Circle High School
Team Thor

PROJECT NOTEBOOK
2010

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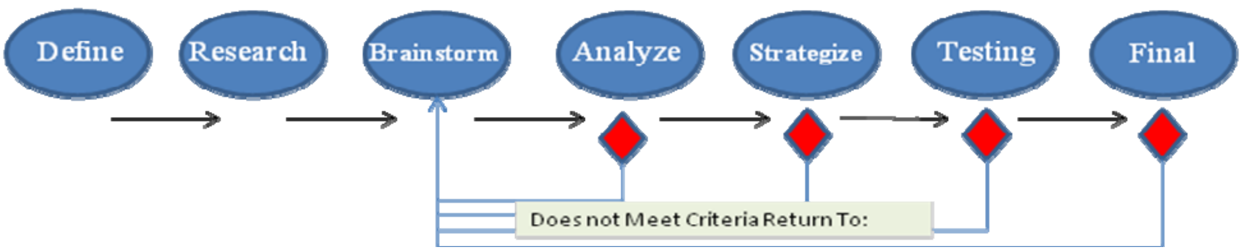
ENGINEERING NOTEBOOK
2010

Circle High School

Executive Summary

BEST Robotics Inc. (BRI) challenged Team Thor to create a robot capable of manipulating and synthesizing compounds to create alternative fuels. The following report thoroughly documents the phases and processes Team Thor incorporated to complete the challenge.



Team Thor utilized an engineering process to meet the requirements of the challenge, *High Octane*. This process included defining the problem, conducting research relevant to the game theme, brainstorming, analyzing prototypes, evaluating scoring strategies, testing, and defining the final design.

Team Thor reviewed robot specifications and the operational requirements needed to insure robot efficiency. Size and weight restrictions, mobility, individual component designs, and arm extension were all considered necessary to ensure robot efficiency while completing the challenge.

In preparing for the competition, research was conducted to identify historical, current, and futuristic content related to the challenge. Team Thor's research uncovered inventors and their inventions. Further research revealed the distinct correlations between *High Octane* components and real-world energy supplies.

The engineering process required Team Thor to conduct several brainstorming sessions relevant to the development of the robot. The team brainstormed ideas and designs for the base, arm, gripper, and CO_2 Retrieval designs. A scoring strategy was incorporated in the brainstorming process and functional requirements were established. The acquired information assisted Team Thor in creating, evaluating, and selecting robot designs.

Thorough analysis was conducted for each component prototype. Design parameters were established while strengths and flaws were identified. Analysis matrices determined efficiency ratings. The data obtained from analysis directed the design process.

Team Thor identified and evaluated offensive and defensive scoring strategies. Game considerations and complexities guided the decision-making process in determining the appropriate offensive and defensive approach. Strategies that complemented the robot design and yielded high point values were implemented. Game simulations were integral in selecting the final strategy for execution on Game Day.

Testing processes were incorporated to finalize the design and construction of the robot. Calculations were conducted to determine a wheel size that enabled the robot to travel maximum distance in a minimal amount of time. Robot prototypes were constructed to assist team members in evaluating the effectiveness of different robot components. Based upon testing and evaluation, modifications were determined and recommended for the final design.

The final phase in the engineering process entailed constructing the robot. All phases, evaluation procedures, analyses, and design parameters were significant in ensuring the efficiency of the robot design. Team Thor considered the efficacy of the robot components, their capability of completing game tasks, and their maximum scoring potential. They designed and created a robot that executed these requirements.

The engineering process required participants to utilize and integrate engineering, science, and technology skills. Collaboration was necessary to incorporate individual strengths and talents. Due to effective employment of the engineering process, Team Thor created a robot that will complete the BRI challenge.

Phase 1
Introduction: Defining the Problem

The C.H.S. BEST Team divided into groups to brainstorm.

1.1 Operational Scenario

BRI challenged Circle High School's Team Thor to complete the *High Octane* challenge: collect compounds, move these compounds to storage receptacles, and synthesize alternative fuels in three-minute rounds throughout the course of the game.

1.2 Defining the Goal

Team Thor discussed the challenges to define their goal. They agreed that in order to achieve their goal they had to create a mobile, agile robot capable of retrieving the specific compounds. Steps for achieving this goal started with a series of brainstorming sessions including the entirety of Team Thor. Analyses were conducted for each design idea to determine a final product design. The engineering process was utilized in order to create a functioning robot ready for Practice Day on October 31, 2009. Team Thor's engineering process took place in seven phases. These phases included defining the problem, researching relevant information, brainstorming, analyzing, evaluating offensive and defensive strategies, testing design alternatives, and making final design changes.

1.3 Criteria for Robot

Certain criteria restricted the design ideas of Team Thor's robot. Such criteria included operational requirements, building materials, physical requirements, and derived requirements.

1.3.1 Operational Requirements

Team Thor's robot was required to activate the infrared sensor, be able to grip, transport, and store various sized compounds, and transport a Benzene tanker. The final design must transport and place all compounds required to synthesize the alternative fuels.

1.3.2 Building Materials

BRI's approved list of building materials limited the design of the robot. Materials included parts donated by Igus, Inc., polyvinyl chloride (PVC) pipes and fittings, wood, plastic and metal stock, fasteners, tape, adhesives, brackets, hinges, and electrical components. Team Thor's final design could only incorporate the approved materials.

1.3.3 Physical Requirements

The operating robot was required to meet size and weight specifications. Size requirements specified that the robot must fit, unconstrained, in a 24″ cube. Weight requirements specified that the robot must weigh less than or equal to 24 pounds.

1.3.4 Derived Requirements

Team Thor derived additional requirements from strategic analysis. They concluded that the three-minute time constraint required a stable robot capable of quickly maneuvering the game field. It was also concluded that a zero turn radius would prove essential for a successful robot. After conducting scoring analysis, the importance of CO_2 in each formula required that the final robot be capable of retrieving and placing both CO_2 compounds during each round.

Phase 2
Research

2.1 Objective

Energy is the immovable mover that transforms the world around us. Aristotle noted the fundamental role of energy when he said, “Now nothing is moved at random, but there must be always something there to move it.” When the human element is added to energy, it becomes controlled movement—movement specified toward a purpose. Our complex modern world is powered by oil, natural gas, wind, solar, hydroelectric, etc. *High Octane* attempts, in some part, to address the societal effects of these power sources. The current energy dilemma can be solved by combining our ability to create new energy technologies with our ability to transform the *way* energy is used. *High Octane* demonstrates how the solution to society’s energy dilemmas lies not only in breakthrough technologies, but also in using current energy technologies more efficiently.

2.2 Game Correlation

Team Thor concluded that *High Octane* models historical, current, and future energy uses. The correlations between *High Octane* components and their real world counterparts are described in *Table A*.

High Octane Correlation	
Historical Energy Use	H_20, Catalyst
Current Energy Use	CO_2, Energy
Future Energy Use	Ethylene, Benzene, Naphtha, Isooctane

Table A

The challenge of *High Octane* is to create a solution to our energy needs. Catalyst, Water, Energy, and CO_2 are combined to form Ethylene, Benzene, Naphtha, and Isooctane. Thus, the solution appears to be the creation of a unique energy source. However, Team Thor believes that humanity’s energy dilemma will be resolved primarily through existing energy technologies.

High Octane’s purpose is not merely the manipulation of game components to achieve victory on Game Day; rather, it is the achievement of more enduring lessons. *High Octane* guides participants towards increased knowledge of historical, current, and future uses of energy.

2.3 Historical Energy Uses

High Octane inspires BEST teams to evaluate historical uses of energy. The first two game components, Catalyst and Water, model these uses. Harry Truman said, "There is nothing new in the world except the history which you do not know." Truman's quote implies that current technologies are byproducts of past creations, leading to the inference that the inclusion of Catalyst and Water details their importance in the discovery of a viable energy solution.

Energy and humanity are uniquely interlinked. Without human influence, energy lacks direction and purpose. We manipulate energy to accomplish desired tasks. Essentially, humans are the catalyst that directs and eases the flood of power from kinetic to potential energy and back to kinetic again. Our catalysis of energy began well before the Industrial Age.

Mechanization is required to utilize current energy sources. Before mechanization, all energy sources operated sans-mechanics. The primary energy source prior to mechanization was the sun. The Romans demonstrated the human role in catalysis in the first century. They invented windows to trap solar heat within buildings and prevent other weather conditions from entering (Silvi). The human element is instrumental in the creation of technologies to catalyze energy. Without the human influence, energy truly is an immovable force.

The mechanization of energy began to occur primarily during the early Industrial Revolution (Montagna). The energy applied by the human catalyst during this revolution was steam. As such, steam is represented in *High Octane* by Water. Hero of Alexandria used steam for the first time in the First Century AD. However, Hero's invention did not harness steam's full capabilities. Thomas Newcomen invented a practical steam engine in 1710. Steam became the standard energy source when James Watt increased the efficiency of Newcomen's engine. In 1775, Watt made a steam engine that was 75% more efficient than Newcomen's and this spurred the Industrial Revolution (FSU).

2.4 Current Energy Uses

High Octane's next components, CO_2 and Energy, teach lessons about current use of energy. Analysis of current energy consumption is incomplete without the inclusion of petroleum, coal, and natural gas. Fossil fuels provide for 86.1% of the world's energy demand (IEA). Reliance on fossil fuels for energy endangers societal stability. Because a large percentage of our energy comes from a limited resource, any severe fluctuations within the market can have disastrous effects. In the summer of 2008, oil prices peaked at $147.27 per barrel (Officer). As the cost per barrel increased, energy prices rose dramatically. Energy affects all sectors of an economy because any item produced and/or shipped possesses traces of the energy used to manufacture and transport that product. As oil prices rose, all prices rose. The economy was strained and all consumers suffered the hardship of oil dependence.

Within *High Octane,* CO_2 possesses the same importance as fossil fuels. There are eight components of CO_2 in *High Octane*. A lack of CO_2 paralyzes any BEST team attempting to complete the game. Fortunately, there is another way to achieve CO_2 should resources be limited. *High Octane* operates on a Base-4 system. When the quantity of any component reaches four, that component is converted into one unit of the next component. The component that may be converted to CO_2 is Energy. *High Octane's* Energy represents the real-world application of alternative energy sources.

Alternative energy sources provide for the remaining 13.9% of the world's energy demand (IEA). Just as *High Octane* Energy may be used to supplement CO_2, alternative energy is the current supplement to fossil fuels. Alternative energy does not produce enough energy to meet demand. However, alternative energy does provide a realistic supplement to fossil fuels. The Hoover Dam supplies 10.5% of Nevada's electrical needs (NREP). Although alternative energy resources cannot meet all energy requirements, when combined with fossil fuels they provide meaningful energy benefits. *High Octane* represents this real-world nexus between fossil fuels and alternative energy.

2.5 Future Energy Demands

Current energy production sources meet global energy demand. However, this demand is increasing rapidly. The United States (U.S.), which constitutes 4.5% of the world's population (~300 million people), uses 25% of the world's fossil fuels (IEA). Industrializing countries such as China, India, and Brazil (~2.7 billion people) are dramatically increasing their demand for fossil fuels. As these nations approach the per capita consumption rate of the U.S., the global energy supply will be stressed beyond its capabilities. China will account for much of the increased energy demand. In 2009, China added 80 to 100 gigawatts of electricity to its power grid – many of these produced by already limited resources (Powell).

The first four components of *High Octane* are combined to form Ethylene, Benzene, Naphtha, and Isooctane. These energy technologies represent the solution to future energy demands. Some proponents of new technologies promote an one-alternative solution. However, Team Thor believes that energy *efficiency*, represented by Isooctane, is the realistic solution. Isooctane cannot be formed without the efficient combination of all *High Octane* components. In each round, BEST competitors must target these required components. If they fail to efficiently combine these components, the result could be a failed round or a lost game. As efficiency delivers success in *High Octane*, improved efficiency will deliver superior results for society.

The potential of enhanced efficiency is apparent in light bulbs, power plants, and automobiles. An incandescent light bulb converts only 4% of its total electricity to light (Grunwald). Power plants convert only 33% of the total energy in fossil fuels to electricity and have not improved since 1957 (Lozanova). The average automobile operates at only 15% efficiency (Jagadees). Most devices can operate more efficiently. While energy efficiency may not be a revolutionary solution to meet energy demands, it is an *efficient* one. Enhanced efficiency could reduce the increase of energy demand in 2020 by 50% (McKinsey). Bar none, the most realistic method of resolving future demand issues is the efficient consumption of current energy sources.

2.6 Conclusion

The theme of *High Octane* is the manipulation of energy. Without energy, society cannot function. Unfortunately, we often forget the critical role of energy. The manipulation of *High Octane* components to create Isooctane represents the realistic solution. In order to combat rapidly increasing demand, we must fully utilize all available technologies. Humanity will develop a viable solution through the efficient combination of past and current energy technologies. *High Octane's* challenge *efficiently* directs BEST programs toward the recognition and realization of a viable energy solution.

2.7 Works Cited

Florida State Univ. Steam Condensing Engine. Los Alamos National Laboratory. 17 Oct. 2009. http://www.magnet.fsu.edu/education/tutorials/museum/steamengine.html.

Grunwald, Michael. "America's Untapped Energy Resource: Boosting Efficiency." TIME. 31 Dec. 2008. http://www.time.com.

International Energy Annual (IEA). June – Dec. 2008. Energy Information Administration, U.S. Government. http://www.eia.doe.gov.

Jagadees. "IC Engine Automobiles : 15% Fuel to Wheel Efficiency." Oct. 2007. 27 Oct. 2009. http://www.jagadees.wordpress.com.

Lozanova, Sarah. "Power Plant Efficiency Hasn't Improved Since 1957." Clean Technica. 26 June 2008. http://www.cleantechnica.com.

McKinsey. The Case for Investing in Energy Productivity. McKinsey Global Institute, Feb. 2008.

Montagna, Joseph A. The Industrial Revolution. New Havens Teachers Institue, Yale U. 2009. 25 Oct. 2009. http://www.yale.edu.

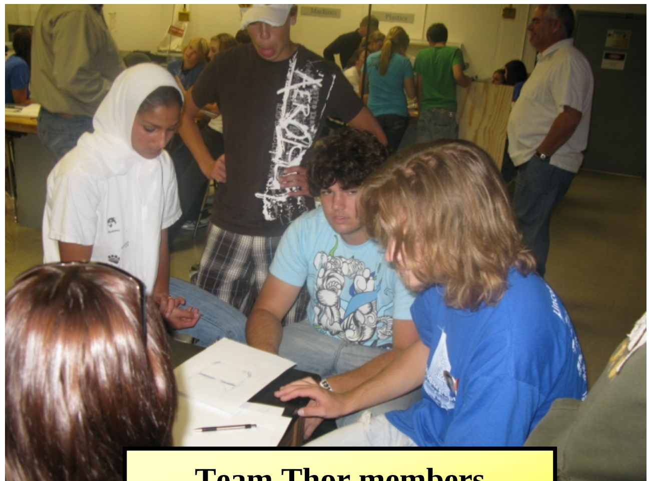
Nevada Renewable Electricity Profile (NREP). June 2010. Energy Information Administration, U.S. Government. http://www.eia.doe.gov.

Officer, Ari J. "What Caused the Big Slide in Oil Prices." TIME. 14 Nov. 2008. http://www.time.com.

Powell, Bill. "Has China Really Gotten Serious About Climate Change?" TIME. 24 Sep. 2009. http://www.time.com.

Silvi, Cesare. "History and Future of Renewable Solar Energy." Development. Houndmills: Sep. 2008. Vol 51, Issue 3. 409-415. Proquest. Nixon Library, El Dorado, KS. 23 Oct. 2009.

Phase 3
Brainstorming: Defining Requirements



Team Thor members discuss necessary robotic requirements.

3.1 Overview

Brainstorming sessions were conducted in two processes. The first process consisted of two individual brainstorming sessions in which team members discussed scoring requirements and robot designs. Ideas drawn from the first brainstorming session were then reviewed in the second brainstorming process. The second process was completed by the robot team in order to finalize the robot design.

3.2 Brainstorming Process One

The initial brainstorming session incorporated all 51 members of Team Thor. The team reviewed, evaluated, and presented new ideas throughout this brainstorming process. Descriptions of the two brainstorming sessions are specified below.

3.2.1 Session One

The first brainstorming process began after Kick-Off on September 26th, 2009 (Appendix A.1). A Chief Operations Director (COD) was appointed for project management. Sub-teams were formed and student team leaders were selected (Appendix A.2). Game and robot requirements guided the brainstorming session and assisted in understanding and defining the goal. In this session, Team Thor discussed the game, potential scoring strategies, and robot ideas. It was quickly recognized that the complexity of scoring would guide the robot design.

The team first discussed the scoring requirements for each round. The first formula to complete was Ethylene: two compounds of H_2O, one Catalyst, one Energy, and two compounds of CO_2. Once that was completed, Team Thor would repeat the process three times to complete the formula for Benzene: three compounds of Ethylene, one Energy, and one Catalyst. To complete Naphtha, the next formula level, the robot would need to attain one Energy, one Catalyst, and four compounds of H_2O. The final formula is Isooctane, which consists of one compound of Benzene, Ethylene, Energy, Catalyst, and four compounds of H_2O. The compounds in the game were represented as follows:

- H_2O= Racket Ball
- Catalyst= Tennis Ball
- Energy= Tomato Paste Can
- CO_2= Beach Ball
- Benzene= Tanker Truck (only in Semi-Finals and Finals)

It was then explained to Team Thor that if, at the end of each round, a team had attained more than four of any component, each set of four would automatically convert into the next component (Five H_2O = One Catalyst + One H_2O). Team Thor recognized that this rule could both help and hinder their advancement.

Team Thor then discussed Critical to Satisfaction (CTS) criteria and Functional Requirements. This criterion was necessary in assisting the design process. Team Thor acknowledged the CTS criteria and Functional Requirements and defined them as follows:

- Activate Infrared Sensor
- Fit within a 24 in^3 starting area
- Meet the weight requirement: $\leq$ 24 pounds
- Combine different compounds to synthesize alternative fuels

Sketches of possible robot designs were created by team members that incorporated the CTS criteria and Functional Requirements. The sketches were collected for later review. A sample of Team Thor's brainstorming sketches may be viewed in Appendix A.4-A.4.3.

3.2.2 Session Two

Team members used the subsequent brainstorming session on September 28th (Appendix A.1.1) to evaluate the designs brainstormed after the first session. The designs were presented by students for team consideration. Team Thor then evaluated the student drawings and conducted dialogue concerning the robot ideas. CTS criteria and the Functional Requirements guided this process.

Several designs were brainstormed for a CO_2 Retrieval device. This device, used in conjunction with the arm, would allow the robot to reach different height levels. Three main designs were presented by team members for consideration. The first design was the Slider Offshoot. This device was an addition to a gripper design known as the Slider. The Offshoot would consist of a wire hanger attached to the gripper that extended upwards. The Offshoot would sever the CO_2's Velcro attachment, dropping the CO_2 to the floor where the gripper would retrieve it.

The second design was the Shepherd's Hook. The Shepherd's Hook consisted of ¼" all-thread rod. Hanger wire would be attached to the end of the all-thread to form the hooking device. The hook extended from a central tower. The arm's downward motion would drive the hook toward the CO_2. The hanger wire would encompass the string connecting the Velcro and the CO_2. As the robot moved, the tension between the CO_2 and the hanger wire would release the CO_2, dropping it to the floor for the gripper to retrieve.

The third design was the Lasso. The Lasso was made of PVC, a 1” x 4” wood block, Velcro, and sheet metal. A 3” diameter wheel retracted and extended the PVC strap by the attached Velcro. The Lasso extended to a 12” diameter. Because of the Lasso’s ability to extend, it would be able to retrieve the CO_2 while remaining attached to the arm of the robot. The arm’s pivot point was 20” above the ground and the arm length, in addition to the lasso extension, would reach up to 52”. The Lasso’s variable diameter allowed for it to also manipulate smaller game objects. After prototyping, the team’s consensus was to employ the Lasso design because it served as a CO_2 Retrieval device and as a functional gripper.

3.3 Brainstorming Process Two

Once Team Thor finalized their recommendations, the conclusions were given to the robot team. The robot team conducted their own brainstorming sessions to refine the suggested designs. Functional Requirements were considered in this process. Based on the requirements of the suggested designs, further ideas were developed for the base, arm, gripper, CO_2 Retrieval, and wheel configurations. Options were then discussed for each of the robot components. Design, material needs, and perceived effectiveness of the designs were considered. *Table A*, located on page 14, identifies the ideas and material needs that were discussed for each of the robot components. An analysis was conducted for each of the robot components (Appendix B.1-B.4), counterweight requirements (Appendix B.5), and motors (Appendix B.6). Design parameters were identified and weighted for importance. Evaluations, efficiency ratings, and statistical performances were also considered.

Robot Component	Design Idea	Materials
Base	Bulldozer	Plywood
	Trapdoor	Plywood
	White V	PVC
Arm	Rotating Disk	PVC/ plywood
	Elevator	Igus chain/ PVC
	4-Bar	PVC
Gripper	Slider	PVC
	Lasso	PVC/ plywood/velcro
	Wire Trap	Igus rod
CO2 Retrieval Device	Shepherd's Hook	Igus rod/coat hanger
	Slider off-shoot	Coat Hanger
	"Lasso"	PVC/ plywood/velcro
Wheels/Casters	14" diameter	Plywood
	Caster	Plywood
	PVC Elbow	PVC Elbow

Table A

Prototypes and Computer Aided Design (CAD) drawings for the component ideas were created. Following the process of sketching, discussing, testing, and analyzing the overall effectiveness, final designs were selected for the base, arm, gripper, CO_2 Retrieval device, and wheels. The design selections for each of these robot components were:

- **Base**: Bulldozer/ Construction Plywood (Appendix E.2)
- **Arm:** Rotating Disc/ Construction PVC Pipe and Plywood (Appendix E.3)
- **Gripper:** Lasso/ Construction PVC (Appendix E.4)
- **CO_2 Retrieval:** Lasso Extension / Modified PVC pipe (Appendix E.4)
- **Wheels**: 14" diameter / Construction Plywood (Appendix E.5)

Once final determinations were made concerning each robot component, the robot team created a fully functioning robot prototype. Team Thor was confident that the completed robot would successfully meet the BRI challenge.

Phase 4
Prototype Analysis

A student makes evaluations based on a prototype.

4.1 Overview of Analytical and Mechanical Prototyping

Team Thor's first step in the analysis process was to identify CTS criteria and Functional Requirements of the robot. The CTS criteria allowed Team Thor to identify requirements for construction. The Functional Requirements were developed to identify how the robot should perform. Based on the CTS criteria and the Functional Requirements, Team Thor established parameters for each of the design elements and established priority-based weighting for the analysis matrices. The ratings are listed in *Table A.* Once these guidelines were developed, Team Thor determined how effectively each design met the parameters.

Analysis Ratings	
Score	**Interpretation**
1	Minimum Efficiency
2	25% Efficiency
3	50% Efficiency
4	75% Efficiency
5	Maximum Efficiency

Table A

The design parameters were assigned a value according to their perceived importance in the overall design. Prototypes were then built for the designs based on analysis of the efficiency ratings. Cardboard was used to create some prototypes, but CAD drawings and to-scale prototypes proved more useful. This mechanical prototyping was used to finalize design concepts.

4.2 Base Design

The design parameters established to evaluate the base design were ease, strength, weight, and scoring. Three designs were considered and evaluated using the weighted Base Analysis Matrix (Appendix B.1). The three designs evaluated were the Bulldozer, the Trapdoor, and the White V. Each design needed to meet the following requirements: easy assembly, synchronization of components with robot design, and a sufficient weight.

After Team Thor discussed the three base designs, evaluated strengths and weaknesses, and considered the statistical data drawn from the Base Analysis Matrix, the Bulldozer was selected for further prototyping. Team Thor's engineers evaluated proper dimensioning for height of the base. Initially, the base rested 1" above the ground. However, it was discovered that at this height Water and Catalyst could slip underneath and high-center the bulldozer – paralyzing operations. A new base was created that would rest 2.5" above the ground. At this height all game components, except for CO_2, could move freely under the base. Team Thor determined that the size of CO_2 did not allow it to paralyze the robot. The Bulldozer created by Team Thor could effectively manipulate game components to maximize scoring potential.

4.3 Arm Design

The design parameters established to evaluate the arm design were movement, total rotation, motor requirements, extension, and weight. Three designs were considered and evaluated using the Arm Analysis Matrix (Appendix B.2). The three designs were the Rotating Disc, the Elevator, and the Four Bar. Each design needed to meet the following requirements: reach CO_2 compounds, reach the ground, and extend 17" in front of the robot.

After Team Thor discussed the three arm designs, evaluated strengths and weaknesses, and considered the statistical data drawn from the Arm Analysis Matrix, the Rotating Disc design was chosen for further prototyping. Team Thor's engineers evaluated the diameter and location of the Rotating Disc. It was initially determined that a larger disc would allow for quicker rotation. While this was true, Team Thor discovered that in order to satisfy all CTS requirements, a larger disc must be placed further from the top of the 24" cube. As a result, the maximum height the arm could reach would be decreased, hindering the ability to reach CO_2. A 7" diameter disc was chosen. The center of the disc would be located 4" below the top of the 24" cube. The Rotating Disc was able to complete a 270 degree rotation in 23 seconds. Team Thor's arm design enabled the arm to complete all facets of the game.

4.4 Gripper Design

The design parameters established to evaluate the gripper designs were speed, weight, accuracy, compatibility, and extension. Three designs were considered and evaluated using the Gripper Analysis Matrix (Appendix B.3). The three designs were the Slider, the Lasso, and the Wire Trap. Each design needed to meet the following requirements: grasp compounds, accurately place game components, and perform quickly.

After Team Thor discussed the three gripper designs, evaluated strengths and weaknesses, and considered the statistical data drawn from the Gripper Analysis Matrix, the Lasso was chosen for further prototyping. Team Thor's engineers evaluated the retraction and extension mechanism for the Lasso. The Lasso retracted and extended through the force of friction. The initial prototype relied on friction created by tension between two wooden wheels. It was discovered that the tension created by these wheels was inconstant. The wheels effectively retracted the Lasso, but were unable to maintain ample tension to grasp objects. A second prototype was created that generated friction through Velcro. The Velcro hook was attached to a wheel and the loop was attached to the Lasso strap. When the hook rotated counterclockwise, it pulled the loop inward, retracting the Lasso. When the hook rotated clockwise, it pulled the loop outward, extending the Lasso. The Lasso's second prototype enabled the robot to manipulate all game components.

4.5 CO_2 Retrieval Design

Team Thor has defined CO_2 Retrieval as the robot's ability to recover the CO_2 compounds which are suspended from the elevated game floor. The design parameters established to evaluate the CO_2 Retrieval designs were height, functionality, motor requirements, compatibility, and stability. Three designs were considered and evaluated using the CO_2 Retrieval Matrix (Appendix B.4). The three designs were the Shepherd’s Hook, the Slider Offshoot, and the Lasso. Each design needed to meet the following requirements: reach CO_2 compounds, ascertain height quickly, and maintain stability.

After Team Thor discussed the three CO_2 Retrieval designs, evaluated strengths and weaknesses, and considered the statistical data drawn from the CO_2 Retrieval Design Matrix, the Lasso was chosen for further prototyping. Team Thor's engineers evaluated the length of the Lasso's strap. The Lasso extended away from the robot. As a result, it was able to add length to the arm. This extended length eased the process of retrieving high-floating CO_2. Initially, the strap was 35" long. At this length it extended 15" away from the end of the gripper. However, it was discovered that this strap length interfered with normal robot operations. Team Thor shortened the strap length to 25". This new length still enabled the retrieval of CO_2, but did not interfere with other operations. The Lasso was an especially effective CO_2 Retrieval design because it did not require an additional mechanism to be added to the robot. The design served a dual purpose.

4.6 Force Moment Analysis

Team Thor also conducted a Force-Moment Analysis (Appendix B.5) to determine the amount of force required to operate the arm mechanism. The team weighed all components of the arm and gripper to create this analysis. These measurements were calculated and combined with the Motor Analysis (Appendix B.6) to determine appropriate counterweight. Team Thor determined that the counterweight should offset the total weight of the gripper and arm. This would minimize the stress placed on the drive motors. After the Force-Moment Analysis, Team Thor concluded that a 6-pound weight would minimize the stress placed on the motors. After further prototyping and testing, they realized that the 6-pound weight was not an effective counterweight mechanism. The team replaced the 6-pound weight with an elastic cord.

4.7 Analytical and Mechanical Prototyping Summary

After analyzing prototypes using Parameter Matrices, CAD drawings, to-scale models, and a Force-Moment equation, Team Thor was confident in their design choices. The prototyping process enabled Team Thor to determine the optimal structure for each component. The team was confident that their prototyping prepared them to construct an effective robot that would succeed at the state, regional, and national competitions.

Phase 5
Offensive and Defensive Evaluation

Students discussing scoring strategies.

5.1 Overview

Team Thor was required to consider all elements and factors of the game in their evaluation of the offensive and defensive strategies. The team recognized their strategies would be crucial to success in competition.

5.2 Elements of Game and Robot Design

Dialogue during team brainstorming sessions revealed *High Octane's* many complexities. The formulas for higher compounds were the most restrictive limitations. Other limitations included the time constraint and the risk of becoming temporarily disabled. Team Thor gave consideration to speed, agility, and efficiency. A thorough understanding of these limitations was necessary in creating the offensive and defensive strategies. Once they were taken into consideration, scoring strategies were evaluated and finalized.

5.3 Offensive Strategies

High Octane's scoring mechanism is definite. Specific formulas must be employed throughout the game. As a result, different offensive strategies are not feasible. However, Team Thor discovered that Isooctane could be achieved through an aggressive approach (Appendix C.1) or a conservative approach (Appendix C.2). Team Thor considered these two approaches in their evaluations. They determined that the main objective was to collect a combination of compounds to acquire Isooctane by the end of the preliminary rounds. Team Thor's course of action would be to collect all possible CO_2, a surplus of Energy in order to convert to CO_2, and enough Catalyst and H_2O to complete required formulas. Team Thor would also use the same Plant Operator for all rounds to maximize efficiency within the strategy.

Team Thor's aggressive strategy was the Pelican R4 – IO (Appendix C.1). This strategy allowed them to create Isooctane by Round Four. The Pelican R4 – IO also placed greater requirements upon Field Specialists to obtain more compounds in earlier rounds. The Pelican R4 – IO avoided the creation of Naphtha in all rounds and Benzene after the final preliminary round. Team Thor realized the creation of Naphtha would hinder their success because this synthesis prevented the team from attaining Isooctane. Benzene was avoided because it was eliminated from inventory before the Semi-Finals begin.

Team Thor's conservative strategy was the Pelican R5 – IO (Appendix C.2). This strategy allowed Team Thor to create Isooctane by Round Five. The Pelican R5 – IO placed less strain upon Field Specialists than the Pelican R4 – IO because the accumulation of compounds was extended over one additional round. The Pelican R5 – IO also avoided the creation of Naphtha in all rounds and the creation of Benzene after Round Six.

Once a thorough analysis was conducted, a preferred scoring strategy was selected by voting. Before the Kansas and Regional Game Days the Pelican R5 – IO was the chosen strategy because it ensured the consistent production of Isooctane.

5.4 Defensive Strategies

During brainstorming sessions Team Thor determined that hoarding could be used as a defensive strategy in all rounds. The team would collect as many game components as possible.

Even if all collected compounds were not utilized, their possession would limit other team's abilities to retrieve the hoarded components held by Team Thor. The team determined their most effective defensive strategy could be utilized during the Semi-Finals and Finals. In these rounds, four Benzene tankers are placed into the neutral zones of the game field. The acquisition of a tanker greatly increases a robot's scoring potential because the synthesis of Benzene through formulas requires three rounds. Team Thor decided that they would collect two Benzene tankers per round during the Semi-Finals and Finals, which would eliminate another team's capability to collect a tanker – hindering their ability to produce Isooctane. The team would not focus upon scoring the second Benzene tanker unless time allowed for the tanker to be scored.

5.5 Final National Scoring Strategies

After the Kansas and Regional Game Days, Team Thor finalized their offensive scoring strategy for the national competition in Dallas. They determined the Pelican R4-IO was feasible. Team Thor will utilize the aggressive offensive scoring strategy in the national competition. The defensive strategies were also discovered to be effective. At both the Kansas and Regional Game Days, Team Thor acquired two Benzene tankers in three of the final six rounds. Also, the team's hoarding strategy limited other team's ability to combine game components. Team Thor's offensive and defensive strategies prepared them for the challenges of a national competition.

Phase 6
Testing: Evaluating and Analyzing Design Alternatives

A student tests the lasso design.

6.1 Wheel Speed Analysis

Based on the scoring strategy and design of the robot, the team determined it was necessary to acquire the maximum amounts of components each round. Given the three-minute time constraint, speed was a factor. Thus, a wheel design was a critical consideration. In order to travel the necessary distance within the time limit, the robot needed to travel a minimum of 2.25 in/sec. In calculating the wheel diameter, the team first measured the revolutions per minute (rpm) of the large motors, as they would be used to drive the wheels. The wheels could rotate at 44 rpm. The Forward Velocity vs. Wheel Diameter graph (Appendix D.1) shows the relationship between wheel diameter and velocity (in/sec). This was calculated with the following formula: Forward Speed (in/sec) = $(\pi d * \text{rpm}) / 60$. Based upon this analysis, Team Thor decided a 14” diameter wheel was most capable of meeting speed requirements.

6.2 Testing and Modifications

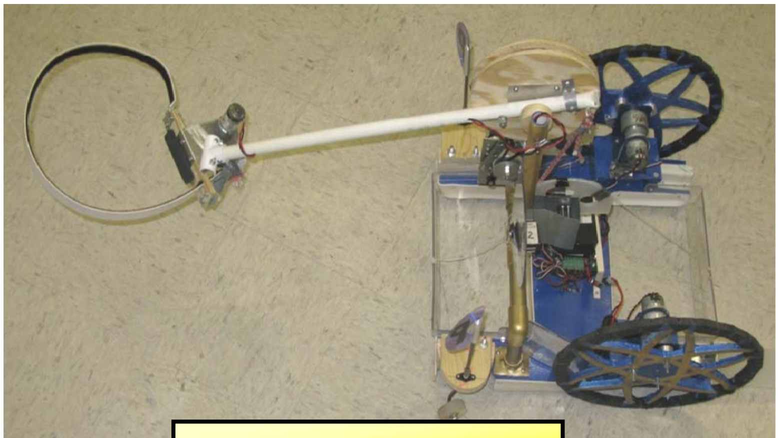
Following the development and construction of the robot design, Team Thor tested the base, arm, gripper, and CO_2 Retrieval designs in order to evaluate the effectiveness of each segment. CAD drawings of the potential robot were created to assist the evaluation (Appendix

D.2-D.2.1). The design allowed Team Thor to analyze the effectiveness and capabilities of each component. CAD drawings were then created of the final robot component designs as well as the completed robot.

Robot team members evaluated arm length and gripper efficiency in the process of collecting and storing the required game components. In addition, the team performed mock game scenarios by attaining and transporting the required components in order to evaluate each design. They also tested the compatibility of the designs. Team members analyzed each component's effectiveness and discerned necessary modifications.

Due to the testing and analysis, the team determined modifications should be made to the arm tower, gripper, and base. Team Thor discovered the arm tower extended beyond the 24" box. The arm tower was disassembled and shortened so the robot would meet game requirements. They also realized during testing that the gripper design was inadequate. The initial PVC strip of the Lasso was ½" wide. However, this width did not provide enough surface area to successfully manipulate all game components. The width of the PVC strip was increased to 1" and now operates at optimal efficiency. During testing, Team Thor discovered weight was not distributed evenly across the base. As a result, the 14" wheels did not possess enough traction to maneuver the robot. Team Thor added weights to the base behind the wheels, improving traction considerably. The combination of the testing and analysis processes, the initial prototype analysis, and the final revision of the robot designs ensured Team Thor's completed robot would meet and exceed the standards of the BRI challenge.

Phase 7
Defining Changes and Final Design



Team Thor's final robot.

7.1 Final Design for Kansas Game Day

Team Thor designed their competitive robot from the ground up, completing the construction in four steps: base, wheels, arm, and gripper. By building the robot in this order, the team ensured that all elements functioned properly together. Each finalized design was incorporated into the finished product. During the construction process, slight design modifications were made to improve robot performance.

The first step in the construction process was to build the base. The base was an 18"x16" sheet of ¾" plywood shaped to form an "H" that rested 1.5" off the ground. This shape was chosen because it allowed for the robot to push multiple game components in the 4" deep nook of the "H", instead of requiring the gripper to manipulate all objects individually. The base provided a location to mount the wheel motors, brain, and arm tower. It was designed to provide support and agility, while remaining lightweight. A CAD drawing of the final base design is in Appendix E.2.

The next step was to create the wheels. The drive wheels were constructed from plywood with a 14″ diameter. Torque, RPM, and distance calculations were used to determine the wheel size. Wooden casters were mounted on the rear of the base to improve speed and stability. A CAD drawing of the final wheel design is in Appendix E.5.

The third step in the manufacturing phase was to create the arm. The arm started at a length of 28”. The pivot point was located at 20”. The arm was connected to a 7” diameter wheel rotating around the arm tower. The tower’s rotation point was 18.5” above the base. The combined height of the arm and tower reached 40”. The 7” diameter wheel was connected to a motor mounted below the wheel by a gear. A CAD drawing of the final arm design is in Appendix E.3.

The last step in building the robot was to create the gripper. The gripper consisted of flattened PVC, ½” plywood, Velcro, and aluminum. This gripper was inspired by a rope lasso and would constrict around all components of *High Octane*. The flattened PVC was cut into a 1” strip and Velcro was attached to the interior. Constriction was initiated by the motor-controlled rotation of a wheel with the attached Velcro hook. The gripper extended 12” from the end of the robot and increased the total reach of the robot to 52” – enough height to retrieve CO_2. A CAD drawing of the final gripper design is in Appendix E.4.

7.2 Final Design Modifications for Regional Game Days

After Kansas Game Day, Team Thor identified certain design modifications would improve the robot’s performance. These modifications were made to the gripper, base, and counterweight.

Initially, the gripper design relied solely on Velcro to constrict objects. When the PVC strip reached its innermost position the Velcro on the strip detached from the drive mechanism. A guide was constructed of sheet metal that directs the PVC strip to remain attached to the drive mechanism. However, when the PVC strip reached its innermost position the guide alone was not sufficient to maintain the Velcro attachment. Team Thor corrected this problem by connecting an elastic cord to the guide and gripper assembly. The elastic cord applied ample tension to maintain the attachment. The gripper now operates at optimal efficiency.

Originally, the recessed regions of the base were 4” deep. However, 4” did not allow enough area to hold all necessary game components. When Team Thor’s robot utilized its zero turn radius, the game components rolled out of the nook. The nook was extended to a 6” depth to eliminate this problem.

The robot’s arm executes 300 degrees of rotation. A 6-pound counterweight was first attached to the arm to assist this rotation. However, this weight did not sufficiently assist the arm’s rotation. Team Thor considered adding more weight to the counterweight. However, they realized additional weight would exceed the 24-pound weight requirement. The counterweight was replaced with an elastic cord. The cord provides enough tension to assist the arm’s rotation. This cord also proved to be a superior design because it eliminated weight from the robot.

7.3 Final Design Modifications for National Competition

On Regional Game Day, Team Thor discovered the increased nook depth still allowed game components to exit the base. The team constructed gates for the “H” shaped base, which were connected to a servo that operated in conjunction with the drive motors. The brain was programmed to operate the servo and the drive motors simultaneously. When the robot drove forward, the gates closed in the back of the robot, blocking components that would have otherwise exited the nook. An image of the gates is present in Appendix E.2.1. The gates will enable Team Thor to complete their scoring strategies at the national competition. A CAD drawing of the final robot design for the National Competition is in Appendix E.1.

Executive Conclusion

The Circle High School BEST Robotics Team stands behind their design. They are confident their product will accomplish all necessary tasks with accuracy and efficiency. The engineering process guided them in every aspect of the project. The creativity of Team Thor's design was grounded in the foundational concepts of incorporating a variety of materials, considering all game components, and developing a scoring strategy. Their final robot was designed for speed, agility, and efficiency.

Team Thor participated in a number of brainstorming sessions and held discussions concerning game considerations, scoring strategies, and offensive/defensive approaches. Conclusions drawn from the brainstorming sessions assisted the team in identifying their strategic scoring approach – The Pelican. The team determined they needed to focus on utilizing the Plant Operator to create Isooctane by the fourth round. Their scoring strategy directly correlated to design criteria and robot development.

Testing and evaluation were essential in developing a successful robot. Speed was a necessary requirement in the robot design. Therefore, analysis was conducted concerning wheel diameter. Evaluations were conducted regarding the efficacy of each robot component. Prototypes and CAD drawings were constructed to assist in this evaluative process. As a result, modifications were determined, designs were created, and final robot production was completed.

The primary materials required for the robot design included plywood, PVC pipe, polycarbonate, and aluminum. Each of these supplies was creatively incorporated and designs were specifically developed for the robot components. The base was designed for scoring ability and minimum weight. The gripper paired with the arm was developed for superior manipulation of components and maximum reach. The overall robot design allowed the team to successfully implement the Pelican scoring strategy and maximize the robot's scoring potential.

Team Thor's engineering process proved effective. The engineering process was strengthened as a result of individual talents and team dedication. These factors provided for the development of a successful robot capable of meeting game requirements. Team Thor successfully competed in the Kansas State and Arkansas Regional competitions, and believes their prior success will be repeated at the Dallas National competition, exceeding the challenges presented by BEST Robotics, Inc.

NOTEBOOK APPENDICES 2010

Circle High School

BEST Robotics – MEETING MINUTES
September 16, 2009

Attendees: 53 Students
1 Mentor

I. Mr. Hogoboom and senior member, Ben Harstine, provided a brief overview about B.E.S.T. Robotics.
II. Our senior members explained the expectations of the students.
III. Reviewed schedule for the B.E.S.T. season and answered any questions about Kick Off Day on Sat. 26, 2009.

BEST Robotics – MEETING MINUTES
September 21, 2009

Attendees: 40 Parents
8 Mentors

I. Parent Meeting
   a. Explained what this year's game was.
   b. Showed last year's video
   c. Explained Meeting schedule
   d. Conducted a question and answer session

BEST Robotics – MEETING MINUTES
September 26, 2009

Attendees: 44 Students
7 Mentors

I. Attendance was taken
II. Game floor and the game in more detail.
III. Team members were divided into separate sub teams based on their preferences.
IV. Chief Operations Director appointed.
   a. Ben Harstine
V. Began brainstorming.
   a. Scoring Strategies.
   b. Basic robot ideas.
   c. Sketches.

BEST Robotics – MEETING MINUTES
September 28, 2009

Attendees: 39 Students
8 Mentors

I. Meeting Expectations
   a. Mr. Hogoboom, Mr. Jaax, and Mr. Crisler explained expectations for the group meetings.
      i. No idea is a bad idea
      ii. Wacky = Good!
      iii. No Criticism
II. Group Robot Brainstorming
   a. Brainstormed ideas for a gripper able to pick up the various shaped molecules.
      i. Vacuum
      ii. Gripper with suction cups
      iii. Net
      iv. Lasso
   b. Brainstormed ideas for a base
      i. Bulldozer
      ii. Base with a storage bin
III. Broke into Sub Teams and continued brainstorming
   a. Display team
      i. Old Gas Station
      ii. Molecule Frame
      iii. Milk-Jug Igloo
   b. Spirit Team
      i. Assigned jobs within sub team
      ii. Wrote fundraising letters
      iii. Started T-Shirt and Button Designs
   c. Presentation
      i. Assessed previous year's PowerPoint
      ii. Created tips for this year's presentation

BEST Robotics – MEETING MINUTES
October 8, 2009

Attendees: 45 Students
5 Mentors

I. Robot Team
   a. Designing and building a prototype
   b. Presented results to the sub team
II. Brain Team
   a. Set up the gate closing software.
III. Gamefloor Team
   a. Made Spotter's Circle
   b. Worked on the storage bin
IV. Award Team
   a. Marketing
      i. Notebook cover design completed
      ii. Recruited new school
   b. Display Team
      i. Designed Mural
      ii. Designed inside of the display
   c. Spirit Team
      i. Designed back of the t-shirt
      ii. Brainstormed Spirit Ideas
   d. Notebook Team
      i. Made Daily Group Goals worksheets.
      ii. Presented Research Paper idea which was approved
      iii. Started the research for the Research Paper
      iv. Assigned people for all phases of the Notebook

BEST Robotics – MEETING MINUTES
October 13, 2009

Attendees: 57 Students
8 Mentors

I. Robot Team
   a. Built motor mount for arm assembly
   b. Attached arm assembly
   c. Created wheel blocks to set height at 7”
   d. Extended lasso length
II. Notebook Team
   a. Ideas scanned
   b. Worked on C.A.D
III. Display team
   a. Got major parts structually designed
   b. Found 10 years of B.E.S.T pictures
   c. Designed buttons
   d. Began mural designs
   e. Braid and died cords

BEST Robotics – MEETING MINUTES
October 15, 2009

Attendees: 45 Students
6 Mentors

I. Robot Team
   a. Wheels mounted
   b. Arm assembly mounted
   c. Gripper created
   d. Figured out counterweight
   e. Arm mount fixed
II. Display Team
   a. Discussed schedule and deadlines
      i. Gas station
      ii. Old to futuristic
III. Notebook Team
   a. Worked on C.A.D
   b. Individuals worked on their part of the notebook

Circle B.E.S.T. Attendance

Students	5-Oct Monday	7-Oct Wednesday	8-Oct Thursday	10-Oct Saturday	12-Oct Monday	14-Oct Wednesday	15-Oct Thursday	17-Oct Saturday
Robot:								
Seth Blaha		x	x	x		x	x	
Emmitt Lechner		x	x		x		x	
Ryan Davis	x	x			x		x	
Logan Breault	x		x	x	x			x
Molly Jaax		x				x		
Matt Pello			x	x			x	x
Brian Kessler	x		x			x	x	
Sahar Hossinei		x	x		x		x	
K.C. Roberts	x	x		x		x		x
Haley Barrett		x	x		x			
Chris Robins	x		x		x		x	
Gulcin Polat				x		x		x
Mitch Horner		x	x		x	x	x	
Lucas Dugan	x		x		x			x
Nick Bovee		x		x			x	
Presentation:								
Will Gregg	x	x	x		x	x		x
Perry Gowdy		x	x		x	x		x
Ben Harstine		x		x	x		x	
Blair Benton	x		x		x			x
Michaela Schaal		x	x		x	x		x
Rachael Bruce		x			x	x		x
Britnee Pond	x	x		x	x	x		x
Nick Hale		x		x	x		x	
Display/Spirit:								
Amber Junkins		x	x		x		x	x
Karley Sechler		x		x			x	
Courtney Hogoboom	x			x		x		x
Leslie Geist		x	x		x		x	
Sarah Gile		x		x			x	x
Elissa Failes	x	x	x	x		x		
Josephine Delborg				x	x		x	
Briana Reece	x	x			x		x	x
Megan Reece			x	x				
Kimberlyn Stephens	x		x		x	x		x

Circle B.E.S.T. Team Organization						
Head Coach:	Matt Hogoboom					
Assistant Head Coach:	Brian Jaax					
Mentors:	Tracy Crisler, Brad Davenport, Steve Persons, Larry Pond, Susan Sellers, Mary Stephens, Mary Reece					
Chief Operations Director (C.O.D.):	Ben Harstine					
Robot Production Managers:	Mitch Horner, Ryan Davis, Matt Pello					
Award Team Managers:	Kimberlyn Stephens, Brianna Reece, Liz Jaax, Will Gregg					
Robot:	**Presentation:**	**Display/Spirit:**	**Notebook:**	**Game Floor:**	**Fundraising:**	**Website:**
S. Blaha	W. Gregg	A. Junkins	L. Jaax	T. Blevins	L. Geist	A. Longshaw
E. Lechner	P. Gowdy	K. Sechler	A. Crisler	S. Drinnen	S. Gile	N. Summers
R. Davis	B. Harstine	C. Hogoboom	M. Schaal	K. Sage	E. Hoover	G. Hamlin
L. Breault	B. Benton	L. Geist	K. Wagner	D. fisher	M. Stephens	M. Bruce
M. Jaax	M. Schaal	S. Gile	B. Harstine	K. Hayes	J. Droste	J. Behncke
M. Pello	R. Bruce	E. Failes	W. Gregg	J. Davenport	A. Ronnebaum	J. Nitcher
B. Kessler	B. Pond	J. Delborg	B. Pond		L. Weber	
S. Hossinei	N. Hale	B. Reece				
K.C. Roberts		M. Reece				
H. Barrett		K. Stephens				
C. Robins		A. Signorini				
G. Polat		M. Stephens				
M. Horner						
L. Dugan						
N. Bovee						

CHS BEST ROBOTICS AND AWARD TASKS: **GOALS FOR SEPTEMBER 28, 2009**

I. **General Announcements:**

a. Food and drink only in Mr. Reilly's room…keep it out of CAD lab and Mr. Guthrie's room. Thanks for your cooperation on this.

b. Good job picking up last night. It is the responsibility of each team (and their sub-team leader) to make sure the area in which you worked is cleaner than you found it.

c. See me for your email password. This email account allows you to email me and vice versa. If you need to email a BEST team member, email it to me with instructions and I will forward it. You will start checking emails next week when you come into a session. Computers in the CAD lab are for constructive use. Let's try to minimize the amount of gaming, surfing, etc. We've way too much to get done. If you're looking for more tasks to complete, talk to a C.O.D., mentor, team-manager, or coach.

d. We're off and running. Make sure that you are recording your assigned / completed tasks in your sub-team notebook. Make sure that I have your notebook at the end of each session.

II. **Break into Sub-Teams**

a. Your sub-team leader (or someone from the team) will need to get your 3-ring binder. If it does not have paper, get some from the stack. Make sure it is clearly labeled. Keep all Task-sheets and record of completed tasks in this notebook and turn in every session.

b. You need to go to the sub-team you started with last night.

III. **Robot Teams-**

a. 1. Continue Brain Storming evaluation process. 2. Begin planning on specific division(s) of labor for prototyping. 3. Discuss construction of "tester" for BRAIN using extra motors / servos / sensors.

b. **Game Floor Team**- 1. Evaluate what pieces we have from last year that may be used this year (Black Shirts did say that we should save last year's game floor for this year…what can be used from it?). 2. Begin calculating list of materials needed to complete the game floor. 3. Begin compiling list of needed materials so we can create purchase order(s).

IV. **AWARD TEAMS-**

a. **Presentation Team**- 1. Continue Brain Storming process for presentation ideas. Record these per the Brain Storming process you've learned…especially important- don't dismiss ideas yet, as there may be good ideas that would otherwise be lost. 2. Look at last year's presentation materials on the file server. See what you'd like to keep and what to modify / punt. 3. Pull out last year's panels and evaluate…what is appropriate for this year, what should be changed, topical bells and whistles to include this year, etc.

b. **Display Team**- Work with Presentation Team tonight. There is enough overlap at this stage that you should be able to work as one unit. Your team managers may divide labor.

c. **Web Page Team**- 1. Pull up last year's website. Look at it briefly. 2. Develop a list of criteria regarding a high quality website. What makes people want to visit a website? What makes them want to return? What should and shouldn't be included in a BEST website? Develop this list of criteria and then evaluate last year's site. This should give you some direction in developing this year's site. 3. Continue Brain Storming process to explore ideas for this year's site.

d. **CAD Team**- 1. Make sure that you are adept at using CAD and Inventor. If you need to practice, then practice. 2. Determine if Robot Teams need you to start creating scale drawings for refining ideas during their Brain Storming prototyping process.

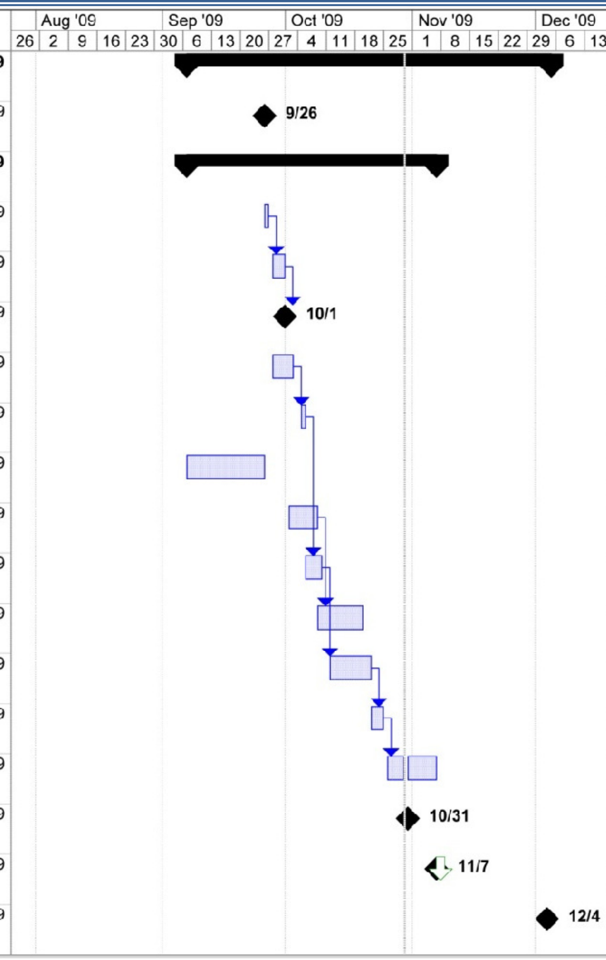
e. **Notebook Team**- 1. Review notebook from last year. Make sure that you are not removing any pages from the hardcopy notebook. You can also access all of these pages on the file server. 2. Compile team demographics. You can get the list of BEST participants from Mr. Hogoboom.

f. **Spirit Team**- 1. Compile list of possible cheerleaders, flag team members, and band members that would be willing to come to practice day and game day. 2. Brainstorm ideas for posters based on this year's theme. 3. Generate "good luck" letter #1 for other teams.

g. **Marketing Team**- 1. Brainstorm ideas for recruiting opportunities. 2. Brainstorm ideas for fundraising opportunities. Pull up last year's fundraising file from the file server. Record these benefactors and make sure we have their contact information. Then try to expand on this list. 3. Brainstorm ideas for business cards, bumper stickers, magnets, etc.

ROBOT SCHEDULE

ID		Task Name	Duration	Start	Finish
1		**2009 Circle BEST**	**69 days?**	**Mon 9/7/09**	**Fri 12/4/09**
2		Kick-off	1 day?	Sat 9/26/09	Sat 9/26/09
3		**Robot Design**	**48 days?**	**Mon 9/7/09**	**Fri 11/6/09**
4		Functional Requirments Capture	1 day?	Sat 9/26/09	Sat 9/26/09
5		Brainstorming	3 days?	Mon 9/28/09	Wed 9/30/09
6		Conseptual Design	1 day?	Thu 10/1/09	Thu 10/1/09
7		Analitical Analysis	5 days?	Mon 9/28/09	Fri 10/2/09
8		Lines Control Developement	1 day?	Mon 10/5/09	Mon 10/5/09
9		Standard Parts Design	15 days?	Mon 9/7/09	Fri 9/25/09
10		Detail Part Design	5 days	Fri 10/2/09	Thu 10/8/09
11		Assembly Design	4 days	Tue 10/6/09	Fri 10/9/09
12		Detail Part Build	7 days	Fri 10/9/09	Mon 10/19/09
13		Assembly Build	8 days?	Mon 10/12/09	Wed 10/21/09
14		Wire Bundles and Equipment Install	3 days	Thu 10/22/09	Sat 10/24/09
15		Driver Practice	10 days	Mon 10/26/09	Fri 11/6/09
16		Mall Day	1 day	Sat 10/31/09	Sat 10/31/09
17		Game Day	1 day	Sat 11/7/09	Sat 11/7/09
18		Frontier Trails Regionals	1 day	Fri 12/4/09	Fri 12/4/09



Project: 2009 Schedule
Date: Fri 10/30/09

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Page 1

Student Brainstorming

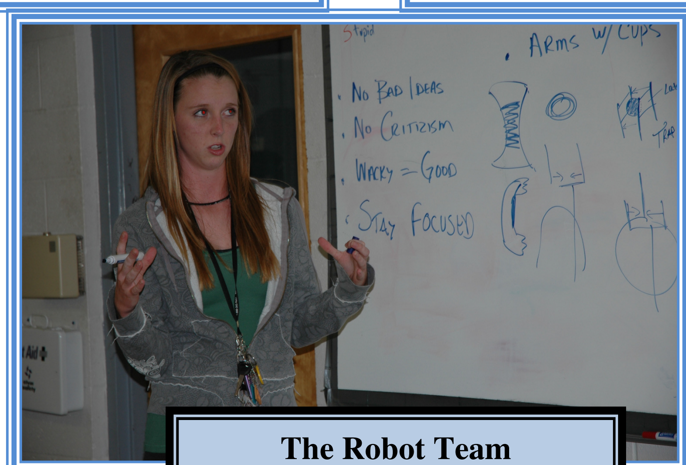
During the first brainstorming session, Team Thor members were given time to sketch their robot design ideas. The sketches were later presented to the whole team.

Working together, students brainstorm ideas for robot designs. They drew their sketches on whiteboards and grid paper.

Robot Team Brainstorming

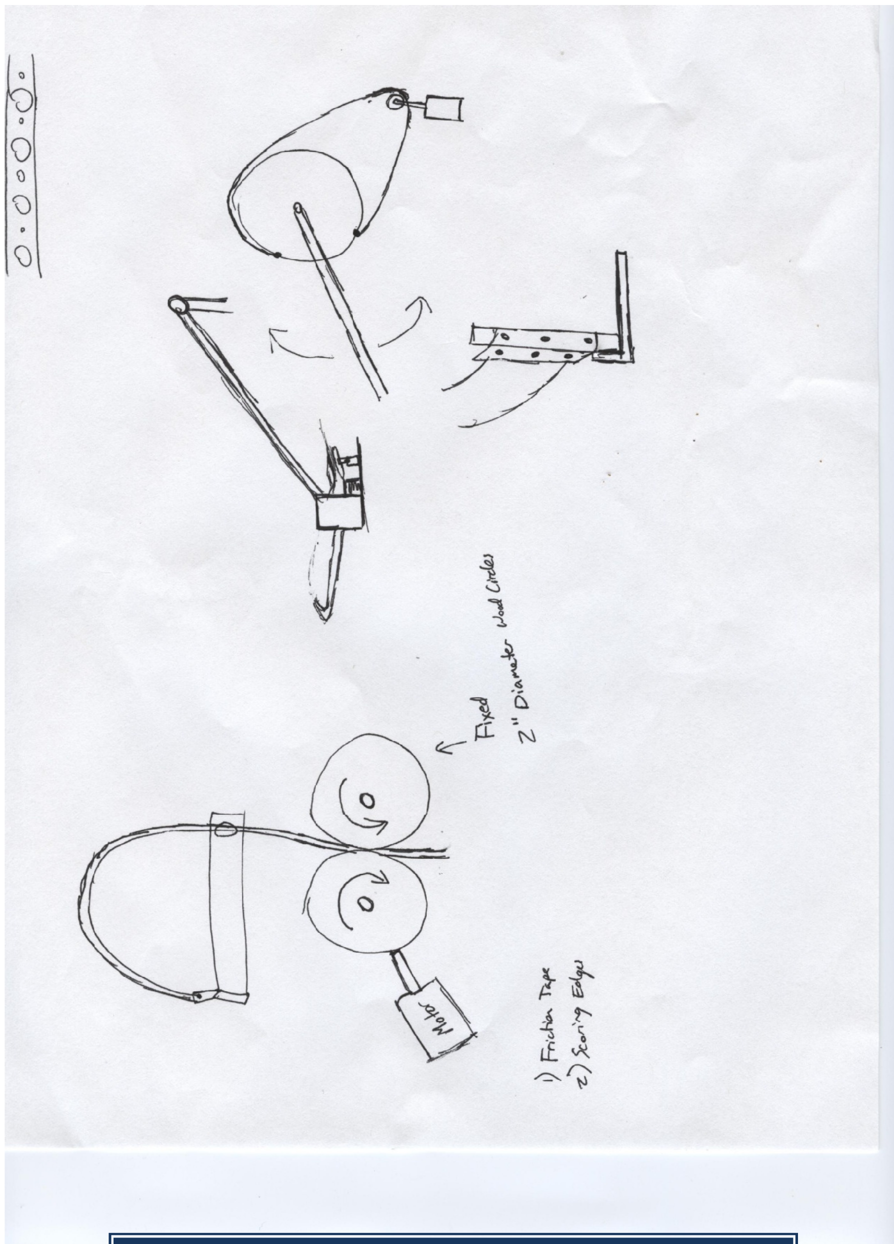
Robot team members brainstorm robot ideas with mentors, sketch ideas, and compare/contrast the robot concepts.

Students explain concepts to fellow peers and mentors.



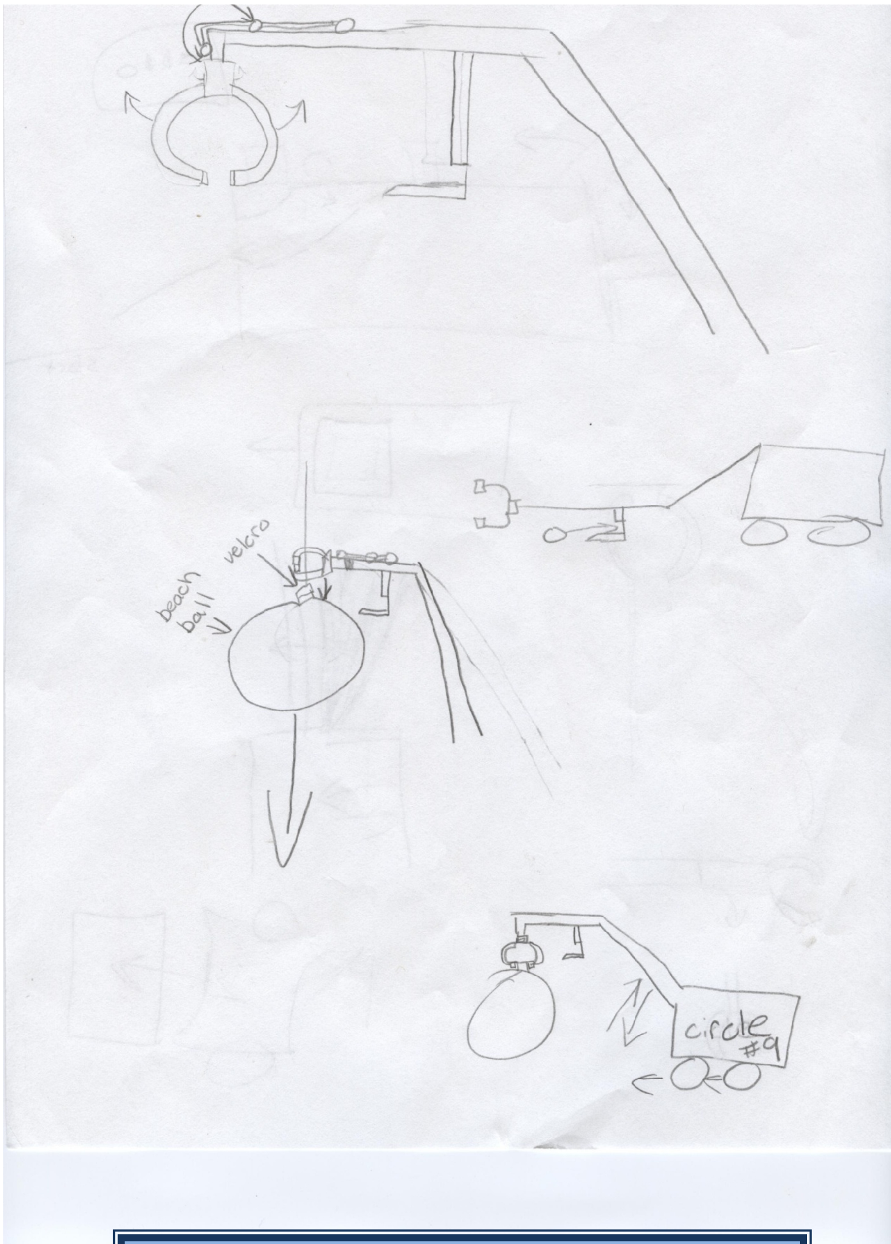
The Robot Team brainstorms to finalize robot designs.

TEAM THOR
BRAINSTORMING SKETCHES



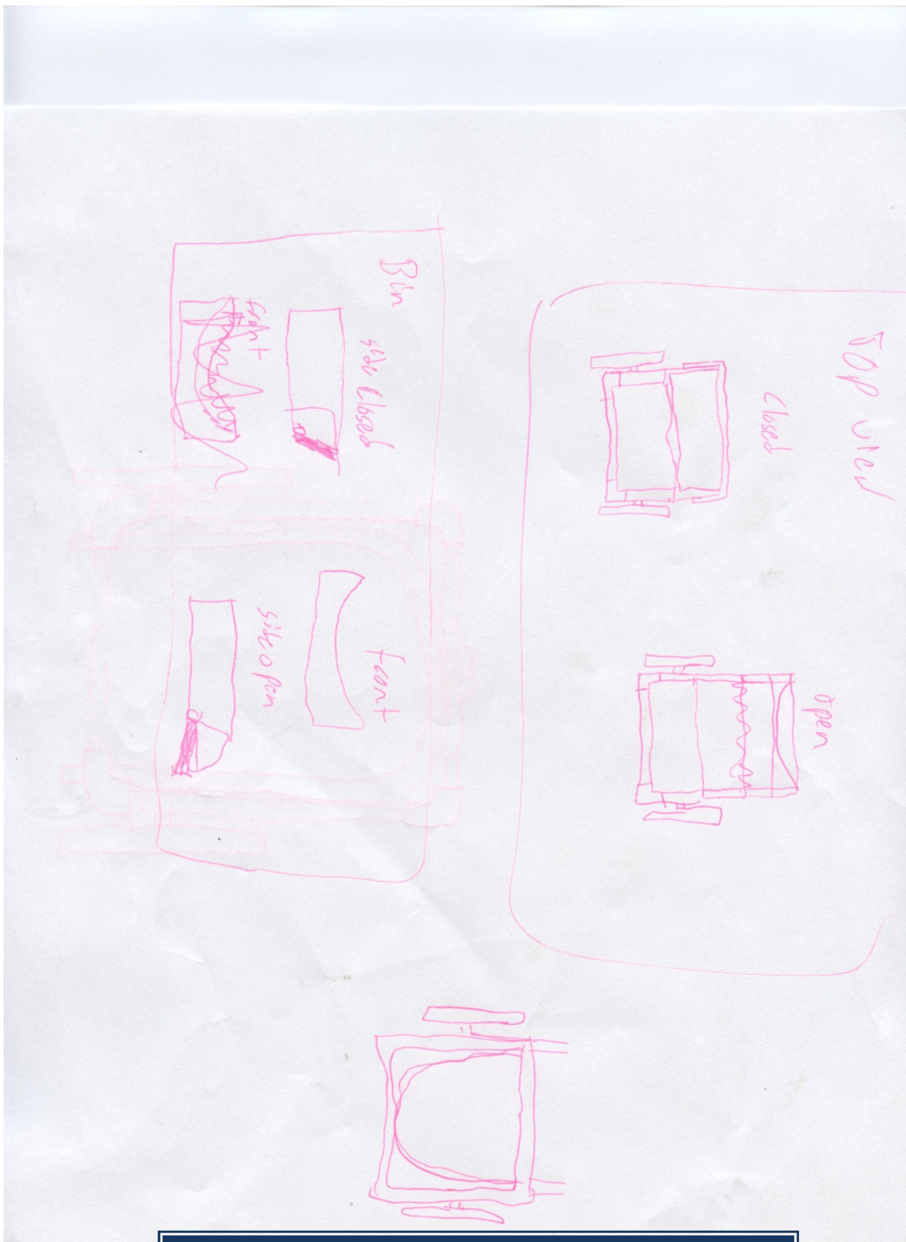
A Team Thor member's drawing of a Gripper design.

TEAM THOR
BRAINSTORMING SKETCHES



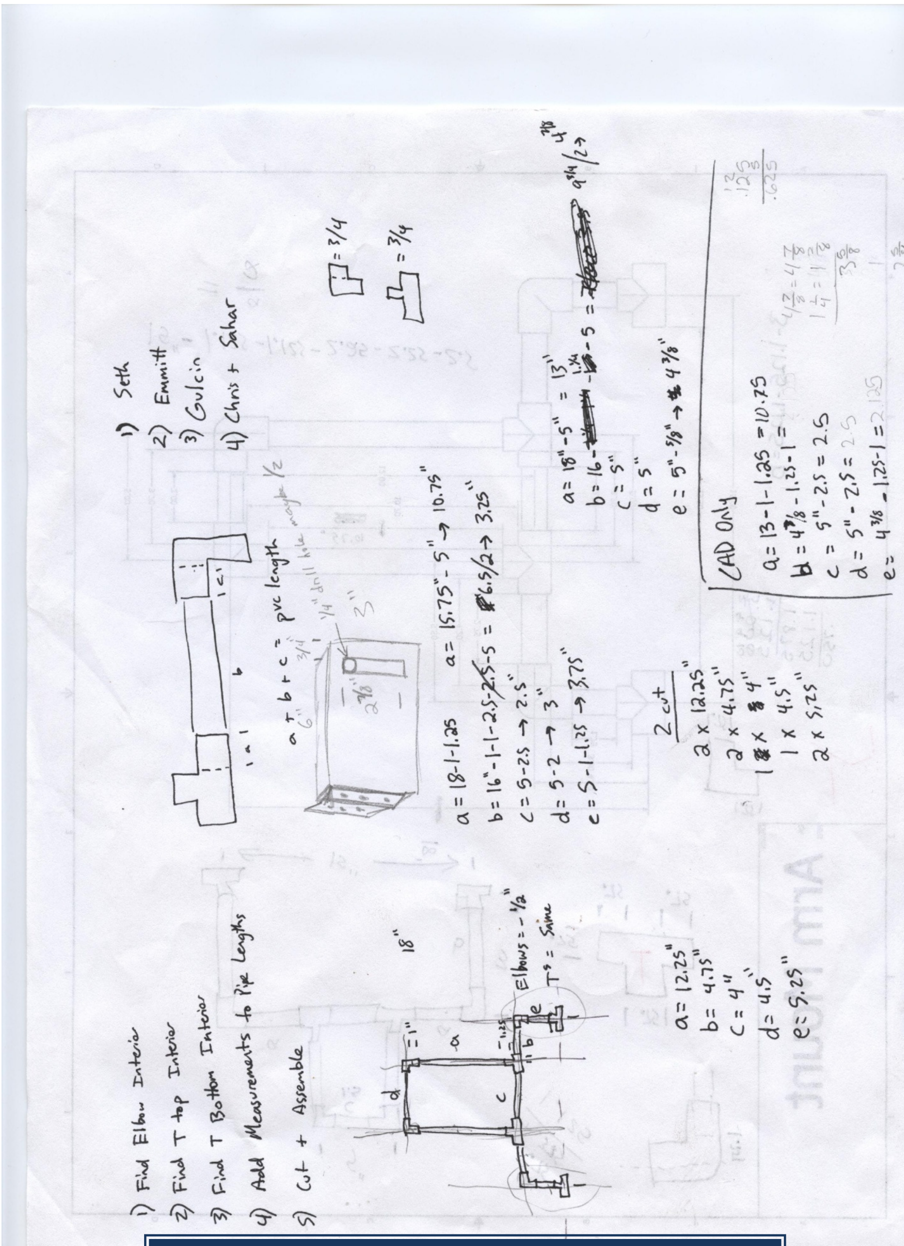
A Team Thor member's drawing of a Gripper design.

TEAM THOR
BRAINSTORMING SKETCHES



A Team Thor member's drawing of a Base design.

TEAM THOR
BRAINSTORMING SKETCHES



A Team Thor member's drawing of an Arm design.

BASE ANALYSIS MATRIX

Team Thor evaluated the advantages of different base materials. The team evaluated using PVC pipe or plywood as a frame for the base. Four basic areas were evaluated:

- Ease: The ease of assembly for prototypes and the ease of repair on game day.
- Strength: The durability of the base.
- Weight: Amount of weight base would create.
- Scoring: The ability of the base to assist in scoring process.

After weighing all these features and examining each base's individual scoring on a scale of 1-5, Team Thor determined the priority ratings. These numbers represented the importance of each parameter. Team Thor then multiplied each basic area's evaluation by the priority rating, and then added the totals together to calculate the total base efficiency. For this graph the rating scale is as follows:

- 1 = Meets requirements with minimum efficiency
- 2 = Meets requirements with 25% efficiency
- 3 = Meets requirements with 50% efficiency
- 4 = Meets requirements with 75% efficiency
- 5 = Meets requirements with maximum efficiency

BASE DESIGN	DESIGN PARAMETERS				
	EASE	STRENGTH	WEIGHT	SCORING	
PRIORITY	0.75	1	0.5	0.75	
DESIGN IDEAS	SCALE 1-5 1 = Poor 5 = Exceptional				TOTAL
BULLDOZER	4	2	5	4	10.5
TRAPDOOR	3	2	3	3	8
WHITE V	4	3	4	1	8.75

ARM ANALYSIS MATRIX

Team Thor chose several key elements on which to base our decision. We needed the arm to perform in five key areas. The five key areas were as follows:

- Movement: How well the robot arm can move to the ground and to the maximum height.
- Total Rotation: The ability of the arm to rotate in a circle.
- Motor Requirements: How taxing is the movement of the arm upon the motors available for the arm.
- Extension: The total length the arm would extend towards the CO_2.
- Weight: Amount of weight the arm will create.

After weighing all these features and examining each base's individual scoring on a scale of 1-5, Team Thor determined the priority ratings. These numbers represented the importance of each parameter. Team Thor then multiplied each basic area's evaluation by the priority rating, and then added the totals together to calculate the total base efficiency. For this graph the rating scale is as follows:

- 1 = Meets requirements with minimum efficiency
- 2 = Meets requirements with 25% efficiency
- 3 = Meets requirements with 50% efficiency
- 4 = Meets requirements with 75% efficiency
- 5 = Meets requirements with maximum efficiency

ARM DESIGNS						
	DESIGN PARAMETERS					
	MOVEMENT	ROTATION	MOTOR REQUIREMENTS	EXTENSION	WEIGHT	
PRIORITY	0.5	0.75	0.5	0.75	1	
DESIGN IDEAS	SCALE of 1-5 1 = Poor 5 = Exceptional					TOTALS
Rotating Disc	3	3	5	4	3	12.25
Elevator	3	4	3	1	4	9.25
Four Bar	4	2	4	3	3	10.75

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GRIPPER ANALYSIS MATRIX

Team Thor evaluated the different types of gripping mechanisms. The design parameters were set in accordance to the performance required for Thor's robot. Each parameter was given a weight of importance. The descriptions of the parameters were as follows:

- Speed: The amount of time it takes for the gripper to close on the object.
- Weight: The weight of the gripper on the end attachment of the arm.
- Accuracy: Amount of precision required to manipulate game components.
- Compatibility: Level of unity with the arm design determined.
- Extension: The length the gripper extended from the arm.

After weighing all these features and examining each base's individual scoring on a scale of 1-5, Team Thor determined the priority ratings. These numbers represented the importance of each parameter. Team Thor then multiplied each basic area's evaluation by the priority rating, and then added the totals together to calculate the total base efficiency. For this graph the rating scale is as follows:

- 1 = Meets requirements with minimum efficiency
- 2 = Meets requirements with 25% efficiency
- 3 = Meets requirements with 50% efficiency
- 4 = Meets requirements with 75% efficiency
- 5 = Meets requirements with maximum efficiency

GRIPPER DESIGN						
	DESIGN PARAMETERS					
	SPEED	WEIGHT	ACCURACY	COMPATIBILITY	EXTENSION	
PRIORITY	0.5	0.75	0.75	1	0.5	
DESIGN IDEAS	SCALE of 1-5 1 = Poor 5 = Exceptional					TOTAL
SLIDER	4	1	3	3	3	9.5
LASSO	4	3	4	4	5	13.75
WIRE TRAP	3	4	2	2	2	9

CO_2 RETRIEVAL MATRIX

Team Thor chose several key elements on which to base their design. There were five areas in which it was essential that the CO_2 retrieval device performed well. The five key areas were as follows:

- Height: How high the design will lift the arm.
- Functionality: How well the design works.
- Motor Requirements: How taxing the design will be upon the motors.
- Compatibility: How well the extension design meshes with other components.
- Stability: How stable the design will be when lifted to the required height.

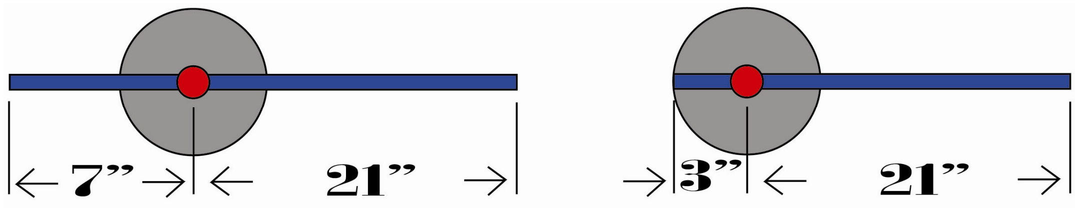
After weighing all these features and examining each base's individual scoring on a scale of 1-5, Team Thor determined the priority ratings. These numbers represented the importance of each parameter. Team Thor then multiplied each basic area's evaluation by the priority rating, and then added the totals together to calculate the total base efficiency. For this graph the rating scale is as follows:

- 1 = Meets requirements with minimum efficiency
- 2 = Meets requirements with 25% efficiency
- 3 = Meets requirements with 50% efficiency
- 4 = Meets requirements with 75% efficiency
- 5 = Meets requirements with maximum efficiency

CO2 RETRIEVAL						
	DESIGN PARAMETERS					
	HEIGHT	FUNCTIONALITY	MOTOR REQUIREMENTS	COMPATIBILITY	STABILITY	
PRIORITY	1	1	0.75	0.5	0.75	
DESIGN IDEAS	SCALE 1-5 1 = Poor 5 = Exceptional					TOTALS
SHEPHERD'S HOOK	3	3	4	2	4	13
SLIDER OFFSHOOT	4	3	2	3	2	11.5
LASSO	3	5	3	4	3	14.5

Force-Moment Analysis

Weight of 1" of 1/2" PVC Pipe: .12 lbs **Weight of Gripper:** 2.73 lbs



Introduction: Comparison of two lengths of counterweight arm (7" and 3"). The purpose of this analysis is to minimize the stress placed upon the drive motors to ensure that the drive motors possess sufficient torque to control the arm.

Formula: (**LCa**)*(**wPVC**) + (**wC**)*(**dF**) = (**Lga**)*(**wPVC**) + (**wG**)*(**dF**)

LCa = Length of Counterweight Arm
wC = Weight of Counterweight
LGa = Length of Gripper Arm
wPVC = Weight of PVC
dF = Distance from Fulcrum
wG = Weight of Gripper

Analysis for 7" Counterweight Arm	Analysis for 3" Counterweight Arm
7(.12) + **wC**(7) = 21(.12) + 2.73(21)	3(.12) + **wC**(3) = 21(.12) + 2.73(21)
wC(7) = 7(.12) + 2.73(21)	**wC**(3) = 18(.12) + 2.73(21)
wC = .12 + 2.73(3)	**wC** = 6(.12) + 2.73(7)
wC = 8.19 lbs	**wC = 19.83 lbs**

Counterweight needed to equalize arm at 7" = 8.19 lbs
Counterweight needed to equalize arm at 3" = 19.83 lbs

Decision: A 7" arm extends beyond the 24" spacial constraint. As such, the 7" arm is not a viable counterweight option. However, the 3" arm considered that follows spacial constraints requires too large of a weight to conform to the 24 lb weight constraint. Team Thor discovered that an elastic cord would supply ample tension to simulate the 19.83 lb required counterweight. The elastic cord also conforms to both spacial and weight constraints.

Testing: Team Thor attached the small motor to the drive mechanism for the arm. Team Thor recognized that the application of the Bungee Cord negated all additional strain placed upon the motors by the gripper. Using the torque analysis, Team Thor concluded that the small drive motors could operate the arm. After testing, Team Thor discovered that the small motor was indeed capable of operating the drive mechanisms.

MOTOR ANALYSIS

Team Thor conducted motor analysis to discover the RPM and torque of each motor provided by BRI. The large motors would be used to drive the wheels while the small motors would be used to operate the arm and gripper. This analysis was conducted by combining the motor information provided in the kit and Team Thor's test results. The results are displayed in these two tables for the large and small motors respectively.

12-volt batteries were used to calculate the motor specifications included in the kit. Team Thor's batteries are 7.2 volts. A 7.2/12 ratio were used in measurements to reflect the change in battery charge.

Process	Large Motor	Small Motor
External RPM Calculation	11 revolutions/15 seconds = 44 RPM	24 revolutions/15 seconds = 96 RPM
Internal RPM Calculation	Output x Reduction Rate = Internal RPM 44 * 65.53 = 2883.32	Output x Reduction Rate = Internal RPM 96 * 30.96 = 2972.16
Efficiency Calculation	Real RPM / Listed External RPM 44/47.61 = .924	Real RPM / Listed External RPM 96/100.78 = .95
Torque Rating	Battery Ratio = Real Torque/Listed 7.2/12 = x/4 (7.2 * 4)/12 = x x = 2.4	Battery Ratio = Real Torque/Listed 7.2/12 = x/1.5 (7.2 * 1.5)/12 = x x = .9

Team Thor's motor analysis assisted in the Wheel Speed Analysis and in the Force-Moment Analysis. The Wheel Speed Analysis utilized the External RPM Calculation. The Force-Moment Analysis utilized the Torque Rating to calculate the feasibility of design concepts.

SCORING STRATEGY ANALYSIS

Pelican R4 - IO

The Pelican R4 – IO is Team Thor's aggressive strategy. This strategy accumulates enough elements to synthesize Isooctane by Round Four.

THE PELICAN - R4 - IO									
	Overflow	Isooctane	Naphtha	Benzene	Ethylene	CO2	Energy	Catalyst	Water
Round 1						2	4	5	3
Conversion					1	0	3	4	1
					1	1	0	0	1
Score					**1**	**1**	**0**	**0**	**1**
Round 2						2	4	5	3
Conversion					2	1	3	4	2
					2	2	0	0	2
Score					**2**	**2**	**0**	**0**	**2**
Round 3						2	4	5	3
Conversion					3	2	3	4	3
				1	0	2	2	3	3
				1	1	0	1	2	1
Score				**1**	**1**	**0**	**1**	**2**	**1**
Round 4						2	4	5	5
Conversion		1	0	0	0	2	4	6	2
		1	0	0	1	0	3	5	0
		1	0	0	1	1	0	1	0
Score		**1**	**0**	**0**	**1**	**1**	**0**	**1**	**0**
Round 5						2	5	5	4
Conversion		1	0	0	1	1	4	5	2
		1	0	0	1	2	1	1	2
		1	0	0	2	0	0	0	0
Score		**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**
Round 6						2	5	1	3
Conversion		1	0	0	3	0	4	0	1
		1	0	0	3	1	0	0	1
Score		**1**	**0**	**0**	**3**	**1**	**0**	**0**	**1**

The blue-shaded regions express the elements collected during the round. The green-shaded regions depict the conversion process that occurred after the conclusion of the round. The red-shaded regions display the total score after the conclusion of the conversion process.

Team Thor identified two potential hazards, and the Pelican R4 - IO successfully avoids the production of Naphtha after Round Three and the production of Benzene after Round Six. By avoiding these hazards, the Pelican R4 - IO produces an aggressive per round requirement ensuring qualification for final rounds.

SCORING STRATEGY ANALYSIS

Pelican R5 – IO

The Pelican R5 – IO is Team Thor's conservative strategy. This strategy accumulates enough elements to form Isooctane by Round Five. The Pelican R5 – IO was the strategy selected by Team Thor for Game Day.

THE PELICAN - R5 - IO									
	Overflow	Isooctane	Naphtha	Benzene	Ethylene	CO2	Energy	Catalyst	Water
Round 1						2	3	3	3
Conversion					1	0	2	2	1
Score					1	0	2	2	1
Round 2						2	3	3	3
Conversion					1	0	4	4	2
						1	1	0	2
Score					**2**	**1**	**1**	**0**	**2**
Round 3						2	3	3	3
Conversion					1	1	3	2	3
				1	0	1	2	1	3
Score				**1**	**0**	**1**	**2**	**1**	**3**
Round 4						2	2	3	0
Conversion					1	1	3	3	1
Score				**1**	**1**	**1**	**3**	**3**	**1**
Round 5						2	3	3	5
Conversion		1	0	0	0	3	5	5	2
					1	1	4	4	0
						2	1	0	0
Score		**1**	**0**	**0**	**1**	**2**	**1**	**0**	**0**
Round 6						2	4	4	3
Conversion					1	2	4	3	1
						3	0	3	
Score		**1**	**0**	**0**	**2**	**3**	**0**	**3**	**1**

The blue-shaded regions express the elements collected during the round. The green-shaded regions depict the conversion process that occurred after the conclusion of the round. The red-shaded regions display the total score after the conclusion of the conversion process.

Team Thor identified two potential hazards, and the Pelican R5 – IO successfully avoids the production of Naphtha after Round Four and the production of Benzene after Round Six. By avoiding these hazards, the Pelican R5 – IO produces a conservative per round requirement ensuring qualification for final rounds.

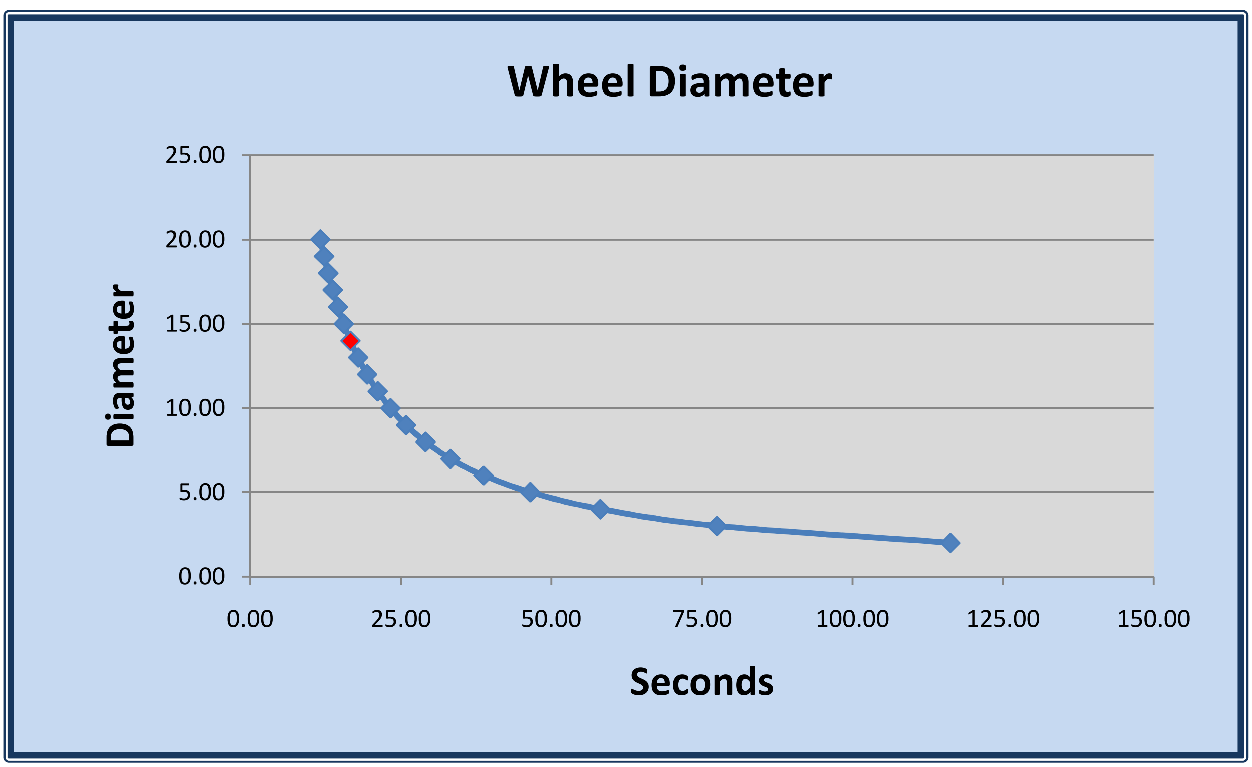
Forward Velocity vs. Wheel Diameter

In order to calculate the ideal wheel diameter, Team Thor evaluated the mathematics of force and propulsion. This process was conducted in order to determine the size of wheel that would best fit our robot and the game floor. Team Thor used a formula derived from torque formulas, movement formulas, and diameter formulas. The formula was as follows:

- Forward Speed = (πd * rpm) / 60

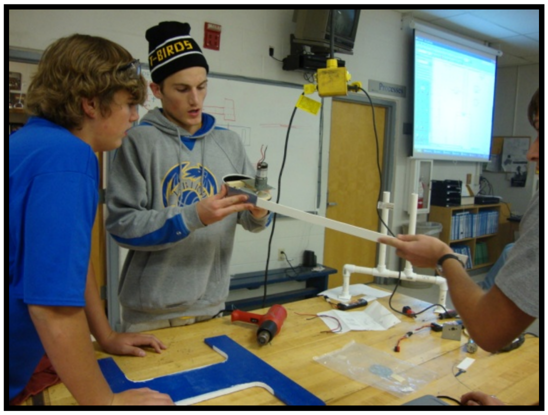
While calculating this formula, Team Thor subtracted 60 seconds from the total time needed to advance across the game floor surface. These 60 seconds were subtracted for the time needed to turn the robot, trigger the infrared sensors, and maneuver components.

'Seconds' on the graph represents the time needed to traverse the game floor, while 'Diameter' is the size of the wheel required to complete the journey in the time provided. The red data point indicates Team Thor's selected wheel diameter, 14".



Robot Prototype Construction

A model of the robot design was constructed from cardboard material. The cardboard prototype was used to analyze the effectiveness of the base, arm, and gripper design.

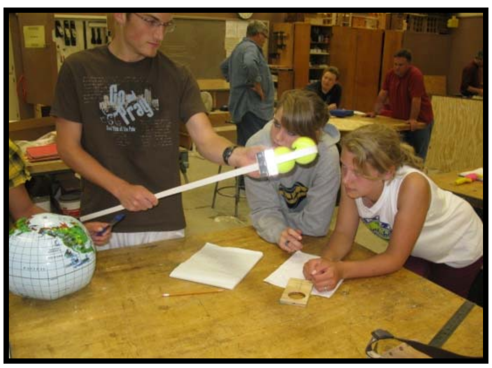


Robot team members evaluate and test the developed prototypes.

Students developing CAD prototypes.

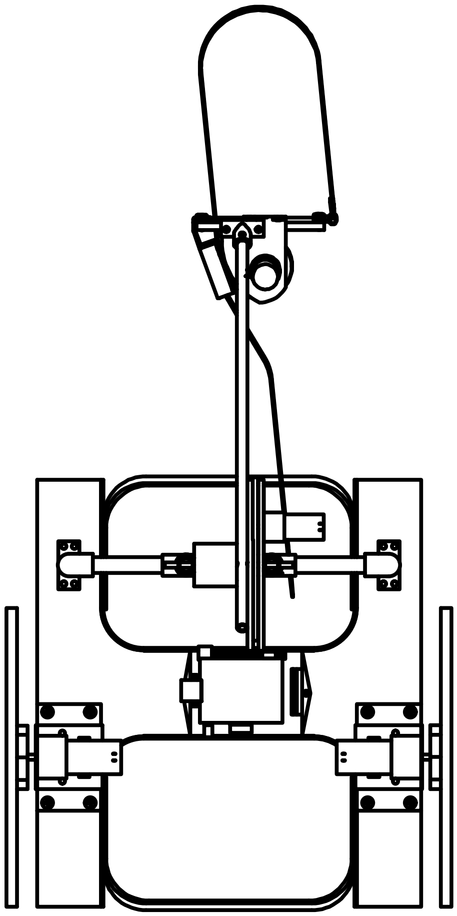
Robot Prototype Testing and Modification

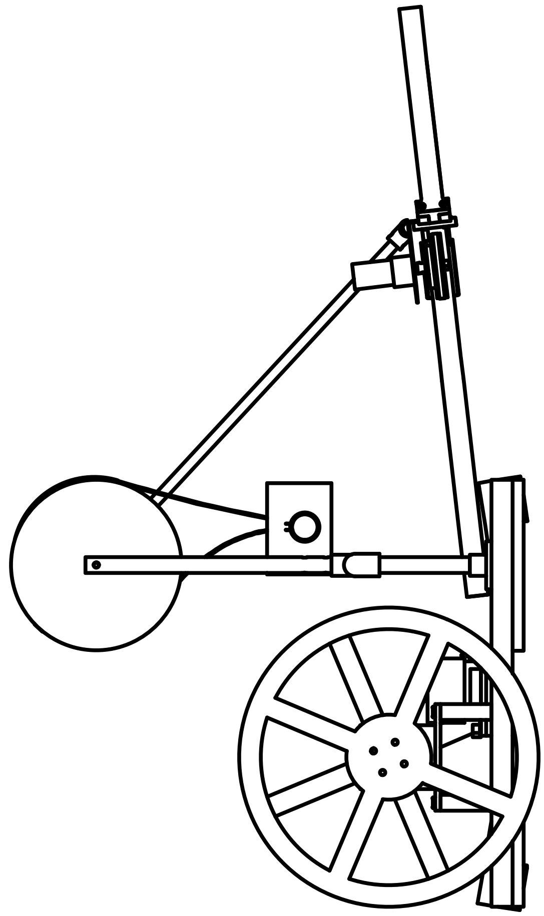
By placing the prototype robot at the edge of the ASV, Team Thor was able to use mock game scenarios to determine the effectiveness of the robot base, arm, and gripper capabilities. This testing process and evaluation was used to analyze the prototype's effectiveness and determine modifications.

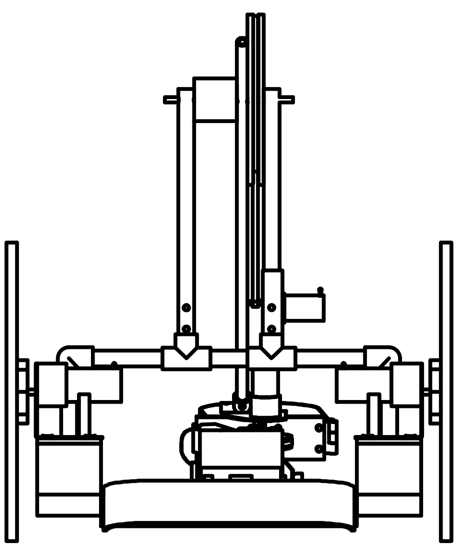


Prototype analysis assisted in the determination to modify the design and develop the base with PVC

Robot team members tested the base. The prototype's effectiveness was analyzed and modifications were determined.



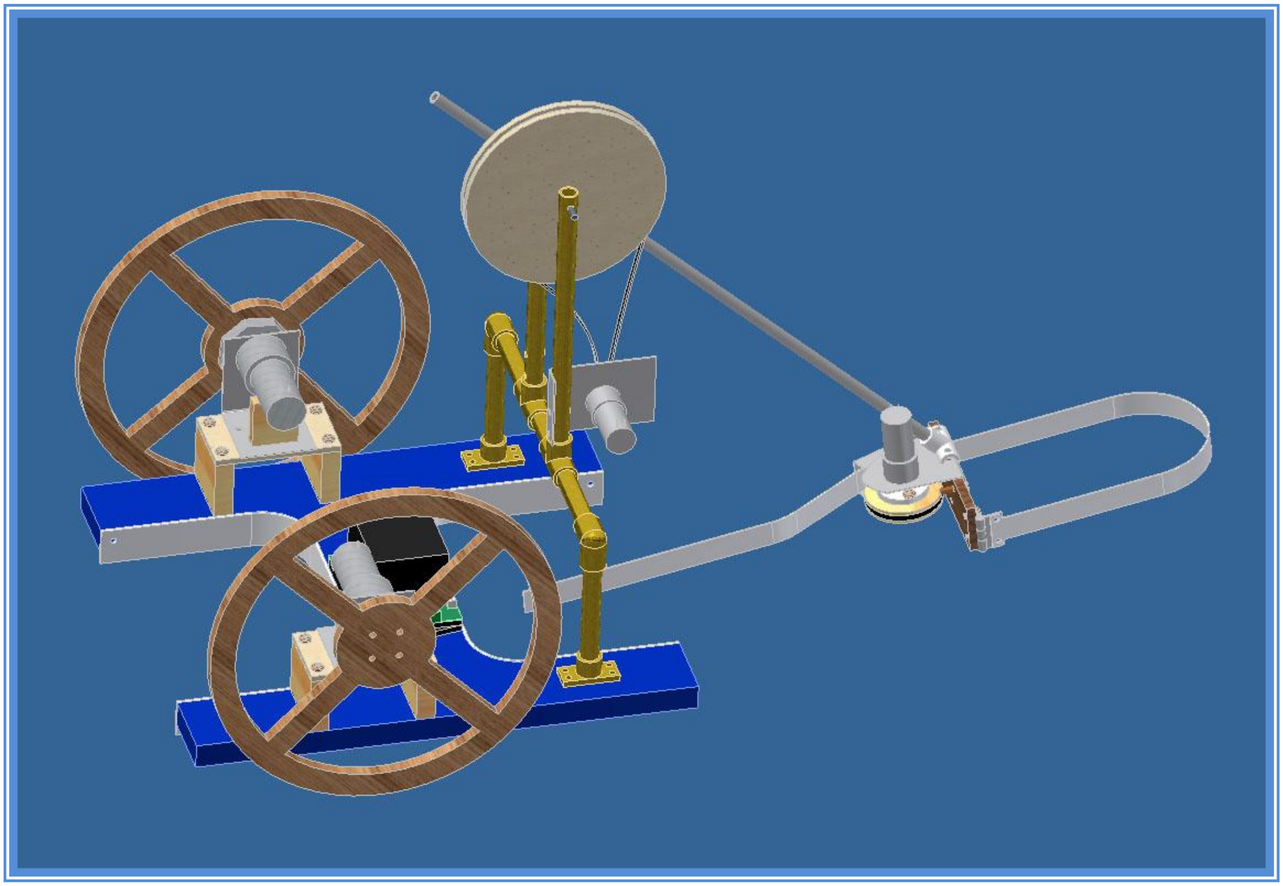


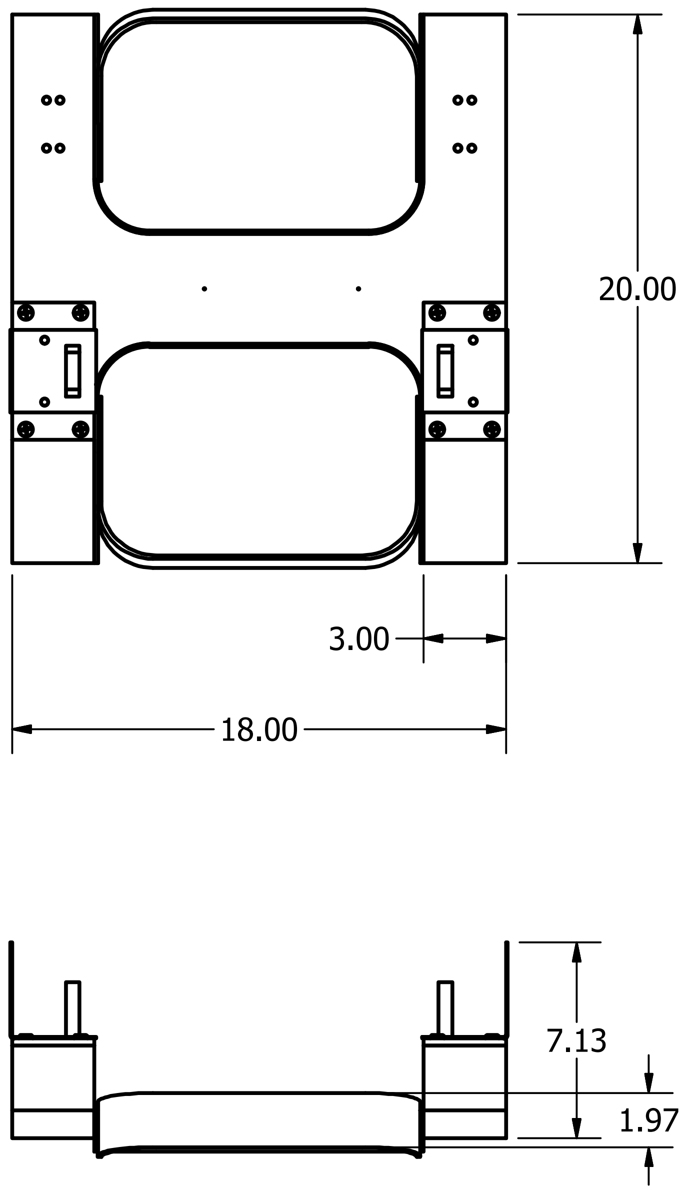


Final Design

E.1

Final Robot Design

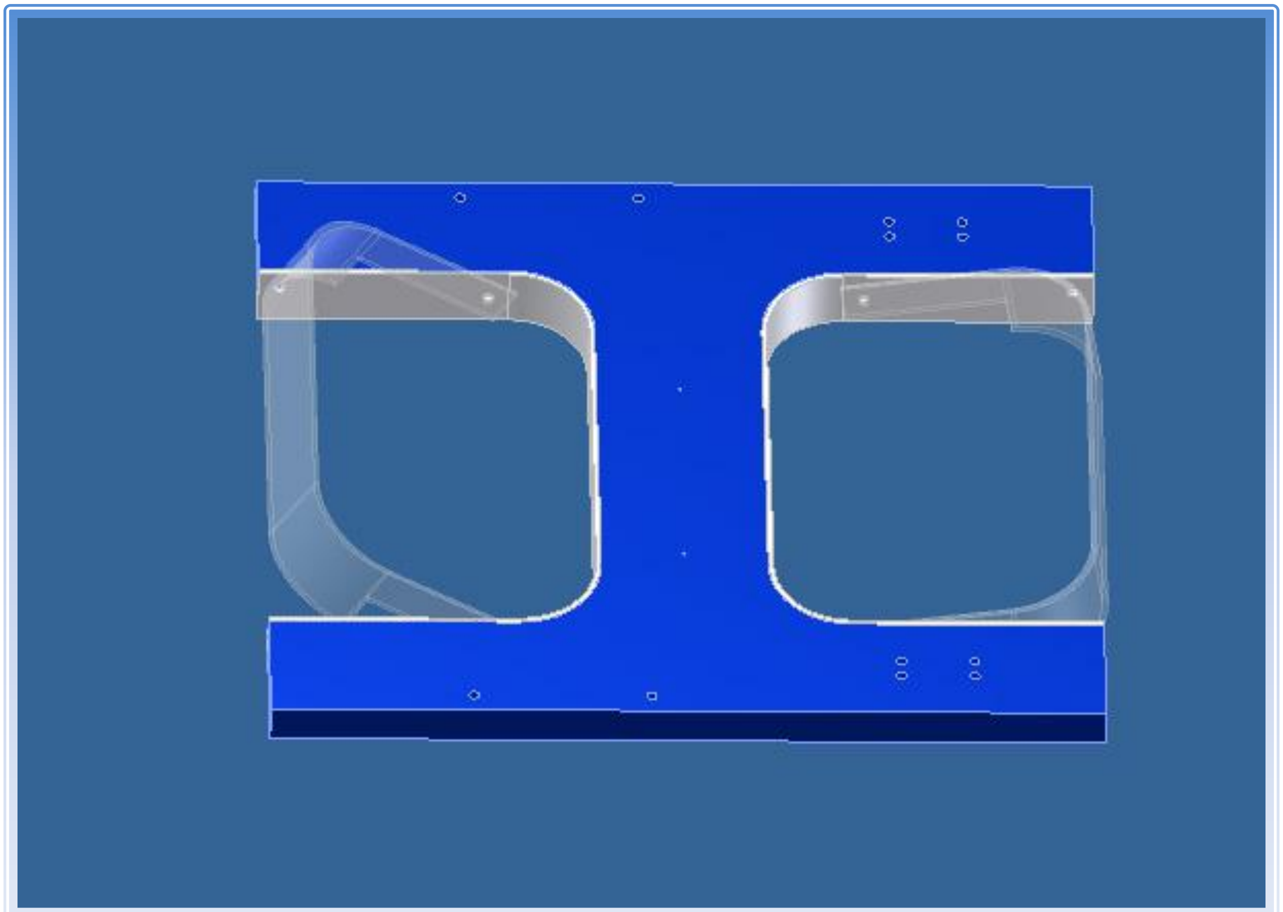


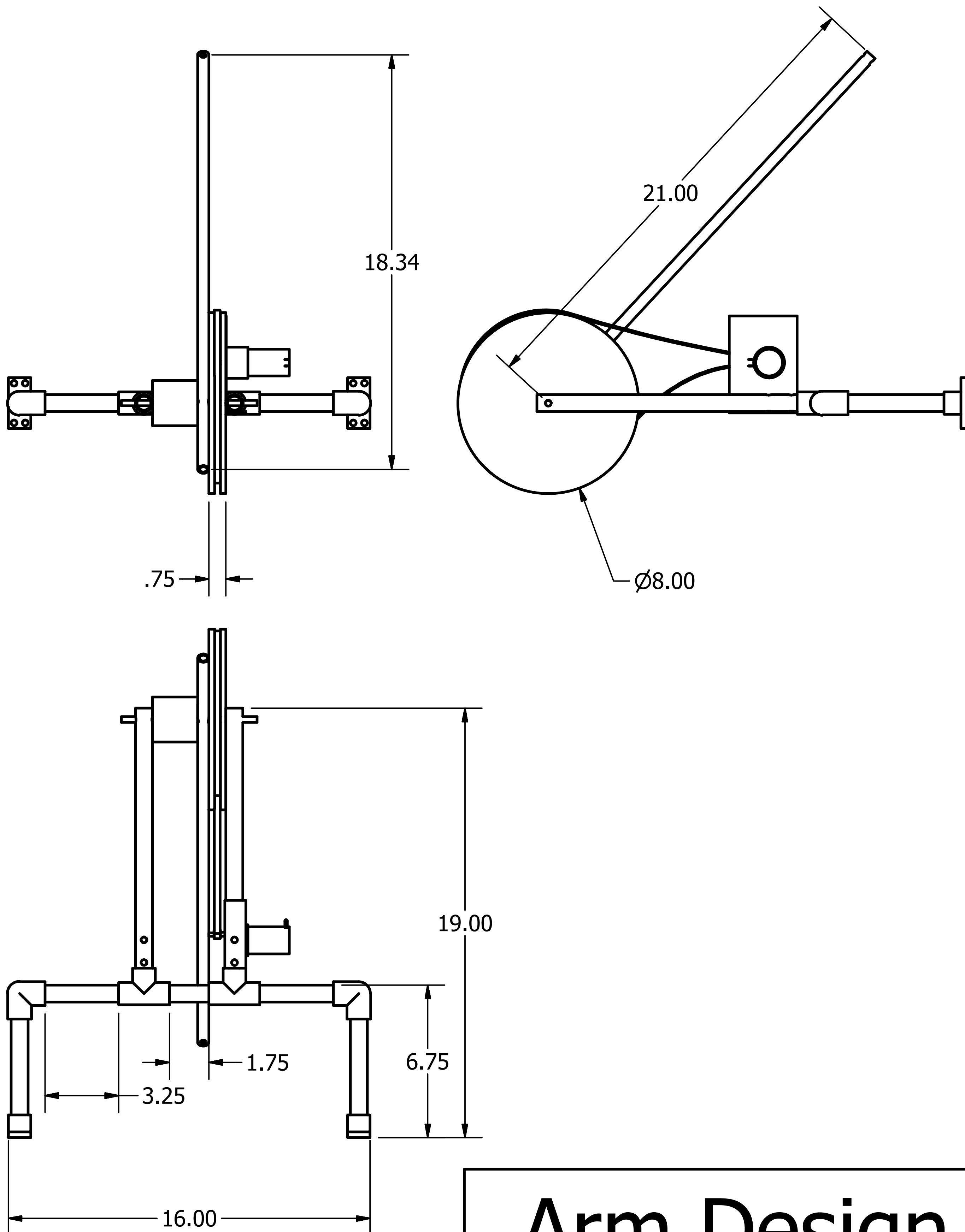


Base Design

E.2

Final Base Design

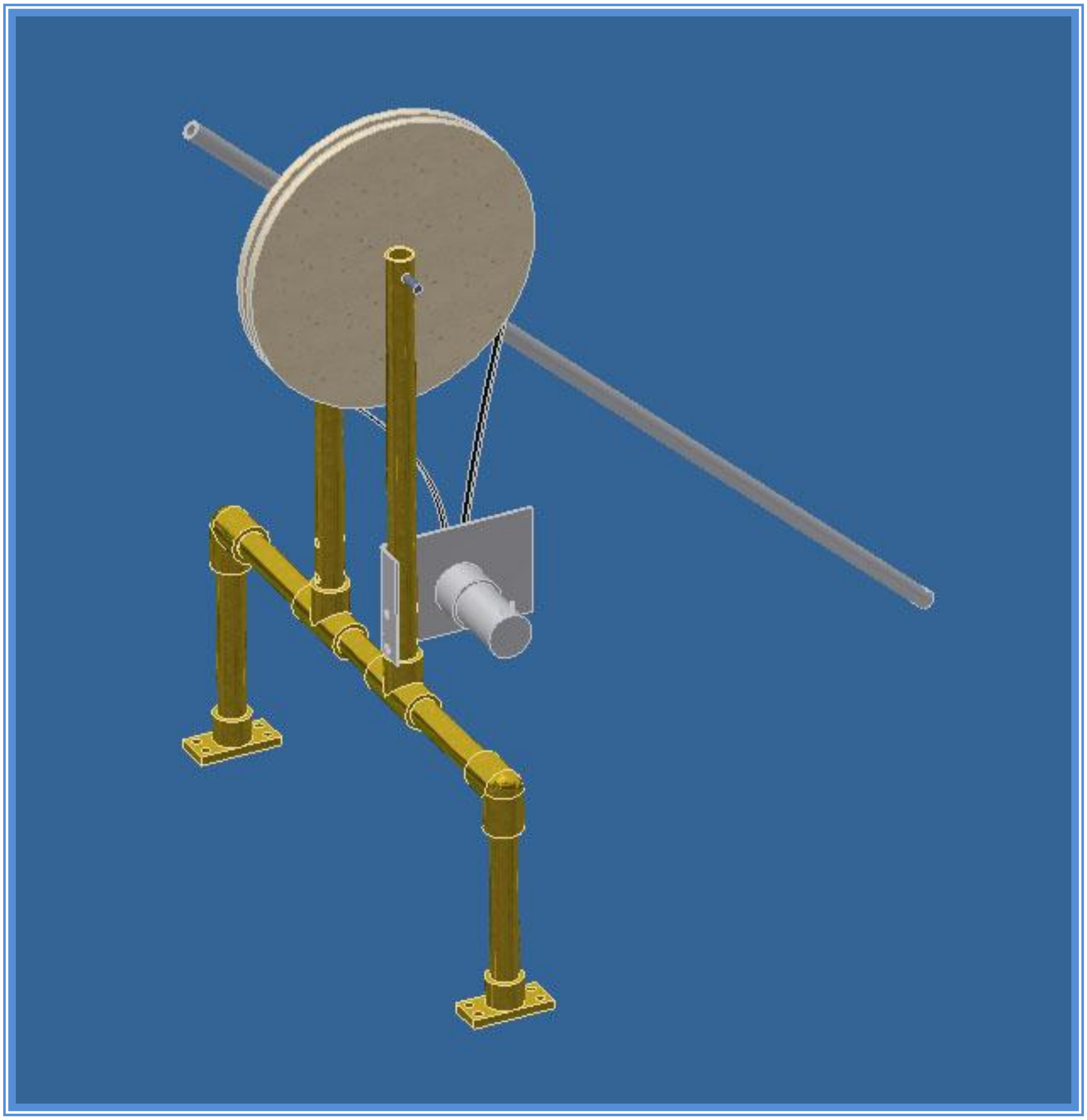


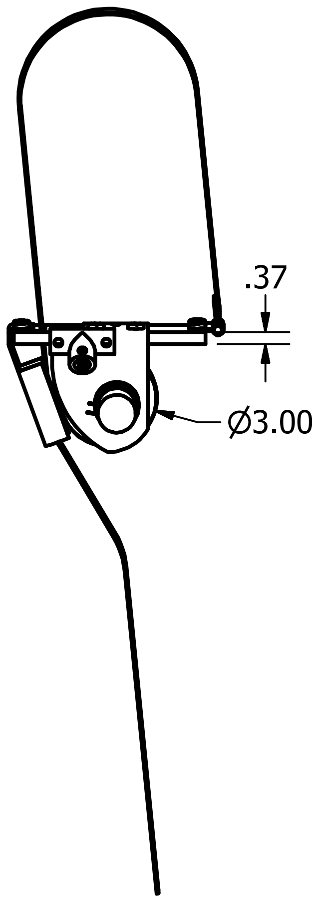


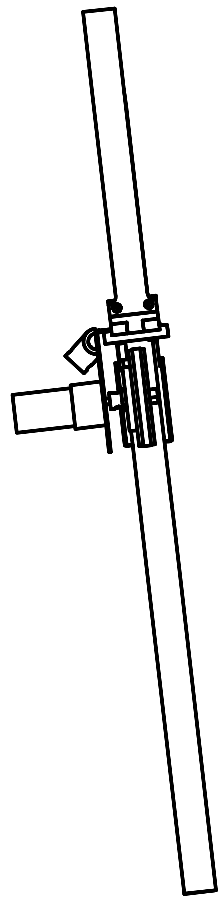
Arm Design

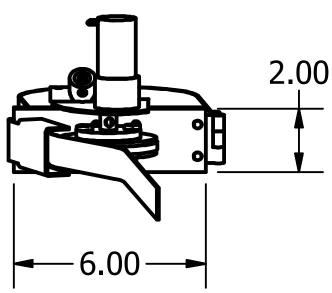
E.3

Final Arm Design





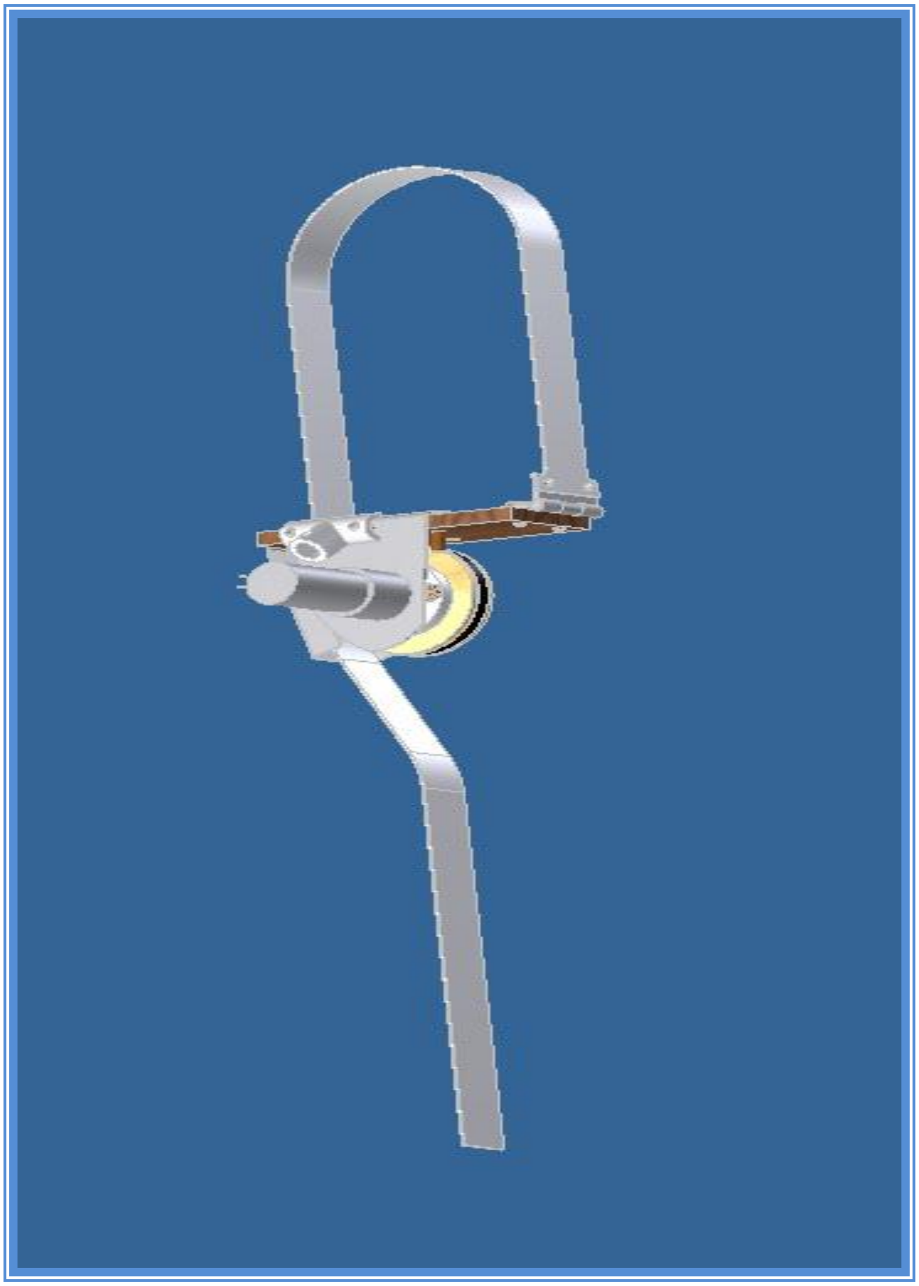


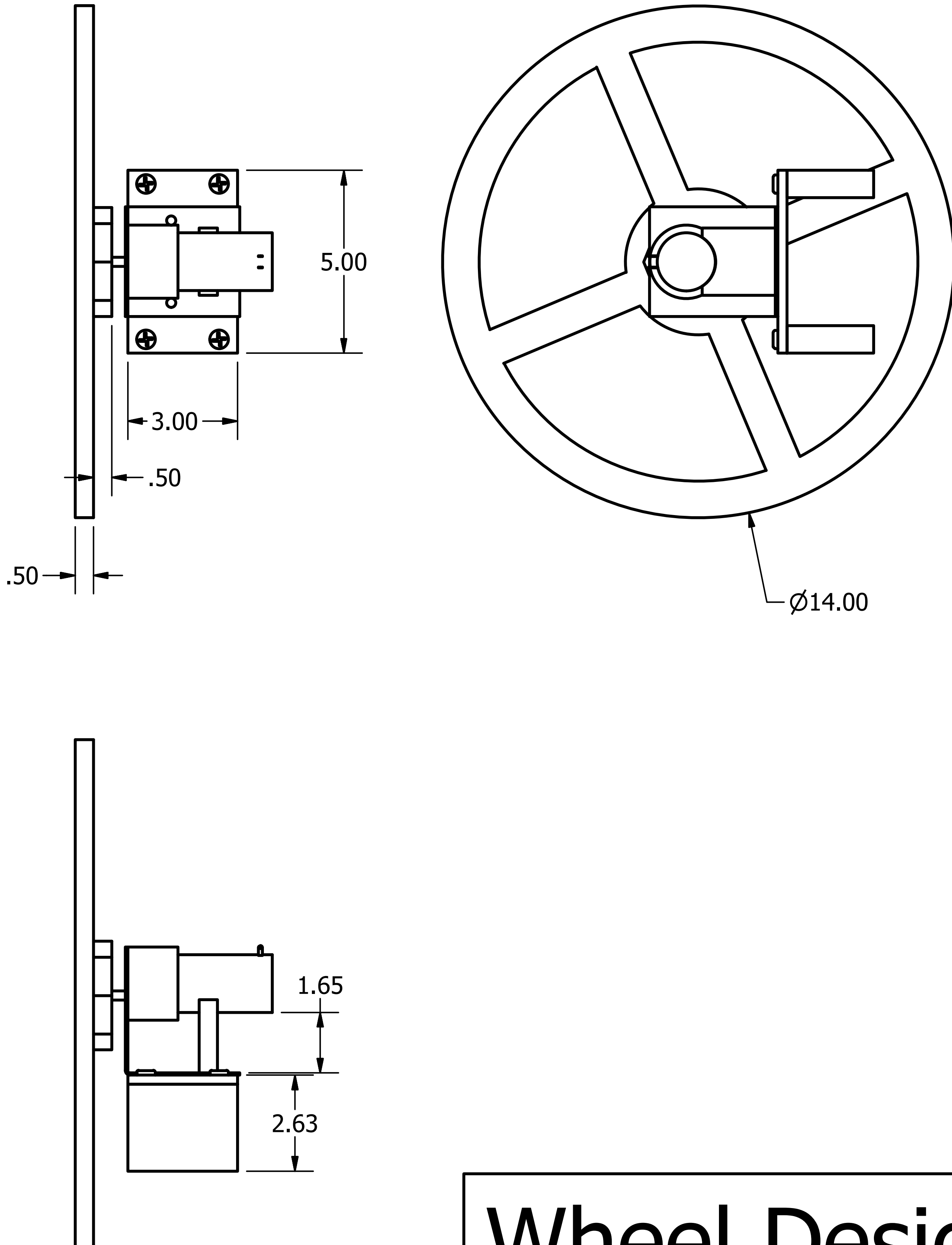


Gripper Design

E.4

Final Gripper Design





Wheel Design

E.5

Final Wheel Design