# WICHITA HOMESCHOOL WARRIORS

# BEST AWARD NOTEBOOK 2009

# TEAM #121

Teacher Contact: Gordon Crook
Telephone Number: (316)304-2813
Email Address: gccrook@yahoo.com

## Table of Contents


**1. Introduction ..... 1**
**2. Research Paper ..... 1**
**3. Implementation of the Engineering Process ..... 6**
3.1 Stage 1 - Gather Requirements ..... 7
3.1.1 External Requirements ..... 8
3.1.2 Internal Requirements ..... 9
3.1.3 Derived Requirements ..... 9
3.2 Stage 2 - Preliminary Design ..... 9
3.2.1 Develop Preliminary Design Concepts ..... 11
3.2.2 Develop Prototype Components ..... 11
3.2.3 Perform Preliminary Analysis ..... 12
3.2.4 Evaluate Component Performance ..... 12
3.2.5 Preliminary Design Review ..... 13
3.3 Stage 3 - Final Design and Construction ..... 13
3.3.1 Integrate Robot Design ..... 14
3.3.2 Build and Assemble Robot ..... 15
3.3.3 Evaluate Robot Performance ..... 16
3.3.4 Final Design Review ..... 16
3.4 Stage 4 – Test and Evaluation ..... 16
**4. Brainstorming Approaches ..... 17**
4.1 Gathering Requirements ..... 17
4.2 Game Strategy ..... 17
4.3 Robot Design Elements ..... 18
**5. Analytical Evaluation of Design Alternatives ..... 19**
5.1 Wheel Analysis ..... 19
5.2 Arm Design Alternatives ..... 20
5.3 Torque and Center of Gravity Analysis ..... 20
**6. Offensive and Defensive Evaluation ..... 22**
6.1 Game Strategy Evaluation ..... 22
6.2 Robot Design to Accomplish Strategy ..... 26
**7. Design Creativity ..... 26**
7.1 Claw Design Evolution ..... 26
7.2 Arm Design Evolution ..... 27
7.3 Infrared Sensor Design Evolution. ..... 27
**8. Summary ..... 28**

**Support Documentation – Appendices**

## 1. Introduction

This notebook documents the four-stage engineering process that the Wichita Homeschool Robotics Team used to design, build, and test their robot. This process took the standard BEST nine-stage engineering process and simplified it into four stages with sub-stages to better show the design reviews as feedback loops. The first stage was gathering requirements from the BEST game rules. The next stage involved developing preliminary design based on the team's game strategy. Stage three focused on final robot design and construction, and during the fourth stage, the team performed tests and evaluations on the completed robot. Brainstorming was primarily used in stages one and two, while analysis was conducted in stages three and four. To ensure that the robot met all of the requirements and could effectively compete, the team held design reviews after the second and third stages. As a result of this four-stage engineering process, Wichita Homeschool Robotics Team was able to manufacture a successful and reliable robot to compete in *High Octane.*

## 2. Research Paper

### Introduction

We live in a world that runs on fuel: we use it to heat our houses, drive our cars, and produce electricity. The average person seldom goes a day without using some kind of fuel. Gasoline has become a largely central topic in politics and our lives, particularly the environmental impact and manufacturing thereof. This has led to much debate and a world-wide search for a more available energy source. In its exploration of potential fuels and fuel additives, industry has formulated a method of producing gasoline more convenient to mechanical purposes (Ki-moon). The addition of isooctane to gasoline has greatly reduced engine trouble, making

driving an automobile more comfortable and practical. The goal of this year's game is to synthesize isooctane molecules using the compounds provided to make a more available fuel.

**History of Isooctane**

The first acknowledged gasoline-powered car was invented in 1885 by Karl Benz. The automobile continued to develop after Benz's original patented vehicle, becoming popular in the early 1900's. However, the 1920's revealed one unappealing feature of the automobile: knocking. Knocking occurs in a car's engine when combustion of the air and fuel mixture in the cylinder starts off correctly in response to ignition by the spark plug. However, one or more pockets of air and fuel mixture explode outside the envelope of normal combustion. As a result, the peak of combustion does not occur at the ideal moment for the four-stroke process by which most engines run. Knocking is most often recognizable by the rapping or knocking sound heard by the driver. The effects of knocking range from insignificant to completely destructive. Car manufacturers saw knocking as a threat to the popularity of cars (Tomov et al.).

The solution began in 1919 with Charles Kettering and Thomas Midgley, Jr. when the pair discovered that the addition of tetraethyllead to gasoline greatly reduced the occurrence of knocking. Despite its phenomenal success as an antiknock agent, tetraethyllead's toxic lead content caused this ethyl additive to be discontinued (Wilbraham et al.; "What is a Refinery?").

Springboarding off the work of Kettering and Midgley, Graham Edgar discovered the usefulness of *2,2,4-Trimethylpentane*, or *isooctane*, as an antiknock additive. Edgar found that isooctane significantly reduced knocking while *n-heptane* increased knocking. He experimented with different ratios of isooctane to n-heptane, thus forming the *octane scale*, a scale rating gasoline's antiknock qualities (Wilbraham et al.).

## Current Uses of Isooctane

*Octane Scale*. On the octane scale, pure n-heptane has an octane rating of 0 due to its high knocking tendencies, while a mixture of 80% octane to 20% n-heptane has a rating of 100, the best mixture for an antiknock agent. The octane ratings that are present at gas stations are determined by anti-knocking tests calibrated to isooctane. The higher the number, the more isooctane is in the gasoline and the more expensive it is. Isooctane led to the creation of higher efficiency engines and contributed to the popularity of the automobile (Wilbraham et al.).

*Pollution.* Increased efficiency and mobility caused the manufacturing and purchasing of cars to become less expensive. This made cars more available to people of many different lifestyles, increasing the number of cars and toxic fumes from exhaust pipes. Many acts and laws have been established trying to limit the toxic gases emitted from automobiles, including the 1970 Clean Air Act and Kyoto Protocol. The 1970 Clean Air Act requires the Environmental Protection Agency to develop and enforce regulations to protect the general public from exposure to contaminants in the air. It set new limits on emissions from motor vehicles, and increased funds for air pollution research. The Kyoto Protocol is a plan to reduce the emissions of carbon dioxide by 5% in 2010 from the levels in 1990. There are many laws that have been created to try to limit the amount of hazardous gases to human health, but these gases have already caused problems and will still continue to cause problems in the world (Tomov et al.).

## Future Uses of Isooctane

*Pollution*. Because automobiles have come under scrutiny as a large contributor to atmospheric pollution, the government has taken steps to minimize the environmental effect of cars. Recently, laws have been passed limiting the amount of ozone and sulfur that a new car is permitted to emit (Leffler). This law is enforced on car manufacturers rather than drivers, and

does not apply to old or used cars. Car and gasoline manufacturers' search for cleaner components has led them to isooctane as an additive. This is because it has a low-sulfur content and is able to replace other sulfur-containing additives with less expense. However, there is a drawback to this solution—the additive used previously, MTBE (methyl tertiary butyl ether), has an octane number of 110, while isooctane has an octane number of only 98. This may not seem like much of a difference, but the difference in fueling power allows the gasoline companies to charge about eight cents more per gallon on the MTBE-gasoline ("Analysis of Selected Transportation Fuel Issues"). Despite its environmental advantages, the switch to isooctane-gasoline would not be financially beneficial to the gasoline companies, making the switch that much less likely. However, the switch to a more environmentally friendly fuel is still a concern, and the changing to isooctane-gasoline is still a plausible option.

*Gas Prices.* Because of the automobile's popularity, gasoline scarcity has become a major world problem, as the price of gasoline continues to increase. The price of gasoline affects people's daily lives, including consumer spending. If the price of gasoline increases at the same pace, man's priorities and spending will change significantly. People will also respond by switching to smaller cars, decreasing the demand for gasoline.

The scarcity of gasoline will not only affect people's decisions to purchase smaller cars, but will affect the future of the world. The world's major powers, including the United States, Europe, and China are beginning to suffer from the higher oil prices. Isooctane has shaped history, but also continues to impact the future (Trimble).

**Relation to the Game**

In the game, *High Octane*, students try to maneuver their robot to accumulate a large chemical inventory. The two chemicals, ethylene and benzene, are additive ingredients to naphtha and the most valuable compound, isooctane.

Like in the game, real-life gasoline production uses robots to improve the efficiency and safety of the industry. For example, in 2007 the U.S. Department of Energy commissioned a small robot to advance gasoline assessment. The small, self-propelled robot, Explorer II, used cameras and sensors, including an eddy current field sensor, to evaluate the condition of gas lines ("DOE: Pipeline Robots"). This developing technology provides engineers with information from previously inaccessible locations.

Similarly, a test lab in Oslo, Norway is currently working on a robot that inspects gasoline and facilities under circumstances that would be hazardous to humans (Skourup and Pretlove). Gasoline is a particular challenge to humans due to its flammable and volatile nature. Robots continue to replace humans in many dangerous, dirty, and time-consuming tasks. For this reason, it is monumentally important for students to have an understanding of how robots work in industry. The BEST program provides students with opportunity and incentive to become familiar with and interested in robotics and technology.

**Conclusion**

The gasoline industry has evolved greatly since the first automobile, through the experimentation of engineering, science, and technology. Isooctane was first discovered as a solution to the problem of knocking and is now a major step towards finding a clean, efficient energy source. Similarly, through the processes of brainstorming, building, and operating a robot, students gain experience and knowledge of the scientific advances that form the infrastructure of today's mobile society. Industry's understanding of a useable fuel is always broadening, and whether it chooses an isooctane alternative or another, the scientists and engineers currently working on it will come up with a *High Octane* solution. (Sources cited are found in Appendix G.)

## 3. Implementation of the Engineering Process

Wichita Homeschool knew that understanding and using the engineering process (Figure 1) was the key to successfully competing in *High Octane*. The team used this four-stage engineering process to design, build, and test a competitive robot (Table 1). In the first stage, *gathering requirements*, team members read the BEST game rules and brainstormed external, internal, and derived requirements. Next, a preliminary game strategy was chosen by

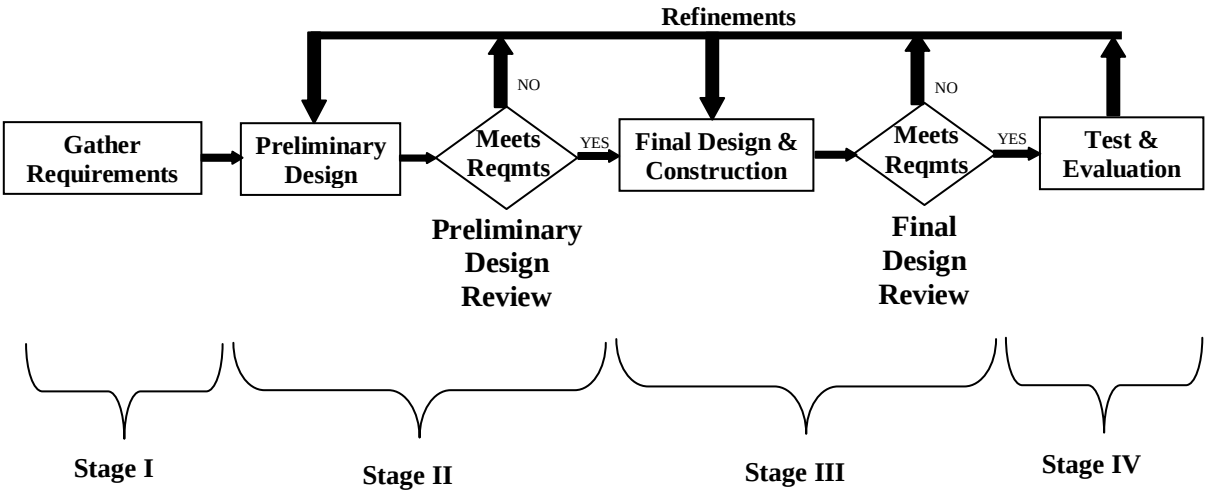



**Figure 1 - The Engineering Process**

| The Engineering Process | |
|---|---|
| **Stage 1 - Gathering Requirements** | **Stage 3 - Final Design & Construction** |
| • Read rules, brainstormed requirements | • Sub-teams built sub-components |
| • Brainstormed for preliminary offensive and defensive strategies | • Sub-components were integrated into the complete robot |
| • Voted to select game strategy | • Final design review |
| **Stage 2 - Preliminary Design** | **Stage 4 - Test & Evaluation** |
| • Developed design concepts | • Tests and evaluations |
| • Constructed prototypes of concepts | • Driver try-out & practice |
| • Voted to select best parts of each rapid prototype & advanced prototypes | • Participation in Mall Day and Game Day |
| • Design review | |

**Table 1 - The Engineering Process**

brainstorming for offensive and defensive strategies. This strategy was then evaluated to determine the effects that it would have on the preliminary design. In stage two, *develop preliminary design*, the requirements that were brainstormed in stage one were converted into rapid prototypes to match the strategy. The best elements of these prototyped designs were then chosen through multi-voting. In stage three, *final robot design and construction*, the various components were integrated into the final robot. During the final stage, *tests and evaluations*, the team conducted tests and evaluations on the robot and drivers practiced operating the robot. Design reviews were conducted after the second and third stages to ensure that the robot met all of the requirements. These design reviews exposed shortcomings that the team had to overcome before continuing to the next stage (Figure 2). For example, the original design to retrieve the energy was an attachment on the front of the claw that would flip the energy can from horizontal to vertical. After testing this design, the team found it was more efficient to have the spotter set the energy can upright, and then pick up the energy with notches cut on either side of the claw's scoop. Scenarios such as this are shown in Figure 1 as "refinements."

**Figure 2 - Original and Final Designs to Grip Energy**

### 3.1 <u>Stage 1 - Gather Requirements</u>

Stage one, *gathering requirements*, was the most important stage of the engineering process because it established the requirements for robot design. The team brainstormed three types of requirements: external, internal, and derived (Figure 3). External requirements were

defined as *requirements imposed by an external force or agency such as BEST*. The definition of internal requirements was *requirements imposed by the team based on past year's experience, judgments, and this year's game.* Derived requirements were those *requirements obtained based on strategies and other requirements or analysis.*

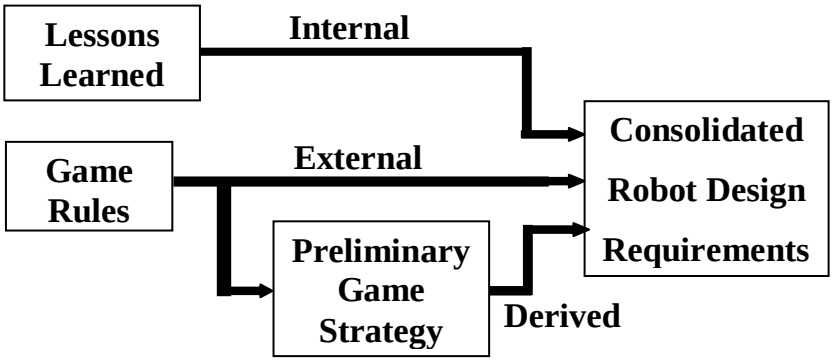



**Figure 3 - Gather Requirements**

### 3.1.1 External Requirements

External requirements were found by reading the BEST game rules and brainstorming. The team listed fifty-eight requirements that affected robot design and game strategy. The requirements fell into four categories: weight, size, materials, and miscellaneous. For weight and size, the team found that the robot could weigh no more than twenty-four pounds and must fit into a twenty-four inch cube. Under the materials category, the rules stated that the robot could only be made out of the materials in the returnable and consumable kits. Some of the miscellaneous requirements that were brainstormed were that the robot could not damage any game pieces, only one battery could be on the robot at a time, and the spotter's waist could not go outside of the spotter's box. After the team had brainstormed for external requirements, a team member independently searched the specific and generic game rules to ensure that all the requirements had been found. A complete list of external requirements can be found in Appendix A, page A-1.

### 3.1.2 Internal Requirements

Next, the team brainstormed for internal requirements. In order to do this effectively, the robot leaders gave a PowerPoint presentation of the lessons learned in previous years. From this, the team concluded that the robot needed to be simple, robust, and easily driven; adaptable to the game strategy; and completed in time for adequate driver practice. Some of the twenty-six internal requirements brainstormed were that the robot needed to be able to move the benzene tankers and either trigger the infrared sensor or activate the pushbutton. Because of the complexity of this year's game, the requirement that drivers and spotters must to be able to mentally calculate the chemical formulas during their rounds was also added. A complete list of internal requirements can be found in Appendix A, page A-2.

### 3.1.3 Derived Requirements

The team discussed and imposed six derived requirements in order to achieve the preliminary game strategy. One of these was that the arm needed to be long enough to reach the $CO_2$. Another was that the claw had to be able to handle multiple game pieces at a time. Several derived requirements were implemented because of the team's defensive strategy. One of these was that the robot's wheels must be twelve inches in diameter in order to be fast enough to elude other robots when taking pieces from their quadrants. Because many of the team's defensive strategies this year involved transmitting signals, the requirement was added that the robot needed to be able to activate the infrared sensor. A complete list of derived requirements can be found in Appendix A, page A-3.

## 3.2 Stage 2 - Preliminary Design

In stage two of the engineering process, *developing preliminary design*, the team focused on transforming preliminary designs into realistic components. This was the longest stage of the

engineering process. To begin this stage, the team brainstormed a wide variety of design concepts. These design concepts were then converted into rapid prototypes made of cardboard, duct tape, and PVC. Next, advanced prototypes were built from kit materials and tested to help the team foresee future difficulties. The team then determined which concepts to carry through to the preliminary design review and ultimately to the final design stage. This portion of the engineering process is cyclical because all of the design components must pass the design review before advancing to the next stage. Any component that failed this design review was modified, redesigned, or discontinued. When the necessary changes had been made, the robot underwent a second preliminary design review. The preliminary design stage continued to cycle until all the components passed the design review (Figure 4). This repetitive approach had many benefits including rapid development of design concepts, the ability to combine the best elements from each idea, and improvement of final design. The team also developed an understanding for what designs would and would not work. This knowledge could be applied to future design and construction.

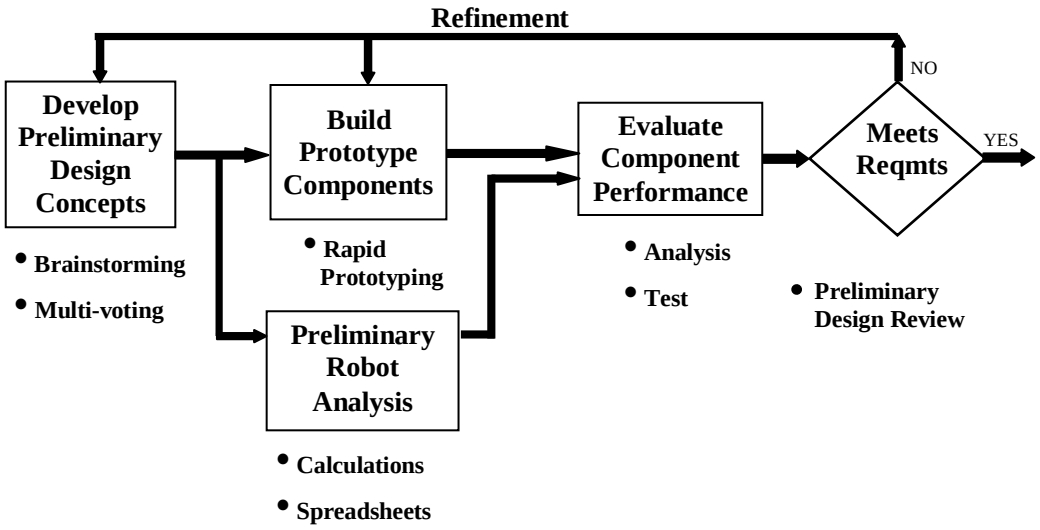



**Figure 4 - Preliminary Design**

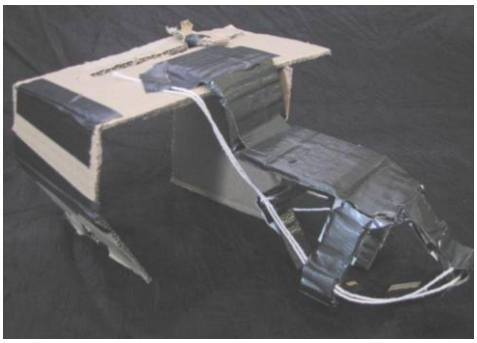
### 3.2.1 Develop Preliminary Design Concepts

The team held a preliminary design brainstorming session in which forty-six design concepts were generated. Some examples of these were the golf ball retriever, the vacuum sweeper design, and the grapple fork claw. After brainstorming these ideas, the team broke up into small groups and each chose several designs to rapid prototype. These rapid prototypes allowed the team to evaluate the pros and cons of each design, helping them select a preliminary design. The ideas not prototyped were saved for possible later use. A complete list of design concepts can be found in Appendix C, page C-1.

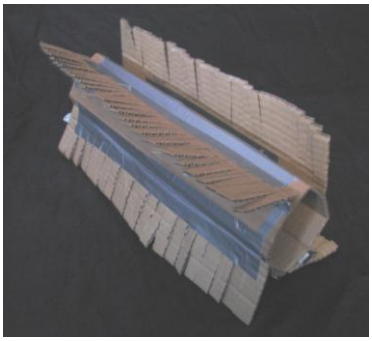
### 3.2.2 Develop Prototype Components

After brainstorming for design concepts, the team broke up into small groups and each group was assigned the ideas that they had generated. Using cardboard, duct tape, and PVC, each group made rapid prototypes of their design concepts. Then, they demonstrated their prototypes in a "show and tell" session to help the team visualize each idea. Twenty-four prototypes including designs for claw, arm, chassis, vacuum, and bumper were made. One idea prototyped was a double lasso for the $CO_2$. Another prototype was a support on the chassis to assist the claw with the benzene tanker. Examples of prototypes are shown in Figure 5.

**Golf Ball Retriever**



**Bricktong with Grapple Claw on Front**



**Vacuum for Pieces on the Floor**

**Figure 5 - Examples of Prototypes**

### 3.2.3 Perform Preliminary Analysis

After the rapid prototypes had been made, the analysis sub-team began evaluating the scoring system with manual calculations and computer programs (see Section 6.1, Game Strategy Evaluation). These analyses helped to find the most effective use of the three-minute rounds. The team found that maximizing the $CO_2$ and energy along with various combinations of catalyst and $H_2O$ was the best way to maintain a high score. Because of the complexity of this year's game strategy, the team did not vote on the results of this analysis. However, they did discuss strategies, for achieving the high score. (For a complete list of strategies see Appendix B, page B-1.) Some of these strategies were to block or catch the catalyst as it was dispensed, to push most of the pieces to the offload area for the spotter to score, and to use the infrared sensor for both offense and defense (see Section 7.3, Infrared Sensor Design Evolution).

### 3.2.4 Evaluate Component Performance

The claw was the most difficult component of the robot to design and build because it had to manipulate many diverse pieces. In order to comply with this year's strategy, the claw needed to be light, easily controlled, and able to handle all of the game pieces. By multi-voting, the team narrowed the list of claw ideas down to four. When multi-voting, team members could vote for up to half of the total number of ideas, and then the top ideas were carried forward. The strengths and weaknesses of these four designs were evaluated with pro/con lists (Appendix C, C-3). The team then multi-voted to choose the praying mantis claw as their primary design (Table 2). A record of secondary claw designs was kept for possible later use. The praying

| Top Four Claw Designs | Votes |
|---|---|
| Praying Mantis Claw | 27 |
| Bricktong | 23 |
| Interweaving Claw | 7 |
| Horseshoe Claw | 5 |

**Table 2 - Multi-voting to Select Primary Claw Design**

mantis claw was chosen because it was reliable, versatile, and able to handle more than one game piece at a time (Figure 6). The bricktong was kept as the secondary design.

**Figure 6 - Rapid Prototype of the Praying Mantis Claw**

### 3.2.5 Preliminary Design Review

Between the second and third stages, the robot leaders conducted a preliminary design review. Each component's performance was observed and analyzed to ensure that it met all the requirements as well as effectively competing in this year's game. For example, the team chose to add tread to the wheels for better traction. Once the necessary changes had been made, the team was ready to move on to the final design stage (see Section 3.3, Final Design and Construction).

## 3.3 Stage 3 - Final Design and Construction

The third stage of the engineering process was final design and construction (Figure 7). During this stage, all the sub-components were integrated into the completed robot. The team then conducted a final design review to evaluate the robot's effectiveness.

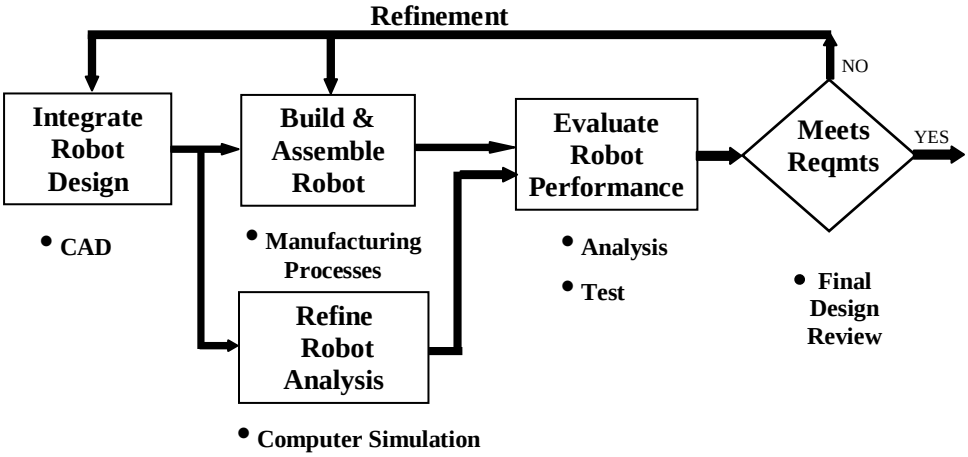



**Figure 7 - Final Design and Construction**

### 3.3.1 Integrate Robot Design

Before integrating robot design, sub-teams had been building their components separately. (Appendix C, pages C-4 through C-6, contains sample robot builder forms, a form the robot builders filled out to explain how they designed and built their component.) Now, all of the sub-components were integrated into a completed robot. Sub-teams had to continually communicate and compromise as refinements were made. After all the advanced prototypes were finished and assembled into the completed robot, the team tested the robot's performance during the preliminary design review. They noted several modifications that were necessary to integrate the prototypes into a working robot. Some of these modifications were lengthening the extension for the $CO_2$ retriever and shortening the arm.

The use of technology was vital as the team integrated the components into a successful robot. Three team members used Computer Aided Design (CAD) to simulate how the components would fit together and how the playing field would look. These simulations were helpful in assembling the robot. The CAD drawing of the robot is found in Figure 8 and Appendix C, page C-7, and the CAD drawing of the playing field is found in Figure 9 and Appendix C, page C-8.

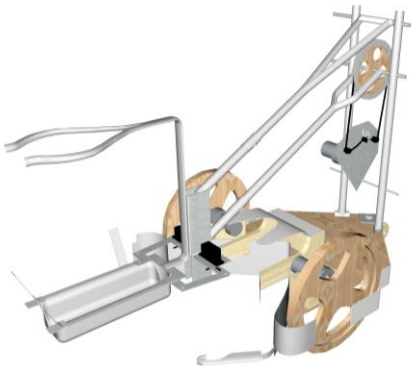


**Figure 8 - CAD of Robot**

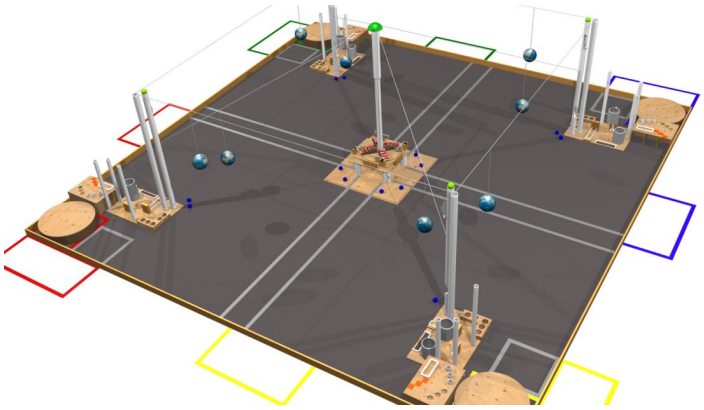


**Figure 9 - CAD of Playing Field**

During the final assembly of the robot, fewer changes were necessary because the sub-teams were constantly communicating while working independently on their component. For example, the wheel and arm sub-teams had to communicate to ensure that the robot would not be taller than twenty-four inches.

### 3.3.2 Build and Assemble Robot

After the necessary changes had been made to integrate robot sub-components, the team selected the final claw design and assembled the final robot (Figure 10). This servo powered praying mantis claw was able to retrieve the $H_2O$, catalyst, and $CO_2$, while notches on either side of the scoop allowed it to pick up the energy. It also utilized a horseshoe-shaped extension to aid in scoring the $CO_2$. The robot's always vertical parallelogram arm was powered by a pulley, driven by two small motors. The chassis was made from half-inch plywood with a V-shaped bumper in the front to assist in collecting game pieces from the floor. A device to activate the pushbutton and a hook to pull the benzene was also mounted on the bumper. In order to maintain speed, power, and maneuverability, the team chose twelve inch wheels coupled with an innovative low-friction caster wheel. While building and assembling the final robot, the team used such common manufacturing methods as sawing, drilling, and sanding.

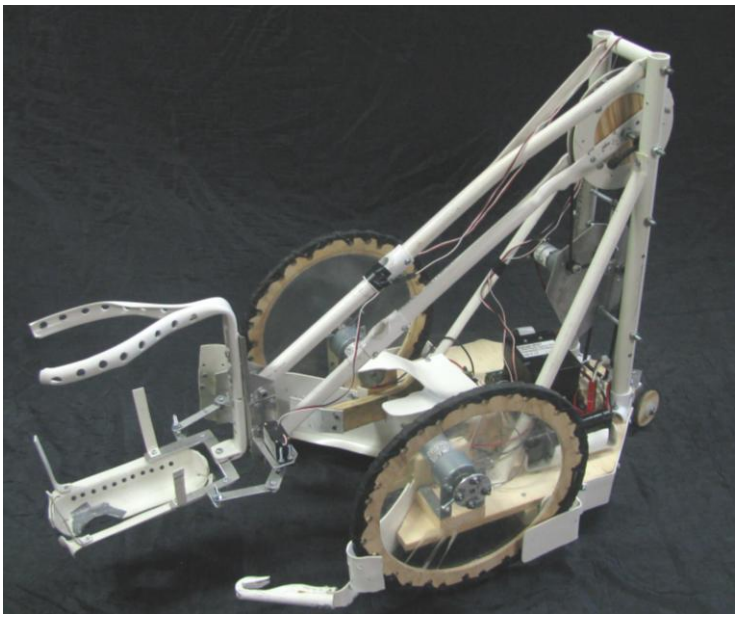


**Figure 10 - Completed Robot**

### 3.3.3 Evaluate Robot Performance

The team evaluated the final robot's size, weight, and maneuverability to ensure that it met all of the external, internal, and derived requirements. Any failure to comply with the requirements was analyzed and corrected. One of these adjustments was shortening the arm to ensure that the robot fit into the twenty-four inch cube. Once all the necessary changes had been made, the team tested the robot again to ensure that it complied with the requirements. The results of this evaluation were documented and presented during the final design review.

### 3.3.4 Final Design Review

After completing robot testing and analysis, the robot leaders conducted a final design review to ensure that the robot met all of the external, internal, and derived requirements. Minor changes were agreed upon and incorporated by the team. For example, because the bumper on the front of the chassis had difficulty pushing the $H_2O$, the team chose to flange the bottom of the bumper to cause the $H_2O$ to roll instead of slide when pushed across the floor. The team also aligned their game strategy with robot performance and finalized it for Game Day. One of these alignments was having the spotter set the energy upright and then having the robot score it.

## 3.4 Stage 4 - Test and Evaluation

The last stage of the engineering process was final testing and evaluating. This included verifying robot performance, fine-tuning the robot, conducting driving practice, and participating in Game Day. To assist with driver practice, a playing floor was built. Team members practiced driving on the playing floor and participated in driver tryouts. Competition drivers were selected by the amount of time it took them to collect a set number of game pieces. The team simulated competition conditions with a timer, crowd noise, and other distractions during driver practice. Practicing under game conditions was very helpful especially for the younger, less experienced

drivers. The points scored were recorded and used to evaluate both driver and robot performance (Appendix E, page E-4).

## 4. Brainstorming Approaches

The entire team brainstormed requirements, design concepts, and strategies. (The rules for brainstorming found in Appendix F, page F-1.) Before each of these brainstorming sessions, the team reviewed the rules. Each member suggested an idea in turn until all the ideas had been generated. Any consideration or criticism was held off until voting. When all the members had contributed their ideas, similar ideas were combined into categories to eliminate repetition and to allow the team to focus on the different design elements. The team did demonstrations and pro/con lists of each design to analyze their advantages and limitations. (Pro/con lists of claw designs can be found in Appendix C, page C-3.) To reduce the number of designs, the team multi-voted to decide which concepts to carry on to the next stage. When multi-voting, team members could vote on up to half of the ideas and the top designs were carried forward. Secondary designs were recorded for possible later use.

### 4.1 Gathering Requirements

By reading the BEST game rules and brainstorming, the team found fifty-eight external requirements. After robot leaders gave a presentation of lessons learned in past years, the team brainstormed twenty-six internal requirements. Derived requirements were implied from the external and internal requirements and this year's game strategy. The requirements were used as guidelines throughout the engineering process (Appendix A).

### 4.2 Game Strategy

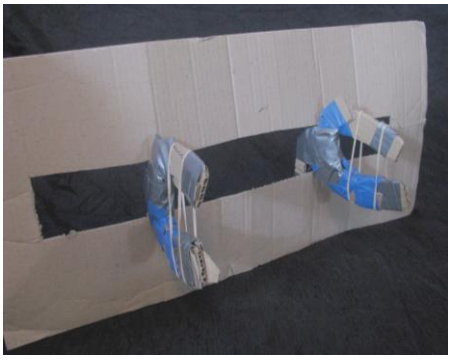
Although much of the strategy for this year's game was found through analysis (see Section 6.1, Game Strategy Evaluation), the team did brainstorm offensive and defensive

strategies. (A complete list of strategies can be found in Appendix B, page B-1.) *High Octane* presented many possibilities for scoring, and many ideas were introduced. One idea was to catch the catalyst with the robot as it was dispensed or to set up a detachable fence to catch it. Other strategies brainstormed were to retrieve the $CO_2$ first, to get the benzene tankers first in the semifinal and final rounds, and to push game pieces to the offload area for the spotter to score. Possible defensive strategies were to hoard extra $CO_2$, to score in other teams' processing cells and storage areas to disrupt their scores, and to tag any robot that invaded the home quadrant. After brainstorming these strategies, the analysis sub-team presented the results of their calculations of the scoring system. This helped the team to focus on several strategies that would enable them to use the three-minute rounds most efficiently. For their offensive strategy they chose to push most of the pieces to the offload area for the spotter to score. The team also realized that taking pieces from other teams' quadrants was not only a good defensive strategy, but also a necessary part of achieving a high score. Lastly, it was decided that the computer program used during analysis should be modified and used in the pit on Game Day to help the team decide which round to drop (see flowchart in Appendix B, page B-2).

### 4.3 Robot Design Elements

After many brainstorming sessions, the team decided to focus on two main preliminary design elements: claw and arm. They kept in mind the challenges of clamping both cans and differently sized balls. Claw, arm, and vacuum designs were rapid-prototyped and presented to the team for visual examination (Figure 11). This allowed team members to observe the capabilities of each design. The list of claw designs was then narrowed down by multi-voting. Next, the team made pro/con lists for the top four designs to evaluate the advantages and limitations of each. By multi-voting a second time, the team chose the praying mantis claw as

their primary design and the bricktong as their secondary design. After this, sub-teams began to construct advanced prototypes of both the primary and secondary claw designs.



**Horseshoe Bricktong**

**Interweaving Talon Claw**

**Figure 11 - Runner-Up Designs**

## 5. Analytical Evaluation of Design Alternatives

The team conducted analysis to verify design, development, and construction of the robot. These analyses were performed through evaluation of test data and by manual calculations.

### 5.1 Wheel Analysis

Before the wheel sub-team chose a wheel size, they analyzed which size wheels were the fastest, easiest, and most accurate to drive. They tested wheels with diameters from 9 inches to 16 inches. The test consisted of driving the robot in a straight line for a distance of 20 feet. The results of this analysis are shown in Figure 12, page 20 (Appendix E, page E-3). Evaluation of driving practice allowed the sub-team to determine which size wheels were the most precise. Combining these analyses, the wheel sub-team selected 12 inch wheels to allow the robot the greatest precision and power while maintaining speed. Rubber was added to the wheels to provide better traction.

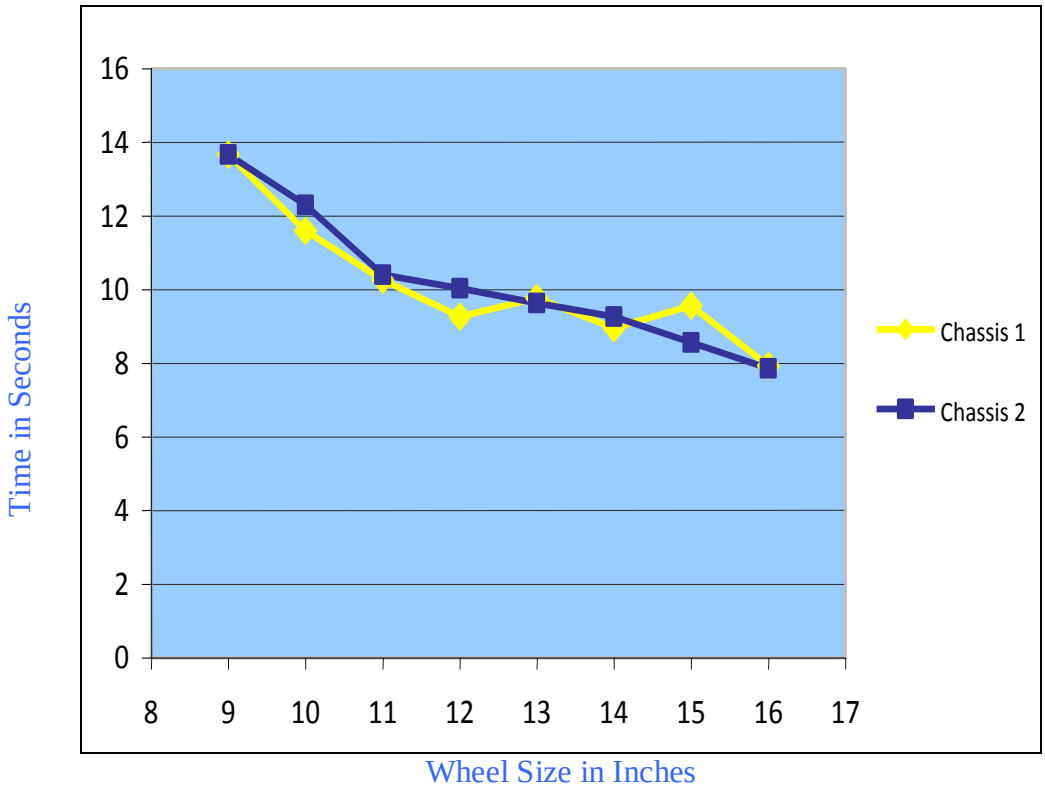



**Figure 12 - Wheel Size Selection Analysis**

## 5.2 Arm Design Alternatives

The entire team brainstormed and rapid-prototyped arm design concepts. Then, the arm sub-team analyzed these ideas based on their reliability, strength, and complexity of design. They also kept in mind that the arm needed to be compatible with the claw design. Some of the designs considered were the parallelogram arm, the telescoping arm, the crane arm, and the scissor lift arm. Because of its strength and its ability to keep the claw horizontal, the parallelogram arm was chosen as the most efficient design to complete the tasks of *High Octane*!

## 5.3 Center of Gravity and Torque Analysis

The arm sub-team did calculations to find the robot's center of gravity with two energies in its claw. To begin, the sub-team balanced the robot on a dowel rod to find its center of gravity. They also weighed and measured the robot while its arm was in the critical horizontal position. This position was critical because if the robot were to tip over, it would most likely

happen while two energies were in its claw. The sub-team used the combined weight of the robot and the two energies to calculate the rear wheel and front wheel reactions using formulas A and B. These formulas express the summation of moments and vertical forces equal to zero.

(A) $\Sigma M1 = 0$

(B) $\Sigma F = 0$

After the wheel forces were determined, the team used the results to find the new center of gravity with two energies in the claw (formula C).

(C) $\Sigma M = 0$

Since the center of gravity was still positioned between the front and rear wheels, the arm sub-team concluded that the robot would not tip over while its arm was in a horizontal position and carrying two energies. The results of this analysis are shown in Appendix E, page E-1.

The arm sub-team also calculated the maximum torque of the arm. They began doing this by measuring the force, or the weight that the arm could lift. This was done by adding small weights to the arm until it could no longer lift the payload. The sub-team found that the arm was able to lift 2.2 pounds without the claw or game pieces. Because the claw weighed 14 ounces, the weight that the arm could lift was 1.6 pounds. The arm length was 27 inches. Next, they used the equation *Torque = Force × distance* ($T = F \times d$). This equation showed that the arm's torque was 59.1 inch × pounds. Then, they analyzed these results by calculating the torque required to lift two energies (14.5 ounces), the maximum weight that the arm would ever need to lift at once. Once again, using the equation $T = F \times d$ with a total weight of the claw plus 2 energies (1.8 pounds), the arm sub-team found that the most torque the arm would ever need was 48.1 inch × pounds. Because 48.1 inch × pounds were less than 59.1 inch × pounds, the sub-

team confirmed that the arm was strong enough to lift any of the necessary game pieces. The results of this analysis are shown in Appendix E, page E-2.

## 6. Offensive and Defensive Evaluation

Offensive and defensive strategies were found through a combination of brainstorming (see Section 4.2, Game Strategy) and analysis (see Section 6.1, Game Strategy Evaluation). The team's primary offensive strategy was to be able to score all the pieces on the playing floor. However, they decided that maximizing the $CO_2$ and energy would achieve the highest score. A computer program in Python was developed to aid the team in calculating scores to choose the best combination of game pieces for each round. The team also discussed and brainstormed defensive strategies. This year's main defensive strategy was to take pieces from other quadrants which would create a shortage for other teams. The team's other defensive strategies were to tag any robot invading their quadrant and to score in other teams' processing cells and storage areas to disrupt their strategy. This year, the Infrared (IR) Sensor introduced several more defensive strategies. The team decided to use codes 100, 600, and 800. The 100 code would defend their quadrant from other teams' offensive codes. The 600 code gave them the option of dispensing energy from the left and right dispenser. The 800 code allowed them to take their neighbor's catalyst.

### 6.1 Game Strategy Evaluation

Because of the nature of this year's game, the analysis sub-team conducted extensive analysis before selecting the optimum offensive strategy. On Kickoff Day, Kansas BEST teams were informed that each team would be allowed to compete in six preliminary rounds and one of those rounds would be dropped at the discretion of the team. With this in mind, the analysis sub-team worked to find what combination of rounds would yield the highest score in five rounds.

Since all scores, except benzene, would be carried over into the semifinal rounds, they realized that the team with the highest score at the end of the preliminaries would have the best chance of maintaining the highest score throughout the rest of the rounds. They began by calculating the number of points that each compound was worth, converting from a $base_4$ to a $base_{10}$ number for ease of comparison (Table 3).

| Points Each Compound Is Worth – $Base_{10}$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| Isooctane | Naphtha | Benzene | Ethylene | $CO_2$ | Energy | Catalyst | $H_2O$ |
| $4^7$=16,384 | $4^6$=4,096 | $4^5$=1,024 | $4^4$=256 | $4^3$=64 | $4^2$=16 | $4^1$=4 | $4^0$=1 |

**Table 3 - Points Each Compound Is Worth**

Next, they found what number of game pieces would be needed in the preliminary and final rounds to make each compound (Figure 13). Because the benzene became one game piece during the semifinal and final rounds instead of being created, the number of game pieces needed to make the compounds changed from the preliminary rounds to the semifinal and final rounds.

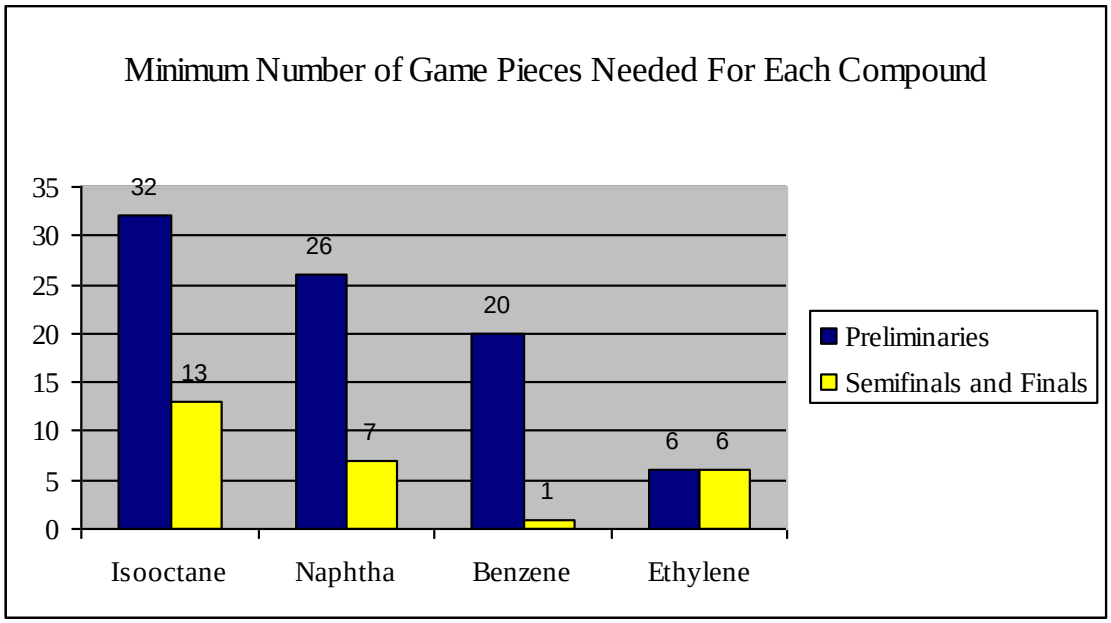



**Figure 13 - Number of Game Pieces Needed For Each Compound**

Finally, the sub-team calculated how many points per game piece in the preliminary and final rounds each compound would yield (Figure 14).

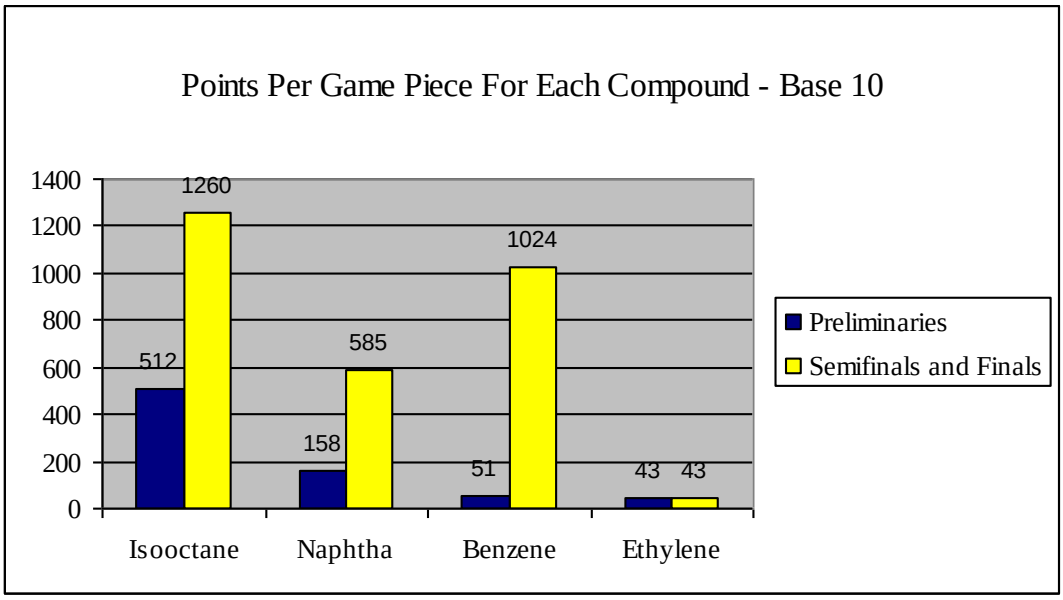



**Figure 14 - Points Per Game Piece For Each Compound**

These analyses showed that in the preliminary rounds, it took only 19% (or 6) more game pieces to make isooctane than naphtha, but the score was 69% (or 354) higher. In the final rounds, it took 46% (or 6) more pieces to make isooctane, but the score was 54% (675) higher. These charts were developed to show how many points could be gained for each game piece that was scored depending on the various compounds. Since isooctane is identical to naphtha except for the addition of one ethylene, the analysis sub-team found that it was more efficient to make isooctane than naphtha.

The sub-team also realized that because of the base$_4$ scoring system each component was worth four times more than the lower compound. When a given component reached four, the score would roll over and increase the next compound by one. Thus isooctane could be made by creating four naphthas. However, the analysts found that this was not the most efficient way to increase their score because it required over three times more game pieces than when using the

isooctane formula. Using this formula, the team's robot would be able to create an isooctane in 3 preliminary rounds and in only 2 semifinal and final rounds because it was able to average 13 game pieces in each round.

The analysis sub-team used two different approaches to analyze and to select the best strategy. In the first approach, they manually calculated the number of game pieces needed to achieve a high score. In the second approach, the sub-team wrote computer programs, one in Python and another in C, to generate random numbers within a set domain for each game piece. Then they ran the five preliminary rounds as well as the semifinal and final rounds using the program (See flowchart in Appendix B, page B-2). Each random number represented the number of each game piece the robot acquired. The programs would keep track of the highest final scores and inform the team what game pieces to pick up in each round. Through this process, the team was able to analyze the final numbers that the programs generated and select the optimum strategy. The analysts found that the programs needed to run about 1,000,000 times before producing a high score.

By combining the hand and computer calculations results, the sub-team found that maximizing $CO_2$ and energy with varying numbers of $H_2O$ and catalyst generated the highest scores. After observing this, they rewrote the program to automatically maximize $CO_2$ and energy, which allowed the program to produce a high score in far less time. These programs were not only developed for analysis, but also for use in the pit on Mall and Game Days to help the team decide which round to discard. If the inventory was different from what had been previously calculated, the new inventory would be re-entered into the program to calculate what new game pieces would be needed to maximize the score.

## 6.2 Robot Design to Accomplish Strategy

In order for the robot's design to comply with the strategy found by the analysis team, several specific design requirements were added. One of these was that the claw had to be able to score more than one game piece at a time. It also needed to efficiently score the $CO_2$ and energy. Another requirement added was that the robot needed to be able to activate the infrared sensor in order to effectively compete. The strategy guided the refinements on the robot during all stages of the engineering process.

# 7. Design Creativity

Creativity played a vital role as the team designed and built a robot that met all the requirements and was able to successfully compete in *High Octane*, yet still remain simple, robust, and reliable. The components that required the most creativity were the claw, the arm, and the infrared sensor.

## 7.1 Claw Design Evolution

Through brainstorming, the team generated thirty-two claw design concepts. After making and presenting rapid prototypes of these concepts, the team multi-voted to select the top four designs. They made pro/con lists for each of these four ideas to evaluate the strengths and weaknesses of each one. This helped the team to multi-vote more intelligently for a primary claw design. While voting, they kept in mind that their chosen game strategy required the claw to be able to score all the game pieces. The praying mantis claw (Figure 15) was chosen

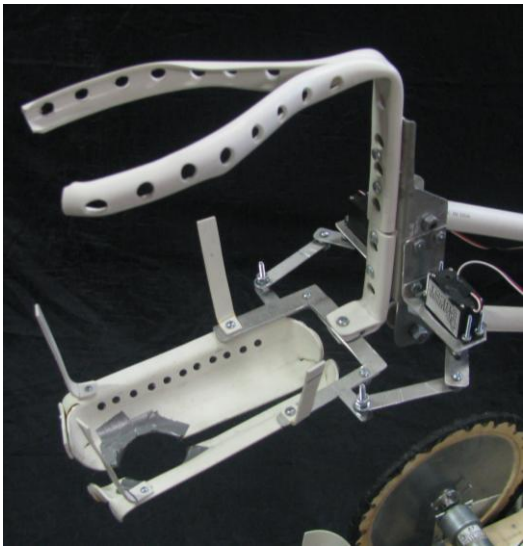


**Figure 15 - Praying Mantis Claw**

because it was reliable, versatile, and able to handle more than one game piece at a time. This servo-powered scoop was able to retrieve the $H_2O$, catalyst, and $CO_2$ while notches on either side of the claw allowed it to pick up the energy when it was upright. It also utilized a horseshoe-shaped extension to aid in scoring the $CO_2$.

## 7.2 Arm Design Evolution

The arm sub-team chose the parallelogram arm for its simplicity and its ability to keep the claw level while collecting and scoring game pieces. The first prototype that the sub-team built had a single large pulley powered by two small motors. These motors were connected in parallel by a single drive shaft which drove the belt to the pulley. To simplify this design, the arm sub-team put the motors into a series which allowed the motors to be attached to a single sheet of metal (Figure 16). This not only provided more stability, but also reduced the number of couplers which had caused difficulty. To make this design work, a second drive pulley was added. A shoulder bolt and pulley pulled down by a spring were used as an idler pulley to keep tension on the drive belt.

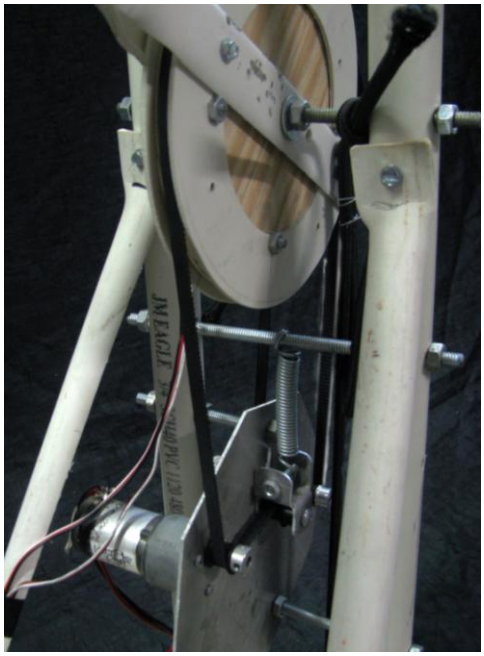


**Figure 16 - Arm Pulley and Motors**

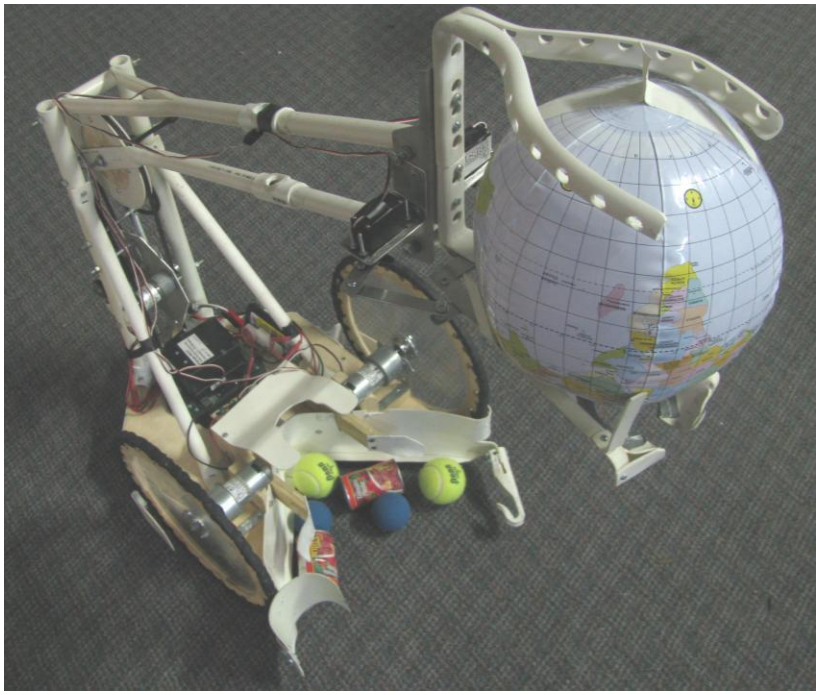
## 7.3 Infrared Sensor Design Evolution

A new component of the robot this year was the Infrared (IR) Sensor. Using this sensor instead of activating the pushbutton allowed the robot to be more efficient. The electronics sub-team chose to place the sensor on the right front corner of the chassis which made it easy for drivers to send signals to the receiver. Because they had chosen to use three IR codes, the

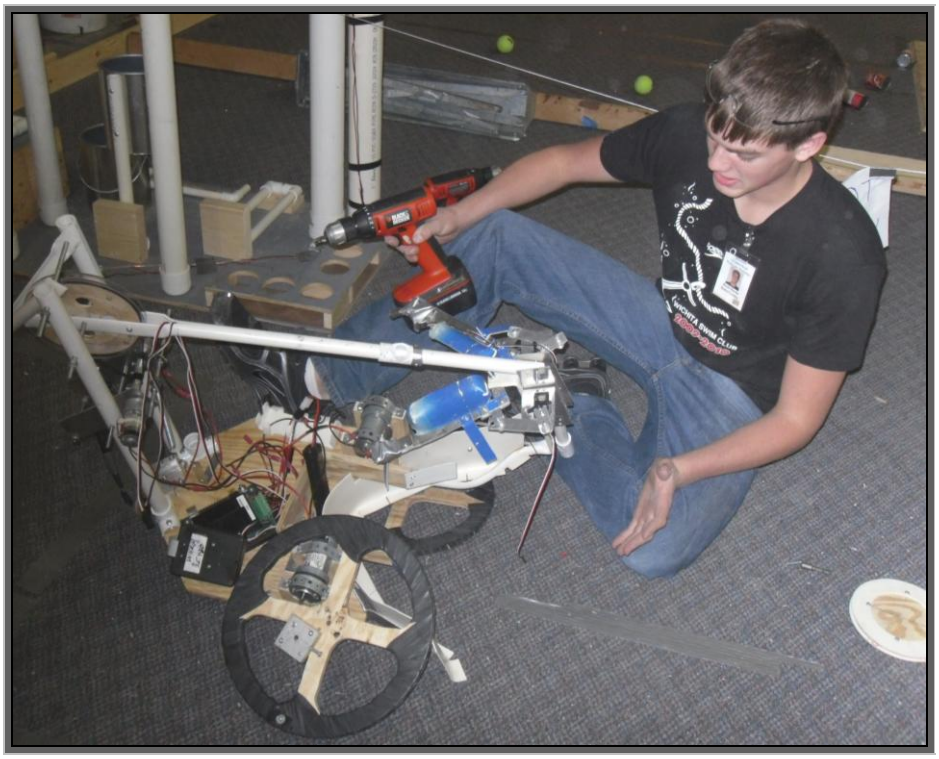
controller stick was programmed into thirds. Each third sent out a different signal. This allowed the drivers to know which signal the robot was sending.

## 8. Summary

Wichita Homeschool implemented a four-stage engineering process to design, build, and test their robot. In stage one the team found external, internal, and derived requirements. The second stage included brainstorming design concepts, prototyping, and developing a preliminary design based on the strategy. During stage three, the team focused on building and assembling the final robot. This robot was tested and evaluated in stage four, and any necessary refinements were incorporated into the final design. Frequent design reviews were conducted to evaluate component performance and to ensure compliance with the requirements. The final design, which used a praying mantis claw, was attached to a parallelogram arm. The arm was supported by a robust chassis that utilized a V-shaped bumper in the front to collect game pieces from the floor. By this four-stage process, Wichita Homeschool Robotics Team manufactured a robot that could effectively meet the challenges of *High Octane*.



# Support Documentation

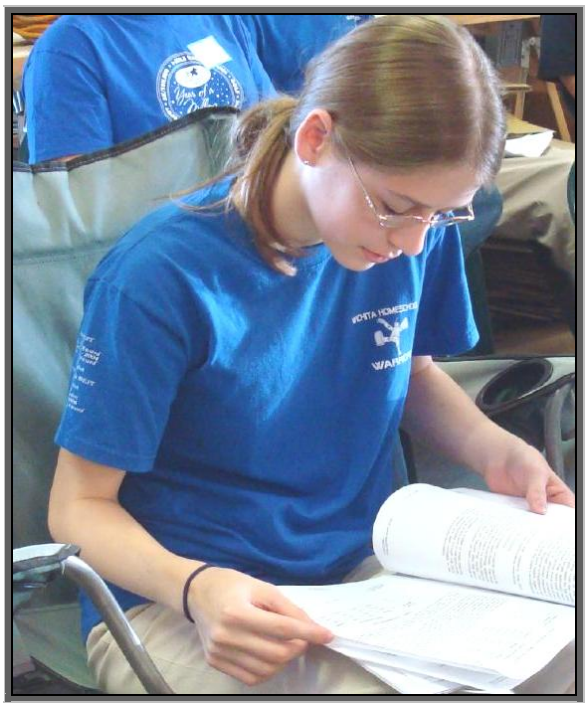


# Table of Contents for the Appendices

Appendix A: External, Internal, and Derived Requirements
External Requirements.....A-1
Internal Requirements…….…A-2
Derived Requirements…….....A-3
Appendix B: Game Strategies
Strategies list……..……B-1
Flowchart……..……..B-2
Appendix C: Robot Design and Construction
Design Concepts……..C-1
Pros and Cons of Top Four Claw Designs.....C-3
Robot Builder Forms……...C-4
Alibre CAD……..C-7
Blender CAD……...C-8
Appendix D: Team Information
Organization Chart……...D-1
Meeting Minutes……..D-2
Appendix E: Data and Analysis
Center of Gravity Calculations……E-1
Torque Calculations……E-2
Wheel Size Test Data……...E-3
Final Robot Test Results……..E-4
Appendix F: Brainstorming Rules
Brainstorming Rules……F-1
Appendix G: Works Cited
Works Cited……G-1

Support Documentation contains a total of 19 double-sided pages.

# Appendix A: External, Internal, and Derived Requirements



**Reading the BEST rules.**

# External Requirements

**Weigh**

1. Robot can weigh no more than 24 pounds.

**Size**

2. Robot must fit in a 24 inch cube.

**Materials**

3. PVC cannot be melted or changed chemically.
4. The robot can only be made out of materials in the returnables and consumables kits.
5. Stickers, paint, and adhesives cannot be applied to returnable items.

**Miscellaneous**

6. The spotter cannot touch $CO_2$.
7. The spotter's waistline cannot go over the edge of the platform.
8. Projectiles are not allowed.
9. Spotters cannot touch or pick up anything outside playing field.
10. A robot cannot attack other robots.
11. The spotter cannot touch the lower platform.
12. The robot cannot touch the energy generating station.
13. The spotter cannot touch benzene tankers.
14. Benzene accumulated during preliminary rounds is lost in semifinal and final rounds.
15. Teams must rotate drivers.
16. Drivers and spotters must stay in their space.
17. You are allowed thirty seconds to remove robot from playing floor after a match.
18. The spotter cannot touch a piece that is touching the robot.
19. The robot cannot destroy game pieces or playing floor.
20. Robots are not allowed to steal from other team's storage area or processing cell.
21. Drivers and spotters cannot have electronic communication devices.
22. A robot cannot enter operator area of another team.
23. Spotter can place or remove pieces in the storage area.
24. Teams can hoard items in their starting area.
25. Only one battery is allowed on robot at a time.
26. Each match is three minutes long.
27. Inventory is carried over through all the rounds.
28. A robot in a quadrant other than its own is frozen for twenty seconds if tagged by that quadrant's robot.
29. The driver cannot touch anything except the remote control.
30. Referees will not be questioned.
31. The robot must remain on playing field during round.
32. At the end of a round, the inventory is put into the equations that will give the points.
33. In order to score, the benzene must go into the 'shed' wheels first without any of the PVC cylinder touching the ground and with the red tape under the 'shed.'
34. Students wear safety glasses when driving, spotting, or using power tools in the pits.
35. The tie breaker will be decided by the first infrared symbol or pushbutton activated.
36. Water may be used as the free hydrogen in any equation.
37. An error with the playing floor will be disclosed one week before competition.
38. Processing cell and storage area can hold eight of every thing except $CO_2$.

39. The driver can only stand or kneel.
40. Benzene tankers will only be available during the semifinal and final rounds.
41. During semifinal rounds, one push button or IR ray causes all team resources to be discharged.
42. No spotter rotation is required.
43. A robot may place blocking devices on ground but it cannot trap robot in one area.
44. Energy generating station spins faster after seeding rounds.
45. A code may be put into BRAIN in order to discharge other team's catalyst.
46. Waste gas $H_2$ in Equation 2 is not added to the inventory.
47. Any pieces touching the robot at the end of the game do not count towards inventory.
48. Each team must drop one seed match.
49. Dropped matches do not affect your inventory.
50. Wildcard match does not affect your inventory.
51. A code in the BRAIN will protect your catalyst or to dispense three energy cans.
52. The robot cannot touch the stratosphere but it can touch suspension strings for $CO_2$.
53. The order of the tie breaker affects the speed of the catalyst.
54. Beach ball's diameter may be overinflated, underinflated, or normal within ± 1 inch.
55. The lower $CO_2$ molecules start at thirty inches above ground and move up.
56. Energy must be completely into designated area in order to score.
57. Energy-using blocking devices are not allowed.
58. No foul language.

## Internal Requirements

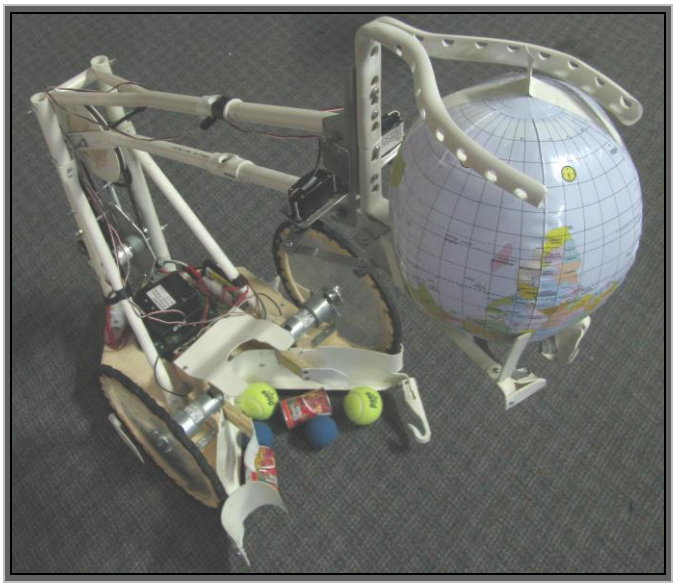
1. K.I.S.S.
2. No blocking devices because we consider that bad sportsmanship
3. Fast
4. Lightweight
5. Easy to drive
6. Robust design to handle blocking
7. Maneuverable
8. Light claw
9. Able to handle all pieces
10. Able to use infrared
11. Good center of gravity
12. Able to activate the pushbutton
13. Precise
14. Able to move benzene
15. Adaptable
16. Beautiful
17. No pink
18. Pink
19. Multiple strategies
20. Adaptable strategies
21. Spotters and drivers must know how to calculate inventory
22. Blue and Orange

23. Clean
24. Built quickly
25. Final design before Mall Day
26. Consistent and reliable

## **Derived Requirements**

1. Arm must be long enough to reach the $CO_2$.
2. Arm must be short enough to easily score game pieces.
3. Claw must be able to pick up and score all the game pieces.
4. Claw must be able to handle multiple pieces at a time.
5. Robot must be able to activate IR sensor and pushbutton.
6. Wheels must be 12 inches in diameter.

# Appendix B:  Game Strategies

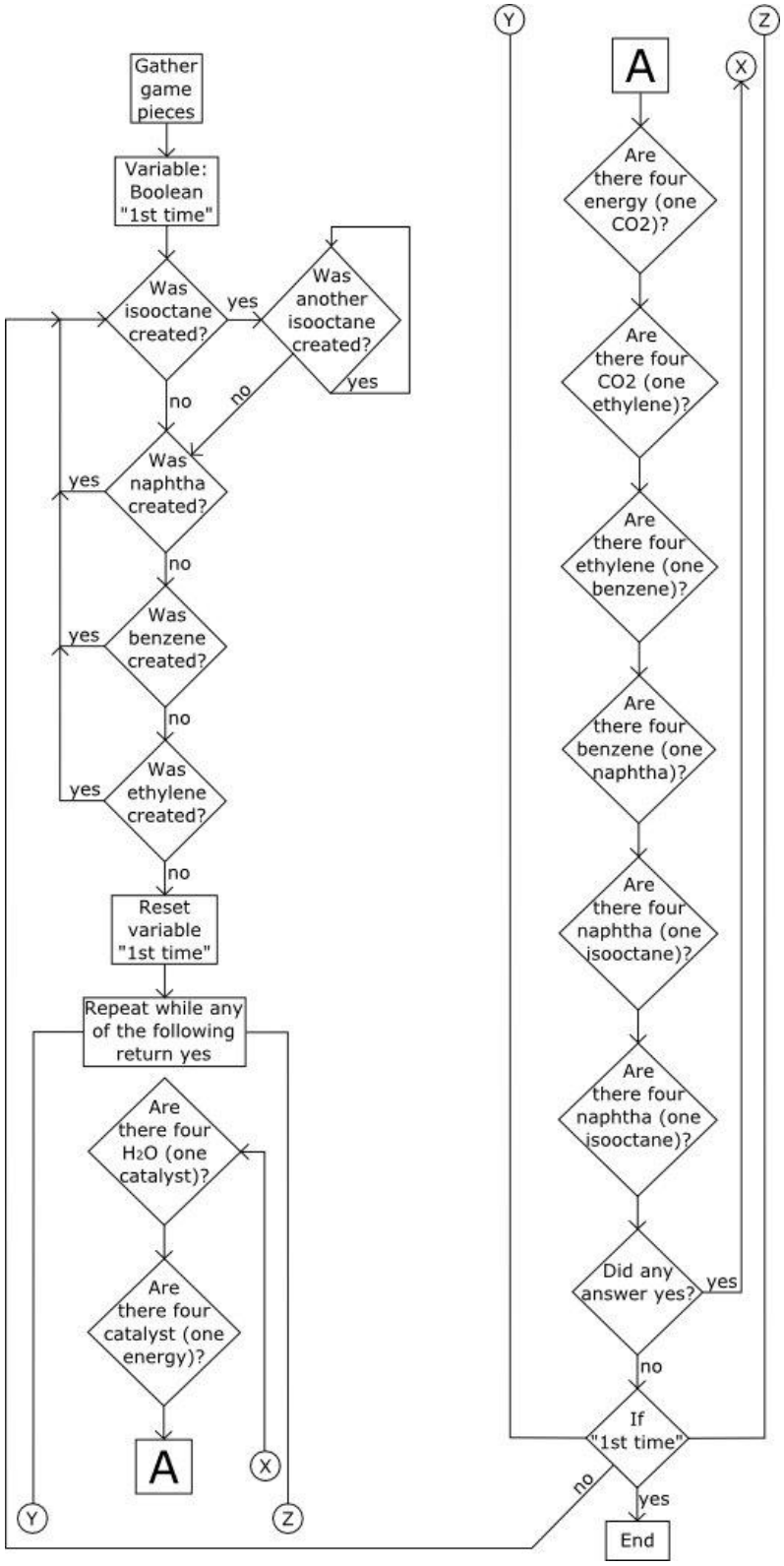


**Retrieving game pieces.**

# Strategies

1. Tag any robot in our quadrant.
2. Set up detachable wall to catch catalyst from the dispenser.
3. Take stuff out of another team's quadrant while their robot is frozen in our quadrant.
4. Catch the catalyst from the dispenser with the robot.
5. Get to energy generating station first to dispense energy.
6. Ramp to send catalyst from the dispenser to the storage area.
7. Get Benzene tankers fast.
8. Go for $CO_2$ first in preliminary rounds.
9. Activate Tsunami.
10. Get extra $CO_2$ to disrupt other team's scoring.
11. Use IR in order to be first to tie breaker.
12. Be able to push button if IR doesn't work.
13. Push balls and cans to the spotter to put the processing cell.
14. Score in other teams processing plant to disrupt their scoring.
15. Create a computer program that can calculate scoring to give us the best pieces to score in each round.

# Flowchart


Gather game pieces
Variable: Boolean "1st time"
Was isooctane created?
yes
Was another isooctane created?
yes
no
no
Was naphtha created?
yes
no
Was benzene created?
yes
no
Was ethylene created?
yes
no
Reset variable "1st time"
Repeat while any of the following return yes
Are there four H2O (one catalyst)?
Are there four catalyst (one energy)?
A
X
Y
Z
Y
Z
A
X
Are there four energy (one CO2)?
Are there four CO2 (one ethylene)?
Are there four ethylene (one benzene)?
Are there four benzene (one naphtha)?
Are there four naphtha (one isooctane)?
Are there four naphtha (one isooctane)?
Did any answer yes?
yes
no
If "1st time"
no
yes
End

# Appendix C: Robot Design and Construction

**Making a motor mount on the drill press.**

# Design Concepts

**Claw**

1. Double lasso wire claw for $CO_2$
2. Fully adjustable clamp/pincher claw
3. Bricktong
4. Grapple fork claw
5. Interweaving "finger" claw
6. $CO_2$ grabber with v hook on top and "horseshoe" on bottom
7. Golf ball retriever
8. Flexible finger claw
9. Constricting tendon finger claw
10. Brick tong with grapple fork on front
11. Ice tong claw
12. Tripod claw
13. Wrist rotating claw
14. Funnel claw with servo dispenser to catch catalyst
15. Cade's Chameleon claw
16. Tightening noose claw
17. Clincher claw (like teeth)
18. Semicircle claw
19. Can flipper bricktong
20. Expanding webbed horseshoe
21. Spinning cylinder clamp
22. Excavator/backhoe arm
23. Rotator for energy like Ambassadors
24. Mechanical rotating energy drop off claw
25. Three quarter pipe energy grabber
26. Rake claw
27. Velcro to pick up $CO_2$
28. Conner's hair clip claw
29. Small claw on bottom and big claw on top
30. Multiple-piece claw
31. Hand gripper claw
32. Forklift joint claw

**Arm**

33. $220^{o}$ rotating arm
34. Parallelogram arm
35. Telescoping arm
36. Raising and extending arm
37. Arm like Ambassadors (able to rotate can with mechanical device)
38. Forklift arm that goes straight up and down
39. Forklift with extending rails
40. Crane arm
41. Ferris Wheel arm with multiple claws
42. Scissor lift arm

**Chassis**

43. Benzene fork lift with bricktong
44. Driveby scooper for energy
45. Ball collector cage with arm and claw
46. Street cleaner spinner on bottom of robot

# Pros and Cons of Top Four Claw Designs

| Multi-piece Claw | Bricktong | Interweaving Claw | Horse Shoe Bricktong |
|---|---|---|---|
| 27 votes | 23 votes | 7 votes | 5 votes |
| **Pros:**<br>- More than one ball<br>- Easily get CO2<br>- Can get all pieces<br>- Easily score<br>- Can flip cans without servo<br>**Cons:**<br>- Anti-KISS<br>- May require motor<br>- Possibly hard to drive<br>- Possibly big<br>- Can't get Benzene tankers with claw | **Pros:**<br>- Every Piece<br>- KISS<br>- Experience building<br>- Strong<br>- Small<br>- Adaptable<br>**Cons:**<br>- Only one at a time<br>- Needs power<br>- Trouble with ball<br>- Trouble with $CO_2$<br>- Can't flip cans<br>- Hard to get benzene<br>- Heavy | **Pros:**<br>- Strong grip<br>- Simple to use<br>- Scary<br>- Cool!<br>**Cons:**<br>- Can't get all pieces<br>- Anti-KISS<br>- Hard to pieces of claw to work together<br>- One piece at a time<br>- Problems with $CO_2$<br>- May need motor<br>- Hard to get Benzene<br>- Can't flip can<br>- Hard to attach to arm | **Pros:**<br>- KISS<br>- Easily pick up all pieces<br>- Good grip on balls<br>- Easy to drive<br>- Could be operated like a normal bricktong<br>- Unique<br>**Cons:**<br>- Large<br>- One piece at a time<br>- Hard to make with kit materials<br>- Trouble with $CO_2$<br>- Can't flip can<br>- May require motor |

# Robot Builder Forms

Name: Brett Hawns Date: 10-6-09

Part: Claw

What did you build today and how did you build it? Include the materials used and draw a picture.

Today we worked on our mutiple size game piece claw.

Step 1: First, we started out by taking a piece of flattened and bending it in a "u" shape. So it looked like this.

Step 2: Next, we bent the edges down and folded the ends in so it looked like this. Then we cut it in half the long way, and added pieces of PVC to help hold the $CO_2$. side view

Step 3: Next, we build the hinges. They were made out aluminum. Then we built the $CO_2$ catcher. It looked like this. Lastly, we built the servo mounts. They were also out of aluminum.

What is the function of this part?

To pick up the game pieces.

Why did you choose this design? Please give two-three *different* reasons.

1. This design was one of the top voted claw ideas.
2. It is relatively simple.
3.

Did you encounter any problems or difficulties? How did you solve them?

We did not encounter any problems.

Is this your final design?

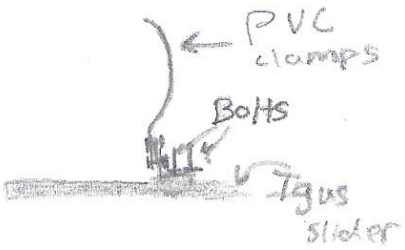
For now it is.

Name: Ryan Dunn, Connor Udd, David Dirks Date: 10/5/09

Part: Claw

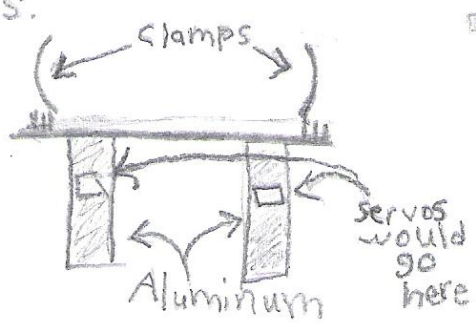
What did you build today and how did you build it? Include the materials used and draw a picture. Today we built a sideways brick tong. We used sheet aluminum, PVC, and Igus sliders. We fastened them together using 8/32 bolts and nuts.

Step 1: We cut PVC and bent it to form the tongs. We attached them using sheet aluminum to the Igus sliders.




Step 2: We attached aluminum clamps for the servo mounts.

Step 3:




What is the function of this part?

To grab the pieces on the gamefield.

Why did you choose this design? Please give two-three *different* reasons.

1. Because the team voted it into second place choice.
2. Because we have had past experience with it.
3. Because it has good grip.

Did you encounter any problems or difficulties? How did you solve them?

No

Is this your final design?

Possibly

Joey Botros

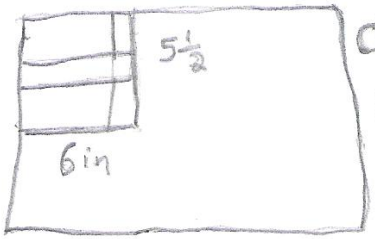
Name: David Dinks, Ryan Dunn Date: 10-12-09

Part: Claw mount

What did you build today and how did you build it? Include the materials used and draw a picture.

The Claw Mount was the dimensions shown with lines for bending

Step 1:




Step 2:

Bend at dotted line

Step 3:

Final Claw Mount

What is the function of this part?

Why did you choose this design? Please give two-three *different* reasons.

1. It would work the best
2. It wouldn't have to have extra holes drilled
3.

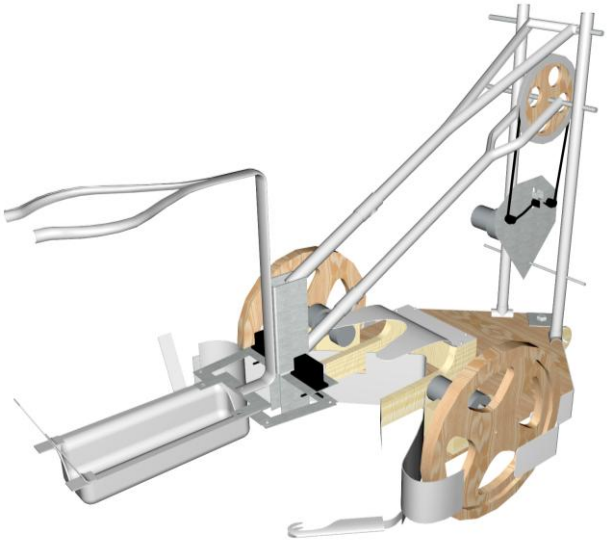
Did you encounter any problems or difficulties? How did you solve them?

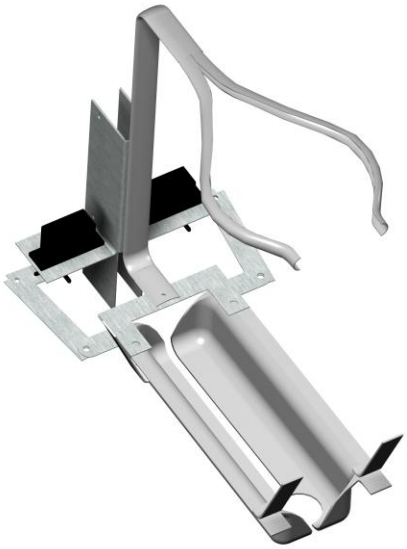
yes, we originally made it out of PVC but it was weak so we made it out of steel

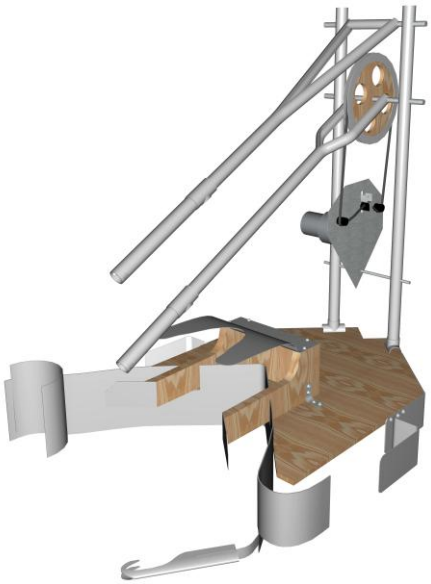
Is this your final design?

yes

# Alibre CAD of the Robot, Claw, and Arm

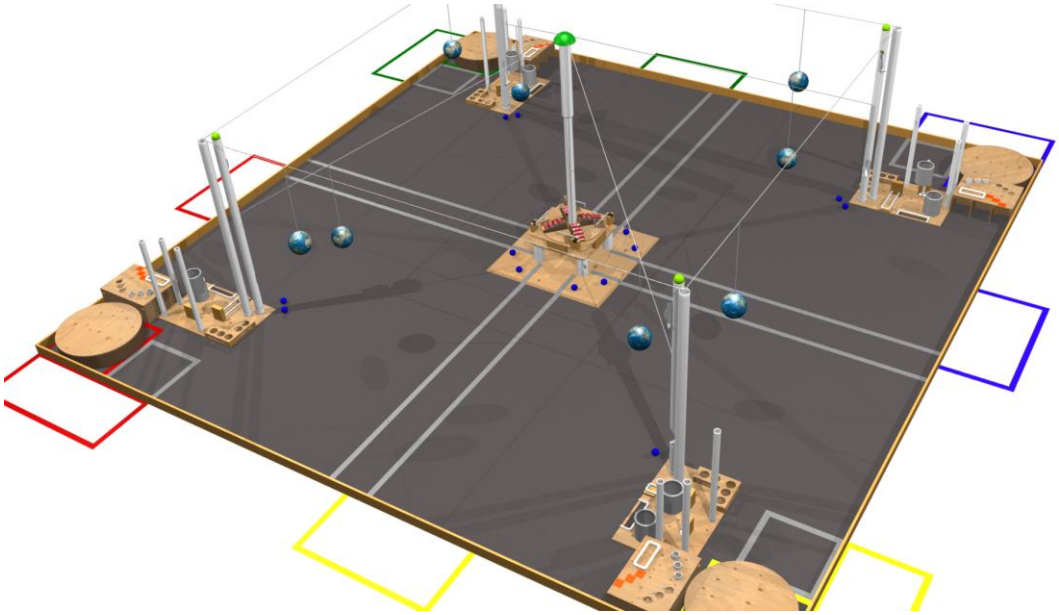




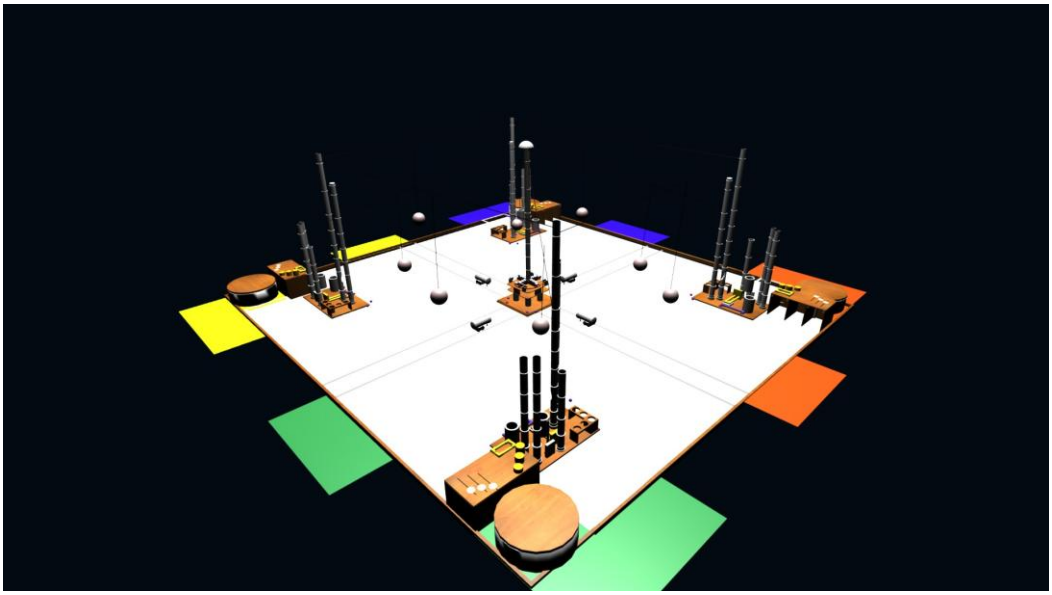


**Aaron Alexander, grade 12**

# Blender CAD of the Playing Field



**Jonny Fosnight, grade 11**

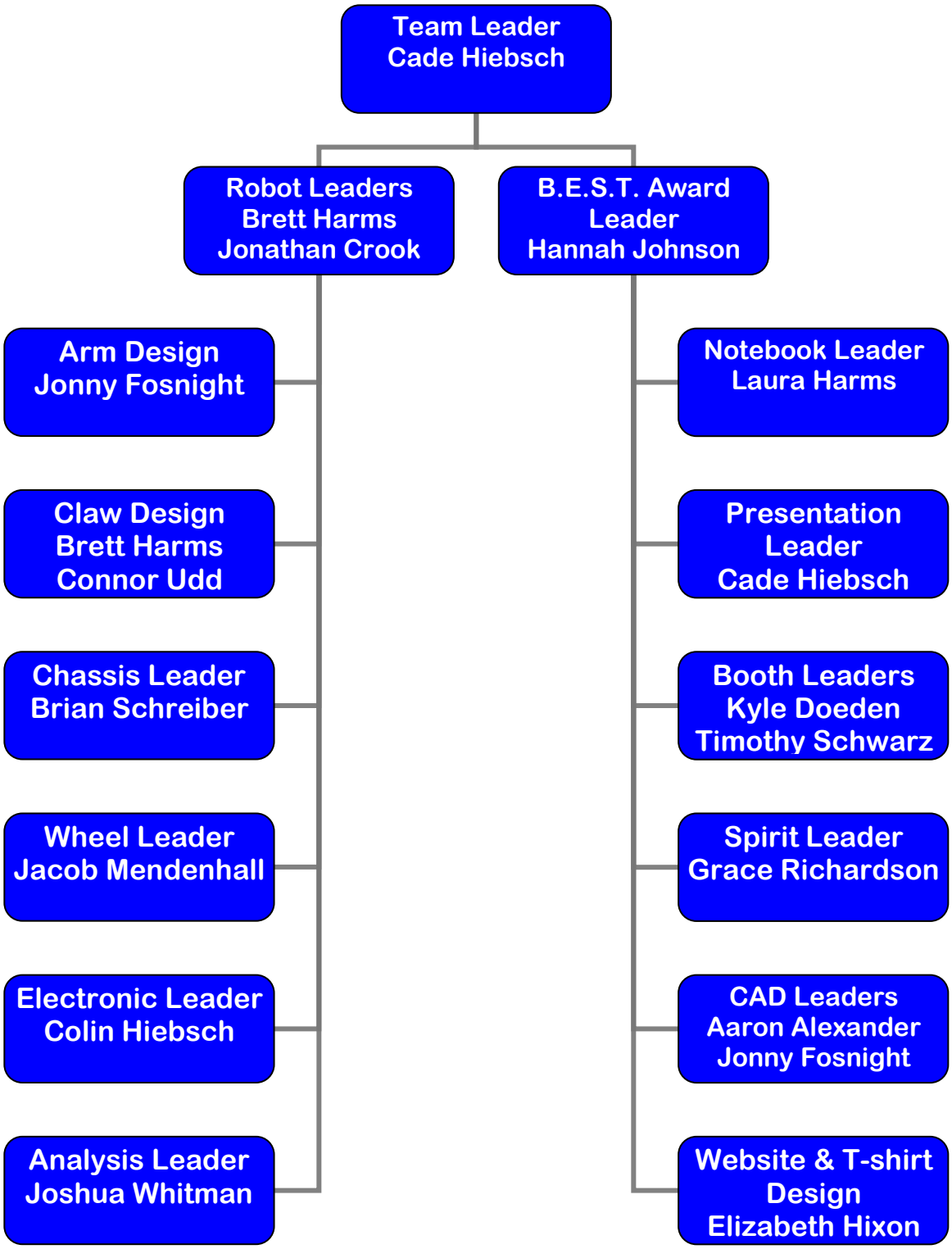


**Andrew Dirks, grade 10**

# Appendix D:  Team Information

**Creating rapid prototypes of design ideas.**

# Organization Chart



# September 28, 2009 Meeting Minutes

Cade opened in prayer

Jonathan and Mentors explained the $base_{10}$ and $base_4$ systems

Jonathan explained the scoring process

Brett reviewed where the game pieces were on the game field

Team discussed general scoring ideas

Jonny Fosnight simulated several rounds with a Python and explained the results

Jonny Fosnight ran 6 rounds in Python to give an idea of the end result

Mr. Alexander made rules about not playing with game pieces (especially the balls)

Team brainstormed for capabilities of the robot to aid in finding strategy ideas

Team began brainstorming for claw design concepts

Mr. Alexander reminded students to bring T-shirt order forms to the next meeting

Mr. Alexander previewed tomorrow night's meeting

Mr. Alexander told students how to create T-shirt designs

Cade closed in prayer

Team "sang" Happy Birthday to Mrs. Hixon

# October 26, 2009 Meeting Minutes

Mr. Alexander reminded the team that we have four working days till Mall Day

Mr. Alexander set deadlines for the different sub-team's projects

Cade opened in prayer

Cade gave a presentation about working for God's glory

Team broke up and began work

Brett had each sub-team leader report on their progress

Cade talked about driver tryouts

Hannah gave report of BEST side

Grace asked the team members to make cookies for Mall Day

Cade conducted the team in "singing" Happy Birthday to Kyle

Mr. Alexander gave information about a mandatory parent meeting and Mall Day

Mr. Alexander told team about taking a team picture on Mall Day

Cade closed meeting in prayer

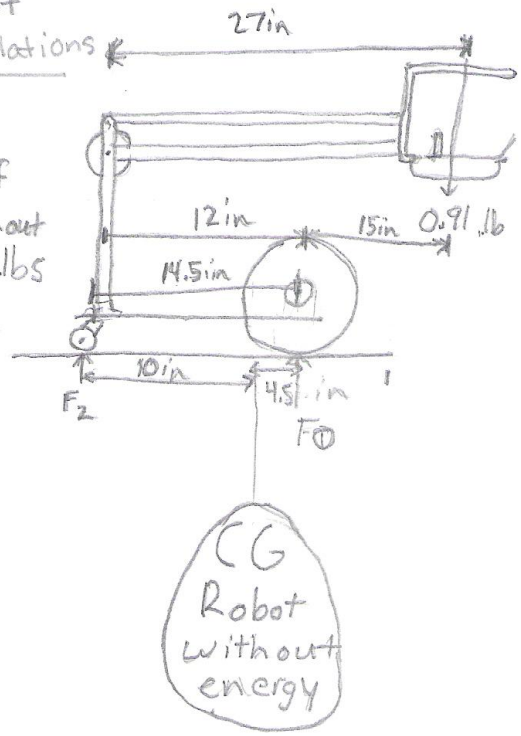
# Appendix E:  Data and Analysis

**Performing hand calculations for analysis.**

# Center of Gravity Calculations

Center of Gravity Calculations

Weight of Robot without energy = 13.9 lbs



$= 0.91$ lb

$\circlearrowleft + M_{①} = 0$

$0 = 13.9 \cdot 4.5 - 14.5 \cdot F_2 - .91 \cdot 11$

$14.5 \cdot F_2 = 62.6 - 13.7$

$\frac{14.5 \cdot F_2}{14.5} = \frac{48.9}{14.5}$

$F_2 = 3.4$ lb

$\Sigma F = 0$

$F_2 + F_1 = 13.9$

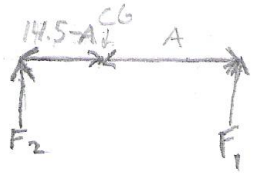
$3.4 + F_1 = 13.9 - 3.4$
$-3.4$

$F_1 = 10.5$

Since $F_1$ and $F_2$ are positive, the robot will not tip over with the energy in the claw.

Brett Harms
Grade 10

Calculation of robot and energy cans center of gravity.




$\circlearrowleft + M_{C.G.} = 0$

$F_1 \cdot A - F_2 \cdot [14.5 - A] = 0$

$10.5 \cdot A - 3.4[14.5 - A] = 0$

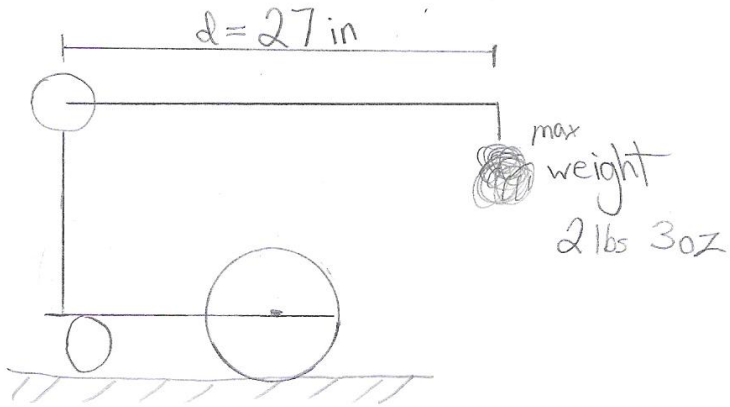
$10.5 \cdot A \quad -49.3 + 3.4A = 0$

$13.9 \cdot A = 49.3$

$A = 3.5$ in

This shows the CG is still between the wheels so the robot will not tipover.

# Torque Calculations




Torque Calculations

Torque = T  Force = F  d = distance

total weight needed = claw + max playing pieces (ie. two energy)

14 oz (claw) + 14.5 oz (2 energy) = 28.5 oz = 1.78 lbs

T = F × d  T = 2.19 lbs. × 27 in = 59.13 in·lbs. max

max needed  T = F × d  T = 1.78 lbs × 27 in = 48.1 in·lbs. max needed

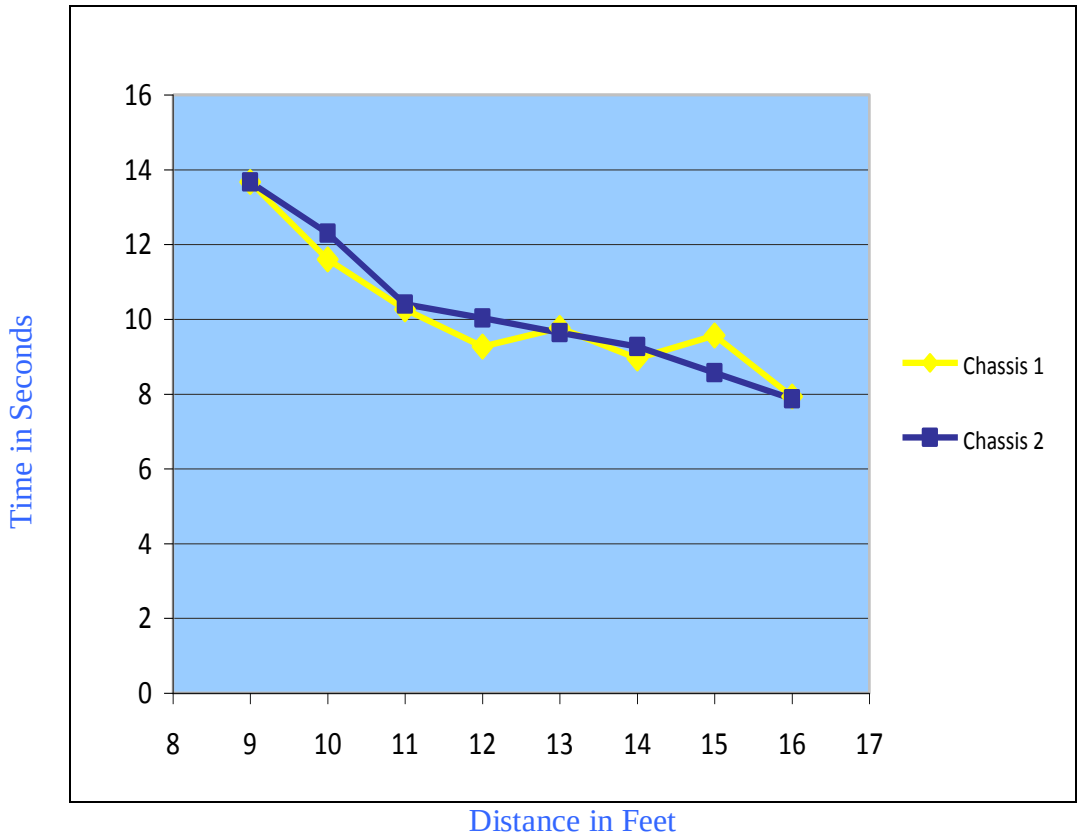
59.13 in·lbs (max) > 48.1 in·lbs (max needed)

Jonny Fosnight
Grade 11

# Wheel Size Test Data

| Chassis 1 | | | | Average |
|---|---|---|---|---|
| 9 inch | 13 | 13.5 | 14.5 | 13.7 |
| 10 inch | 11.4 | 11.4 | 12 | 11.6 |
| 11 inch | 10.2 | 10.3 | 10.3 | 10.3 |
| 12 inch | 9.2 | 9.5 | 9.1 | 9.3 |
| 13 inch | 9.7 | 9.4 | 10.2 | 9.8 |
| 14 inch | 8.6 | 9.9 | 9.0 | 9.0 |
| 15 inch | 9.6 | 9.3 | 9.8 | 9.6 |
| 16 inch | 7.7 | 7.9 | 8.2 | 7.9 |

| Chassis 2 | | | | Average |
|---|---|---|---|---|
| 9 inch | 14 | 13 | 14 | 13.7 |
| 10 inch | 12.2 | 12.1 | 12.6 | 12.3 |
| 11 inch | 10.5 | 10.3 | 10.4 | 10.4 |
| 12 inch | 10.2 | 9.8 | 10.1 | 10.0 |
| 13 inch | 9.3 | 9.6 | 10 | 9.6 |
| 14 inch | 9.5 | 9.3 | 9 | 9.3 |
| 15 inch | 8.3 | 9.1 | 8.3 | 8.6 |
| 16 inch | 7.9 | 7.4 | 8.3 | 7.9 |




**By Maggy Botros, grade 9**

# Final Robot Test Results

Drivers were given three rounds to make the following scores.

| | $CO_2$ | Energy | Catalyst | $H_2O$ |
|---|---|---|---|---|
| Trial 1 | 3 | 4 | 4 | 3 |
| Trial 2 | 2 | 6 | 1 | 2 |
| Trail 3 | 2 | 3 | 2 | 6 |

They were allowed a maximum of four minutes per round. If a driver finished scoring before the four minute limit, the time was recorded. At four minutes, those who were not finished were stopped and their score was tallied.

In the three middle columns of the table below, a time recorded shows that the driver scored the maximum number of points in that time. If a score is recorded, the driver was able to achieve that score during a four minute period.

| | **Round 1** | **Round 2** | **Round 3** | **Total Time** |
|---|---|---|---|---|
| Colin Hiebsch | 3:49 | 2:30 | 2:57 | 9:16 |
| David Dirks | 3:05 | 3:04 | 3:30 | 9:39 |
| Cade Hiebsch | 3:13 | 3:51 | 3:04 | 10:08 |
| Connor Udd | 3:29 | 2412 | 3:29 | 10:58 2412 |
| Jeremy Marshall | 3:38 | 2512 | 2314 | 11:38 4826 |
| Tucker Wilkes | 2432 | 2523 | 2325 | 12:00 612710 |
| Ryan Dunn | 2333 | 2512 | 2313 | 12:00 61158 |
| Josh Chase | 2331 | 2412 | 2323 | 12:00 61066 |
| Joshua Whitman | 2343 | 2312 | 2324 | 12:00 6979 |
| Dillion Dishman | 2322 | 2312 | 2323 | 12:00 6957 |
| Andrew Dirks | 2312 | 2102 | 2323 | 12:00 6737 |
| Kyle Doeden | 2123 | 1412 | 2322 | 12:00 5857 |
| Elizabeth Hixon | 2012 | 1311 | 2323 | 12:00 5646 |

# Appendix F:  Brainstorming Rules

**Multi-voting to select a claw design.**

# Brainstorming Rules

- Review rules before starting
- One topic at a time
- Members participate, in turn
- Accept ideas at face value; no discussion
- Record all ideas
- Members may elect to "pass"
- Continue until all have "passed"
- Open discussion on all ideas
    - Originator explains his idea to the team
    - Ensure everyone understands each idea
- Members vote for as many as half of ideas
    - Tally up the votes, selecting top two or three ideas
- Re-evaluate the reduced list of ideas
    - List pros and cons of each
    - Compare and contrast
- Members vote once for <u>one</u> idea of their choosing
    - Tally the final votes and pick the winner
    - Keep a record of secondary ideas for possible future use

# Appendix G:  Works Cited

**Reading sources for the research paper**.

# Works Cited


"Analysis of Selected Transportation Fuel Issues Associated with Proposed Energy Legislation." Energy Information Administration. U. S. Department of Energy. September 2002. 26 October 2009 <http://www.eia.doe.gov/oiaf/servicerpt/fuel/appendixc.html>.

"DOE: Pipeline Robot Revolutionizes Inspection Process." IHS. 7 December 2007. 23 October 2009 <http://energy.ihs.com/News/petrochemicals/2007/doe-pipeline-robot-120707.htm>.

Leffler, William L. *Petroleum Refining in Nontechnical Language*. Third Edition. Tulsa, OK: Pennwell Corporation, 2000.

Ki-moon, Ban. "The Right War: The U.N.'s Chief on Why a Greener Planet Would Be a More Peaceful One." *Time Magazine* Special Environmental Issue (April 2008.)

Skourup, Charlotte, and John Pretlove. "Robots Under Review for Role in Hazardous, Remote Locations." 1 August 2009. Offshore. World Trends and Technology for Offshore Oil and Gas Operations. 23 October 2009 <http://www.offshore-mag.com/index/article-display/7879127916/articles/offshore/volume>.

Tomov, Alexander, et al. "Origins of Isooctane." Department of Chemistry, Dickinson College. 21 April 2008. 26 October 2009 <http://itech.dickinson.edu/chemistry/?p=243>.

Trimble, Tyghe. "Suck It Up." *Discover Magazine* Better Planet Issue (May 2008).

"What is a Refinery? A Lesson in How to Make Gasoline." San Joaquin Geological Society. 27 October 2009 <http://www.sjgs.com/refinery.html>.

Wilbraham, Antony C., Dennis D. Staley, and Michael S. Matta. *Chemistry*. Fourth Edition. Menlo Park, CA: Addison-Wesley Publishing Company, 1997.