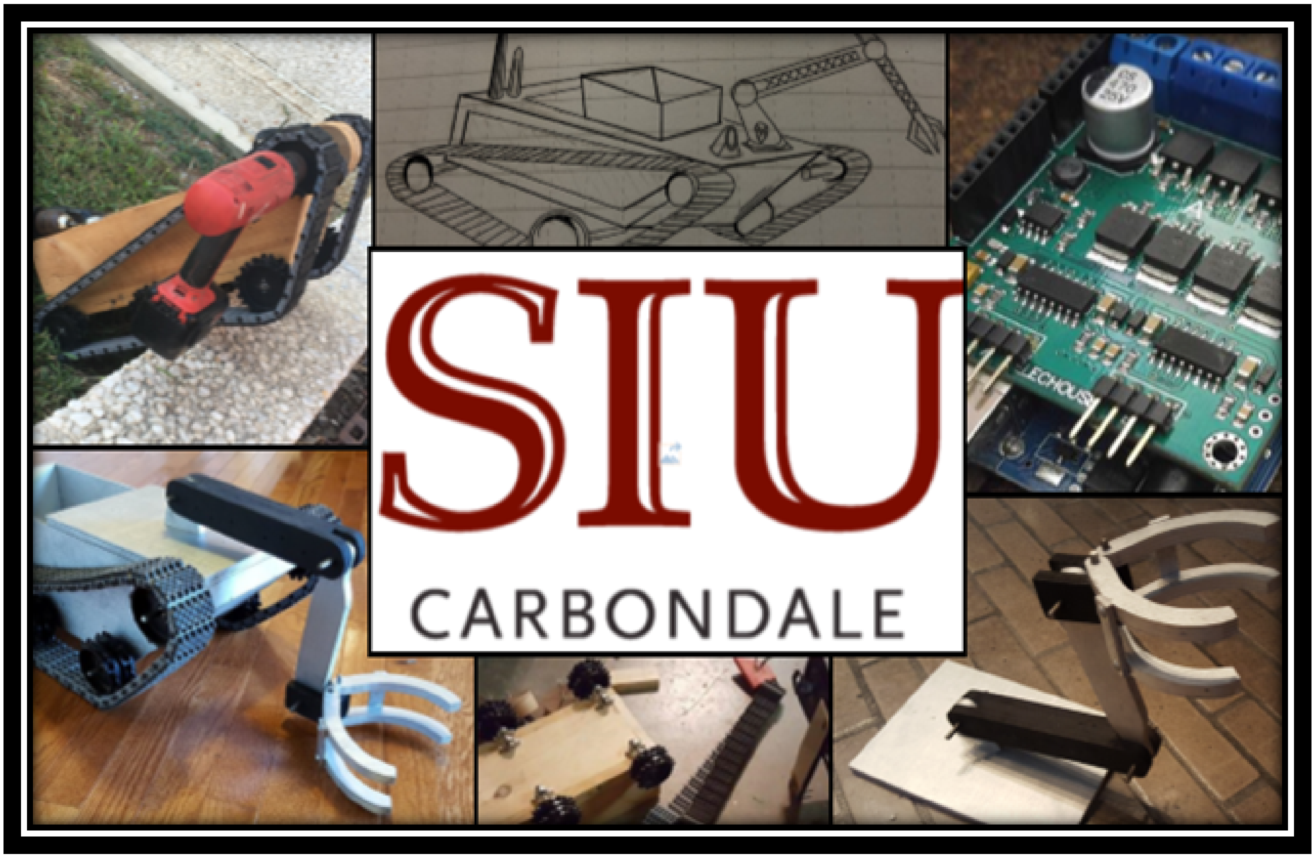

2016-2017
PRELIMINARY DESIGN AND PROPOSAL
BOEING ROBOTICS COMPETITION

SAMUEL MORRIS
SEC #: F16-55-BOE2

Figure 1— Left to right: Caleb Nehrkorn, Jacob Churchill, Matt Crawford, Samuel Morris, Nick Whetstone, Kane Rodriguez, Jonathan Allen, Nick Nezamis, Kyle Walgenbach, and Nathan Brady

Boeing Robotics Design Competition

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Transmittal Letter (KW):

4 November 2016

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Dean Hooks, Senior Manager
Advanced Product Support Program Management
The Boeing Company
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Hazelwood, MO 63042

Dear Mr. Hooks,

On behalf of Team F16-55-BOE2 of the Saluki Engineering Company, we are honored to have the opportunity to be included in the bid to propose a plan to design and build an amphibious, search and retrieval robot. Attached is our proposal, "Boeing Team 2".

We plan to create this robot as a tracked vehicle, able to traverse over a 4 inch square post, over a 6 inch diameter log, through 4 inches of water, and up a 20 degree incline of sand. Constructed with aluminum, its lightweight but strong frame will support and protect the equipment inside. The arm will be able to grab all objects required with ease. The metal detector will raise and lower for easy storage and use, making sure it is out of the way while traversing obstacles. The interface capabilities to move the vehicle will be very user friendly and have a very simple design.

Please feel free to contact me at k.walgenbach@siu.edu with any questions regarding this report. Thank you again for your time and this opportunity. I hope you find this proposal informative and captivating.

Sincerely,

Kyle Walgenbach, Team leader

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A. Executive Summary (KW, SM)

Boeing has created a competition in which two teams from Southern Illinois University Carbondale will compete to design and build an integrated surface vehicle. This vehicle must search for and retrieve cargo in any terrain and should be waterproof to an extent.
This vehicle could be adapted for many things, including remote system maintenance, environmental data retrieval, and things involving hazardous environments. The end design should minimize cost while including systems necessary to complete all the objectives outlined by the competition. Many different mechanical and electrical systems will be integrated into our design including the frame, arm and associated claw, drivetrain, wireless controls, metal detection, and a live video stream.

The robot will be controlled wirelessly through a tablet connected with a Raspberry Pi and Arduino Uno. The tablet will be used to show information about the robot such as motor speeds, servo positions, and a video stream from the camera. Furthermore, the vehicle will be capable of carrying and storing Styrofoam objects using an arm and built-in storage space. With its track drive system, the robot will have no problem traversing obstacles such as a 6-inch tall log, 4 inches of water, loose sand at a 20-degree grade, and flat surfaces. This design is better than others in this competition because of the amount of research and testing being performing on it. Its lightweight and waterproof frame will allow it to efficiently complete all tasks with great success. The final design will be completely operational by the time of the competition in spring 2017.

Successfully completing all of this will allow the robot to earn the following competition points: 20 for size less than 2 cubic feet. 20 for cell phone or tablet control. 20 for picking up every object. 20 for crossing every obstacle. And finally, 20 for a 2-axis camera. Additional points may also be gained if the robot wins the best speed, size, power or weight. Also if the robot is the fastest to locate the metal objects more points will be attained. Currently the project budget is at $696.12 which leaves over $300 contingency.

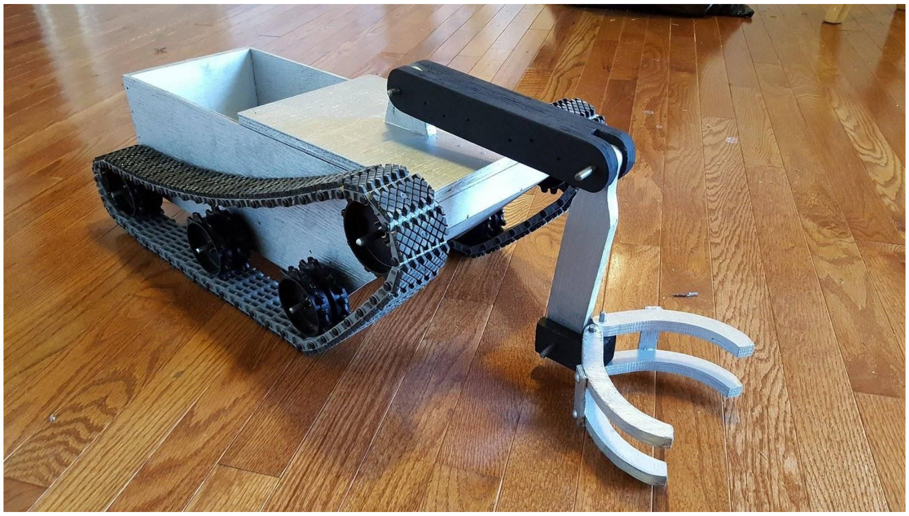


Figure 1 – Design Model

B. Non- Disclosure and Validity Statement (NW)

The contents of this document are confidential property of Saluki Engineering Company (SEC) of Carbondale, Illinois, USA. All content within and directly related to this document must be immediately returned to SEC upon request by SEC. This information may be used for purpose of review only by those to whom this document has been submitted. Neither possessing nor sharing any version of this document in any way grants a right to disclose or use information herein for any reason, whether commercial, educational, or personal. This document and its information may be used only according to terms of agreement explicitly specified and agreed upon by both SEC and any external parties involved.

C. Introduction (SM)

This project proposes a plan to create an all-terrain robot with a variety of sensors and accessories. The design should be practical for both operation and manufacturing. The solution will need to be able to reliably transverse a large variety of terrain. It needs to have the ability to find, capture, and carry objects. It will need to have sensors for both metal detection and video recording. The solution should be light, small, and easy to operate. It is important to find a good design balance for each element. Creating a robot capable of efficiently meeting these requirements will require good teamwork and very careful planning.

A well-designed robot is a sophisticated blend of mechanical, electrical, and computer subsystems. Because robots are dynamic, it is important that the subsystems work well together. Every subsystem must be designed precisely to keep the robot running correctly. If either the electronics or the mechanics are prone to failure the robot becomes unreliable and useless. Creating this will require the design of a complete mechanical system that is light, strong and water-resistant. An electrical system must be designed to work with the mechanics to provide power and sensors to the robot. A computer system must be created to interact with and control the electronics.

The number of robots is steadily increasing due to the wide spectrum of usefulness. Robotics design is a very large branch of engineering, with companies around the world constantly researching new design techniques and applications. Robots are regularly used in many fields, including manufacturing, medicine, and defense. Using robots is becoming more efficient than humans in more and more places. They are very good in fields that require higher precision than humans are capable of. The robot built will be useful in several fields. Robots similar to this are important in bomb disposal where their use saves lives every day. Similar robots are also constructed by NASA as planetary and lunar rovers.

D. Literature Survey (NB, NN, SM)

Past reports were obtained from teams who participated in this design challenge. Six teams built a robot, but none of them succeeded in completing all of the tasks. The designs of the teams varied extensively. While many teams had similar designs, the ones that performed best integrated their subsystems well and thoroughly tested all of the components.

Previous teams have experimented with different control systems, different frames, and different methods of propulsion. The use of treads and the use of wheels have been used with some degrees of success. Designs using the wheeled approach have struggled to traverse the required obstacles. Designs using treads have had trouble with having enough power and having enough tension.

US Patent 3703321 is an expired patent that defines a tensioning system designed to mitigate stress induced tension issues. The patent also discusses different materials for tracks, stating that stress “makes mandatory the use of a highly flexible track, such as one including belts, or of a very strong pin and pad linkage system.” [1].

Another relevant patent is US Patent 5363937, which is for a battery operated tracked vehicle. It specifically defines the use of two separate motors, one for powering each track. It determines that this is an excellent system because “Both the hydraulic and mechanical systems exhibit inefficiencies” [2]. This patent has also expired, nearly ten years ago.

Research on the use of tread systems underwater has already been conducted by the Korea Maritime and Ocean University [3]. The researchers discussed the effects of buoyancy and the losses surrounding working underwater. “When a belt machine is operating under water, there is additional resistance and power loss caused by churning of the water” [3]. It is important to design the power and track system in such a way that it can compensate for these losses.

Studies from Azad University of Central Tehran Branch describe the effects of robot shapes on climbing obstacles. Researchers have analyzed and dynamically tested three different tread configurations. [4]. They determined the maximum obstacle height that a given shape can climb. The Nanjing University of Science and Technology conducted similar research, but they also discussed the effects of a suspension system [5]. These articles have been used to help determine tread shape and properties.

The market for robotics has been accelerating for the past several years. Figure 2 below shows that, according to the International Federation of Robotics in 2015, robot sales increased by 15% to 253,748 units, the highest level ever recorded for one year.

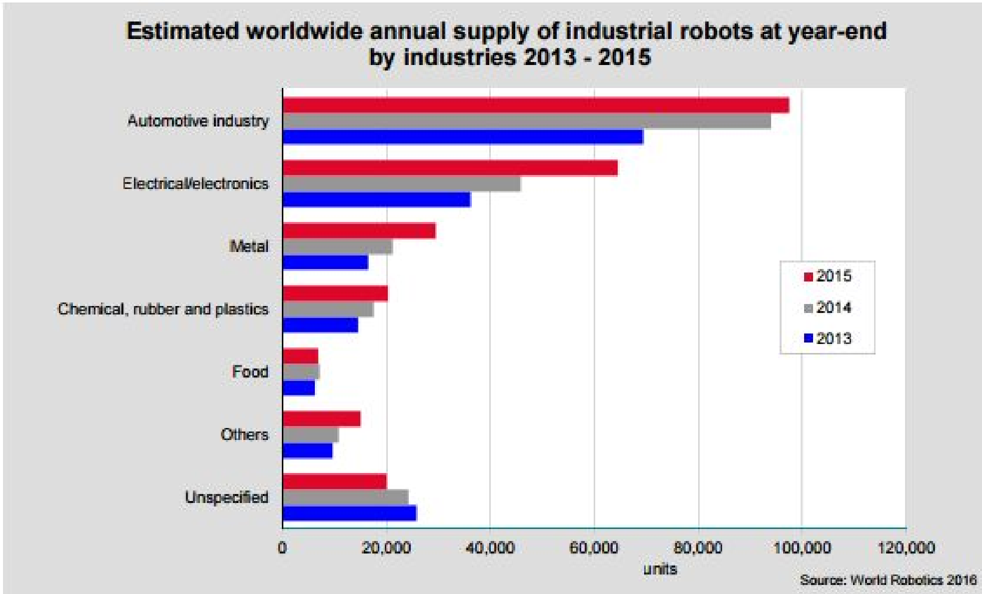


Figure 2- Estimated worldwide annual supply of industrial robots

Available Materials/Design Selection Matrix

Chassis:

The chassis designs varied the most between the past teams. Many different options are available, most of which are not useful. Table 1 below is a list of available materials that will be considered, having a range from 4-1, with 4 being the highest/hardest. All of these resources are commonly available on the market.

Table #1- Chassis Materials List

Table 1:

	Cost	Weight	Ease of Fabrication	Strength	TOTAL SCORE
Aluminum	2	4	4	3	13
Steel	3	1	3	4	11
3D Print	4	2	2	2	10
Polyurethane Foam	1	3	1	1	6

Drive System:

Based on market availability, and previous designs, the drive systems have been analyzed in a few categories. (See Table 2)

Table #2-Drive Systems

	Cos t	Weigh t	Mechanical Complexity	Control Complexity	All Terrain Ability	Steering Ability	TOTAL SCORE
Tracks	2	1	2	2	3	3	13
Wheels	3	1	3	2	1	1	11
Legs	1	1	2	1	2	1	8

Summary

The research from previous teams is very useful for demonstrating pitfalls. Mainly, their research shows that more time needs to be spent testing the product before completion. It also helps to demonstrate the practicality of a tread system. The information combined with the IEEE research will be used to create a treaded robot with improved performance.

Standards Summary

IEEE Standard Ontologies for Robotics and Automation, IEEE Standard 1872, 2004.

IEEE Standard 1872-2015-Standard Ontologies for Robotics and Automation- The purpose of this standard is to provide a methodology for knowledge representation and reasoning in robotics and automation (R&A) together with the core ontology for the R&A domain. The standard provides a unified way of representing knowledge and provides a common set of term definitions, allowing for unambiguous knowledge transfer among any group of humans, robots, and other artificial systems. The standard aims to provide a common vocabulary along with clear and concise definitions from the R&A domain. With the growing complexity of behaviors that robots are expected to perform, as well as the need for multi-robot collaboration and human-robot collaboration, the need for a standard and well-defined knowledge representation is becoming more evident. The standard knowledge representation methodology and terminology:

a) More precisely define the concepts in the robot's knowledge representation

b) Promote common understanding among members of the community

c) Facilitate data integration and transfer of information among robotic systems Information included in this knowledge representation encompasses, but is not limited to, robot hardware and software, activities and goals, environment, cause and effects of performing actions, and relationship among other robots and people. The intended audience for this standard is robot manufacturers, system integrators, robot end users (part manufacturers, automotive industry, construction industry, service and solution providers, etc.), robot equipment suppliers, robot software developers, and researchers/developers.

E. Project Description (MC, CN, KW, KR, NN, NW)

This report includes a full project description, estimated cost, and schedule to build the robot. Design requirements include: maneuvering the robot to drive over a twenty-degree incline of dry sand, drive over a 6-inch or 4-inch square log, and be able to be submerged in 4 inches of deep water. The robotic arm will have a clam-shell type of clamp that will be used to retrieve the Styrofoam ball and placed in the storage unit. For the drive system, a chain and tracks will be used to help the robot's mobility on the ground.

The goal of this project will be to improve on past designs to where it will perform more effectively than the past designs, thereby increasing performance. The following tasks have been accomplished: the drawing of frame designs, manually and through CAD design, obtaining an Arduino and Raspberry Pi, determining the gear ratio for the motor, weight of the chassis and total weight between the chassis and motor, and make approximate measurements made for the aluminum sheet metal chassis. The tasks that still need to be accomplished are ordering the remaining parts, which include a DC servomotor for the power-drive system, metal detector, tracks and chain for the means of maneuverability, and the frame.

The sprints that have already been completed include some of the most important aspects of the design process for this robot. The first sprint was to design and create a CAD model of our frame. The frame is an elementary part of the process with no moving parts associated with it, but it is the backbone of the project as all the other moving parts will be housed and attached to it. From here, the second sprint completed was figuring out the drive system and what kind of torque and gear ratio will be needed to work most effectively with our design. The third sprint contains code to make a user-friendly interface for our Arduino and raspberry pi. This will allow a user to move the drivetrain and any other components with ease. These sprints all play off one another and would be very hard to complete without the completion of the sprint before it.

Work on the different sprints and systems has been a collaborative effort in order to minimize error and create a finished product that works successfully and efficiently. This process helps to correct any misunderstandings or lack of knowledge from one or more individuals in a particular sprint subject matter thus creating a learning environment as well as putting skills to use.

Attached is a diagram of our systems and how they coincide with each other:

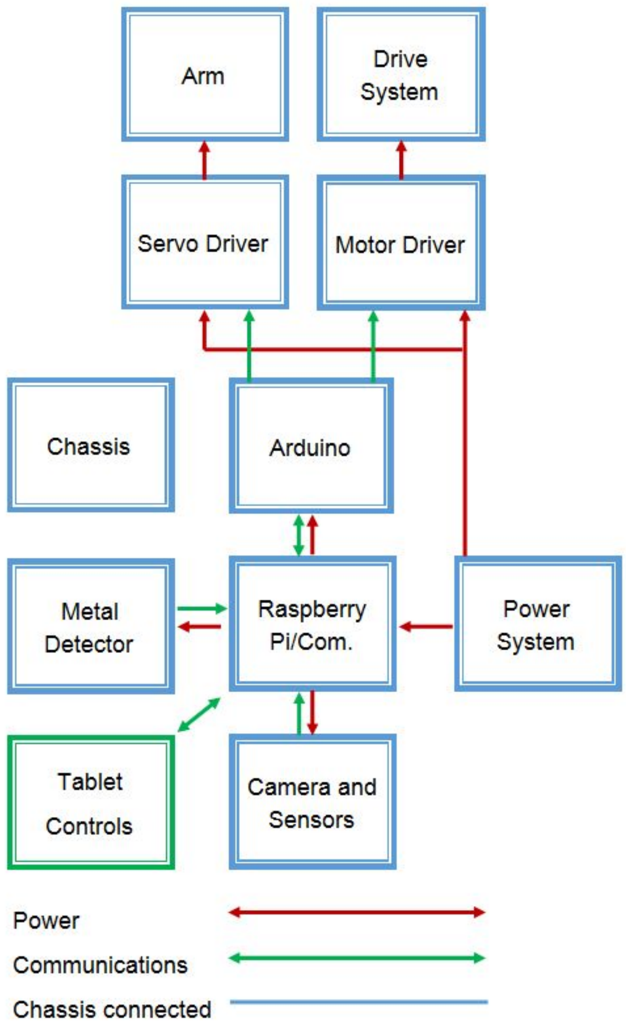


Figure 3 – Block Diagram

F. Design Basis (MC)

Overview

The purpose of this project is to help engage future engineers and help them learn how to work together as a team to solve problems.

- Present a challenging, helpful, and disciplinary project
- Capability of creating innovative and out-of-the-box solutions
- Inspire Systems Engineering and collaborative team approach
- Ability to transition from theoretical aspects to hands-on applications
- Complement the academic curriculum and mission of SIU

- Create a wider range of educational experience
- Help students by teaching them ways to implement designs from any ideas desired

As a challenge, this project will encourage individuals to reach their full potential and become successful engineers. Also, the students will be able to think creatively and critically. This way of thinking will allow them to apply their knowledge to any application they face in life. This process should encourage the following:

- Critical and creative thinking
- Hands-on experience with real life applications
- Convert ideas into design requirements and features
- Effective cooperation and communication as a team
- Understanding the theory and concept
- Ability to resolve conflict

Design Proposal

Included in this document are all the work that has been done up till now and calculations gathered to create an exceptional robot that will meet all of Boeing's standards for this competition. The IEEE standards are taken into consideration and followed, budget proposal is completed and within our designated budget, and all subsystems are mapped out and on their way to becoming finished.

What is proposed is that Boeing team 2 be allowed to continue the work on creating a tracked vehicle capable of maneuvering over all terrains including sand at a 20 degree incline and 4 inches of water, have the ability to grab objects using a camera and a simple retrieval system, as well as detect a buried washer with a metal detector. This will be done with a user-friendly tablet interface coded into a RaspberryPi/Arduino that is attached to multiple batteries to power all the systems.

If permission is given, this robot will complete all obstacles and be able to finish all tasks given to use by Boeing while gathering the most points possible.

Standards Used

1. IEEE 1666-2011 Standard for Standard SystemC Language Reference Manual provides a definition of the SystemC class library. SystemC is an ANSI standard C++ class library for system and hardware design.
2. IEEE C2-2017 National Electrical Safety Code (NESC)®
3. ASTM E2855-12 Standard Test Method for Evaluating Emergency Response Robot Capabilities: Radio Communication: Non-Line-of-Sight Range
4. ASTM E2853-12 Standard Test Method for Evaluating Emergency Response Robot Capabilities: Human-System Interaction (HSI): Search Tasks: Random Mazes with Complex Terrain

5. IEEE 1801-2015 Standard for Design and Verification of Low-Power, Energy-Aware Electronic Systems

G. Subsystem Description (JC, JA, NN, KR, CN, SM)

1. Frame

Definition of Purpose:

The frame will have ample space for the subsystems, as well as being stable enough to hold all of the subsystems.

Constraints on Design

- The frame needs to be waterproof in order to drive through 4 inches or more of water.
- There is no weight limit, but the lighter the robot, the more points awarded.
- The robot cannot exceed 2 cubic feet.

Success Levels

- Frame must be durable enough to withstand testing and competition.
- Thickness will be 1/16 in. throughout.
- Constructed frame will be built to the specified dimensions below with ±0.01 in. for all dimensions.

Design Work

Tools:

- Autodesk Inventor
- Tig welder
- Sheet metal brake
- Plasma cutter

Procedure

Determine best shape for the frame of the robot based off of past projects and robot competitions, prototype, and then build.

Experiment/Tests/Simulation

A prototype has been built and tested. The design of the frame has been adjusted based on the results of those tests.

Calculation

The length of the bottom side was calculated when the top side, the angle between them, and the height were fixed.

Measurements

All of the dimensions of the frame are on the drawing below.

Application of Learned Course Material

ENGR 350A

The stresses applied to the sheets of aluminum while the frame is in motion and moving over obstacles.

ME 477

The knowledge of using Autodesk Inventor in order to build a model of the frame.

Application of Engineering Standards

ASME

Drawings/Tables/Lists

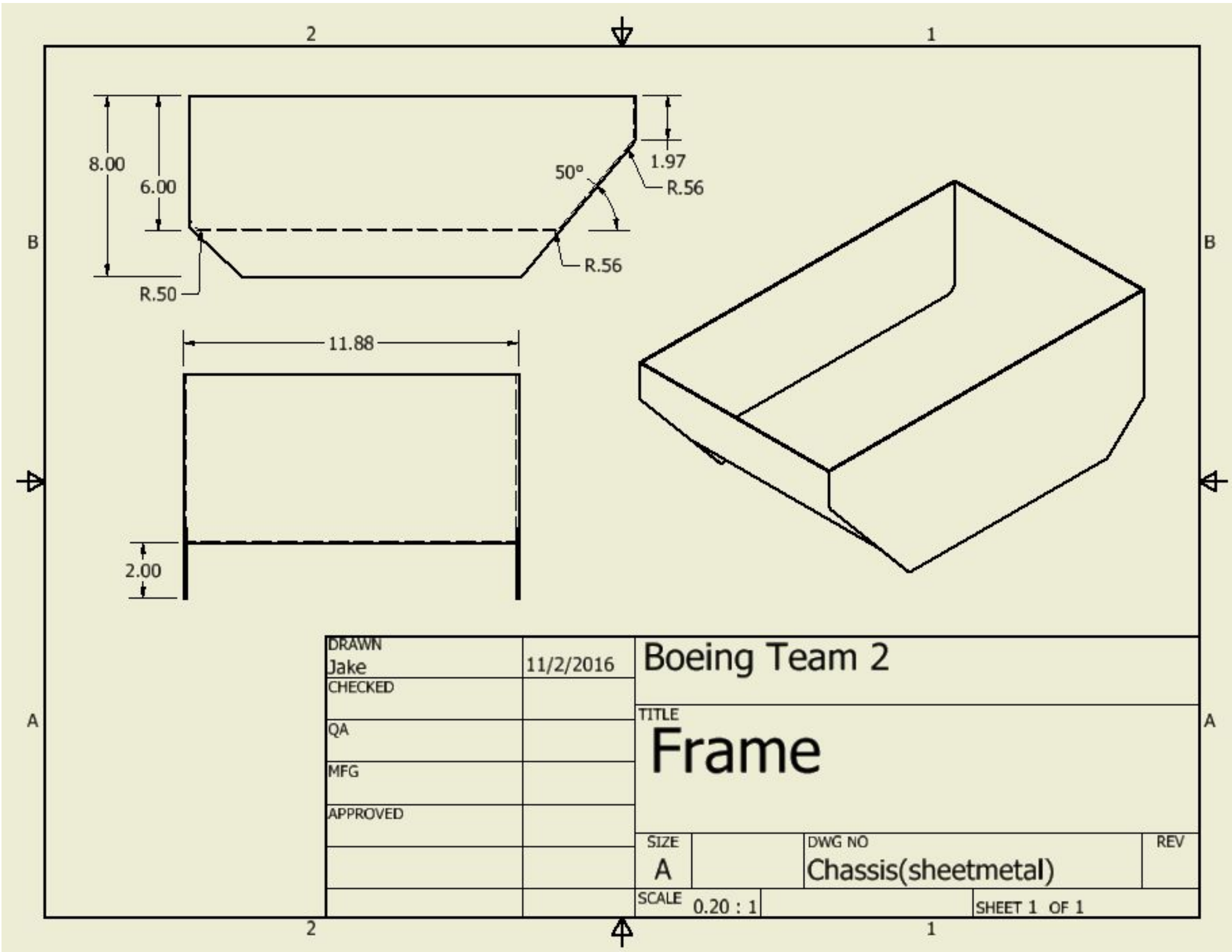


Figure 4 - Frame

Design Activities

Built a basic prototype to test the shape of the frame. Then a design was made on Autodesk Inventor with specific dimensions needed. The design is finalized, unless further problems arise.

Testing Activities

Samuel Morris constructed a wooden prototype. It was powered by a drill and tested driving over an obstacle of 8 inches. The tests were used to optimize the frame and tread shape.

Figure 5 – Testing activity

Subsystem Interaction

Have mounts on the frame that connect to the drive system, retrieval system, sensor system, and metal detection system.

2. Drive System

Definition of Purpose:

The drive system consists of all mechanical and electrical devices that help in the dynamic movements of the vehicle. The motors are essential components of this system as they are connected to drive wheels which drive the tracks.

.

Constraints on Design:

There are no explicit constraints imposed upon the drive system, however, team constraints have been established as to how much power the motors need to pull to successfully achieve maximum efficiency in maneuverability.

Success Levels:

Reach a maximum speed of 4 feet per second

Have the ability to travel up a 20 degrees incline whilst maintaining the speed of 4 feet per second

Be able to travel at a speed of 4 feet per second and taking 1.5 seconds to make a complete stop/accelerate to the top speed in a different direction without making severe damages to the vehicle.

Be able to traverse concrete, dirt, grass, 4 inch water, dry sand, 4x4 and 6x6 inch posts, and a 6 inch diameter log.

Design Work:

Tools:
Metal working tools such as a welder, drill, brake and shear will be used to build most of the drive system.

Procedure:
Research the most effective design for maneuvering over multiple terrains along with required obstacles, prototype and implement.

Experiment/Tests/Simulation:
Field tests have been conducted to observe how our track system withstands the required obstacles. Testing will need to be conducted on the motors to see if they can provide enough power to drive the tracks.

Calculation:
Calculations for torque and power are in Appendix 5.

Measurements:
Tests have been conducted however no measurements have been recorded.

Application of Learned Course Material:

ME 309:
ENGR 261:

ECE 385:

Drawings/Tables/Lists:

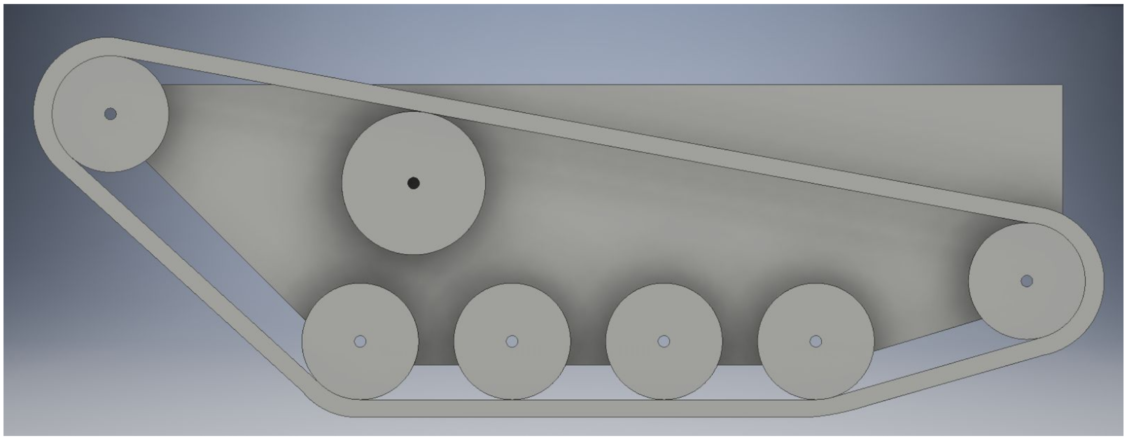


Figure 6 - Cad Model of Drive System

Design Activities:

Ensure track and motor design is capable of moving and powering over multiple terrains and obstacles.

Testing Activities:

Using constructed prototypes, physical tests will be implemented over terrains in individual steps to observe the stability of the system.

Subsystem Interaction:

The motors interact solely with the control system (Reference section E subsection 3 for further detail)

Mobility Calculations:

Simple physics calculations for maximum torque required. Assuming the treads are driven with a 3-inch wheel and the robot weighs 20 pounds. Total force required to lift the robot straight up would be 1.5*20 inch pounds or 2.5 foot pounds. If the robot is traveling up a 20 degree incline the motors will need to provide 2.5*sin(20^{o}) foot pounds of torque or 0.86 foot pounds.

Simple calculations for maximum attainable speed. Assuming a 3-inch drive wheel, the maximum speed will be 3*3.14 inches/revolution. If the motor spins at 198 rpm it will travel at 198*3*3.14/(60*12) = 2.6 feet/sec.

More calculations are shown in Appendix 5.

3. Power System

Definition of Purpose:

Network of electrical components used to supply and distribute electric power to corresponding systems and subsystems. Amplifiers and regulators are integrated into the electrical network to increase, stabilize, or maintain proper voltage, current and power requirements.

Constraints on Design:

Team constraints have been established towards what type of battery is needed in order to achieve the necessary power requirements for the vehicle to perform with the utmost efficiency. Vehicle must run at full power for at least 40 minutes.

Success Levels:

We will have our battery properly charged on the day of competition.
No issues will be present with communication through our network.
The robot will successfully operate at full power for at least 40 minutes.

Design Work:

Tools:
A DC power source was used as a temporary replacement for the testing of other subsystems. Multi-meters and other sensing equipment will aid the development of our power system. Applications such as SolidWorks Electrical will be used to create wiring diagrams.

Procedure:
Research efficient batteries, regulators and amplifiers. Create a well-organized and structured wiring diagram. Implement battery with other subsystems and test performance.

Experiment/Tests/Simulation:
No experiments/tests/simulations have been conducted at this time.

Calculation:
Power requirements have been estimated to ensure the chosen battery can supply all vehicle subsystems with proper voltage and current.

Measurements:
No measurements have been conducted at this time.

Application of Learned Course Material:

ECE 385

Drawings/Tables/Lists:

A wiring diagram will be drawn using SolidWorks Electrical along with power tables and lists indicating details in power distribution.

Design Activities:

Ensure battery is capable of matching the amount of power consumed by each electrical subsystem.

Testing Activities:

Measure and record power consumption of individual electrical subsystems.

Subsystem Interaction:

The power system acts as the head providing proper voltage and current to each electrical subsystem, allowing them to carry out individual tasks and functions.

4. Control System

Definition of Purpose:

Via a well-constructed graphical user interface, the control system wirelessly provides an interface between a user and a Raspberry Pi 3, which, in turn, provides abstraction from the Arduino Uno Microcontroller. The Arduino is the component of the Control System responsible for the controls of the Servo motors and DC motors through a Motor Driver and a Servo Driver.

Constraints on Design

For all code written to handle the communication protocols between Control System components, limitations will be put in place in order to maximize efficiency while taking into account readability and security. The range of motion of Servos and the speed of the motors will be constrained.

Subsystem Interaction

The Control System is at the epicenter of all subsystems. Components of the control system interact with the:

Drive System

With commands received from the user, the Arduino controls both the speed and direction of a specified motor via its manipulation of the Motor Controller.

Metal Detection System/Retrieval System:

The Arduino receives user commands that toggle the positions of the Servo motors that control the positions of the arm of both the metal detector and the retrieval

Design Work

Tools:

The tools used in the Control System were mainly geared toward the development of software. These tools include Integrated Development Environments for both Arduino and Python coding languages. As for the wireless communication between the Raspberry Pi and the User, Putty will be used.

Procedure:

Modularity played a major role in the research and development of the Control System. The design process generally involved: a software/hardware requirement being defined, scouring the internet for resources on solutions to the requirement, planning of the implementation of the solution, implementing the solution, and debugging the solution. This process was repeated with each software/hardware solution building atop of the old, thus providing, *abstraction*.

Application of Learned Course Material

ECE 422:

Knowledge of protocols and packets was utilized when developing the serial communication between the Raspberry Pi and Arduino, and the future wireless communication between the Raspberry Pi and the User.

ECE 321:

Knowledge of C/C++ was used when drafting the code to control the Arduino Microcontroller.

ECE 345:

Laboratory techniques, such as how to use breadboards, DC power supplies, and how to manage the wiring between components, were used for connections between motor/servo drivers and the Arduino.

5. Retrieval System

Definition of Purpose

Mechanical arm that can capture and transfer lightweight objects to a storage container. A retrieval system to pick up a metal washer. This system may be contained within the main mechanical arm.

Constraints on Design

Must be able to grip a 3 and 6-inch diameter Styrofoam ball as well as a 4x4 inch Styrofoam cube. Design needs to be simple with the fewest amount of joints to reduce the power requirement and complexity of the controls. Controls need to be precise and have low latency.

Success Levels

Level 1: Pick up 3-inch ball
Level 2: Pick up 4x4 inch cube
Level 3: Pick up 6-inch ball
A successful retrieval system will be able to lower the arm, pick up the object, and put the object in the container within ten seconds.

Design Work

Only preliminary designs have been discussed and sketched.

Application of Learned Course Material

ME 309:

Analyze mechanisms to determine the velocity, acceleration, position, and force on each link within the mechanism.

ME350:

Mechanics of materials analyses the forces on a material. The stresses will be calculated and used as constraints.

Application of Engineering Standards

Drawings/Tables/Lists

Below is a basic model of what we want our arm to be.

Figure 7 – Prototyped arm

Design Activities

Mechanical arm will be designed that can pick objects up off the ground and put them in a storage area within the frame of the robot.

Testing Activities

No testing has been done at this time.

Subsystem Interaction

Retrieval systems must mountable to the chassis. The objects captured will need to be stored within the frame. The metal detector will need to accurately locate the metal washer and relay the location accurately enough so that the washer can be retrieved.

6. Metal Detection System

Definition of Purpose

The Metal Detection System is vital to the proper detection of the metal washer. Without it, the aforementioned washer would not be available for extraction.

Constraints on Design

Must have low power consumption, and be able to withstand the force from maneuvering over and around obstacles without damaging the coils, or circuit.

Subsystem Interaction

Control System

The metal detector is connected to the Arduino for easier interaction. The Arduino controls the arm, which raises and lowers the detector's induction coil.

Design Work

Tools: The tools to be used in the construction of the metal detector include the following: Digital multimeter, DC power supply, Soldering iron, PCB board.

Procedure: The Metal Detector is based on a Beat Frequency Oscillator (BFO) design, rather than a Pulse Induction (PI) metal detector. From a timely and achievable standpoint, the beat frequency is less complex. Initial construction of the metal detector will be done on a breadboard, for the sole purpose of testing. The schematic used for the metal detector is shown in figure 1. Once constructed, two coils will be made. The first coil being the search coil, and the second coil being the reference coil. The list of components to be used and their quantity is shown in table 1.

Drawings/Tables/Lists

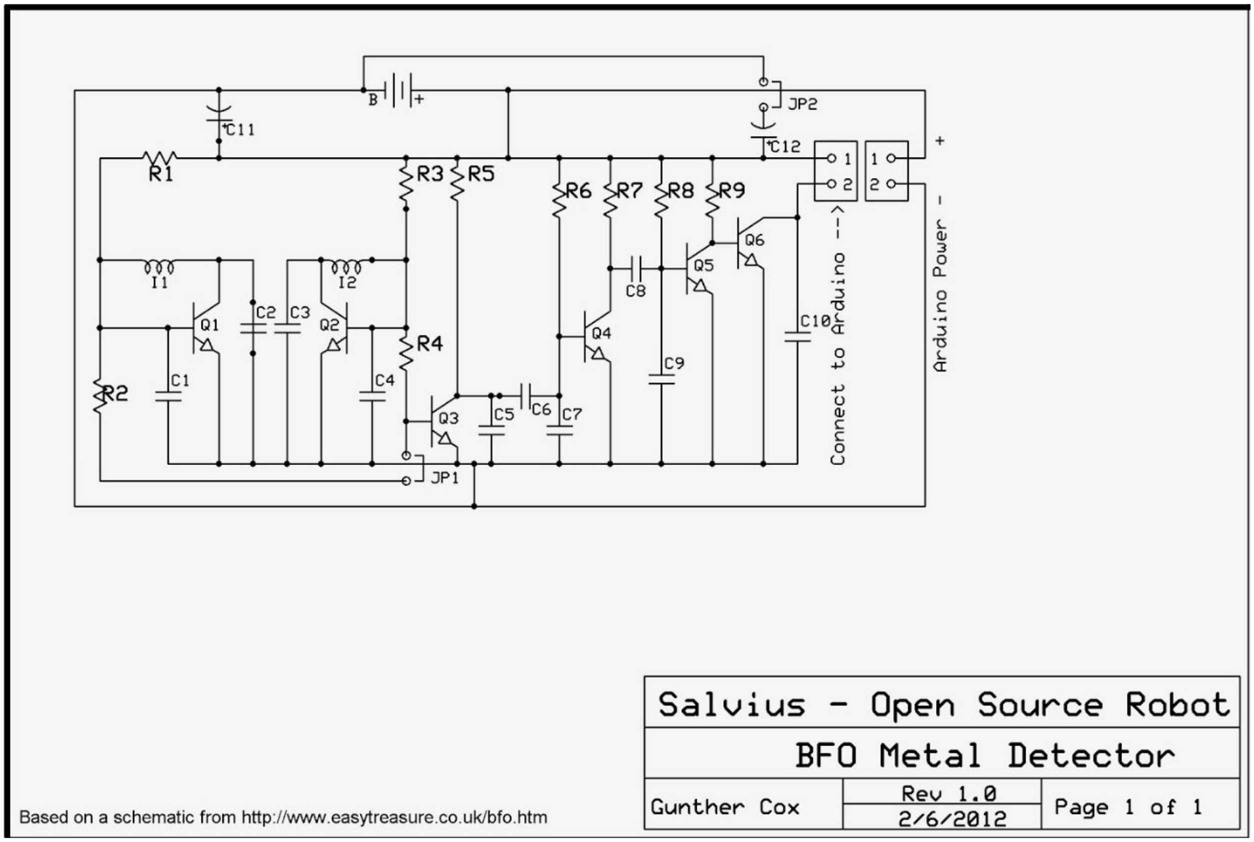


Figure 8 Metal Detector Circuit [7]

Table 3: Metal Detector Components		
Component	**Quantity**	**Price per unit**
220 µF capacitor	2	$0.34
0.01 µF capacitor	5	$0.35
0.1 µF capacitor	1	$0.10
10 kΩ resistor	6	$0.10
2.2 mΩ resistor	1	$0.30
39 kΩ resistor	2	$0.05
2N2222A transistor	6	$0.48
20 AWG wire	1 spool	$7.92

Application of Learned Course Material

ECE 375:

Using laboratory techniques learned to analyze inductance of magnetic fields will be crucial in constructing the metal detector.

H. Conclusion (KW, NN)

As seen, the work that has been done thus far is extensive. The calculations, understanding, and fabrication of certain parts are well underway. The levels of both motivation and dedication within the group are high, and the finished product will meet all standards in accordance with IEEE and The Boeing Company. In order to gain permission to participate in the Boeing robotics competition, outlined below are key benefits concerning this proposal that other teams or competitors may not include:

1. Each sprint will be completed as a team instead of each component being developed by a single individual, allowing for a group understanding and learning environment.
2. Prototyping at a very early stage has proven beneficial in troubleshooting problems with subsystem designs.
3. The organization and structuring concerning project progression using google drive has proven extremely efficient along with incorporating other collaborative platforms such as Github and OneDrive.
4. The way we have established the subsystem arrangement and the timeline to implement them has been beneficial because each sprint ties into the previous so that we move through the design process in a logical and efficient manner.

5. There is a unanimous understanding that maximum productivity is achieved if we all work together as a cohesive unit. To work best together, it is important to understand and get to know each other by incorporating team-wide activities that will boost morale and productivity simultaneously.

Appendix 1. Bill of Materials (KW, JC, SM)

Table 4 – Bill of Materials

Item	Parts Needed	Quantity	Total Cost
1	Raspberry Pi 3 Model B	1	$36.71
2	Raspberry Pi 3 Model B Charger	1	$12.99
3	Aluminum Sheet Metal (36x36)	1	$55.70
4	Stackable Header Pins	4	$6
5	14.8V LiPo Batteries	2	$69.99
6	Voltage Checker	1	$3.23
7	USB A to B Cable	1	$0.87
8	Motor Driver	1	$25.98
9	Electric Motor	2	$118.98
10	XT60 Nylon Connectors	1	$3.10
11	Jumper Wires M/M	1	$1.95
12	Jumper Wires F/F	1	$1.95
13	Dean Connectors	1	$3.68
14	LiPo Battery Charger	1	$14.99
15	Arm	1	$100
16	Metal detector	1	$50
17	Bearings	10	$40
	Shipping Estimate		$150
	Overall Cost		$696.12

Appendix 2. House of Quality (CN)

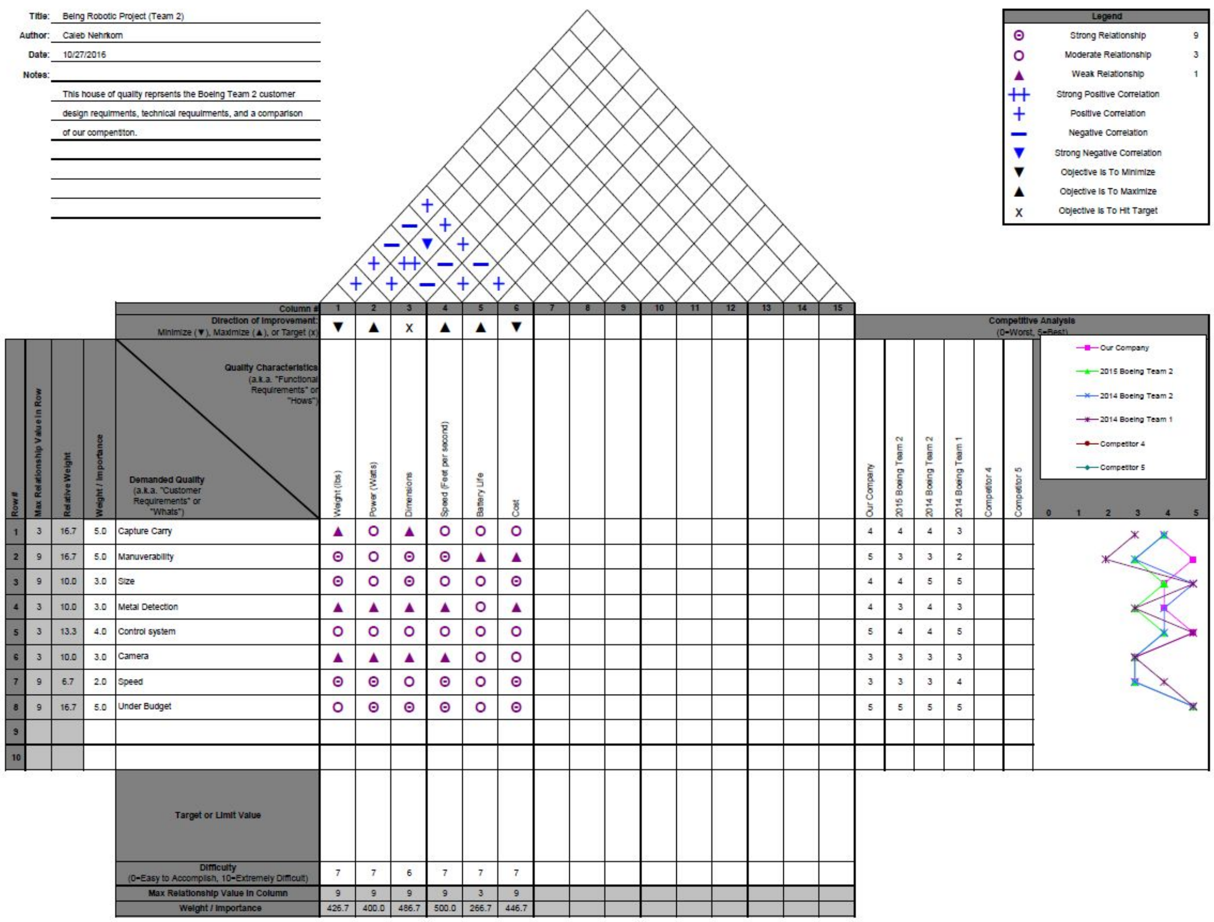


Figure 9 – House Of Quality

Appendix 3 - Block Diagram (NW, MC, KR)

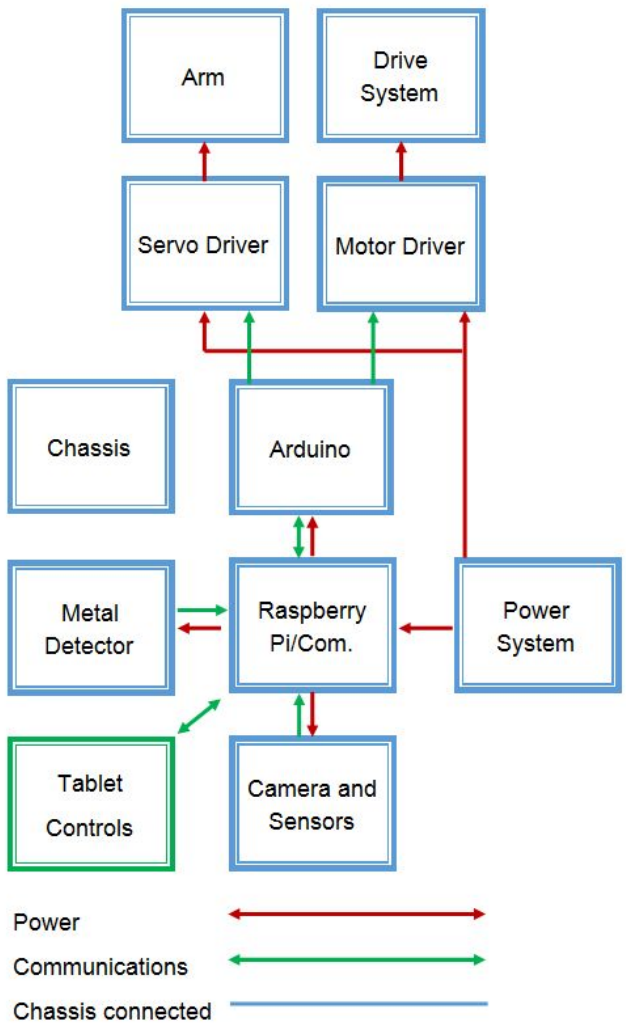
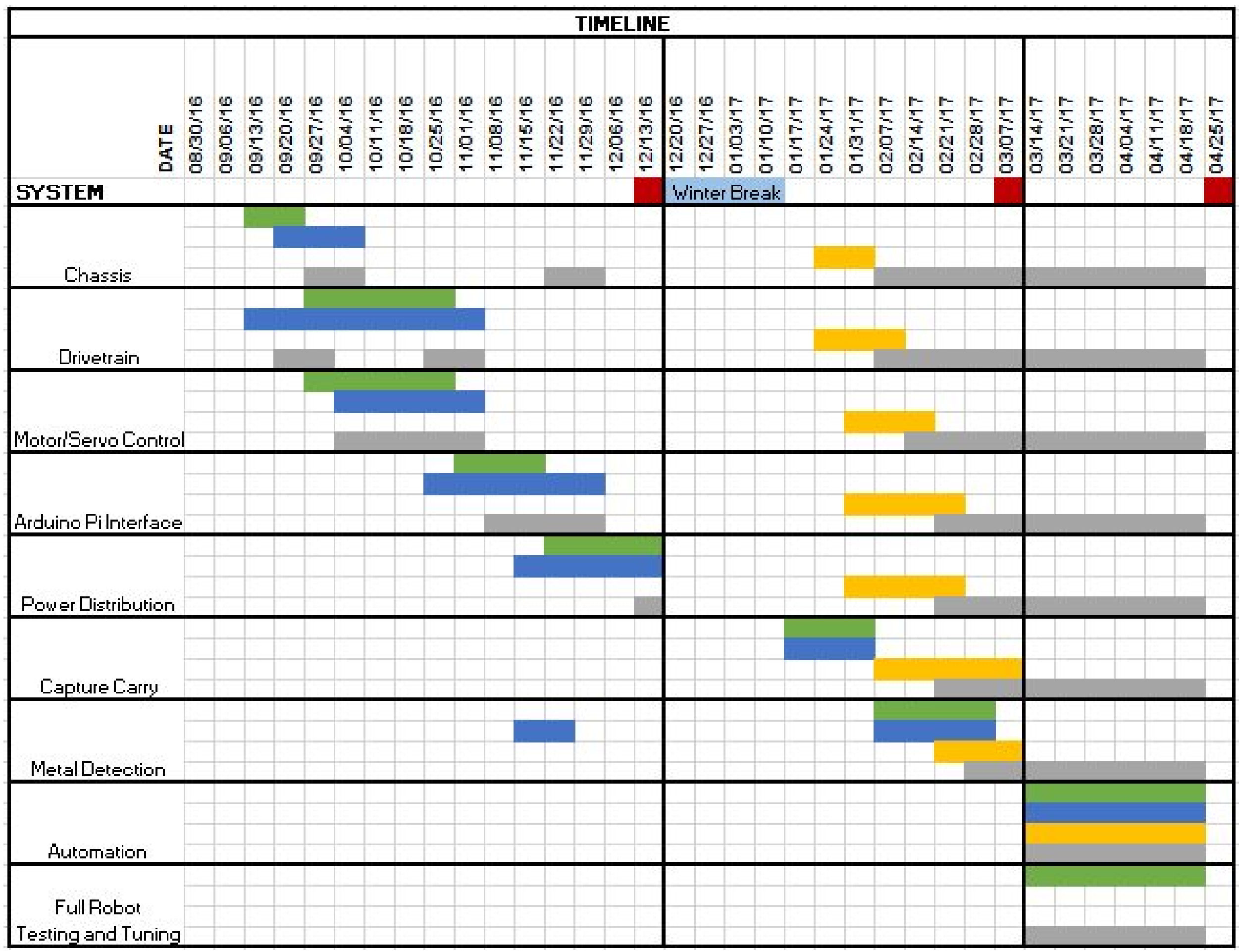


Figure 10 – Block Diagram

Appendix 4. Timeline (KW, NB)

Table 5 - Timeline



Key	
Design Schedule	
Actual Design	
Build	
Test	
Milestone	

Appendix 5. Mathematics (KW)

Table 6 - Calculations

				T= torque					
T= ((a+g*sin(theta))*M*R)/N				a= acceleration					
				g= gravity					
T= (100/e)*((a+g*sin(theta))*M*R)/N				M= mass					
				R= wheel radius					
Total Power (P) =T*w				N= number of drive wheels to determine torque for each drive motor					
				e= efficiency in motor, gearing, and wheel (slip)					
				w= angular velocity					
T= ?							weight(lbs)		
a= 2mph or 3.22kph						20	25	30	35
g= 9.8 m/s			Incline angle(degrees)		20	3.34	4.17	5.01	5.84
M= 20-35 lbs					25	3.74	4.67	5.61	6.54
R= 1 inch or .0254m					30	4.12	5.16	6.19	7.22
N= 1									
theta= 20-30 degrees							Torque needed in N*m (efficiency excluded in these calculations)		
						12"*2"=24 square inches (tread ground coverage)			
						friction coefient of sand=0.6			

Appendix 6. Spring Semester First Sprint (KW)

Sprint Name: Retrieval System and MDS Design

Sprint Goals:

1. Draft a CAD representation of both the Metal Detector Arm and the Retrieval Arm

2. Build the Arms from ordered material

3. Connect the arm controlling servos to the Control System

SMART goals:

1. Both arms will be constructed to within a 1-inch margin of error on the dimensions of their respective lengths and widths

2. Constraints will be put in place to restrict the range of motion of the shoulder and elbow joints of the arms

Product owner: TBD

Scrum Master: TBD

Tasks to do:

Kyle Walgenbach: **1. Research arm design and give input on design.** **2. Plan the construction steps** **3. Help order and build arms from parts** **4. Help with any control coding and incorporation.**
Nick Whetstone: **1. Research how previous teams have designed and implemented their arms.** **2. Write Arduino code for controlling servomotors for arm.** **3. Write Python code to support user controls for the arm.**
Kane Rodriguez: **1. Further develop communication protocols for the User Interface to the Raspberry Pi** **2. Further develop communication protocols for the Raspberry Pi to the Arduino**

3. Develop code for the Arduino that will allow for low-latency control of the multiple servos that make up the arms
Caleb Nehrkorn: **1. Aid in design of arm** **2. Start building and testing metal detector**
Samuel Morris: **1.Work on testing of design.** **2.Determine the shape and number of stepper motors required.** **3.Determine construction process.**
Nathan Brady: **1. Develop servo control** **2. Create wiring diagram and calculate wire constraints** **3. Aid in the design of the physical arm**
Nick Nezamis: **1. Research efficient retrieval system designs** **2. Assist in code for Arduino and Raspberry Pi** **3. Begin constructing wiring diagram.**
Matt Crawford: **1. Help design and create arms in CAD** **2. Order parts needed** **3. Build and test arms/servos**
Jake Churchill: **1. Design and create CAD models for metal detector arm** **2. Help in the construction of arms.** **3. Oversee testing of servos**
Jonathan Allen: **1. Design and create CAD models for retrieval arm** **2. Aid in the construction of arms/ordering of materials** **3. Test servos**

Appendix 7. Arduino Code (KR, NB, NW, NN)

*for control of motors

```
/************************ AUTHOR NOTES ************************
   Please see the attached README for full documentation and
   usage of this code. (NOTE: This has not been made
   available yet, see the following temporary README)
******************** END AUTHOR NOTES *********************/


/************************ README ************************
  Overview:
      This code provides communication between an
      Arduino Uno and the outside world via a serial
      port. Using the given protocols, a user may be
      able to control a wide array of gadgets attached
      to specified pins on the Arduino, such as a Motor
      Driver and a Servo.
  Usage:
      Initialize Motor:
              ---- CREATE OBJECT ----
          The following code initializes a Motor object 'motorA'
          to have the following properties, respectively:
          Motor motorA = Motor('A', 0, 150); // create globally for now
              Motor Name: 'A',
              Motor Direction: 0 (0 => reverse, 1 => forward),
              Motor Speed: 150
              ---- Setup Output Pins ----
          The following code sets the output pins of a motor
          object to the following properties, respectively:
          motorA.setupPins( rpwm, lpwm, en, dis);
      Motor Control:
              ---- Forward and Reverse ----
          The following code toggles the speed and direction that
          the motor travels:
          motorA.reverse(speed); // reverse at a specified speed (sets
direction to 0 if not already set)
          motorA.forward(speed); // forward at a specified speed (sets
direction to 1 if not already set)
              ---- Serial Communication ----
          The following processes a given direction and speed:
             motorA.processCommand(direction, speed);
          For more info on the Serial Communication aspect,
          please see the corresponding code in the 'Process Commands' section
******************** END README *********************/
```

```
/************************ References ***********************
   serialEvent:    https://www.arduino.cc/en/Tutorial/SerialEvent
   object/class:   https://www.arduino.cc/en/Hacking/LibraryTutorial
   stringToInt:    https://www.arduino.cc/en/Tutorial/StringToIntExample
******************** End References **********************/



/******************** General Arduino Functions ************
  pinMode(pin number, output or input)
  digitalWrite(pin number, High or low)
  analogWrite(pin number, speed from 0 to 255)
  delay(time in ms)
**********************End General Arduino Functions*********/



/*********************** Start of Pin Setup ***********************/

// All Motor Pins Initialized within Global Variable Initialization Section

/*
  Extra
*/

const int LED = 13; // test LED


/*********************** End of Pin Setup **********************/

/**************************Libraries**************************/

#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>


/**************************End Libraries**************************/



/*********************** Define Motor Class **********************/

/*
  Motor - Object for controlling motors
  Created by Kane Rodriguez, October 25, 2016.
  Senior Design: Boeing Team 2
*/

class Motor
{
  public:
    // Constructor
```

```
    Motor(char name, int direction, int speed);
    // Destructor
    ~Motor();

    // Get
    char getMotorName();
    int getDirection();
    int getSpeed();

    // Set
    void setMotorName(char name);
    void setDirection(int direction);
    void setMotorSpeed(int speed);

    // Functionality // IMPORTANT: THIS IS WHAT ACTUALLY CONTROLS THE MOTOR

    void setupPins(int rpwm, int lpwm, int en, int dis);
    void processCommand(int direction, int speed);
    void reverse(int speed);
    void forward(int speed);

    // Brake, stop, accelerate, implode, etc. Implement them here

    // consider moving the below variables to a MotorPins object
    int rpwm;
    int lpwm;
    int en;
    int dis;

  private:
    char name;
    int direction;
    int speed;

};

Motor::Motor(char name, int direction, int speed)
{
  // Initialize all of the motor's parameters

  this->setMotorName(name);
  this->setDirection(direction);
  this->setMotorSpeed(speed);

  // consider moving the below variables to a MotorPins object

  this->rpwm = 0;
  this->lpwm = 0;
  this->en = 0;
  this->dis = 0;
}

Motor::~Motor()
{
```

```
  // Nothing to see here... for now ;)
}

// Gets

char Motor::getMotorName()
{
  return this->name;
}

int Motor::getDirection()
{
  return this->direction;
}

int Motor::getSpeed()
{
  return this->speed;
}

// Sets

void Motor::setMotorName(char name)
{
  /*
      name:
          A --> motor A
          B --> motor B
          C --> .......
  */

  // TODO: More/better error checking here?
  if (isalpha(name)) {
    this->name = toupper(name);
  } else {
    Serial.print("ERROR: Motor name must be a single uppercase letter");
  }
}

void Motor::setDirection(int direction)
{
  /*
      direction:
          1 --> forward
          0 --> reverse
  */
  // TODO: More/better error checking here?
  if (direction >= 0) {
    this->direction = direction;
  } else {
    Serial.print("ERROR: Motor direction must be either 1 (forward) or 0
(backward)");
  }
}
```

```
void Motor::setMotorSpeed(int speed)
{
  /*
      speed:
          0 --> 255 (Check Documentation)
  */
  // TODO: More/better checking here?
  if ((speed < 0) || (speed > 255)) {
    Serial.print("Error: Motor speed S must be within the range 0 ≤ S ≤ 255");
  } else {
    this->speed = speed;
  }
}

// Functionality

void Motor::setupPins(int rpwm, int lpwm, int en, int dis)
{
  // set all pins to output

  pinMode(rpwm, OUTPUT);
  pinMode(lpwm, OUTPUT);
  pinMode(en, OUTPUT);
  pinMode(dis, OUTPUT);

  // set all pins

  // consider moving the below variables to a MotorPins object

  this->rpwm = rpwm;
  this->lpwm = lpwm;
  this->en = en;
  this->dis = dis;

  String outputPinsMsg = "";
  outputPinsMsg = outputPinsMsg + "\nrpwm: " + this->rpwm;
  outputPinsMsg = outputPinsMsg + "\nlpwm: " + this->lpwm;
  outputPinsMsg = outputPinsMsg + "\nen: " + this->en;
  outputPinsMsg = outputPinsMsg + "\ndis: " + this->dis;
  Serial.print(outputPinsMsg);

  digitalWrite(this->en, HIGH); // turn enable on
}

void Motor::reverse(int speed)
{
  // if user wants reverse, make the direction reverse

  this->setDirection(0);

  digitalWrite(this->rpwm, HIGH); // reverse
  analogWrite(this->lpwm, speed);
}
```

```
void Motor::forward(int speed)
{
  // if user wants forward, make the direction forward

  this->setDirection(1);

  digitalWrite(this->lpwm, HIGH); // forward
  analogWrite(this->rpwm, speed);
}

void Motor::processCommand(int direction, int speed)
{
  // YOU MUST USE THIS FUNCTION TO CONROL THE MOTOR

  // set parameters
  this->setDirection(direction);
  this->setMotorSpeed(speed);

  // handle direction and speed
  Serial.print("\n Direction");
  Serial.print(this->getDirection());
  Serial.print("\n Speed");
  Serial.print(this->getSpeed());

  if (!this->getDirection()) {
    // direction == 0 => reverse
    Serial.print("\n reverse");
    this->reverse(speed);
  } else {
    Serial.print("\n forward");
    this->forward(speed);
  }
}

/******************* End Motor Class Definition ********************/



/******************* Initialize Global Variables *******************/

// for servos TEST

Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver();

#define SERVOMIN  150 // this is the 'minimum' pulse length count (out of 4096)
#define SERVOMAX  600 // this is the 'maximum' pulse length count (out of 4096)



// Initialize Pi Communication Variables

String userCommand = "";         // a string to hold incoming user command
boolean commandComplete = false;  // indicate whether the command is complete
```

```
// Initialize the two Motors

/*
    motor A pins (subject to change)
    rpwm    => 3;
    lpwm    => 5;
    en      => 2;
    dis     => 4;
*/
Motor motors[] = {
  Motor('A', 0, 0),
  Motor('B', 0, 0),
  Motor('Z', 0, 0)
};

// TODO: Change this back to an int after development is over.
// Using sizeof() so we don't forget to change the int when
// when we add/subtract motors to/from the list.
const int motorCount = sizeof(motors) / sizeof(motors[0]); // size of all
objects / size of 1 object = number of objects

// Motor motorA = Motor('A', 0, 0);

/*
  motor A pins (subject to change)
*/



/************** End Global Variable Initialization ****************/



/*********************** General Setup **********************/


void setup() {

  // change for later
  int aPins[] = {3, 5, 2, 4};
  int bPins[] = {9, 10, 2, 4};

  for (int i = 0; i < motorCount; ++i) {
    if (motors[i].getMotorName() == 'A' ) {
      motors[i].setupPins( aPins[0], aPins[1], aPins[2], aPins[3]);
    } else if (motors[i].getMotorName() == 'B') {
      motors[i].setupPins( bPins[0], bPins[1], bPins[2], bPins[3]);
    }
  }

  // initialize serial:
  Serial.begin(9600);

  // setup LED
```

```
  setupOutputPins();

  // reserve 200 bytes for the userCommand (consider lowering):
  userCommand.reserve(200);

  delay(3000);


  // setup servos TEST

  pwm.begin();
  pwm.setPWMFreq(60);  // Analog servos run at ~60 Hz updates


  yield();
}

void setupOutputPins() {
  pinMode(LED, OUTPUT);
}


/*********************** End General Setup ***********************/
```

```
/**************************** Main **********************************/

void loop() { // main
  // the SerialEvent that listens for incoming command is called with each
iteration of this loop

  if (commandComplete) {

    // ACK the recently received command back to the user.

    String response = "\n\n\nYou commanded: " + userCommand;
    Serial.println(response); // print command back to caller to verify that it
was called

    // Process the command

    processUserCommand(userCommand);


    // clear the command
    userCommand = "";
    commandComplete = false;
  }

}

/**************************** End Main **********************************/



/*************************** Process Commands **********************/

/*
    Protocol for Received Initial Commands:
    |*************************************************************************
|     command MSB1    |   [Packet DATA]
|     Type of Command     Data for Command
|*************************************************************************

Protocol for Received Motor Commands:

|*****************************************************************************
|       command MSB1    |   command MSB2     |    command LSBs
|       MotorName       |   MotorDirection   |    MotorSpeed
|
|       There are 3 Possibilities:
|
|   Command Length is 5:    A0255   => Motor = A; Direction = 0; Speed = 255;
|   Command Length is 4:    A125    => Motor = A; Direction = 1; Speed = 25;
|   Command Length is 3:    B02     => Motor = B; Direction = 0; Speed = 2;
|
|   Command Length > 5 || < 3 will be ignored
|*************************************************************************/
```

```
void processUserCommand(String command)
{
  // implement a lookup table (switch/case statement) later on for different
commands.

  if (command[0] == 'M') {
    command.remove(0, 1);

    processMotorControlCommand(command);
  } else if (command[0] == 'S') {

     // This is test code for the Servos

     // implement error checking in the future

        float tensPlace = ((int)command[1] - 48)*10;
        float onesPlace = ((int)command[2] - 48);

        float percentage = (tensPlace + onesPlace) / 100;
        float difference = SERVOMAX - SERVOMIN;
        float position = difference * percentage + SERVOMIN;

      /*
         You might be asking, what just happened? Well:

From the users command, we converted two of the places of their sent string to
integers, then manipulated them to represent a number between 0 and 99. Then
we:

-Converted the user command to a percentage
-Took the difference between the maximum allowable servo position and minimum
-Multiplied the percentage by the difference and added the minimum

 Therefore, we will never go ABOVE the MAX or BELOW the MIN

      */


        Serial.print(position);
          pwm.setPWM(0, 0, position);


  delay(500);



    Serial.print("\nYou are using a servo, not a motor!\nThe servo code will be
implemented instead of the motor code");
  } else if (command[0] == 'L') {
    digitalWrite(LED, HIGH);
  } else {
    String errorMsg = "";
    errorMsg = errorMsg + "\nWarning: " + command[0] + " is not available
operation.";
```

```
    Serial.print(errorMsg);
  }
}

void processMotorControlCommand(String command) {
  // TODO: Error checking

  // see above for Command Protocol Format

  // Check Command Length

  if ( command.length() > 5 || command.length() < 3 ) {
    // ignore
  } else {
    // acceptable length

    String tmpCommand = command; // save this for later debugging

    // motorName and motorDirection are the first two characters in the string


    char motorName = command[0]; // MSB1

    int motorDirection = int(command[1]) - 48; // MSB2     // see if this works

    // motorSpeed is either 1 bit or 3 bits so...
    int motorSpeed = 0;

    // the 2 msb's are already saved, we will now evaluate the speed so

    command[0] = '0';
    command[1] = '0';

    motorSpeed = command.toInt(); // 'xxx00' => xxx00 // REMINDER: We access
strings differently. The first 2 letters are the MSB's (00 now)

    motorSpeed >> 2; // right shift by 2 locations (Chop off those first 2
letters that we made 0)

    // process the command for the motor
    // motorA.processCommand(motorDirection, motorSpeed);
    int i = 0;
    for (i = 0; i < motorCount; ++i) {
      if (motors[i].getMotorName() == motorName) {
        motors[i].processCommand(motorDirection, motorSpeed);

        // Send the motor info to the Pi
        String parsedCommand = "";

        parsedCommand = parsedCommand +  "\n ---------";
        parsedCommand = parsedCommand +  "\n Motor: " +
motors[i].getMotorName();
        parsedCommand = parsedCommand +  "\n Direction: " +
motors[i].getDirection();
```

```
        parsedCommand = parsedCommand +  "\n Speed: " + motors[i].getSpeed();
        parsedCommand = parsedCommand +  "\n ---------";

        Serial.print(parsedCommand);
      }
    }

    // perhaps do some error checking if the motor could not process the
direction and speed?

  }
}


/*************************** End Process Commands **********************/



/************ Communication with the Pi ***************/

/*
  SerialEvent occurs whenever a new data comes in the
  hardware serial RX.  This routine is run between each
  time loop() runs, so using delay inside loop can delay
  response.  Multiple bytes of data may be available.
*/

void serialEvent() {
  while (Serial.available()) {
    // get the new byte:
    char inChar = (char)Serial.read();
    // add it to the inputString:
    if (inChar != '~') {
      userCommand += inChar;
    }
    // if we recieve a tilde, we are done with the current command (CONSIDER
CHANGING)
    if (inChar == '~') {
      commandComplete = true;
    }
  }
}

/************ End Communication with the Pi ***************/
```

Appendix 8. – Raspberry Pi Python Code

Code for Pi to Arduino Interaction to be completed.

Appendix 9. References (SM, CN)

[1] R. H. A. Schoonover, "Track assembly for tracked vehicles". US Patent 3703321, 31 July 1970.

[2] J. M. Elmer, "Battery operated tracked vehicle". US Patent 5363937, 19 October 1992.

[3] M. T. Vu, H.-S. Choi, J.-Y. Kim, D.-H. Ji, Y.-J. Lee and D.-H. Choi, "A study on underwater track vehicle system," in *Control, Automation and Systems*, 2015.

[4] A. H. Rajabi, A. H. Soltanzadeh, A. Alizadeh and G. Eftekhari, "Prediction of obstacle climbing capability for tracked vehicles," in *Safety, Security, and Rescue Robotics*, 2011.

[5] Y. Zhou and X. Wang, "Obstacle performance simulation of tracked vehicles based on the ADAMS/ATV," in *Transportation, Mechanical, and Electrical Engineering*, 2011.

[6] "Executive Summary World Robotics 2016 Industrial Robots," in *International Federation of Robotics*, 2016.

[7]"Build a Simple Robotic Metal Detector", *blog.salvius.org*, 2016. [Online]. Available: COX, G. Build a Simple Robotic Metal Detector In-text: [1] Your Bibliography: [1]G. Cox, "Build a Simple Robotic Metal Detector", blog.salviuis.org, 2016. [Online]. Available: http://blog.salvius.org/2012/02/build-simple-robotic-metal-detector_15.html. [Accessed: 01-Nov- 2016].

[8]"Metal Detectors - Theory and Practice - VLF, PI and BFO Schematics", *Hobby-hour.com*, 2016. [Online]. Available: http://www.hobby-hour.com/electronics/metal_detectors.php. [Accessed: 01- Nov- 2016]

IEEE Standard Ontologies for Robotics and Automation, IEEE Standard 1872, 2004.

Further research was obtained in the form of previous company reports.

Appendix 10. External Communications (NW, SM)

Boeing Team 2 members,

I've read the ME members submissions for project name and writing sample. Feel free to share the comments I made with other team members. I liked the one team member that I thought gave a good introduction to the project, such as what the robot is intended to do, etc.

I would be happy to give some advice about previous team's downfalls and what could be better. Come see me if you want I'll try summarize (feel free to share with ECE students on the team also).

1. The one robot that worked well would not stop doing a command until it received another command. When it got close to a ball it could not stop in time (the next command came too late) to be in front of the object to pick up. I think there could be 2 modes of driving. One mode it drives until it receives another command when it is far away from the object, another mode it receives a command with a length of time to do that command (0.5 seconds etc.).

2. It always seems like motors are not powerful enough to do the job. I know you can't buy too large of motors but things always seem to need more power than they say they will need.

3. Too heavy is not good but some weight is good it gives traction. One team made a vehicle with 4 wheels but it just slipped on the sand. If it had more weight it would have been better. I really think a tracked vehicle is best.

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618-453-7016, -7658 fax

Appendix 11. Resumes

Nathan T. Brady

nathantb@siu.edu
815-670-4366

Education:

Southern Illinois University Carbondale: — Aug. 2012 - May 2017

- Pursuing Bachelor of Science in Automotive Technology
- Pursuing Bachelor of Science in Electrical Engineering
- SIUC Saluki Academic Scholarship, Ed Wright Memorial Scholarship, Omron Electronics Scholarship, Bakerywala Electrical Engineering Scholarship, theFranaGroup Scholarship
- Cumulative GPA: 3.8/4

Wisconsin Aviation Academy — July 2011 - Mar. 2012

- Studied aviation flight, obtained Private Pilot Certificate March 16, 2012

Work Experience:

Student Worker at Mining and Mineral Resources Engineering Office — Oct. 2013 - present

- Assist in office duties such as accounting and supporting professors
- Provide excellent customer service to callers and guests

Student Worker at the Transportation Education Center — Summer 2015, 2016

- Helped with summer projects such as resurfacing floors in labs
- Cleaned and maintained automotive/aviation labs, classrooms, and offices

Tutor with Saluki Achieve Program — Oct. 2013 - Jan. 2014

- Tutored a student with a learning disability in the automotive program

Internships/Externships:

Internship with Carbondale City Garage — June 2014 – Oct. 2015

- Install custom police equipment and create custom wiring in new police vehicles
- Maintain all city vehicles including lawn mowers, street sweepers, fire trucks, etc.

Externship with Boeing: Defense, Space, and Security in St. Louis — Spring Break 2015

- Received in depth overview of F18 and F15 fighter jets' diagnostic software and hardware development and testing
- Increased leadership skills through personal leadership training and career development activities

Externship with Power Solutions International — Spring Break 2014

- Explored the customer support and maintenance requirements after the sale of an internal combustion engine
- Worked with customer support engineers to diagnose returned (faulty) engines in lab (both propane and CNG)

Skills, Activities, and Interests:

SIUC Marching Salukis Drumline (Section Leader 2015, 2016) — 2012-present

SIUC Formula SAE Racing Team (Vice President, Shop Manager/Chief Fabricator) — 2015-present

SIUC Pep Band — 2013-present

SIUC Men's Club Soccer Team — 2013-present

Soccer Referee — 2009-present

ASE Certified (A1, A4, A5, A6, A7, A8), Mobile Air Conditioning Society Certification

Projects: Boeing Robotics Competition, Formula Race Car, Electric P.T. Cruiser

CALEB NEHRKORN

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Elkville, Illinois 62932
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Calebn9@gmail.com

OBJECTIVE

Obtain an entry level electrical / computer engineering position in a company that will benefit from my experience, education, and design ability to improve projects and processes.

EDUCATION

Bachelor of Science in Electrical Engineering & Computer Engineering, January 2014- May 2017
Southern Illinois University, Carbondale, Illinois

Relevant Courses:

Digital Circuits Design	Programmable ASIC Design
Digital VLSI Design	Electric Circuits
Signals and Systems	Electromagnetic Fields
System and Control	Computer Organization & Design

Senior Design Project: Competed in the Boeing robotic contest, which required a design that could capture & carry, maneuver over obstacles, detect buried objects, and controlled by a phone or tablet.

SKILLS

- C / C++
- Verilog
- Matlab
- Basic MIPS
- Circuit construction
- Microsoft Office
- Fork Lift operation

CERTIFICATIONS

Underground Mining
Surface Mining

WORK EXPERIENCE

Summer Engineering Casual, Consol Energy, Oakwood, VA **May 2014-Aug. 2014**

- Learning various day-to-day operations of a coal mine
- Underwent mine rescue scenarios
- Categorized and stocked parts

Team Member, Tazz Conveyor Corporation, Tazewell, VA **Sept. 2006 – Dec. 2013**

- Operated roller assembly line
- Operated paint assembly line
- Loaded orders
- Welding
- Assembled Structure

Jacob Churchill

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Permanent Address:
19252 White Pine Ln
Petersburg, IL 62675

Carbondale Address:
600 E Campus Dr
Carbondale, IL 62901

Summary

- Dean's List in Fall 2013, Fall 2014, Spring 2015, Fall 2015 and Spring 2016
- GPA: 3.4
- Skills include: Microsoft Office, PTC Creo, SolidWorks, Autodesk Inventor

Education

Bachelor of Science in Mechanical Engineering & Energy Processes, Spring, 2017
Southern Illinois University Carbondale, Carbondale, IL 62901
G.P.A. 3.4/4.0
Relevant Courses

- Mechanical Engineering Design, Material Selection for Design, Controls

Experience

Mechanical Engineering Intern for Henry Technologies in Chatham, IL: Summer 2016

- Evaluated and identified new torque specs, nominal dimensions, tolerances, and causes of waste for a series of packless valves.
- Audited routings and edited them for correctness and consistency.

Machine Operator for Monsanto in Mason City, IL: Seasonal 2013-2015.

- Maintained seed production equipment/machinery.
- Operated forklifts and machinery.
- Communicated with coworkers to complete the tasks.

Volunteer for The Methodist Church in Petersburg, IL: 2010-2013.

- Assisted with yard work, charity events, and church services for the community.
- Participated with mission work within the USA for one week every year.

Honors and Awards

- Dean's List in Fall 2013, Fall 2014, Spring 2015, Fall 2015, and Spring 2016.
- Academic Scholarship

Activities

- SIU Rover Design Team: Fall 2015-present

Skills

- Microsoft Office
- PTC Creo
- SolidWorks
- Autodesk Inventor

Matthew Crawford

401 East Murray Street

Sesser, IL 62884

Email: cardsfn_5@yahoo.com

crawfordm0216@siu.edu

Phone: (618)513-3221

Education

- **Southern Illinois University Carbondale**, IL
    - Bachelors of Science in Mechanical Engineering, May 2017
    - Overall GPA: 3.6/4.0
- **Rend Lake College** Ina, IL
    - Associate Degree in Engineering Science, May 2015
    - Associate Degree in Arts and Science
    - President's List

Technical Skills

- Mathematics: Algebra 1, Algebra 2, College Algebra, Calculus 1, Calculus 2, Calculus 3, Differential Equations, Numerical Methods, Intro to Microeconomics
- Mechanical Engineering and Energy Processes: Electric Circuits, University Physics, Statics, Dynamics, Mechanics of Materials, Material Science, Fluid Mechanics, Thermodynamics
- Programming Experience: Intro to Programming (C++)

Engineering Experience

- Involved with running a full scale Dynamometer in one of the engineering labs on campus.

Additional Work Experience

- Currently work at Lowe's Home Improvement Warehouse in Mt. Vernon, IL
- Positions held are Lawn and Garden Associate and Facility Service Associate
- Worked as a part-time volunteer with community tasks (odd jobs)
- Helped as a part-time tutor in my community and high school Sesser, IL

Leadership and Team Experience

- Played basketball in 2004 during my fourth grade
- Played summer baseball from 2001-2008
- Page in Youth and Government from 2008-2010

- Committee Chair in Youth and Government from 2010-2012
- Math Team member from 2009-2010
- High school office worker from 2009-2010
- Attended Camp Hope as a counselor from 2010-2012, Ewing, IL
- Scholar Bowl member from 2010-2013
- Member of National Honor Society from 2011-2013
- Performed in theatre in the years of 2009 and 2013
- Played high school baseball at Waltonville, while attending Sesser-Valier High School from 2010-2013
- Played high school football from 2010-2011
- Attended Church Training Service (CTS) competition from 2007-2013

Kyle Walgenbach

422 Maves Dr. Batavia Illinois, 60510

Cell: (630) 465 4683 k.walgenbach@siu.edu

Objective

Seeking an entry level job in the Computer and/or Electrical Engineering field to develop/improve any software or hardware, or work on any other system that involves this field.

Education

Southern Illinois University (SIU), Carbondale, Illinois
Bachelor of Science in Electrical and Computer Engineering with a minor in Math, May 2017
GPA 3.42/4.0

Relevant Coursework

- Senior Design (Boeing Robot)
- Software Engineering
- Digital Logic
- Signals and Systems/ Systems and Controls
- Electronics/ Digital Circuits
- Electromagnetic Fields
- Electromechanical Energy Conversion
- Physics

Work Experience

Underway Adventures Facilitator April 2014-Present

Touch of Nature Environmental Center, Carbondale, Illinois

- Facilitate large groups on team building and adventurous activities
- Teach groups about safety and usage of equipment
- Debrief individuals/group about what they learned
- Keep track of all equipment and its sanitation

Infantry Team Leader, Sergeant, US Army July 2006-Sep 2011

101st Airborne (Air Assault), Fort Campbell, Kentucky

- Provided training and development to numerous colleagues
- Analyzed and improved work techniques and procedures
- Managed, supervised, and counseled colleague's monthly
- Gained leadership, communication skills, teamwork, strong work ethic

Achievements and Honors

Dean's List, College of Engineering, SIU Fall 2012, Spring 2013, Fall 2013, Spring 2014

Extracurricular Activities

Saluki Code Club August 2016-Present

Skills

- C#/C++ Programming
- HTML/CSS
- Electrical Wiring and Soldering
- MATLAB
- Oscilloscope Operation
- Java Script (Basic)
- Microsoft Office Suite
- Technical Documentation
- VERILOG HDL (Basic)
- MIPS Assembly Language (Basic)
- Circuit Analysis
- Unix Operation (Basic)

Nick Nezamis
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(618) 980-8492

SUMMARY OF QUALIFICATIONS

To apply my skills, experience, education, and talents in a challenging electrical engineering career.

EDUCATION/TRAINING

Basic Military Training (USAF) 6/12-8/12
Military Technical Training Aerospace Electrical & Environmental Systems (USAF) 8/12-1/13
Southern Illinois University Carbondale, IL 8/15-5/17
Bachelor of Science in **Electrical Engineering**, Spring 2017
SIUC GPA: 3.8
Cumulative GPA: 3.3

PROFESSIONAL EXPERIENCE

Electrical/Environmental (E&E) Systems Technician 1/12-present
126th Air Refueling Wing (Illinois Air National Guard)
Airframe: KC-135 Stratotanker

- Inspects, troubleshoots, and maintains integrated aircraft E&E systems, subsystems, components, wiring and associated test equipment.
    - On-equipment systems include: direct and alternating current; gas turbine compressors and auxiliary power units; landing gear, anti-skid, nose wheel steering; ignition and starting; lighting; master caution and warning; take-off warning; cargo door; non-electro static application (NESA) windows; anti-icing; fire and overheat warning; fire extinguishing and suppression; air conditioning; bleed air; cabin pressurization; auxiliary pressurization; oxygen; and aircraft utility systems.

- Performs off-equipment maintenance on E&E system components and associated test equipment.
    - Systems include: control, protection, caution, and warning panels; lighting equipment; frequency and load controls; anti-icing controllers; inverters; voltage regulators; nose wheel steering and anti-skid amplifiers; integrated drive generators; actuators, relays, motors and valves; aircraft batteries; and test equipment. Maintains, repairs, and fabricates electrical wiring, harnesses and connectors.

- Inspects and evaluates aircraft E&E maintenance activities.
    - Interprets inspection findings and determines corrective actions.
    - Records pertinent data on equipment maintenance data collection (MDC) forms and/or enters data into automated maintenance data systems.
    - Handles, labels, and disposes of hazardous materials and waste according to local, state, federal and international environmental standards.

Sales/Service Porter
Newbold BMW/Toyota Dealership, O'Fallon, IL 6/15-8/15, 12/15-1/16

- Managed lot with simple databases and tables.
- Maintained cleanliness of sold and serviced vehicles

ADDITIONAL RELATED EXPERIENCE

Department of Defense(DoD) Secret Security Clearance	2013
Deployed to RAF Mildenhall	6/13, 6/14
Department of Defense (DoD) German proficiency exam	12/14
Conducted wind tunnel research	8/14-5/15
Designed and constructed a ridable hovercraft earning first place in Eastern Illinois first annual Hovercup race	1/15-5/15
Deployed to Al Udeid Air Base in support of operation Freedom Sentinel	5/16-9/16
Boeing Robotics Competition at Southern Illinois University Carbondale	8/16-Present

COMPUTER SKILLS

Language(s): Proficient at C++
Application(s): WinQcad, XILINX, CST Studio Suite, MATLAB, GO81(Military Database)
Operating System(s): Proficient at Linux

AFFILIATIONS AND VOLUNTEER EXPERIENCE

Physics club member (8/13-5/15), President (8/14-5/15) Eastern Illinois University
Formula Society of Automotive Engineers (FSAE), Electrical Team tasked with wire harness and implementing a digital dashboard (8/15-present) Southern Illinois University Carbondale.

AWARDS

Dean's **List** Southern Illinois University Carbondale College of Engineering 8/15-12/15, 1/15-5/16

KANE RODRIGUEZ
Carbondale, Illinois, 62901
(779) 245-1738 | KaneRodriguez.com | Kaustez@siu.edu

Summary of Qualifications

- Experience with long-term loss-mitigation projects at UTC Aerospace Systems
- Research experience obtained through HVAC optimization involvement at SIUC
- Team oriented experience gained through participation in the Boeing Robotics Competition
- Managerial and leadership experience gained through tenure as Vice President of Saluki Code
- Self-motivated to pursue academic concepts outside of the classroom

Education

SOUTHERN ILLINOIS UNIVERSITY CARBONDALE, Carbondale, IL
Bachelor of Science in Electrical and Computer Engineering, Anticipated graduation, May 2017
University GPA: 4.00/4.00
Overall GPA: 3.84/4.00
Relevant Coursework:

Senior Design - Boeing Robotics Competition
Computer Network Systems Architecture
Digital VLSI Design
Digital Circuit Design with Verilog
Electromechanical Energy Conversion
Introduction to Software Engineering
Computer Organization and Design
Electronics

KISHWAUKEE COLLEGE, Malta, IL
Associate of Engineering Science, May 2015
Overall GPA: 3.73 /4.00

Related Experience

SIUC ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT, Carbondale, IL
Undergraduate Researcher, Aug 2016 - Present

- Involved in the research and development of integrated wireless sensor network nodes that support the optimization of HVAC systems via data collection

UTC AEROSPACE SYSTEMS, Rockford, IL
Electric Systems Supply Chain Intern, Jul 2016 - Aug 2016

- Developed financial software to reduce the cycle time of complex tasks
- Constructed, up-kept, and performed data analysis on several databases in order to detect opportunities for long-term loss-mitigation projects
- Ensured that current loss-mitigation projects were meeting deadlines in order to realize net savings for 2017 STD change

SENTINEL TECHNOLOGIES, Downers Grove, IL
Extern, Spring Break 2016

- Shadowed network engineers and participated in the debugging of C# code

KISHWAUKEE COLLEGE, Malta, IL
Tutor, Sep 2014 – May 2015

- Assisted students with questions involving Calculus, Newtonian Physics, and General Chemistry.

Additional Skills

- Proficient in C/C++, CMOS Schematic/Layout Design with Cadence, JavaScript, and HTML5/CSS3
- Experience with Angular 2, PHP, jQuery, Verilog, Python, and MSP430 microcontrollers

Honors and Awards

- 5 semesters on the Dean's List at Kishwaukee College, 2 semesters at SIUC
- Fall 2016 Recipient of Dean's Scholarship Award

Extracurricular Activities

- Previously the Scrum Master for The Boeing Robotics Competition Team 2 at SIUC
- VP of Saluki Code, a student organization that teaches Front-End and Back-End web development

Nick Whetstone

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SUMMARY OF QUALIFICATIONS

- Collaborating on a team with 9 electrical and mechanical engineers to win the Boeing Robotics Competition at SIU using agile development methodology (Scrum)
- President and Co-Founder of a Registered Student Organization, Saluki Code, with goals of educating the community on programming topics, encouraging teamwork among coders for large projects, and competing in hackathons
- Worked with a volunteer team of over 20 managers, developers, and translators from several countries around the world to support the second-largest free forum software on the internet and to restructure its parent organization

EDUCATION

GPA: 3.73/4.00

Southern Illinois University, Carbondale, IL — May 2017 (Expected)

Bachelor of Science in Computer Engineering and
Bachelor of Science in Electrical Engineering
Dean's List

Wabash Valley College, Mount Carmel, IL — May 2014

Associate of Science
Honors

TECHNICAL SKILLS

Programming proficiencies: C# (.NET Framework), Java, Python, C++, C, PHP, MySQL, HTML5, CSS3, XML, JavaScript (including jQuery and AngularJS)

Software proficiencies: Visual Studio, AutoCAD, ArcGIS, MATLAB, Git, Eclipse, phpMyAdmin, Adobe Creative Suite

Operating Systems: Windows, Mac OS X, Linux (Raspbian, Ubuntu [including Mint], Debian, and Fedora, specifically)

ENGINEERING EXPERIENCE

Intern, IT Applications Development, Ameren, St. Louis, MO — May 2016 — August 2016

- Wrote C# code for Web Services for Ameren-owned asset management software
- Contributed to testing and documentation for interface between asset management and work management software

Formula SAE, Southern Illinois University Team, Carbondale, IL — August 2015 — May 2016

- Worked with a team of over 20 students to design, build, and compete with a car for Formula SAE competition
- Part of the team that designed and built a digital controls system for use in the car

Summer Intern, LAMAC Engineering, Mount Carmel, IL — May 2014 — August 2014

- Created a GIS-based map of the Carmi, Illinois sanitary sewer system including GPS-given locations, images, and detailed manhole condition reports
- Used sea level elevation data to calculate unknown sewer pipe depths and sizes

Modification Author and Support Specialist, Simple Machines, Las Vegas, NV — February 2010 — November 2010

- Volunteered as an official member of the multi-national team working on Simple Machines Forum, one of the largest open source forum software in the world
- Developed user customizations, contributed to software testing and bug fixing, provided technical support to the community free of charge, and aided in the organization's transition from an LLC to a Nonprofit Organization

ADDITIONAL WORK EXPERIENCE

Private Algebra I and Geometry Tutoring for High School Students, Mount Carmel, IL — September 2013 — May 2014

Customer Service, Mount Carmel Municipal Swimming Pool, Mount Carmel, IL — May 2012 — August 2012

COMMUNITY INVOLVEMENT

Faculty-chosen officer of Wabash Valley College Student Senate — August 2013 — May 2014

- Acquired funding and resources for the local community's first 5k Spring into Color Fun Run

Volunteer Youth Football Coach, Mount Carmel, IL — August 2013 — October 2013

- Coached a football team of 3rd through 5th graders to an intercity championship

Web Developer and Church Media Manager, Jacob's Well, Mount Carmel, IL — May 2009 — March 2012

Samuel Morris

87 Fairway Vista Road, Murphysboro IL, 62966

Email: samuelmorris@siu.edu *Cell:* 618-303-6943

Summary

- BS in Electrical & Computer Engineering.
- President's & Dean's List for academic good standing.
- Senior Class summa cum laude academic honors.
- Wide variety of practical skills from programming to fine woodworking.
- SIUC Bakerywala Electrical Engineering Scholarship and Transfer Student Scholarship.

Education

Attended Arkansas Northeastern College from January 2011 through July 2012.
Attended John A. Logan College from January 2013 through December 2014.
Earned an Associate in Science from John A. Logan College.
BS, Electrical & Computer Engineering at Southern Illinois University, Carbondale IL.
Graduating class of 2017.
Current GPA is 3.98/4.0.

Areas of Knowledge & Interest

▪ Circuit Design	▪ Aviation flight
▪ 3D printing	▪ Aircraft design
▪ Laser engraving	▪ Chip design (Cadence & Xilinx)
▪ Linux, Windows, and Unix	▪ Robotics design
▪ Programming (C++ & Java)	▪ Engines and power systems

Employment Experience

Woodshop Assistant, Southern Illinois University, Carbondale IL

- Held from June 2015 through Present
- Supervised shop for customer safety.
- Instructed beginning woodworking classes.
- Worked on electrical equipment repair.
- Management and maintenance of the shop laser engraving system.

Chemistry lab Assistant, John A. Logan College, Carterville, IL

- Held from December 2013 through December 2014.
- Prepared chemicals, managed inventory, and tutored undergraduate chemistry.
- Repaired broken electrical equipment.

Jonathan R. Allen

1816 Testa Drive
Marion, IL 62959
jonathanrayallen7@gmail.com (618)579-3212

Education:

Southern Illinois University, Carbondale, IL
Mechanical Engineering and Energy Processes, May 2017
GPA: 3.77/4.0

Greenville College, Greenville, IL
Bachelor of Arts: Chemistry and Biology
GPA: 3.59/4.0

Relevant Courses: Instrumental Analysis, Computational Methods, Computer-aided Engineering Design, Finite Elemental Analysis

Work Experience:

Acting Aquatics Coordinator/Pool Operator December 2014 - Present

Marion Recreation Center 15-35 Hours/Week

- Optimized pool systems
- Managed and trained lifeguards
- Performed pool system maintenance
- Maintained water quality

Head Lifeguard/Assistant Manager April 2009- October 2013

Marion Park District 40-60 Hours/Week

- Saved $1,000/month in chemical costs by optimizing chemical feed system
- Managed facility/Pool Operation
- Responsible for accounting reports and bank deposits

Extracurricular Activities/Accolades:

- Formula SAE
- SLIAC All-Academic Team 2011, 2012, 2013
- Greenville College Tennis Team
- Gamma Beta Phi Honors Society
- Beta Beta Beta National Biological Honors Society

Volunteer Work:

- First Baptist Church - Marion, IL
- Fair Oaks Nursing Home – Greenville, IL
- Smith Grove Baptist Church - Greenville, IL