehicle will read gages that determine the level of radioactivity at specific location, activate a cooling pump, and have the capability of carrying sensors to and from designated locations.

Introduction

The tragedy that occurred at Fukushima nuclear facility after the March 2011 lead the Nuclear Industry to issue a Request for Proposal to design and build a small, remotely controlled inspection vehicle. The vehicle's main objectives are to determine the level of radioactivity at specified locations and inspect for damages, without exposing the human operator to high doses of radioactive contamination.

At the time, the Fukushima nuclear facility used heavy duty military defense robots to run radiation survey, and monitor the facility. These robots, though performed the required tasks, were much larger than needed, equipped with unnecessary equipment, and costly. The proof-of-concept robot described in this report is being specifically designed to compete in a simulated chemical / radioactive situation.

Problem Statement

The objective of this report is to design and build a remote controlled inspection vehicle. The inspection vehicle will consist of a claw used to pick up a small object and 2 cameras: one pointed at the floor to view gauge reading on the ground, and another placed on top of the platform that will provide a 360 degree view of the surroundings. A laptop computer keyboard will be used to input commands such as rotating the camera, opening/closing the claw, raising/lowering the claw arm, and servo speed/directional movements.

Motivation

The main motivation for this project is to represent Florida International University at the 2013 ASME National Student Design Competition. Winning at the district level will gain the team an invitation to compete with other district winners at the International Mechanical Engineering Congress and Exposition (IMECE), showcasing the quality of engineers that FIU produces on a global platform.

The challenge of bringing the theoretical background taught throughout the course of our studies to a practical setting is also an immense motivation for the team to excel in this endeavor. Furthermore, the opportunity to develop an idea that can be used in such a way that it will save a life by limiting human interaction in areas with dangerously high levels of radiation is very encouraging.

Literature Survey

Most of the search and rescue robots available on the market are heavy duty robots designed to search for victims after a catastrophic disasters, such as an earthquake, a collapsed building, or hurricane effected zone. There are a few robots specifically designed to handle chemical disasters, but they were not in great demand until the March 2011 Tohoku earthquake and tsunami that hit the Fukushima nuclear facility in Japan. This event lead the Nuclear Industry to issue a request for proposal to build a robot that is designed for this type of situation (ASME, 2012).

An article from Popular Science states that the Fukushima nuclear facility is using modified defense robot from American company iRobot and British company QinetiQ to “conduct radiation and oxygen-level survey;” monitor the facility; and remove debris. The article continues to describe that although the robots are providing a certain level of assistance by allowing the operators to assess the situation without being in harm’s way, robots are limited in what they can do. Eventually, workers will have to enter the facility and manually fix structural damages, electrical wiring and the reactors cooling system, in order to get the nuclear facility up and running again (Boyle, 2011).

The two robots that were used at the Fukushima nuclear facility are the 510 Packbot, shown in Figure 1, and the 710 Warrior, shown in Figure 2. These robots are manufactured by Massachusetts based company iRobot. As previously stated, both are classified as defense robots; not purpose designed for chemical disasters. The Warrior and Packbot were modified and equipped with radiation monitoring equipment before entering the facilities but are inherently built to handle war time missions such as explosive disposal.

Figure 1 Packbot

The Packbot, iRobot's first government funded defense robot, was designed to protect soldier's lives by run surveillance from a safe distance, detecting explosives in a building, and disposing of bombs. It is approximately 16 to 21 inches in length and 27 to 35 inches wide depending on how its flippers are positioned. This robot is portable, light weight (about 25 pounds), and can be set up and ready to operate in under 2 minutes. It is equipped with global positioning system that allows the operator to know exactly where it is all times. The robot camera has 3 degrees of freedom, and relaying quality real time video to the operator to control the robots movement. The robot consists of 2 manipulators. The first arm has 8 degrees of freedom (approximately 73 inches when fully extended) and able to lift from 10 to 30 pounds, depending on how far the arm payload is from the center of mass. The second arm is much smaller with only 4 degrees of freedom (approximately 40 inches when fully extended), and able to lift from 5 to 15 pounds, depending on how far the arm payload is from the center of mass. This robot is powered by 2 BB-2590/U lithium-ion rechargeable batteries that provides about 4 hours of continuous use on one charge and can go a maximum of 5.8 miles per hour. Therefore, this robot should stay within a 10 mile radius in order to return to the operator before it discharges. (iRobot, iRobot 510 PackBot, 2012).

Figure 2 Warrior 710

The Warrior is bigger, tougher and heavier than the Packbot. This robot was designed for surveillance on rougher terrain, can climb stair, and recover from a roll. It is approximately 35 inches in length and 21 to 30 inches wide depending on whether the flippers are attach. This robot can weight from 365 to 500 pounds. The robot manipulator extends a maximum of 75 inches and can lift 70 to 300 pounds, depending on the distance the payload is from the center of mass. Warrior is powered by 12 BB-2590/U lithium-ion rechargeable batteries that can run from 4 to 10 hours. The maximum speed is 8 miles per hour. The wireless range is approximately half a mile (2600 feet). (iRobot, iRobot 710 Warrior, 2012).

Figure 3 Talon

The United Kingdom's QinetiQ (pronounced kin-e-tic) Talon robot is also a military defense robot, shown in Figure 3. It was designed to overcome any terrain, weather conditions and/or combat situation thrown at it, including heavy rain, desert storm, steep rocky mountain, ice and snow. This robot is approximately 23 inches in width, 34 inches in length, and weights 115 to 157 pounds, depending on the equipment installed. This robot can be equipped with global positioning system, up to 7 camera, including night vision, thermal imaging and zoom control, and sensors to detect explosives, chemical material, and temperature, depending on the mission. It travels an average of 5 miles per hour. It has 1 manipulator with 3 degrees of freedom that extends up to 82 inches and can lift 10 to 25 pound. Yet, the robot can tow up to 1500 pound. The Talon runs on one lithium battery that lasts about an hour. (Esenturk, 2010).

Each of the previously mentioned robots has their downside, primarily in the cost of producing them. The iRobot Packbot's average cost is $402,874. While the 710 Warrior's exact cost is not yet available, it can be assumed that it will not be cheaper than the Packbot. The Talon, while not as expensive as the Packbot, still comes in at a staggering $112,184. (Army Guide Magazine, 2008)

Project Objectives

The primary objective of this project is to place Florida International University's name on the number one spot in ASME's 2013 student design competition. To obtain this objective, our team must work diligently and efficiently in designing, manufacturing, programming, and testing our robot.

ASME has not placed physical dimensions to the vehicle in order to promote "outside of the box" thinking and ingenuity. The organization does not even require that it be a ground robot; it may be made to fly as long as they follow three simple rules in construction. The vehicle must be powered by rechargeable batteries, the device must only be controlled through wireless communication, and it must have a clearly labeled and accessible master shut off switch.

A "contaminated" area, whose dimensions are 5.00 × 7.75 m (16.4 × 25.4 ft), as shown in Figure 4, will be inspected. The operator will not be allowed to view the competition area prior to starting their run. Inside this area, the operator of the vehicle will navigate through a series of obstacles, report a digital pressure gage, drop off a sensor, push a button, pick up a sensor, and return back to the parking area. The sensor is a 25.4 mm (1 in) in diameter by 50.8 mm (2 in) high cylindrical wooden dowel. The button is a red 25mm (.984 in) diameter button in the middle of a 100 mm (3.937 in) square background.

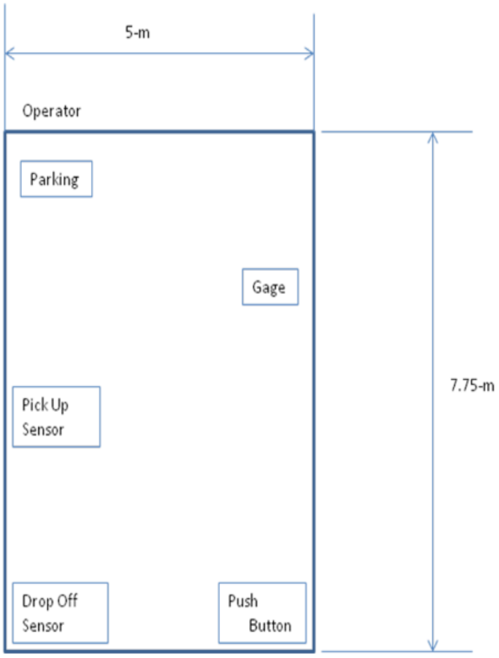


Figure 4 Competition course

There is a maximum of 5 minutes allotted to complete the aforementioned tasks. Each task is rewarded a number of points upon completion. Reporting the correct gage reading is worth 1000 points, dropping off sensor is worth 2000 points, pushing the button is worth 3000 points, and picking up and carrying the second sensor to the designated area is worth 2000 points. The formula for scoring is $S = \Sigma(R) – 10*s – 200*T$, where *R* is the task score, *T* is the times the device touches the boundary, and *s* is the seconds it takes to complete the task.

While the robot is maneuvering through the course, there are strict guidelines that must be adhered to. If the vehicle leaves the course, it must re-enter without the help of any team member. If the course is damaged in any way or the vehicle does not meet any of the three requirements stated earlier, the team will be automatically disqualified. If a team member touches the device while it is competing, the team will be penalized with the maximum time of 300 seconds and an *R* score of 0.

Conceptual Design

All conceptual designs have a basic function of being completely remote controlled as the ASME competition requires. The first design concept that our team developed is a four wheel remote vehicle with rear steering for sharp turns and a robotic arm located in the middle of the platform on the right side. This robotic arm design was developed with the intention of stopping along the side of the item that needs to be picked up. The camera is attached to a pan and tilt assembly for easy maneuverability of camera. The drawing of this concept design is shown in Figure 5.

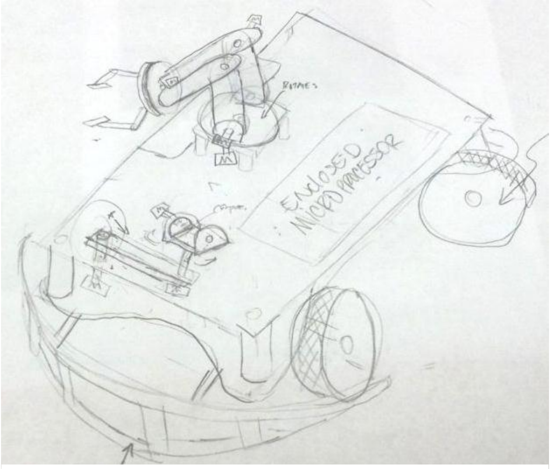


Figure 5 Concept 1

The second concept design is a four wheel drive vehicle whose platform is lower to the ground to reduce drag. It is equipped with a robotic arm located in the front center and dual cameras for a wider view. One of the cameras is located in the robotic arm and the second below the platform in the front. This design is wifi enabled as well. The drawing of this concept design is shown in Figure 6.

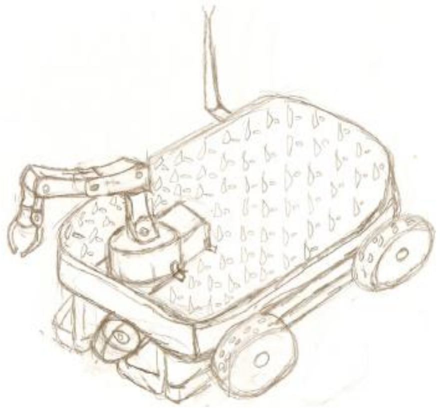


Figure 6 Concept 2

The third concept design is a four wheeled drive remote vehicle equipped with a robotic arm also located in the front center. Two cameras located in the front on both sides of the robotic arm. The platform in this design is slightly raised to increase ground clearance for faster maneuverability. This vehicle is Wifi enabled as well and has indoor and outdoor application as well. The

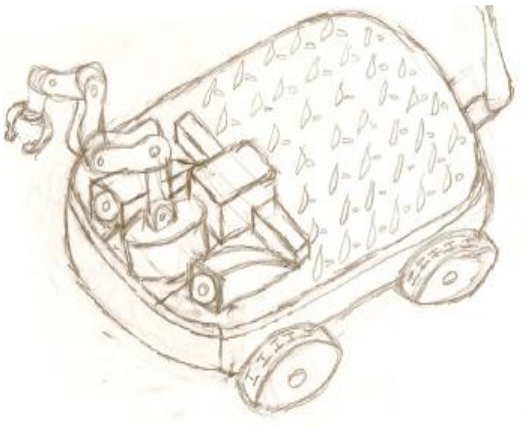


Figure 7 Concept 3

drawing of this concept design is shown in Figure 7.

The fourth concept design is a caterpillar tracked vehicle that has a robotic arm located toward the front center and a front camera and controlled via wifi to a remote host. Caterpillar tracks are mostly seen on vehicles for used in outdoor applications such as construction. The drawing of this concept design is shown in Figure 8.

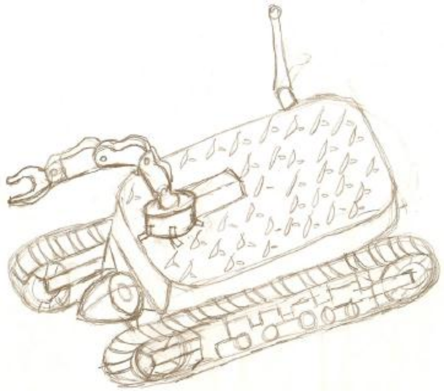


Figure 8 Concept 4

Proposed Design

The proposed design agreed upon is similar to the fourth conceptual design discussed in the previous section (Figure 8). The fourth concept design has been modified to include a single camera that moves with the robotic camera for easy view all around. Also, this design will use radio communication instead of wifi. This design was chosen because of its versatility for indoor and outdoor use, able to turn in sharp corners, and rugged form. Further analysis and simulation will be applied and all of necessary components will be integrated as the project progresses. A 3D drawing of the proposed design is shown in **Error! Reference source not found.**.

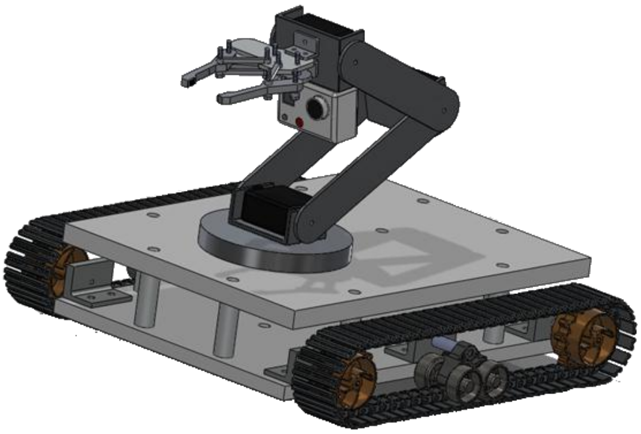
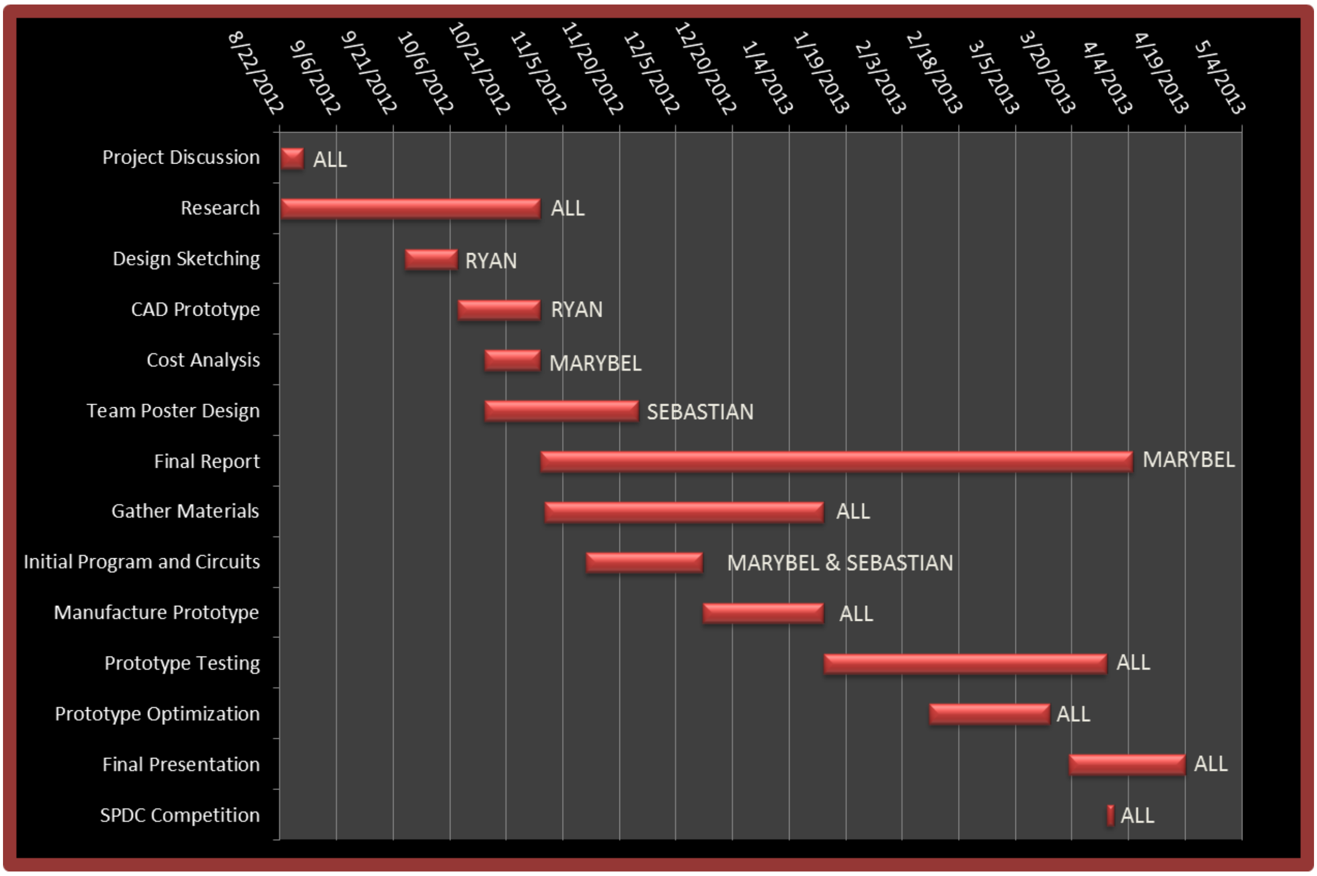


Figure 9 Proposed Design

Timeline

Figure 10 Timeline



The timeline for our project, shown in Figure 10, is shorter than the spring semester due to the date of the actual competition. In past years, the competition has been held in the beginning of April so this is the date we are planning on since the exact date or location for the 2013 event is not yet disclosed.

The approach the team has taken to accomplish the major tasks is mainly a divided team effort. Some tasks will be led by one or the other but each task will have a team input so we are on the same page throughout the entire process.

As things stand, much of the work will be done independently outside of school and then coming together to reflect and modify ideas if needed. Communication of in-process ideas and sharing of literature is being done through email and popular file hosting service, Dropbox. Using these resources will allow the team to work almost as if we were in a single room, increasing teamwork and productivity.

Analytical Analysis

One major component of our project is the robot arm. We need to ensure that our robot arm could carry enough torque as it carries on with its operation. These equations will be used to determine the torque required at any given lifting joint (when the arm moves or rises vertically) of the robotic arm. Not all robotic arms utilized a servo motor, several different actuators can be used such as a pneumatic or hydraulic type.

$$\boldsymbol{T = FL},$$

where T = Torque, twisting or turning force,

F = Force, and *L* = Length.

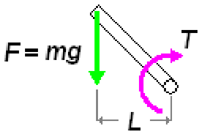


Figure 11 Torque

Force is equal to weight of an object as shown in the Figure 11.

$$\boldsymbol{F_W = mg},$$

where *m* = mass, and *g* = gravity.

Therefore, $\boldsymbol{T = mgL,}$

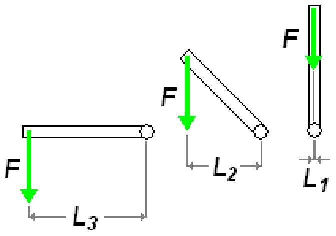


Figure 12 Force due to weight

Figure 12 shows three positions of a link: horizontal, 45 degree angle and completely vertical position. All of these positions are not always expected and, therefore, considered worst case scenario.

Figure 13 shows the summation of torques in each joint, A1, A2, A3 as the actuators and their corresponding weight and lengths.

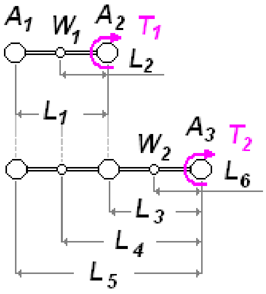


Figure 13 Summation of torques

Doing a sum of torques in link 1,

$$\boldsymbol{T_1 = L_1A_1 + \frac{1}{2}L_1W_1},$$

As you can see, the weight of the actuator 2 is not included as its linear distance and center of mass is zero.

At link 2,

$$\boldsymbol{T_2 = (L_1 + L_3)A_1 + (\frac{1}{2}L_1 + L_3)F_{W1} + L_3A_2 + \frac{1}{2}L_3F_{W2}}$$

The same with the weight of actuator 3, its linear distance is zero.

Another scenario is for the arm to move from a rest position. To solve for this, we use this equation,

$$\boldsymbol{T = I\alpha},$$

where T = Torque, I = Moment of Inertia, α = Angular Acceleration.

To calculate the moment of inertia,

$$\boldsymbol{I = m\frac{r_2}{2}},$$

where r = distance from the center mass to the pivot point in the robot arm.

For n number of actuators, to compute for the moment of inertia, (case by case basis, as the part varies such as hollow, solid, cylindrical or rectangular),

$$\boldsymbol{I_N = \sum_{I=1}^{N-1} I = \frac{1}{2}m_i r_i^2},$$

The required torque required to accelerate the weight being supported by an actuator from a static position can be found using this equation,

$$\boldsymbol{T^a = -\begin{bmatrix} g_{H1}^x & g_{H1}^y & g_{H1} \\ g_{H2}^x & g_{H2}^y & g_{H2} \\ g_{H3}^x & g_{H3}^y & g_{H3} \end{bmatrix} \begin{bmatrix} F_H{}^x \\ F_H{}^y \\ T_H \end{bmatrix}},$$

where F_H^x = Force acting in the *x*-direction at point *H*, F_H^y = Force acting in the *y*-direction at point *H*, T_H = Torque acting on point *H*, g_{Hi}^n = partial derivative of the force in the *n*-direction at point *H* with respect to the reference angle *i*.

Major components

The key components in this project are the Arduino Mega, chassis design, robotic arm, and video feed of the robot. There will be significant amount of time required to learn how to wire, program, and carefully calibrate the hardware to work seamlessly with the Arduino Mega 2560. Since the team is starting from scratch, there is a lot of trial and error projected to take place.

The chassis must be lightweight enough to reduce the size of motors required to move the robot yet heavy enough to anchor it when the robot arm moves. In addition, the plan is to have a very neat looking robot which does not leave wires exposed and cluttered so plans will be made to take that into consideration.

The arm of the robot will be one of the main drivers in how big the rest of the vehicle will be. The placement of the arm along the chassis will depend how heavy the arm physically is due to the danger of tipping when it reaches for the button and sensor. Also, since the arm is planned to have the camera attached to it, it adds more weight and increases the size of motors required to move it.

Caterpillar tracks usually used on tanks provide better maneuverability on diverse types of terrains than regular tire wheels.

In order to efficiently navigate the course, it is imperative that the team employs a camera with quality video output and a large viewing angle. Since the competition is limited to 5 minutes, any time spent getting lost within the course due to poor quality video or too narrow of viewing angle could cost the team number 1 place.

For communication between the operator and robot, the team has chosen to use radio communication. Radio is reliable and consistent regardless of where and under what conditions the robot is being used. More information about the major component can be found in Appendix B. Component Specs.

Cost Analysis

In addition, to the cost of materials for the prototype, there is time invested by each of the engineers in developing ideas; researching competitor’s design, materials, and pricing; sketching conceptual design and drawing the final design; building the prototype; programming and debugging; testing the prototype; and preparing for competitions and class presentations. So far since August, the group has put in approximately 15 hours in meeting discussing potential projects, researching current designs, discussing design concepts and distributing the workload; 5 hours preparing PowerPoint presentations, rehearsing as a group and presenting in the classroom; 8 hours doing researching individually; 5 hours sketching various design concepts; and 20 hours writing, proofreading and editing the report and other documents related to the project. Table 1 Engineering Hoursshows the breakdown of each members contribution to the project and the total hours projected for fall and spring for each member.

Table 1 Engineering Hours

	Hours for Fall			Projected Hours for Spring		
Task	Marybel	Ryan	Sebastian	Marybel	Ryan	Sebastian
Meeting	15	15	15	25	25	25
Research	2	2	4	1	5	5
Presentation	1	2	2	1	3	8
Design	0	3	2	0	6	1
Writing	10	5	5	5	3	3
Building	0	0	0	5	20	20
Programming	0	0	0	20	0	0
Debugging/Testing	0	0	0	8	3	3
Competition	0	0	0	24	24	24
Total per member	28	27	28	89	89	89
Total per semester	**83**			**267**		

Prototype System Description

As the ASME competition specified in their requirements, a mobile robotic arm will be controlled wirelessly and has to travel to a specific path and able to read and capture data via a wireless camera and able to retrieve back and forth a light instrument in an assigned area.

Our prototype will consist of a rover vehicle, which has a caterpillar tracks, the one similarly used in construction, and a good fit either outdoor or indoor terrains. Another part is our robotic arm that could lift and carry parts from one point to another and an integrated camera that will provide as the visuals in controlling the vehicle and obtaining data.

We are using a microcontroller for our prototype that would provide us the control of the vehicle, robotic arm and the camera. We are using a computer to actively display the data coming from the camera as well as driving both the vehicle and moving the robotic arm. Let’s not forget about the wireless method, we will be using radio communication in order to control the vehicle, since it is reliable all around the world under any conditions as long as it is in range.

Prototype Cost Analysis

Our group is self-funding. As a group, we have created a $500.00 budget to buy all the parts and build the robot. In **Error! Reference source not found.**, there s a list of all the materials needed to complete this project, the quantity and prices of each item. The total cost of materials is $459.29, so we are well within our budget. The extra $40.71, we be used for miscellaneous expense such as shipping.

Table 2 Prototype Cost Analysis

Part Description	Quantity	Cost ($)	Total Cost ($)
HDPE Plastic for Chassis	2	$ 18.07	$ 36.14
Tread Kit	1	$ 29.99	$ 29.99
Angle Aluminum	1	$ 16.59	$ 16.59
Aluminum For base spacers	1	$ 9.98	$ 9.98
Hardware (misc.)	1	$ 75.00	$ 75.00
Arduino Mega 2560 R3	1	$ 64.99	$ 64.99
Xbee Explorer	1	$ 24.95	$ 24.95
Xbee Breakout Board	2	$ 2.95	$ 5.90
Xbee Series 1	2	$ 22.95	$ 45.90
Xbee Shield	1	$ 19.95	$ 19.95
High Torque Servo Motors	5	$ 9.99	$ 49.95
FPV Kit	1	$ 79.95	$ 79.95
Overall Total			$ 459.29

Plans for Tests on Prototype

After the robot has been built, a series of test will be performed to debug the program and calibrate each of the robot components and then test the robot as a whole by running simulations. First, robot claw will the tested and calibrated in the program to ensure that it runs smoothly, and at an appropriate speed. Also, this test will show the operator how much pressure is necessary to pick up an object, and if any further adjustments need to be made to the design of the claw in order to be able to pick up objects with more complicated shapes.

Secondly, the robot arm which will have at least 2 motors will be calibrated to ensure smooth movement as the arm rises and falls. At this point, the programmer will decided whether it is best to operate the robot arm using a single command that moves both motors in sync or to control each motor separately using different command for each.

Next, the servo motors and the feedback speed will be tested. The programmer and operator want to verify that the acceleration rate for the robot is neither too slow that it waste time or too fast that it causes the operator to constantly be stopping. The deceleration and stopping time are also important factors so that the robot does not cause more damage to the environment, then what it can fix. Communication lag, microcontroller, video feed and other software will be tested to ensure it works in a timely manner and does not delay in executing commands and relaying information.

Lastly, a practice course will be set up with similar dimension as in the competition and the operator will not be allowed to see the course. This test will show how the robot operates as a whole including all the components. The robot battery will be tested to see how long it can last. The robot will be tested for maneuverability around unknown obstacle and slim path ways as well as picking up objects, carrying them from one place to the other and then, dropping the objects in a specific location. Also, with this simulation, the engineers will test the effects of distance on the feedback speed. This simulation will be run at least 5 times providing new obstacles and path to destination.

Conclusion and Future Work

In this project, our group built a prototype of a robot that can be used in chemical disasters to determine the level of radioactivity at specified locations and inspect for damages, without exposing the human operator to high doses of radioactive contamination. In the future, our group plans to improve the prototype so that it can climb stairs and can maneuver any type of terrains. Also, to present a more competitive product, the group will research ways to improve energy consumption in order to maximize efficiency. Finally, the group will review the budget and consider upgrading visual, sensory and communication equipment.

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Appendices

Appendix A. Engineering Drawings

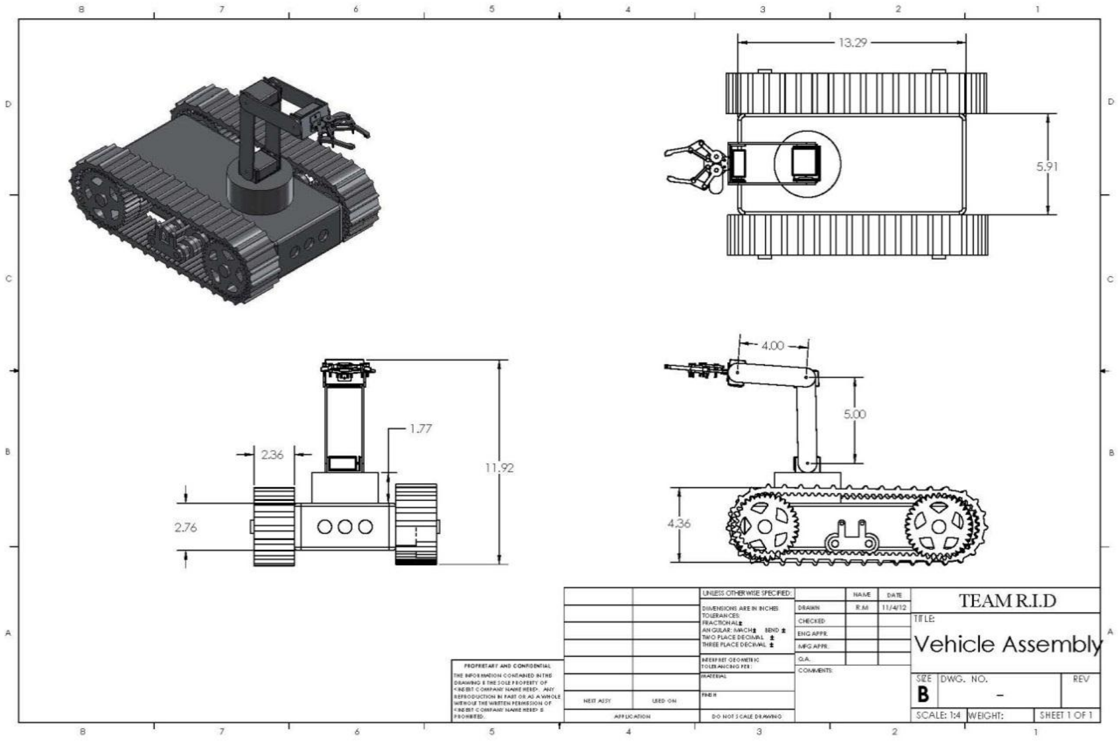

Figure 14 Vehicle Assembly Drawing

Appendix B. Component Specs

HP ProBook 4440s Notebook PC

Overview
Windows 8 Pro or other operating systems available Your Business Partner. Optimized for Windows 8 Pro, these notebooks are ideal for SMBs. They offer multimedia tools, easy-to-use security and a sleek, vertical brushed aluminum casing. Options include two display sizes.

System Features	
Operating system:	Windows® 7 Professional 64
Processor:	Intel® Core™ i5-3210M (2.50 GHz, 3 MB L3 cache, 2 cores)
Chipset:	Mobile Intel® HM76 Express
Featured Model:	SmartBuy

Dimensions and Weight	
Weight:	Starting at 4.55 lb (Starting at 2.07 kg)
Dimensions (w x d x h):	13.35 x 9.27 x 1.1 in (33.9 x 23.5 x 2.8 cm)

Memory	
Memory:	4 GB 1333 MHz DDR3 SDRAM
Memory slots:	1 SODIMM

Storage	
Internal drive:	500 GB 7200 rpm SATA II
Optical drive:	DVD+/-RW SuperMulti DL

Graphics	
Graphics:	Intel® HD Graphics 3000
Display:	14" diagonal LED-backlit HD anti-glare (1366 x 768)

Communications	
Wireless:	Ralink 802.11b/g/n

Network interface:	10/100/1000

Power and operating requirements	
Energy efficiency:	ENERGY STAR® qualified; EPEAT® registered
Power supply:	65W Smart AC adapter; HP Fast Charge
Battery type:	6-cell (47 WHr) Li-Ion
Battery life:	Up to 7 hours 30 minutes

(Hewlett-Packard, 2012).

Arduino 2560 Mega Microcontroller

Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Stronger RESET circuit.

Atmega 16U2 replace the 8U2.

Schematic, Reference Design & Pin Mapping

EAGLE files: arduino-mega2560_R3-reference-design.zip

Schematic: arduino-mega2560_R3-schematic.pdf

Pin Mapping: PinMap2560 page

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V

Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V. This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.

3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND. Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega16U2 USB-to-TTL Serial chip.

External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.

PWM: 2 to 13 and 44 to 46. Provide 8-bit PWM output with the analogWrite() function.

SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.

LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

TWI: 20 (SDA) and 21 (SCL). Support TWI communication using the Wire library. Note that these pins are not in the same location as the TWI pins on the Duemilanove or Diecimila.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().

Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega16U2 (ATmega 8U2 on the revision 1 and revision 2 boards) on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2/ATmega16U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Mega2560's digital pins.

The ATmega2560 also supports TWI and SPI communication. The Arduino software includes a Wire library to simplify use of the TWI bus; see the documentation for details. For SPI communication, use the SPI library.

Programming

The Arduino Mega can be programmed with the Arduino software (download). For details, see the reference and tutorials.

(Mellis, 2011)

ROB-10332 Robotic Claw

This robotic claw arm is great for all your gripping needs. They are made from metal and are pretty heavy-duty. The claw opens to about 2" and depending on the servo motor used, it can pick up some relatively heavy objects. Because the arms move parallel to each other, you get a better grip.

These also have a mounting plate on the bottom which accepts standard spacing found on servo mounts (the extra bits that come with our servo motors). These do not come with a servo motor, so check below, the 'medium servo' is the one that works well.

(SparkFun Electronics).

HS-422 Standard Servo

Size = Standard

Servo Erector Set = ASB-xx Standard Scale line

Range = 180°

Voltage = 4.8 - 6.0vdc

Torque = 57 oz.-in.

Weight = 1.66 oz.

Speed = 0.16s / 60 degrees

(Lynn Motion, 2012).

GoPro HD Naked Hero Camera

Wearable and gear-mountable the GoPro HD NAKED HERO Camera is waterproof to 197', captures professional 170-degree wide angle 720p video and 127-degree semi-wide angle 1080p video plus 5 megapixel photos and has earned a place in history. Whether you're new to GoPro and want the most affordable way to get started or you're looking for a second GoPro to capture your adventures from additional perspectives, the HD HERO Naked is a world famous camera at an incredibly entry-level price.

GoPro HD NAKED HERO Camera:

- Full HD resolution
- 5MP still images
- Takes pictures at 2/5/10/30/60 second intervals or single shot, triple shot or self timer

- Audio excellence
- Rechargeable 1100mAh lithium-ion battery with 2.5 h battery life
- Integrated battery heating system
- Shockproof, waterproof
- Includes 2 adhesive mounts

(GoPro HD NAKED HERO Camera Value Bundle with 16GB SD Card, 2012).

Caterpillar Tracks – Tank Trend Kit

This kit contains over five feet of tank tread designed specifically for the VEX Robotics Design System. Use this tank tread to build robot tracks which can overcome tough terrain, or build a conveyor belt for scooping up objects.

- Climb over obstacles.
- Traverse tough terrain.
- Drive through sandy or soft spongy surfaces.
- Can be used for a robot conveyor belt.
- Every section is a master link, create treads of any length.

Overview

Tank treads will enable your robot to explore much more demanding terrain than ordinary wheels. Tank treads distribute a vehicle's weight more evenly than wheels, allowing your robot to move more easily in sand or on soft, spongy surfaces into which wheels would sink and bog down. This increased surface area also gives your robot more traction for hauling heavy loads up an incline. And because each link can grip the surface over which it's traveling, a robot with tank treads can more easily climb obstacles or traverse crevasses in which wheels would get stuck.

Technical Specifications

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Kit Contents	(170)Tread Links (4)Tank tread drive/idler wheels (4)Double Bogie wheel assemblies (2)Single Bogie wheel assemblies (12)8-32 x 1" Bogie wheel support screws (12)Keps nuts
Downloads & Docs	Inventor's Guide - Tank Tread CAD Models of all motion components can be found on the VEX Wiki.
Compatibility	All VEX Square Shafts 0.125" (3.2mm) Tank Tread Upgrade Kit High Strength Sprocket & Chain Kit Additional High Strength Chain
Material Type	Delrin plastic
Size	Width:1.5" (38.1mm) Wheel Diameter:2.375" (60.3mm) Length:170 Links = 65.5" (1664mm) when laid in one continuous flat section.
Weight	Drive/idler wheels:0.038 lbs each Double Bogie:0.078 lbs each Single Bogie:0.040 lbs each

(Tank Trend Kit, 2012).