Heavy-Weight Sumo Robot

4th Place in National Robotics Challenge

Karl Haworth – Traverse City Central High School

Jack Kerby-Miller – Glen Lake High School

Advisors : Tim Wheatley and Hollianne McHugh

Revised : May 17, 2010

Competition Date : April 15th – April 17th

Abstract

As part of their senior project at the Manufacturing Technology Academy, Karl Haworth and Jack Kerby-Miller designed and built a robot to compete against other schools and tech groups in the heavyweight Sumo Robot Competition at the National Robotics Challenge, April 15th – 17th in Marion, Ohio. Over a period of seven months, the team followed the Plan Do Study Act method for continuous improvement to create their entry. They began by understanding the challenges intrinsic to the Sumo Robot Competition, specifically, reading the rules and synthesizing personal expirience.

It was understood that the robot would need to detect its opponent and autonomously move towards it, forcing it out of the large square arena. To accomplish this end, the team designed its robot to maximize torque and traction. They created a logic system that would use binary distance sensors with adjustable ranges to locate and their opponent and move towards it. The program was made to adjust the robot's course depending on which of the four LED sensors were activated at any one time.

In order to provide the necessary torque and horsepower, the robot was given six CIM motors which were each geared down in a 12:1 planetary gearbox before they were routed to rubberized tank treads to provide superior traction. Two 12 volt Lead-Acid batteries provided the necessary power for these motors. Also to improve traction, the robot was built to weigh exacly 125 pounds.

Finally, as a key advantage, hinged aluminum side flaps were attached to help lift opponents off the playing surface, reducing the effectiveness of their drive mechanisms. After the Robot's completion, the team traveled to compete, earning 5 wins and losing to only 1 robot. Some design issues were identified in competition and were resolved, but not before the team was eliminated. In exhibition matches afterwards, these adjustments resulted in victory over the only robot that the team had lost to.

Contents

Report

Introduction

Every year, seniors at the Manufacturing Technology Academy are required to complete an engineering based project as a part of their integrated technology and English curriculum. These projects vary from the intense chaos of the FIRST Robotics Competition to in depth research and construction of various types of robotics projects including manufacturing cells, automated wheelchairs, computer-mouse gloves and much more. Most of these projects are created to compete at regional and national competitions against other college and high school programs. The National Robotics Challenge in Marion, Ohio is one such competition that draws hundreds of entries in many categories; from head-to-head battles like the Sumo Robot division and robo-hockey, to races against the clock in the tactile and non tactile maze. Through their participation in such involved projects, students are able to gain valuable insight and problem solving experience, learning about the process involved in overcoming engineering challenges.

Plan - Document the Background

Team member Jack went to the National Robotics Challenge (NRC) last spring (2009) and observed the Sumo Robot Competition. He talked to the designers of the winning robot and decided that he could definitely build a robot that would have a chance to win. Team member Karl Haworth joined the Manufacturing Technology Academy (MTA) for his senior year in Fall, 2009. Karl thought he could help the team with his technical skills and computer background. Both Karl and Jack were interested in this project specifically because it allows them to go through the entire design process for the robot. This entailed designing the robot in SolidWorks, choosing components, programming, strategy and assembly.

They attended the National Robotics Challenge in the spring of 2010, in Marion, Ohio, and entered the Heavy-Weight Sumo Robot competition.

Plan - Define the Problem

The team wanted to ensure that the process of preparing for the competition would remain focused on measurable end results. To achieve this end, they began by brainstorming goals and constraints for the project, keeping in mind that discrete specific test values would be most beneficial to understanding what would qualify as a successful end product. The following chart displays the results of the brainstorming process.

Brainstorming : Process Goals

Create a robot that can:

- Push a 125-pound Sumo Robot across its tread pattern, at a speed of at least two inches per second.
- Get under a 125-pound opponent and lift the front end at least an inch off the ground.
- Weigh exactly 125 pounds.
- Detect a robot within two and a half feet and move towards it, adjusting course to keep itself square against the opponent.
- Fit within a two foot cube.
- Operate under full power for three minutes after a full charge.

This chart helped the team to understand what they were hoping to accomplish, and began to focus their efforts towards well defined goals. Both team members now understood the basic constraints and the aspects necessary, such as battery life, maximum dimensions, basic strategy and the expected level of mechanical stress. To consolidate this knowledge and ensure that it would remain at the center of all the team's activities, the team created a concise problem statement, shown in the chart below.

Problem Statement

- **Current:** There are some materials available, and limited knowledge, but no working heavyweight Sumo Robot to compete in the National Robotics Challenge.
- **Impact:** Students are unable to learn and participate in the heavyweight Sumo Robot Competition.
- **Desired:** The completed robot will be competitive in the National Robotics Challenge, and it's design and the principles that are necessary to keep it maintained and running will be imparted to the MTA class of 2011.

The problem statement, an overt statement of the starting conditions and aims of the Robot making process created a reference that the team would refer back to many times in the ensuing months. It served as a reminder of the big picture, and ensured that the knowledge gained through the robot production process would be preserved and passed on to the next class at MTA.

Plan - Document the Current Situation

After determining the their goals, the team moved on to focus on assessing the resources available to them. They needed to take an inventory of parts and materials that they already had that could be helpful in building their robot, so that they could accommodate them in their design. This was done first through a brainstorming diagram.

Brainstorming : Available Resources and Personnel

Available Resources

- Keyence PLC - This acted as the brain of our robot. We learned the programming for it and re-wrote the program multiple times.
- One 12:1 planetary gear box – This geared down our CIM motors and we had to purchase additional.
- Three CIM Motors
- 43 ½" of tracks – These became part of our drive mechanism and were left over from the light-weight robot last year.
- Three wheel cogs – These became part of our drive mechanism and were left over from the light-weight robot last year.

Personnel

- Jack Kerby-Miller
- Karl Haworth
- Assorted interested juniors

This chart was extremely useful because it gave the team a starting point. Knowing the type of PLC they would use allowed them to begin learning the programming and working out the logic that they would need. Having the gearboxes and CIM motors on hand allowed them to build their robot around these basic parts of their drive train. They used gearboxes, motors and tracks similar to those they were already familiar with, thus saving time in researching more motors and mechanical components.

Next, the team needed a way of organizing the components they would need as they continued their research. They began with a budget, using it to record price quotes on shipments of parts and keep a running balance of their funding situation. It was also helpful in coordinating the timing of the shipments with the process Gantt chart.

<u>Budget</u>

Sheet Steel (25x25x0.25)	$ 40.77	1	$ -	$40.77
CIM Motors	$ 28.00	5	$ 10.21	$150.21
CIM Motors	$ 28.00	1	$ 5.81	$33.81
Relays	$ 14.64	4	$ -	$58.56
Relay bases	$ 6.66	4	$ -	$26.64
Treads	$ 38.95	2	$ 6.03	$83.93
Wheel Cogs	$ 9.95	7	$ -	$69.65
Gearboxes	$ 112.09	4	$ -	$448.36
Bearings	$ -	7	$ -	$0.00
Gearboxes	$ 102.75	2	$ 18.15	$223.65
Steel Drive Shafts	$ 6.00	3	$ -	$18.00
P80 Series Gearbox CIM M	$ 7.85	6	$ 27.35	$74.45
White Lithium Grease	$ 4.99	1	$ -	$4.99
Nuts and Bolts	$ 27.68	1	$ -	$27.68
Hinges	$ 47.89	1	$ -	$47.89
Relay (Second Set)	$ 14.64	4	$ -	$58.56
Circuit Breakers	$ 12.89	2	$ -	$25.78
Batteries	$ 34.79	2	$ -	$69.58
		TOTAL SPENT		$2,325.51
		MTA Funding		$ 1,300.00
		Bill Marsh		$ 200.00
		TranTek		$ 250.00
		Sponsor 3		$ -
		FIRST Funding		$ 500.00
		Ending Balance		$ (75.51)

This was the team's actual costs, last updated on April 23, 2010. The team requested $2,400 and received $1,300. Because this amount was inadequate, the team set about finding other sources for funding. Through two corporate sponsors and a donation of excess funds by the MTA FIRST robotics team, the team came up with an additional $950. This was enough to complete the project and order all the necessary parts.

For the final step in the process of documenting the background, the team read and analyzed the previous year's rules and documentation to determine the operating procedures and guidelines. These were recorded and referred back to many times throughout the process, ensuring that the finished robot would both conform to and perform under them.

Rules

- Robot must be self-propelled and autonomous
- Robot weighs less than or equal to 125 lbs.
- Must fit within a 2'x2'x2' space.
- Wheels must be non-destructive to the playing surface.
- Must be safe.
- Weight must not be added after the Sumo Robot has been weighed.
- Must be powered by electric batteries.
- Must use sensing devices to govern its motion by detecting the other sumo or the edge of the square.
- Winners of the competition will be decided by double elimination.
- Robots will be positioned one foot apart as instructed by the judges, in either a front to front, back to back, starboard on starboard, or starboard on port side orientation.
- Must have a visible emergency Stop button
- When any part of one Sumo Robot touches or crosses the outer white circle(Diameter 15'10"), that Robot is declared the Loser
- If both Sumo Robots leave the circle at the same time, a "non-contest" is declared, and the two robots are repositioned and re started.
- If after 3 minutes there is no winner, the two Sumo Robots are repositioned and the contests re-start. If no winner is declared after this, the judges shall decide based on action observed and design.
- A pit area with access to 110V standard outlet will be provided.
- Judges decisions are final and binding.

With this background research completed, the team had a more in depth understanding of their starting point, as well as a much better definition of their goals. They began to move forward through design and construction, often refering back to the charts and lists that they had created to record and synthesize this valuable information.

Do, Study, Act – Programming Process

The timeframe for these tasks is recorded in Appendix I – Gantt Chart on page 20.

	Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
Programming					
	Create first program in Keyence Ladder Builder	Tested program in Keyence simulator	Worked 0%. Program Logic made multiple references to motors.	Appendix V – Original Program on page 37.	Need to create a sensor readout diagram to find out which sensors should be on
	Created a sensor readout diagram to find out which sensors should be on	Created a new program referring to sensor readout diagram and used robot diagram to write sensor locations.	Worked 100% on the simulator	Appendix IV – Sensor Readout on page 36. Appendix VI – Robot Diagram on page 38.	Put program into PLC onboard the robot.
	Put program into PLC onboard the robot.	Ran the robot	Worked 50 %. LEDs on the PLC indicated sensors were on that shouldn't be. Sensors were placed in the wrong spot.		Program was re-worked so the sensors could stay in place.
	Program was re-worked.	Robot was placed on floor to run.	Worked 100%. The robot ran as expected	Appendix VIII – Final Program on page 40.	The sensor numbers were moved around so it would run correctly
	Planned to test robot's finding abilities	Held plywood up to act as object	Worked 25%. Robot did not run as expected	Video in Keynote	Delays in the program were considered as the problem
	Decided to change delay times in the in the program to improve detection.	Changed the delay times in program	Robot worked as expected	Video in Keynote	Lowering the delay times allowed the robot to stop in time and sense the object

Do, Study, Act – Electrical Process

The timeframe for these tasks is recorded in Appendix I – Gantt Chart on page 20.

	Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
Electrical					
	Wire up the relays, circuit breakers, and PLC to motors	Received a crash course in electrical from Mark Perry at TranTek	One side of the track was not running after electrical was completed and in robot.	Appendix VII – Electrical Diagram on page 39.	Needed to check Voltages to make sure motors are getting power.
	Checked Voltages to make sure motors are getting power.	Used a multi-meter to check voltages	The non working side was receiving 24V and not 12V.		Needed to trace wiring to check how voltages are at 24V.
	Trace wiring to check how voltages are at 24V.	Traced wires throughout robot	In order to get 24V to PLC, the batteries were running in series.	Appendix VII – Electrical Diagram on page 39.	Needed to run batteries separately and find new energy source for PLC.
	Run batteries separately and find new energy source for PLC.	Removed jumper required to run in series and bought 9V batteries to run PLC.	Motors ran when there was no resistance, but tripped the circuit breaker when there was resistance		Needed to replace the Circuit Breakers to a higher amperage level.
	Replace the Circuit Breakers to a higher amperage level.	New 30A Circuit Breakers were bought	Wires continually came out of contacts when the robot was running due to vibrations.		Needed to place wires back into wire contacts.
	Wires had to be put back into wire contacts.	The wires were tightened down to prevent wires coming loose.	Motors ran successfully for a long period with resistance.		The circuit breakers were replaced, the wires tightened down, and voltage situation fixed.
	Test robot performance	Ran robot for long periods multiple times.	Sensors were not locking onto the opponent.		Needed to check delay on sensors.
	Check sensor delay times	Delays were reduced	We ran the robot again and PLC didn't turn on.		Needed to replace 9V batteries powering the PLC.
	Replace 9V batteries powering the PLC.	Batteries were replaced.	Robot ran to our expectations.		Replacing the 9V batteries solved the issue.

Do, Study, Act – Financial and Suppliers Process

The timeframe for these tasks is recorded in Appendix I – Gantt Chart on page 20.

	Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
Financial and Suppliers					
	Developed a budget for our project.	Created a spreadsheet and turned it in to instructors	The original budget was $2,400 and we were approved for 54% of our budget ($1,300)	Budget Spreadsheet on page 7.	Needed to try to get discounts and acquire sponsors
	Try to get discounts and acquire sponsors	Called around to suppliers to get discounts and contact businesses for sponsorships.	We were not able to get any discounts but we received a donation from FIRST team 1896 and Bill Marsh Automotive donated $200.	Appendix II – Sponsorship Letter on page 21.	We were able to buy all parts needed using our budget, donations, and technology class supply money.
	Order Parts	Find parts needed online and order	All parts were fast with shipping except for one set of gearboxes.		We continued working on as much as possible without those parts.
	We continued working on as much as possible without those parts.	Continued working	Finally a month later the gearboxes arrived.		The company took a long time to get the parts out but work continued at a slower pace.

Do, Study, Act – Structure

The timeframe for these tasks is recorded in Appendix I – Gantt Chart on page 20.

	Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
Structure					
	Created first SolidWorks model of the robot	Tested that drive train components would fit.	Tank treads were too large, and would not fit in the spaces.	See SolidWorks model 2 on page 23.	Re-worked SolidWorks model to accommodate treads
	Re-worked SolidWorks, to accommodate treads	Tested that drive train components would fit in	Realized flaps were now too high off the ground	See SolidWorks model 3 on page 24.	Re-measured and re-drew flaps
	Re-measured and re-drew flaps	Added new flaps to SolidWorks assembly	The new flaps fit, but the robot needed space for the electrical components, sensors, and batteries	See SolidWorks model 4 on page 25.	Planned to create a SolidWorks prototype for a top section of the robot to hold batteries and electrical components
	Planned to Create a SolidWorks prototype for a top section of the robot to hold batteries and electrical components	Created the SolidWorks drawing, and measured electrical components and battery to ensure they would fit.	Realized we would need more space for electrical components because the PLC and relays were too large, also, we needed space for an extra battery to improve performance	See SolidWorks model 5 on page 26.	Planned to create a new SolidWorks model to provide space for more electrical components.
	Planned to create a new SolidWorks model to provide space for more electrical components.	Created a new, larger SolidWorks top with space for sensors, and two 12 volt batteries.	This new design would fit all of the components we knew we would need, however, it was still necessary to find its weight to ensure it was on target for our 125lb goal.	See SolidWorks model 6 on page 27.	
	Planned to weigh the components and balance the materials of the frame to ensure the weight limit was on target.	Weighed the gearboxes, CIM motors, bearings, batteries, and PLC, then calculated the weights of the structural components on SolidWorks, using both steel and aluminum	To balance the weight, it was decided that the base would be made of steel, to make a lower center of mass, and to better deal with the stress from the motors, while the rest of the structure would be made from aluminum. The final estimated weight was 121 lbs.	See Weighting Datasheet on page 55.	At this point, an effective design for the structure of our robot had been developed. To implement the design, the team moved forward by finding materials and a vendor to weld the assembly.
	To implement the design, the team moved forward by finding materials and a vendor to weld the assembly.	The steel was purchased from Jacklin Steel Co., and the aluminum from the Career Tech Center. Tool North	After much communication with the vendors, the materials were delivered to Tool North, however, our contact needed to know		Planned to Create AutoCAD drawings of the sections to be used for assembly of the robot's structure. These AutoCAD drawings assisted the

		was enlisted to help weld the robot.	the critical dimensions and shape of the sections to be cut and welded.		team in the layout for the bluing process.
	Planned to Create AutoCAD drawings of the sections to be used for assembly of the robot’s structure.	Created AutoCAD drawings and delivered them to Tool North, who cut the steel and aluminum stock to size	The Team realized that the base would have to be assembled with the motors, and that our current design would make the team unable to remove the motors once it was assembled.	See AutoCAD Drawings 1-5 on pages 31-35.	While the team waited for the motor assemblies to be complete, they re-worked the robot to allow the motors to be accessed
	While the team waited for the motor assemblies to be complete, they re-worked the robot to allow the motors to be accessed	Added threaded rods, drilled and tapped holes, and bolts to allow the sides of the base to be secured.	These modifications allowed the sides of the base to be temporarily attached allowing the team access to the motors.	See picture of modifications on page 43.	These changes were implemented by finally welding the robot together,
	The structure was welded, and the team planned to place all the critical components in place on the frame to ensure they would fit.	Placed the sensors, batteries, motors, axles, bearings and cut and placed the DIN rail with the electrical components in the structure.	Placing these parts in the robot caused the team to realize that everything fit, except the two batteries.	See pictures on page 43 and 44.	The team called Ace Welding, and arranged for them to modify the robot to fit the batteries.
	The team called Ace Welding, and arranged for them to modify the robot to fit the batteries.	The sides of the battery casing were cut off and re-welded.	The batteries now fit properly, and there was space for all components on the robot.	See picture of new welds on page 45.	With this last modification, the team proceeded to the final assembly stage.

Do, Study, Act – Assembly

The timeframe for these tasks is recorded in Appendix I – Gantt Chart on page 20.

	Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
Assembly					
	Jack created a SolidWorks model of the axles, reverse-engineered to fit the gearboxes.	The drawings were shown to Mr. Seivert, who had volunteered to machine the axles from aluminum in the NMC machining department.	Mr. Seivert asked for some revisions to be made, then manufactured the parts to the team's specifications.	See SolidWorks models 7-9 on pages 28-30.	.The team next planned to attach the cogs to the axles.
	The team next planned to attach the cogs to the axles.	The cogs on one of the free axles were drilled and bolted with two holes and standard Phillips head bolts.	The nuts wouldn't fit, the head wouldn't fit and snapped off, and the team was concerned that they would need more strength.		To solve these problems, the team experimented with different methods for bolting the cogs on.
	To solve these problems, the team experimented with different methods for bolting the cogs on.	The team found bolts with narrower heads, allowing them to fit into the holes without stress. To solve the problem with the nuts, they filed down one side. Finally, they drilled and bolted each cog in 3 places to increase the strength.	These changes worked, and the filed nuts had the additional benefit of holding themselves from turning against the axle.	See picture of old and new bolts and nuts on page 46.	The team used this method on all the other axles. With the axles complete, the team proceeded in assembling the robot, starting with the base.
	With the axles complete, the team proceeded in assembling the robot, starting with the base.	The motor-gearbox assemblies were put together and loosely bolted in place, then the axles were inserted into them, and the sides and bearings were pressed into place.	The team then rotated each axle to test if it was binding from the pressure. Two axles on each side were fairly bound.		The team decided they needed to adjust the fit of the axles before proceeding with assembly, as it would severely decrease the output horsepower of the motors.
	The team decided they needed to adjust the fit of the axles before proceeding with assembly, as it would severely decrease the output horsepower of the motors.	The team used a set of clamps and a ball peen hammer to adjust the position of the sides of the base to free up the axles.	After this modification, all the axles rotated freely.	See picture on page 47.	These changes were implemented by securely bolting the motors and tightening the bolts attaching the sides of the base. Next, the team focused on assembling the electrical components.
	The team focused on assembling the electrical	The team bolted the DIN rail, circuit breakers, PLC,	All of the parts still fit, and were securely attached where they	See picture of the top assembly on	The components were left attached and in place, and the team moved to

Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
components.	Relays, and sensors in place, and created a harness to hold the batteries in their casing. The robot was then tested by running the treads.	needed to be.	page 48.	focus on attaching the top and side flaps to the base of the robot.
The team focused on attaching the top and side flaps to the base of the robot.	The flaps were machined at a 45 degree angle at the leading edge and secured with eight hinges.	With the flaps attached, it became apparent that they were not perfectly flush with the ground	See close up of hinges on page 49.	To make the flaps more flush, the team planned to do some fine tuning before the competition.
To make the flaps more flush, the team planned to do some fine tuning before the competition.	Karl and Jack used files to sharpen the front and back edges of the robot, bending them flush.	The result was that the front and back flaps were perfectly flush with the ground, however the side flaps would not fit perfectly.	See before and after picture of side flaps on page 50.	The issue that the side flaps would not fit was considered relatively minor, so the team didn't modify the flaps further until after competition.
Once the flaps were complete, the team planned to add surgical tubing springs to keep the flaps pressed against the ground.	The team added the tubing, and tested the robot against the previous year's lightweight Sumo Robot.	The robot was unable to gain purchase on the lightweight, because the springs forced the front flap to catch, lifting the treads off the ground.		The tubing was removed, and the idea scrapped.
During competition, the team noticed that the side flaps got caught on the main competitor, allowing it to gain purchase and push us out. This led to a resolution to fix them.	The team first removed the flaps, and competed against the other robot in an exhibition match, and filed the side flaps to fit flush with the ground.	The robot without side flaps easily lifted and neutralized the competitor, winning the exhibition match. The side flaps were eventually fine-tuned to satisfaction.	See Results on page 41.	At this point, the flaps were perfected to the best our resources would allow.
To attach the top, the team originally planned to set it on top of the base.	Once the team had the robot assembled, the team set the top on the base, and checked to see that there was enough clearance.	Through this, the team came to realize that the tank treads would not clear the bottom edge of the top, and there also was a significant need for additional ventilation.		The team planned to remedy this by using hinges to attach the top section of the frame.
The team planned to remedy this by using hinges to attach the top section of the frame.	The hinges were permanently bolted to the frame on one side, and the bolts were welded into the hinge on the other side to allow them to be pushed through the top and secured with wing nuts for easy access.	This seemed to work well, allowing the team easy access to the inner robot. It also held the top section roughly one inch above the base, giving additional ventilation and clearance for the motors and treads.	See pictures of hinge-assembly on page 51 and 52.	With the robot finally complete, the team planned to weigh it to ensure that it was under the limit.
With the robot finally complete, the team planned to weigh it	The robot was weighed at the UPS store, and tipped the	This test showed us we needed to subtract approximately 5 lbs.	See Weight Datasheet on page 55.	To reduce the weight, it was decided that the team would replace the

	Develop an Action Plan (D4)	Implement and Create a Prototype (D5)	Test Results (S7)	Supported Data	Act (A8)
	to ensure that it was under the limit.	scales at 130 lbs.			aluminum cover for the top with Lexan and drill holes in the aluminum flaps if necessary.
	To reduce the weight, it was decided that the team would replace the aluminum cover for the top with Lexan and drill holes in the aluminum flaps if necessary.	The team created the Lexan top, and made some other small modifications.	The robot weighed in at 124.25 after several attempts, because of the inaccuracy of the scale.	See picture of the new Lexan top on page 53.	124.25 lbs was as close to the team's desired weight as reasonably possible, so the robot was not modified after this point.

Conclusion

After months of preparation, and may repetitions of the Do, Study, Act parts of the PDSA process, the team was able to meet their desired criteria. Through the process, both members learned an enormous amount about the engineering process, from teamwork, logistics, and dealing with persons in industry to documenting their process, wiring, programming, and dealing with mechanical limitations. After testing, and re-testing, trouble shooting, and fine-tuning, the Sumo Robot was finally complete. It cost approximately $2300, and could easily push robots of a similar size around. The modified side-flaps gave it an edge against all-comers, and the 3" rubberized tank treads allowed it to gain a tremendous amount of traction. After 8 matches, 5 wins, two losses, and a draw, the team finally perfected their strategy and function. Through their documentation and involvement of junior assistance in its construction and maintenance, the team was able to ensure that the next generation of students from the MTA would be able to utilize and understand the robot's unique advantages in the next year's competition.

Works Cited

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Appendix I – Gantt Chart

Sumo Robot 1
Jack Kerby-Miller & Karl Haworth
Competition Date : April 15th-17th
Approximate Completion Date : Wed 4/14/10
Currently 100% Complete

ID		% Complete	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	✓	**100%**	**Plan**	**3 days**	**Mon 11/9/09**	**Wed 11/18/09**		
2	✓	100%	Document the Background	1 day	Mon 11/9/09	Mon 11/9/09		Jack Kerby-Miller,Karl Haworth
3	✓	100%	Document the Current Situation	1 day	Wed 11/11/09	Wed 11/11/09		Jack Kerby-Miller,Karl Haworth
4	✓	100%	Define the Problem	1 day	Wed 11/18/09	Wed 11/18/09		Jack Kerby-Miller,Karl Haworth
5	✓	**100%**	**Do**	**54 days**	**Mon 11/9/09**	**Mon 4/5/10**		
6	✓	100%	Develop the Action Plan	2 days	Mon 11/9/09	Wed 11/11/09		Jack Kerby-Miller,Karl Haworth
7	✓	**100%**	**Implement the Action Plan and Create a Prototype**	**54 days**	**Mon 11/9/09**	**Mon 4/5/10**		
8	✓	**100%**	**Structure**	**39 days**	**Mon 11/9/09**	**Mon 3/1/10**		
9	✓	100%	Solid Works Design	16 days	Mon 11/9/09	Wed 1/6/10		Jack Kerby-Miller
10	✓	100%	AutoCAD layout of sections	1 day	Mon 1/18/10	Fri 1/22/10	9	Jack Kerby-Miller
11	✓	100%	Communicate with Welding Dept. at ToolNorth	14 days	Mon 1/25/10	Wed 2/24/10	10	Jack Kerby-Miller
12	✓	100%	Welding of Robot	2 days	Fri 2/26/10	Mon 3/1/10	11	Jack Kerby-Miller
13	✓	**100%**	**Ordering and Research**	**4.88 days**	**Mon 11/9/09**	**Wed 11/25/09**		
14	✓	100%	Order 1/4" Aluminum	30 mins	Mon 11/9/09	Mon 11/9/09		Karl Haworth
15	✓	100%	Order 1/4" Steel	30 mins	Mon 11/9/09	Mon 11/9/09	14	Karl Haworth
16	✓	100%	Order Cogs	30 mins	Mon 11/9/09	Mon 11/9/09	15	Karl Haworth
17	✓	100%	Order Gearboxes	30 mins	Mon 11/9/09	Mon 11/9/09	16	Karl Haworth
18	✓	100%	Order Tracks	30 mins	Wed 11/11/09	Wed 11/11/09	17	Karl Haworth
19	✓	100%	Order Motors	30 mins	Wed 11/11/09	Wed 11/11/09	18	Karl Haworth
20	✓	100%	Order Sensors	30 mins	Wed 11/11/09	Wed 11/11/09	19	Karl Haworth,Mark(Banner Eng.)
21	✓	100%	Batteries	30 mins	Wed 11/11/09	Wed 11/11/09	20	Karl Haworth
22	✓	100%	Order Relays	15 mins	Wed 11/11/09	Wed 11/11/09	21	Karl Haworth,Mark Perry(TranTek)
23	✓	100%	Order and Research Circuit Breaker	6 hrs	Wed 11/11/09	Wed 11/25/09	22	Karl Haworth,Jack Kerby-Miller,Mark Perry(TranT
24	✓	100%	Order Axels	1 hr	Fri 11/13/09	Fri 11/13/09	23	Karl Haworth
25	✓	100%	Order and Research Bearrings	2 hrs	Fri 11/13/09	Mon 11/23/09	24	Jack Kerby-Miller
26	✓	**100%**	**Promotions**	**9.88 days**	**Mon 11/9/09**	**Wed 12/9/09**		
27	✓	100%	Design T-Shirts	2 days	Mon 11/23/09	Mon 11/30/09	25	NRC Group
28	✓	100%	Order T-Shirts	1 day	Mon 11/30/09	Wed 12/2/09	27	NRC Group
29	✓	100%	Design Buttons	2 days	Wed 12/2/09	Mon 12/7/09	28	NRC Group
30	✓	100%	Make Buttons	1 day	Mon 12/7/09	Wed 12/9/09	29	NRC Group
31	✓	100%	Program PLC	1 day	Mon 11/9/09	Mon 11/9/09		Keyence PLC[1],Karl Haworth
32	✓	100%	Get Lodging	30 mins	Mon 11/9/09	Mon 11/9/09		Karl Haworth
33	✓	100%	Electronics Assembly	7 days	Mon 1/18/10	Mon 2/1/10		Karl Haworth,Keyence PLC[1],CIM Motors[1],LE
34	✓	100%	General Assembly	7 days	Mon 3/15/10	Mon 3/29/10	12	Jack Kerby-Miller,Karl Haworth,Steel Plate 1/4"[1
35	✓	100%	Test the Prototype	3 days	Wed 3/31/10	Mon 4/5/10	34	Jack Kerby-Miller,Karl Haworth
36	✓	**100%**	**Study**	**2 days**	**Wed 4/7/10**	**Fri 4/9/10**		
37	✓	100%	Analyze the Test Results	2 days	Wed 4/7/10	Fri 4/9/10	35	Jack Kerby-Miller,Karl Haworth
38	✓	**100%**	**Act**	**2 days**	**Mon 4/12/10**	**Wed 4/14/10**		
39	✓	100%	Troubleshoot and Implement Improvements	2 days	Mon 4/12/10	Wed 4/14/10	37	Jack Kerby-Miller,Karl Haworth

Page 1
Wed 4/21/10

Appendix II – Sponsorship Letter

Manufacturing Technology Academy
Location: 2600 Aero Park Dr.
Mailing address: 880 Parsons Road
Traverse City, MI 49686
Phone: (231)995-1304 **Fax:** (231)995-2204
Website: www.mta.tc **e-mail:** doliver@message.nmc.edu

Wednesday, April 21, 2010

«Company»
ATTN : «First» «Last»
«Position»
«Address»
«City», «State» «Zip»

Dear «Title» «First» «Last»:

We are writing as high school seniors enrolled in the Manufacturing Technology Academy (MTA) in Traverse City, Michigan. MTA is a hybrid of rigorous academic and technical courses designed to prepare students for college study and careers in engineering, manufacturing, and related fields. As seniors, students at MTA are expected to complete a project applying what we have learned in our technology class. This year, all seniors are building robots for either the National Robotics Challenge in Marion, Ohio or the FIRST Robotics Competition in Traverse City and several other locations in Michigan.

We have chosen to compete in the Heavyweight Sumo Robot Competition at the National Robotics Challenge. This entails designing and building a robot that weighs less than 125 lbs. and fits within a two foot cube with the ability to autonomously seek out an opponent and push it out of a 15'2" diameter circle. We will be competing against other high school and college-age teams in April.

After research, consultation with our industry partners, and hours of designing and refining our ideas, we have decided on a detailed plan. Our robot will run off of six CIM motors powering two three-inch-wide tank treads. It will use ladder logic stored on an industrial Keyence Programmable Logic Controller, which is available to us free of charge through the MTA. We plan to use four LED sensors built by Banner Robotics to locate our opponent, and a low, precisely ground aluminum frame to lift our opponents off the playing surface, thus disabling their drive mechanisms. We have enclosed a packet of technical information (please see appendix A) that we have followed during the development of our project.

We began designing our robot last March, after observing the competition in Marion, Ohio. We have developed a winning plan, based upon our perception of the most effective strategies and attributes of the previously competing robots. We have spent three months in the designing and researching process, finding the components and materials we will need to create our robot, and carefully cataloguing suppliers and costs. However, funding for these competitions is outside of our regular school budget. Our MTA Guidance Board, consisting of area manufacturers and other business people, helps provide these additional funds. So far this year, funding for projects has been provided by proceeds from the annual Grand Traverse Manufacturers' Golf Outing and a grant from Grand Traverse Stamping/Alcoa Foundation. We are currently seeking additional grants and donations to complete the funding for our project and others.

After the MTA's contribution, we still need $619.54. At this point, we respectfully request help from «Company» by sponsoring our project. Your company logo will be displayed prominently and proudly on our robot and in our documentation.

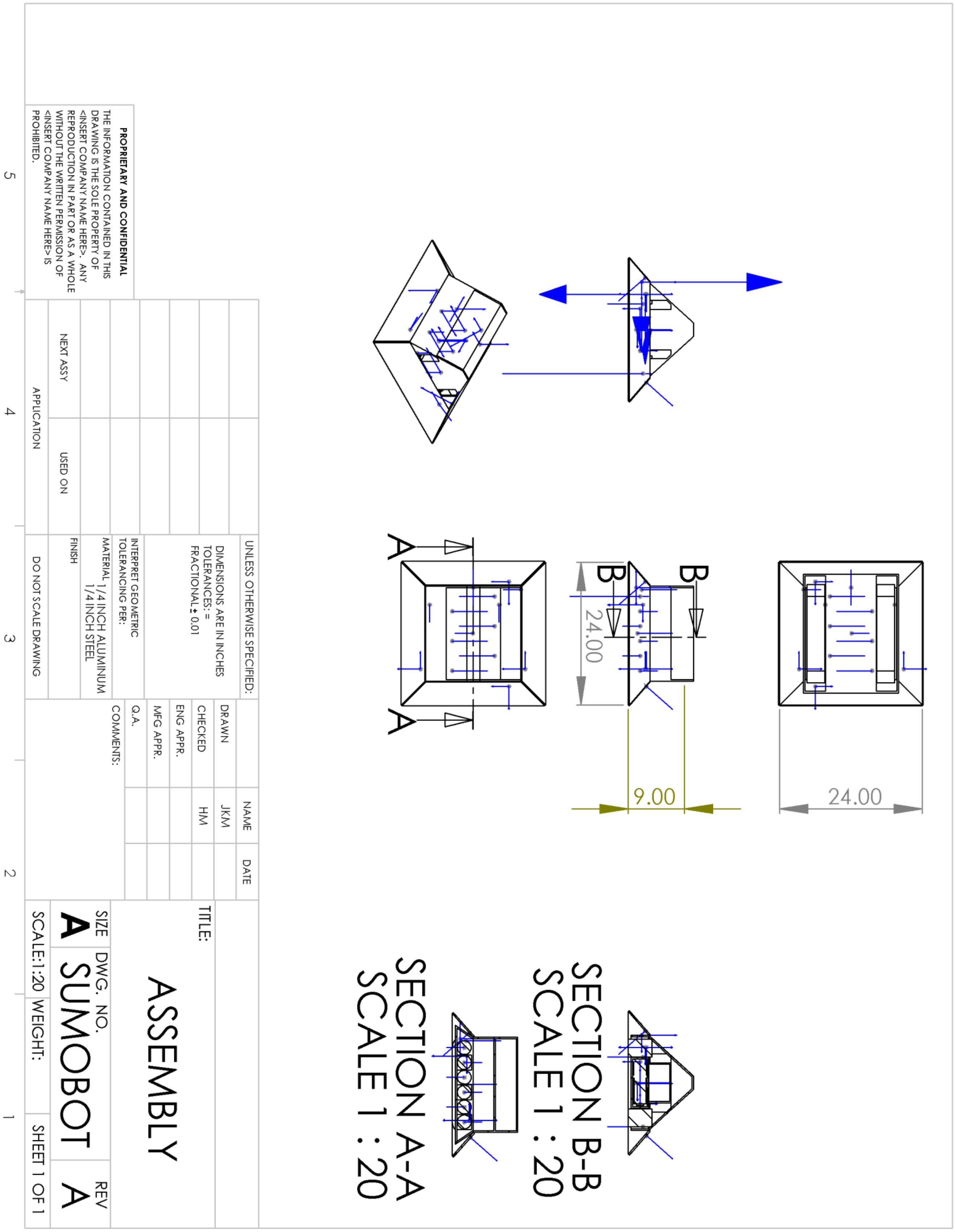
We have included our most recent Annual Report as well as the information described above. If you have any questions, or would like to make a donation, please contact our instructor, Debby Oliver. Her contact information is in the letterhead. Thank you for taking the time to consider our request.

Sincerely,

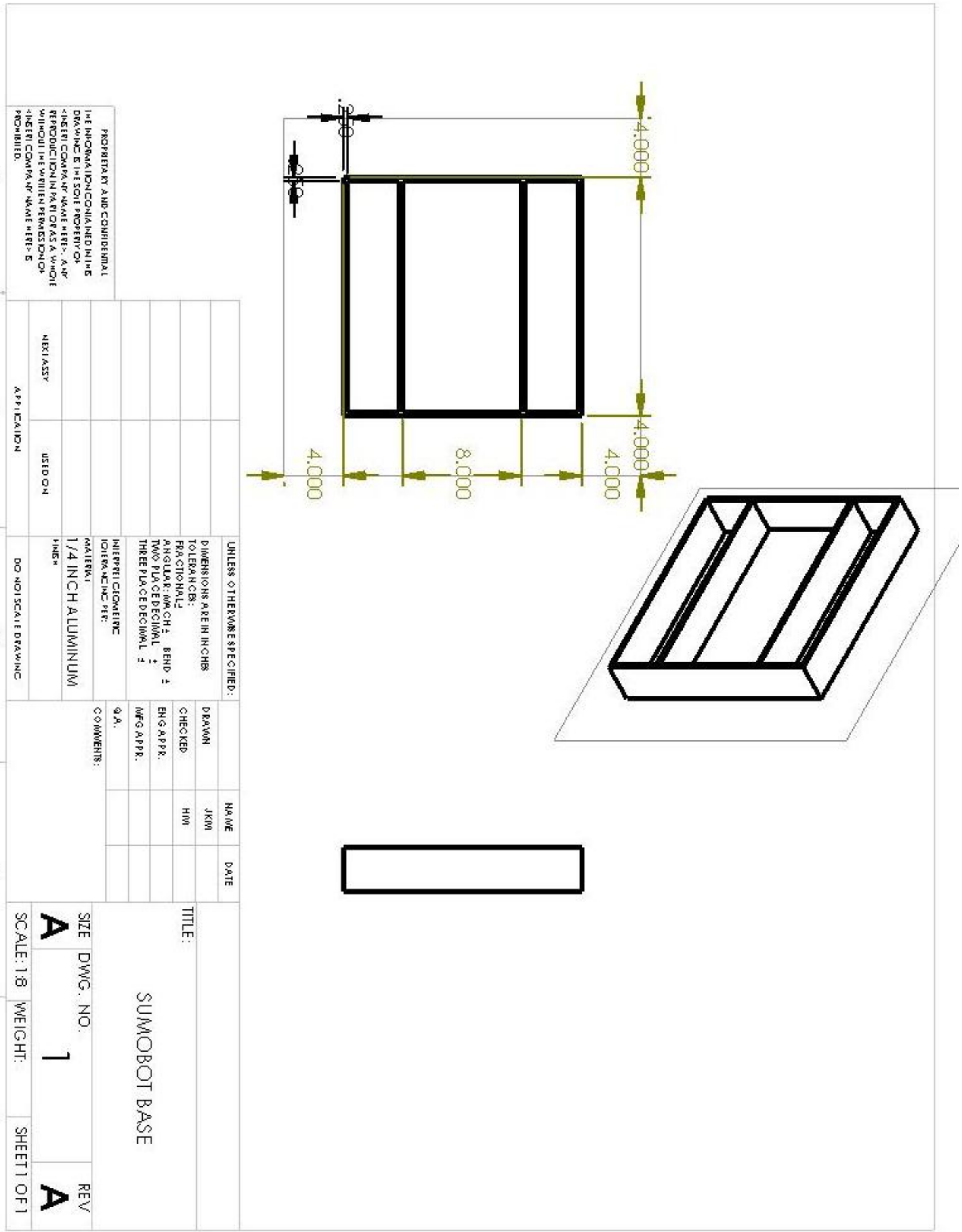
John Kerby-Miller
Jack Kerby-Miller
Karl Haworth
Karl Haworth

MTA is a partnership among TBAISD Career-Tech Center, area manufacturers and is housed in Northwestern Michigan College's M-TEC facility.

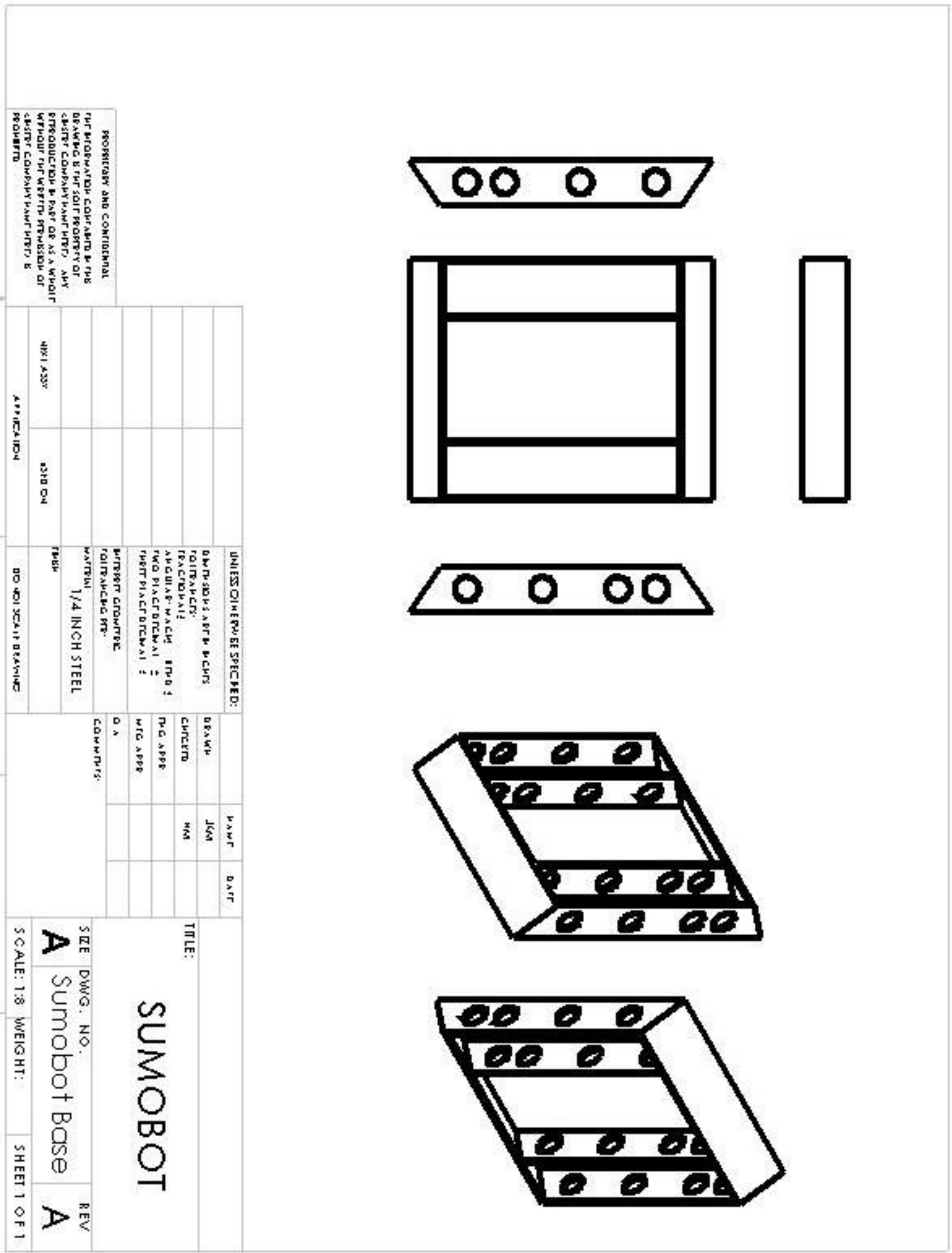
Appendix III – SolidWorks Drawing



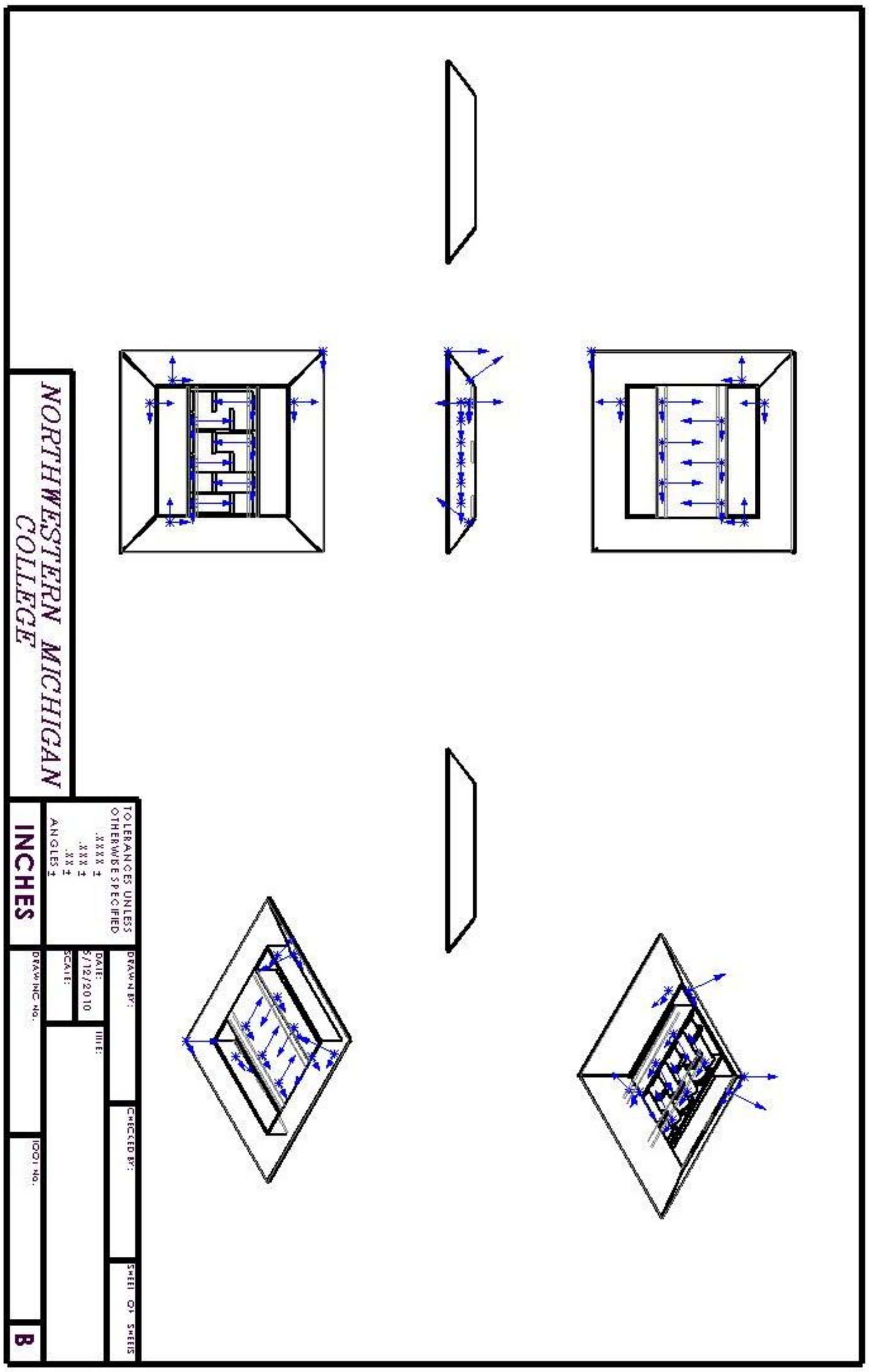
SolidWorks Model 2



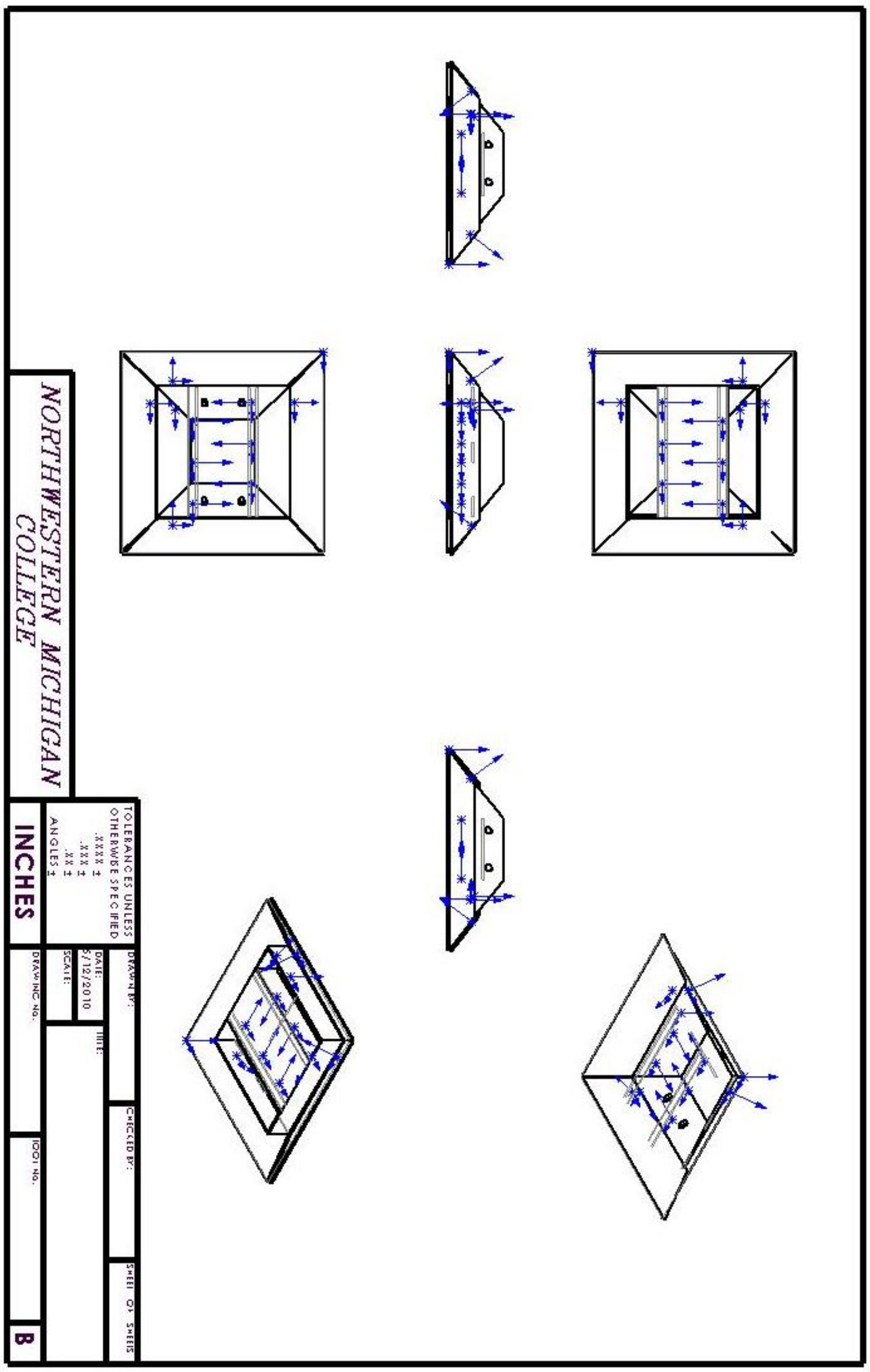
SolidWorks Model 3



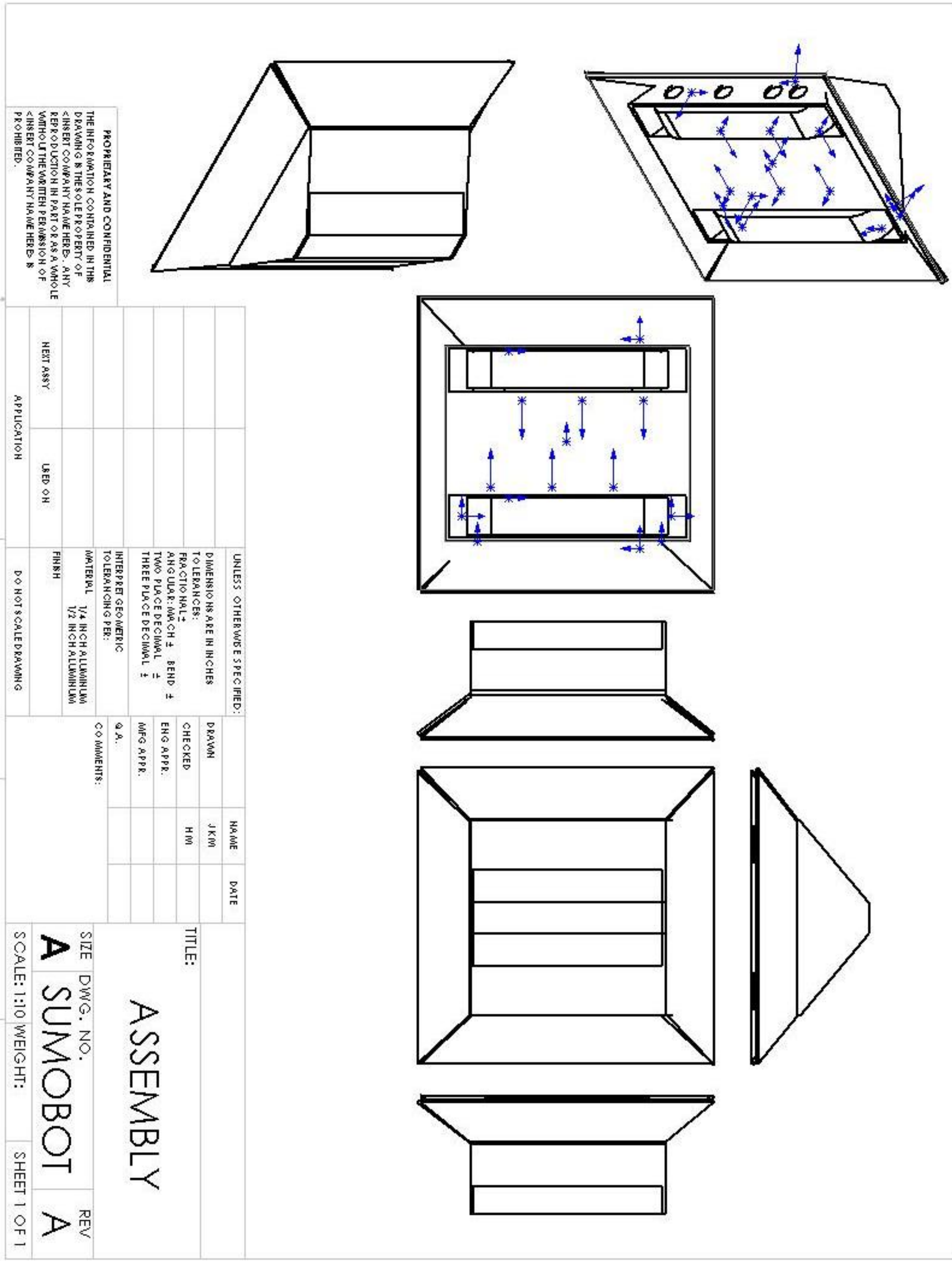
SolidWorks Model 4



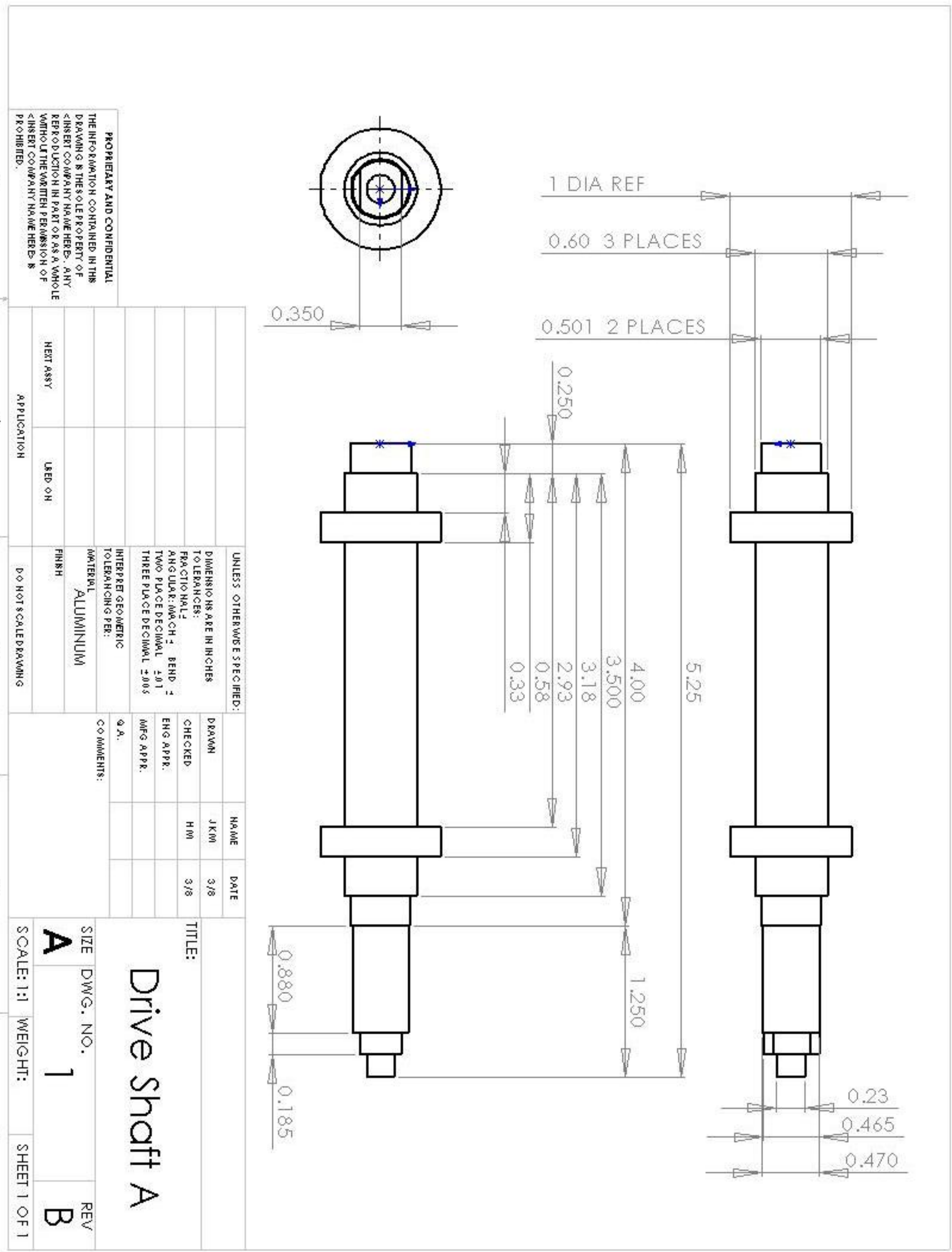
SolidWorks Model 5



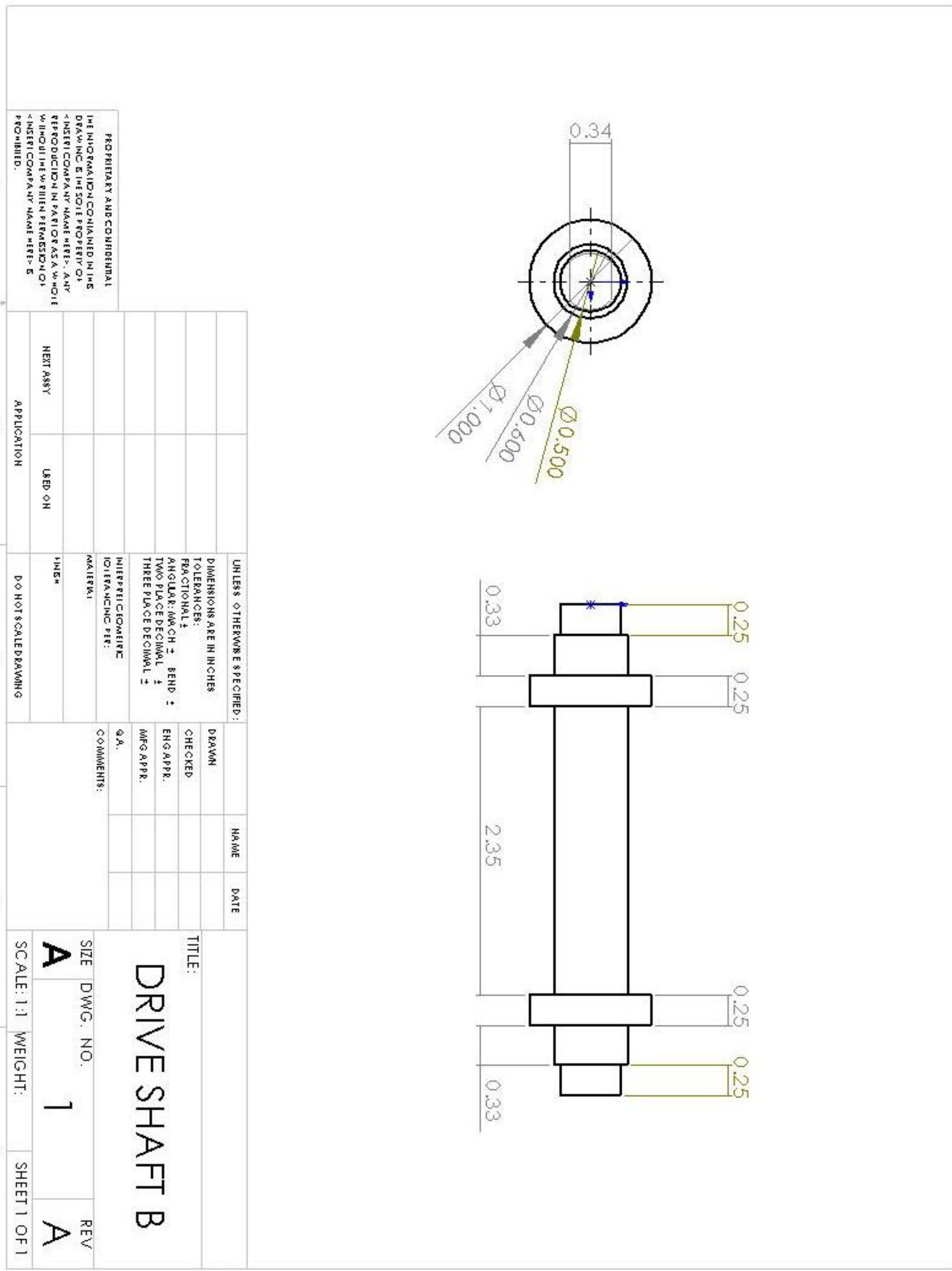
SolidWorks Model 6



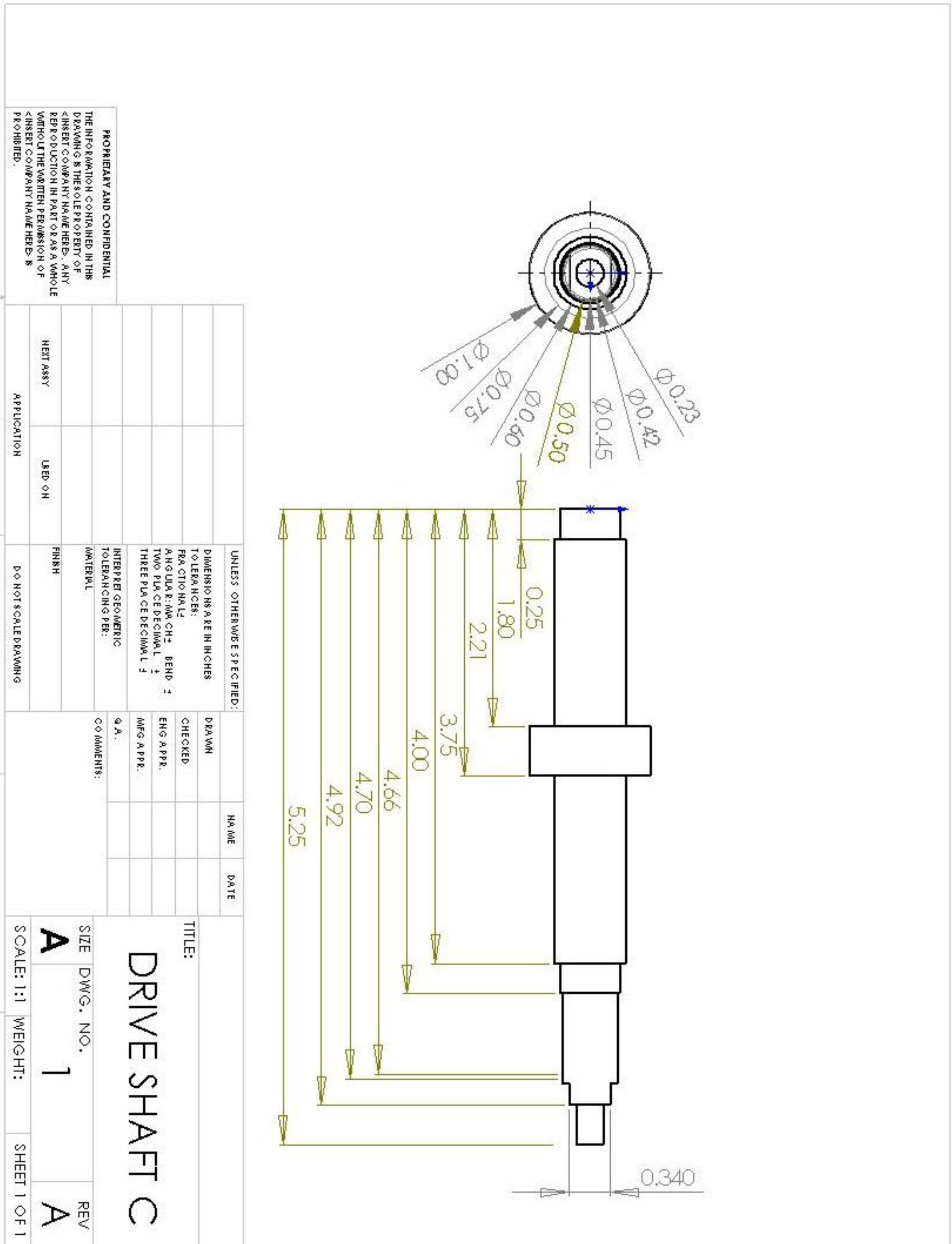
SolidWorks Model 7



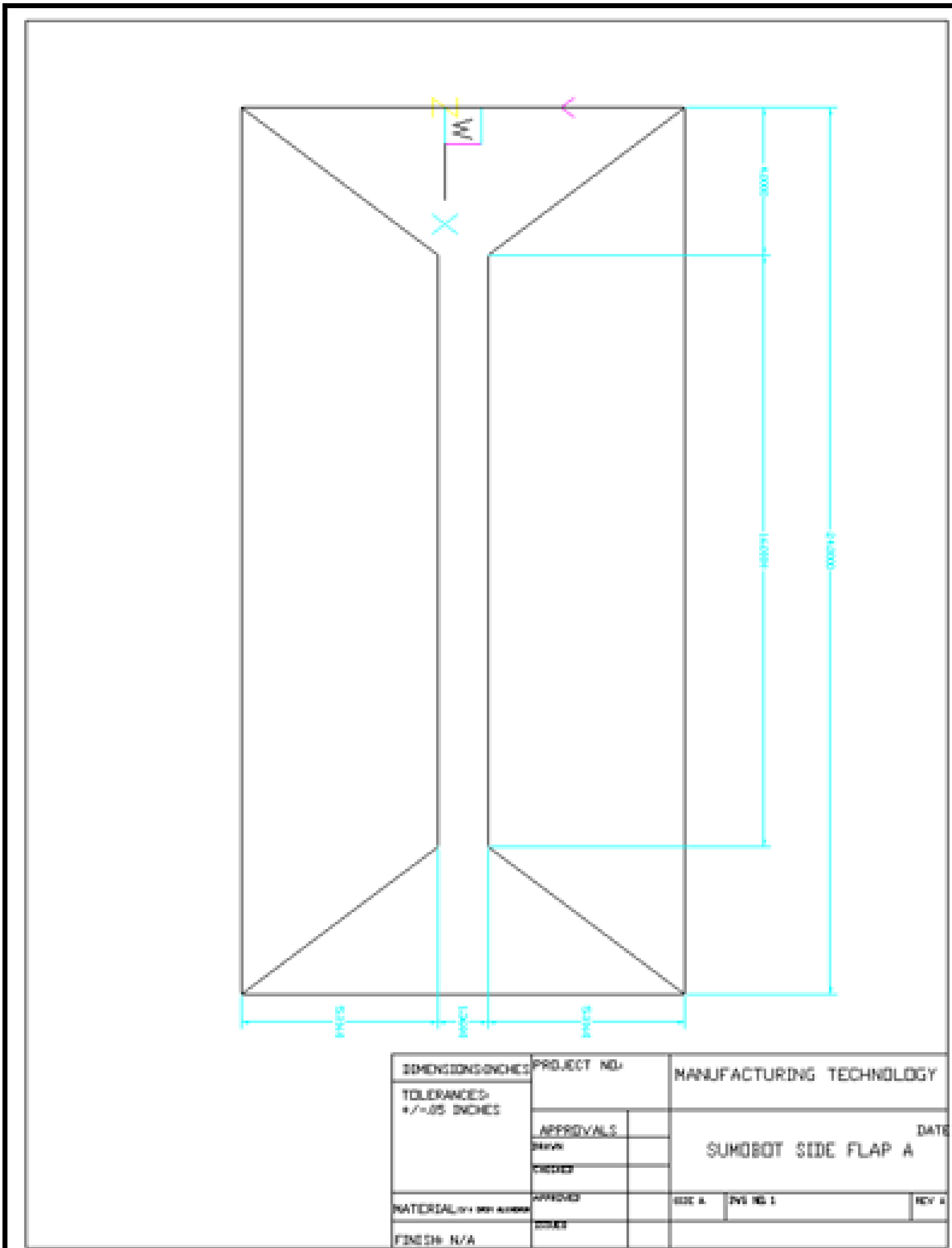
SolidWorks Model 8



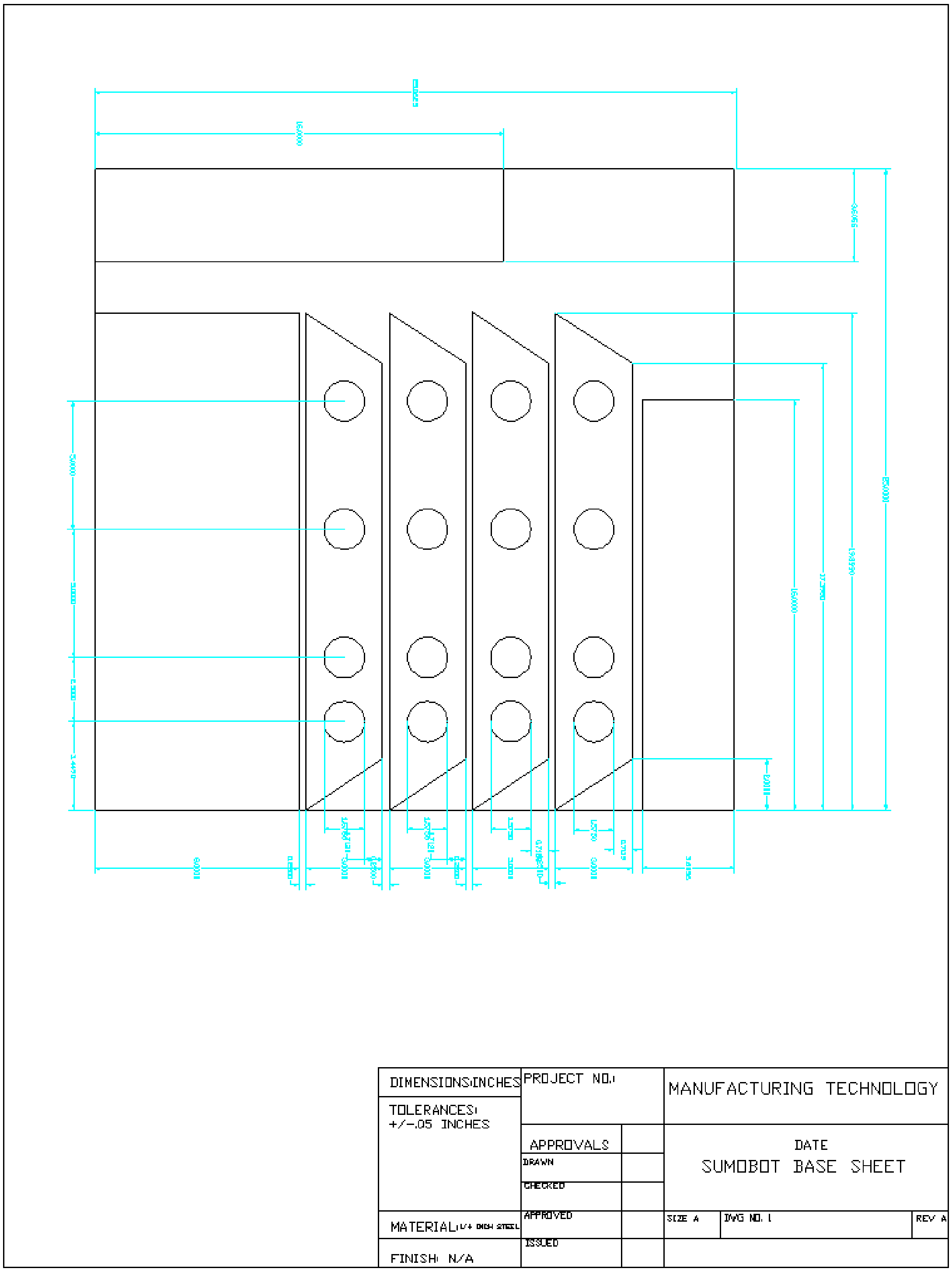
SolidWorks Model 9



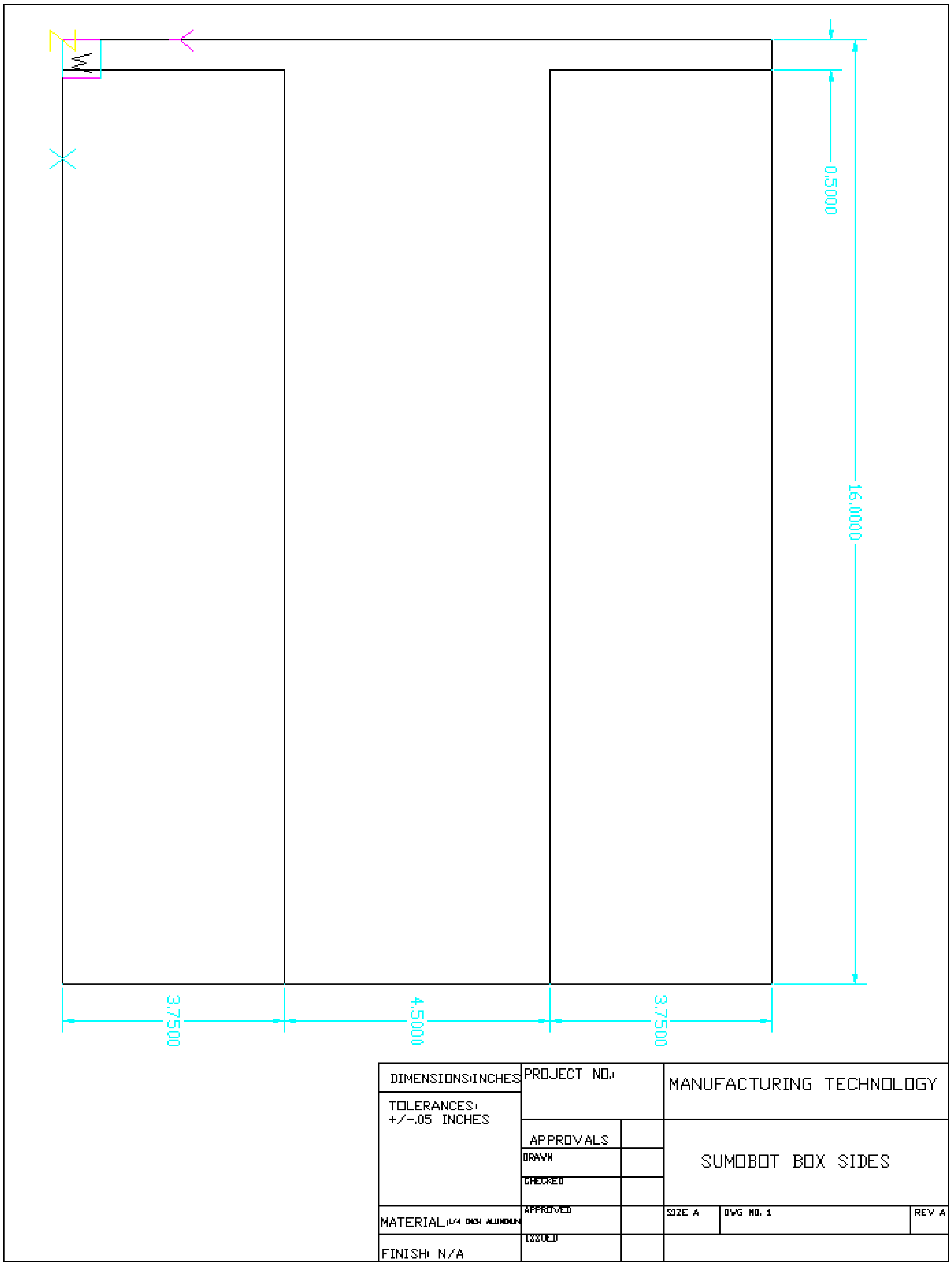
AutoCAD Drawing 1



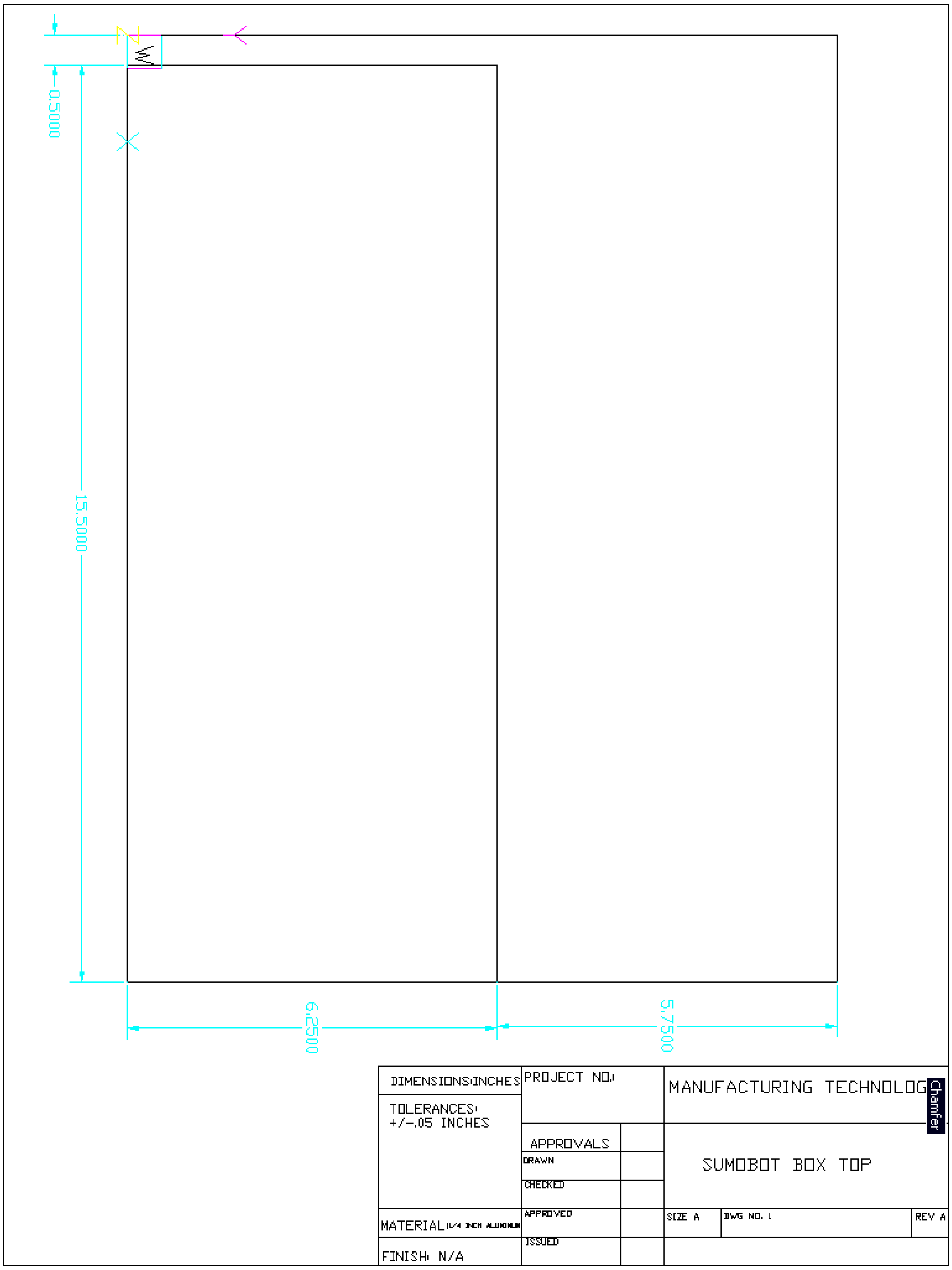
AutoCAD Drawing 2



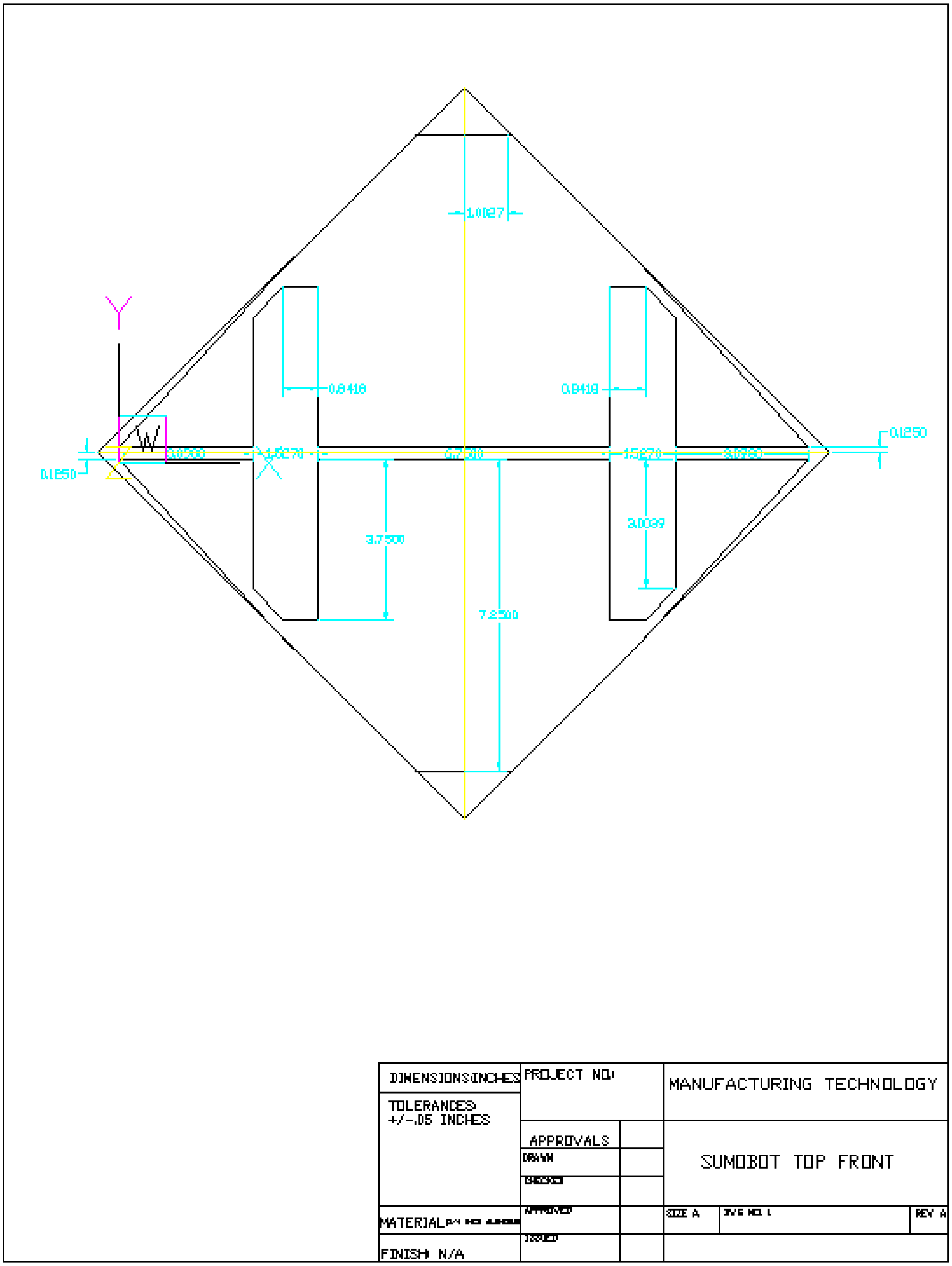
AutoCAD Drawing 3



AutoCAD Drawing 4



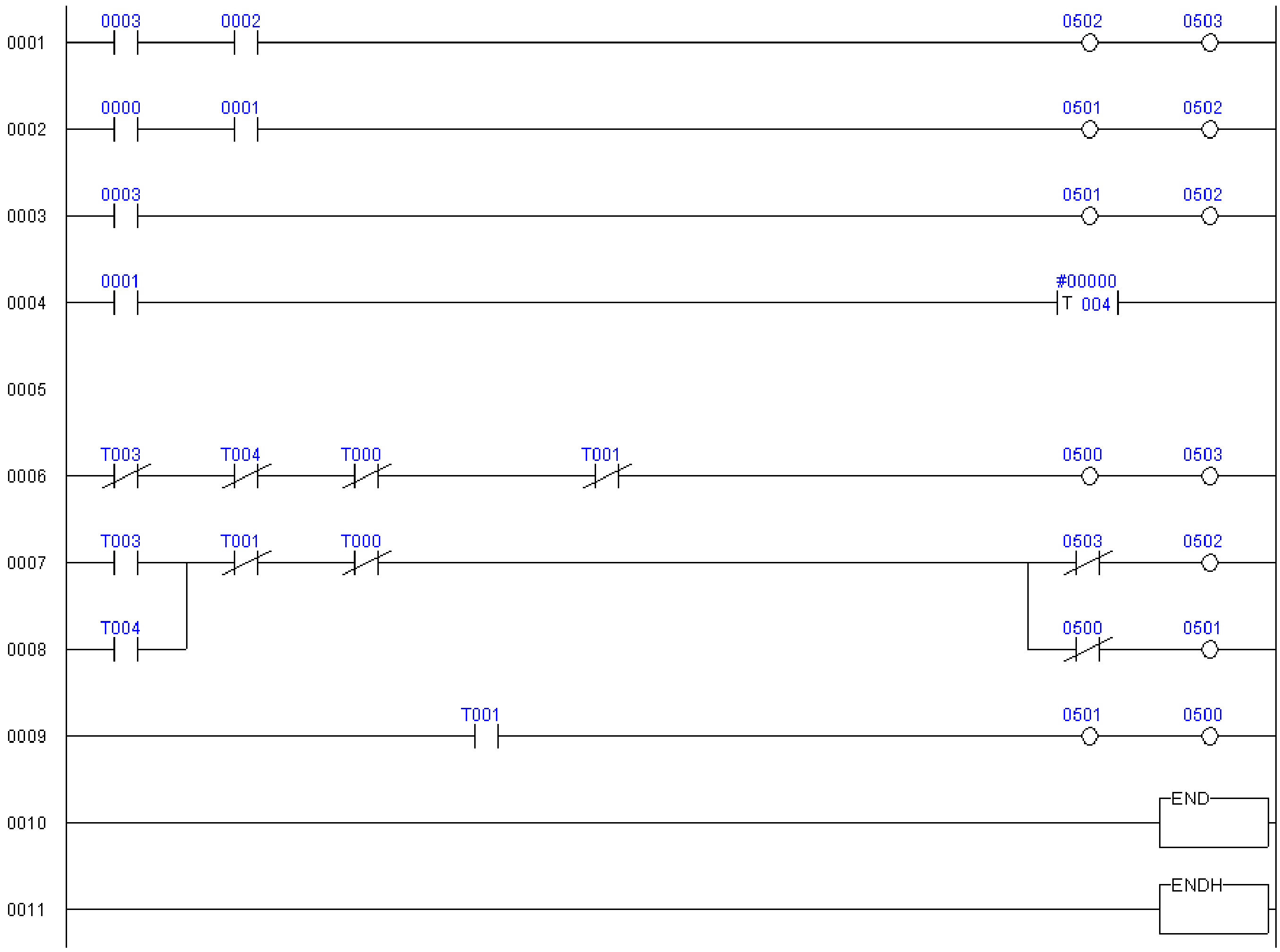
AutoCAD Drawing 5



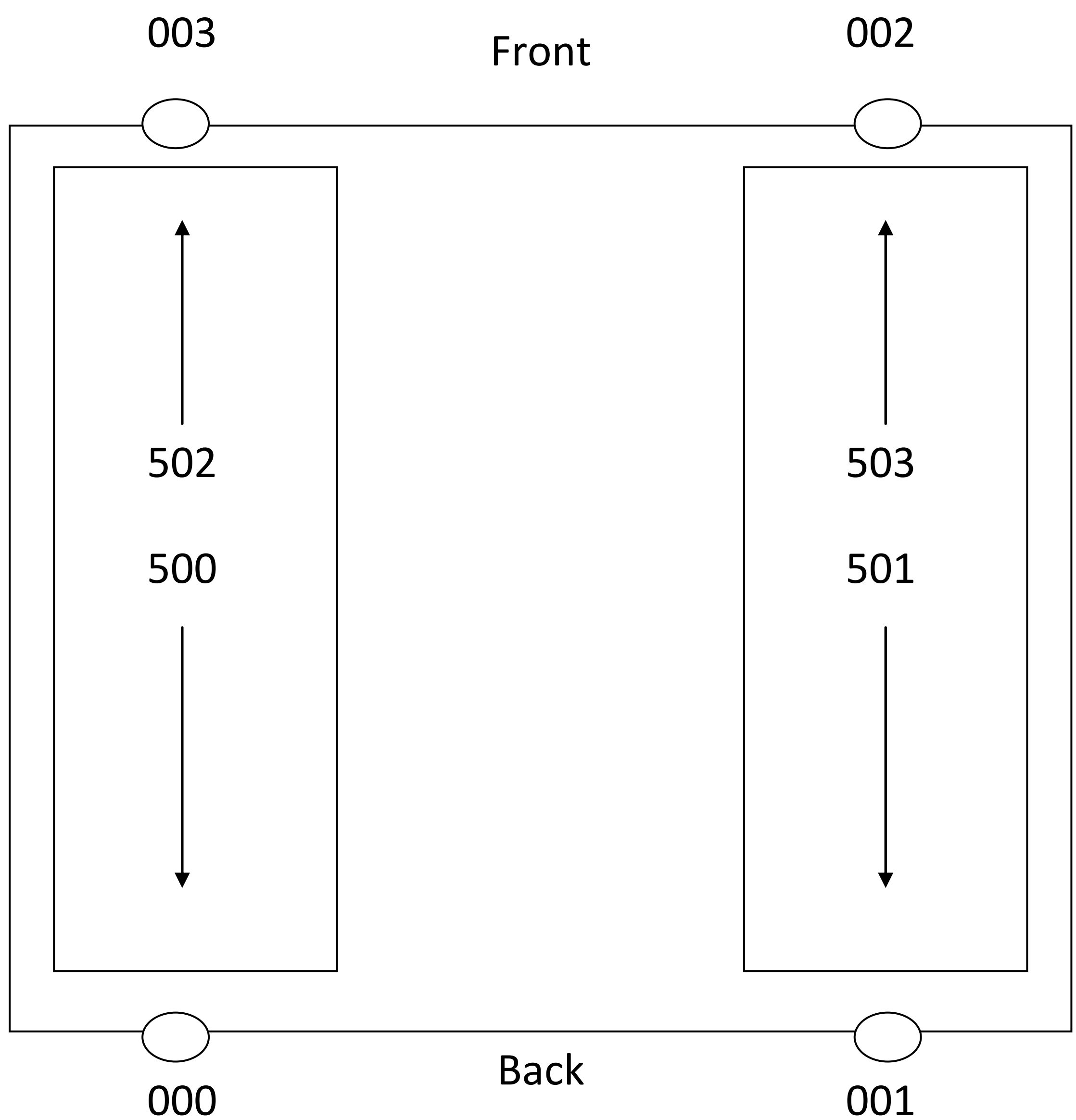
Appendix IV – Sensor Readout

Simulated Correctly?	Sensors				Motors			
Y	**0**	**1**	**2**	**3**	**500**	**501**	**502**	**503**
Y	C	C	C	C				
Y	O	O	O	C				
Y	O	O	C	C				
Y	O	C	C	C				
Y	O	O	O	O				
Y	O	C	O	O				
Y	O	O	C	O				
Y	C	O	O	O				
Y	C	C	O	O				

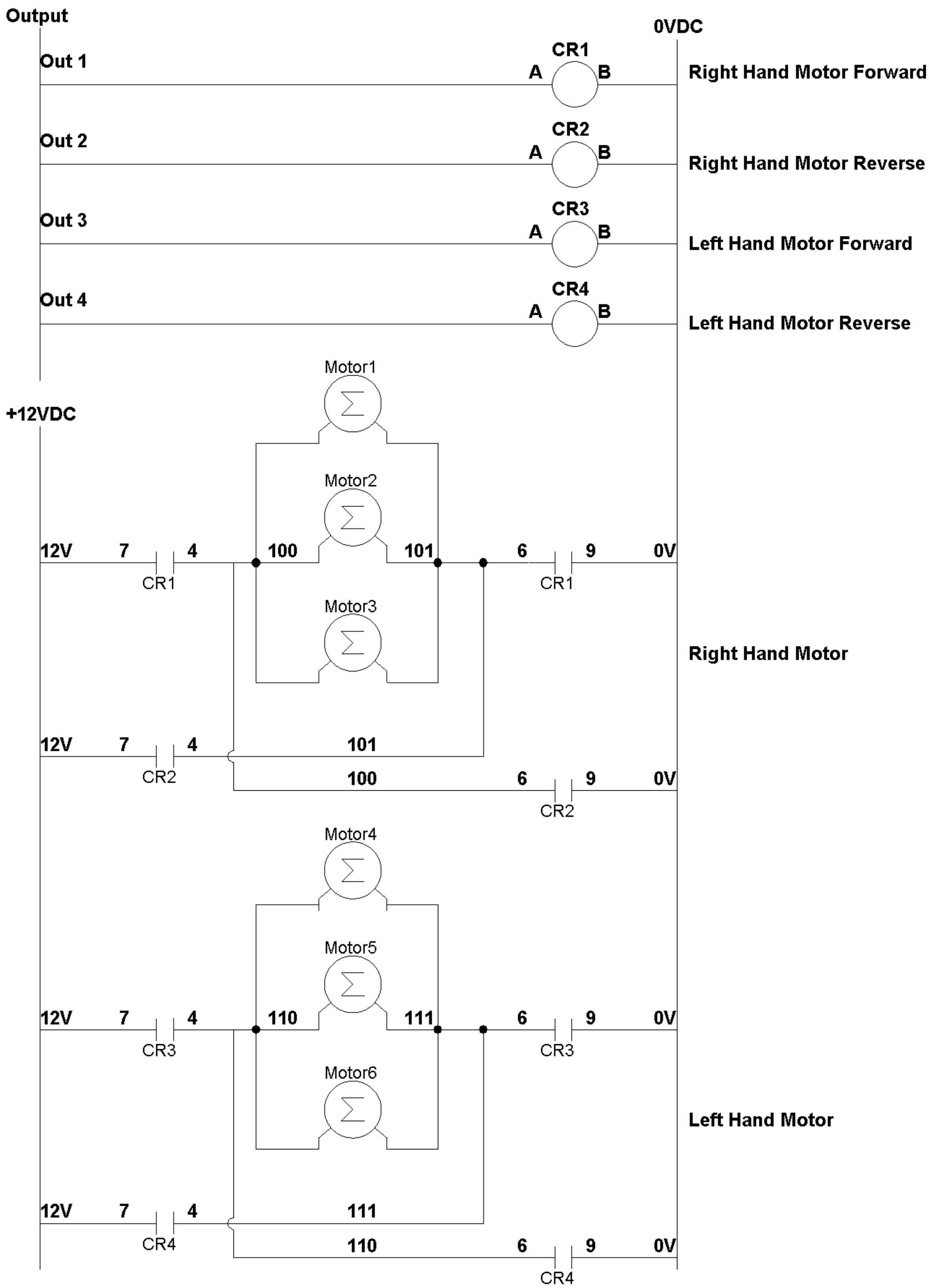
Appendix V – Original Program



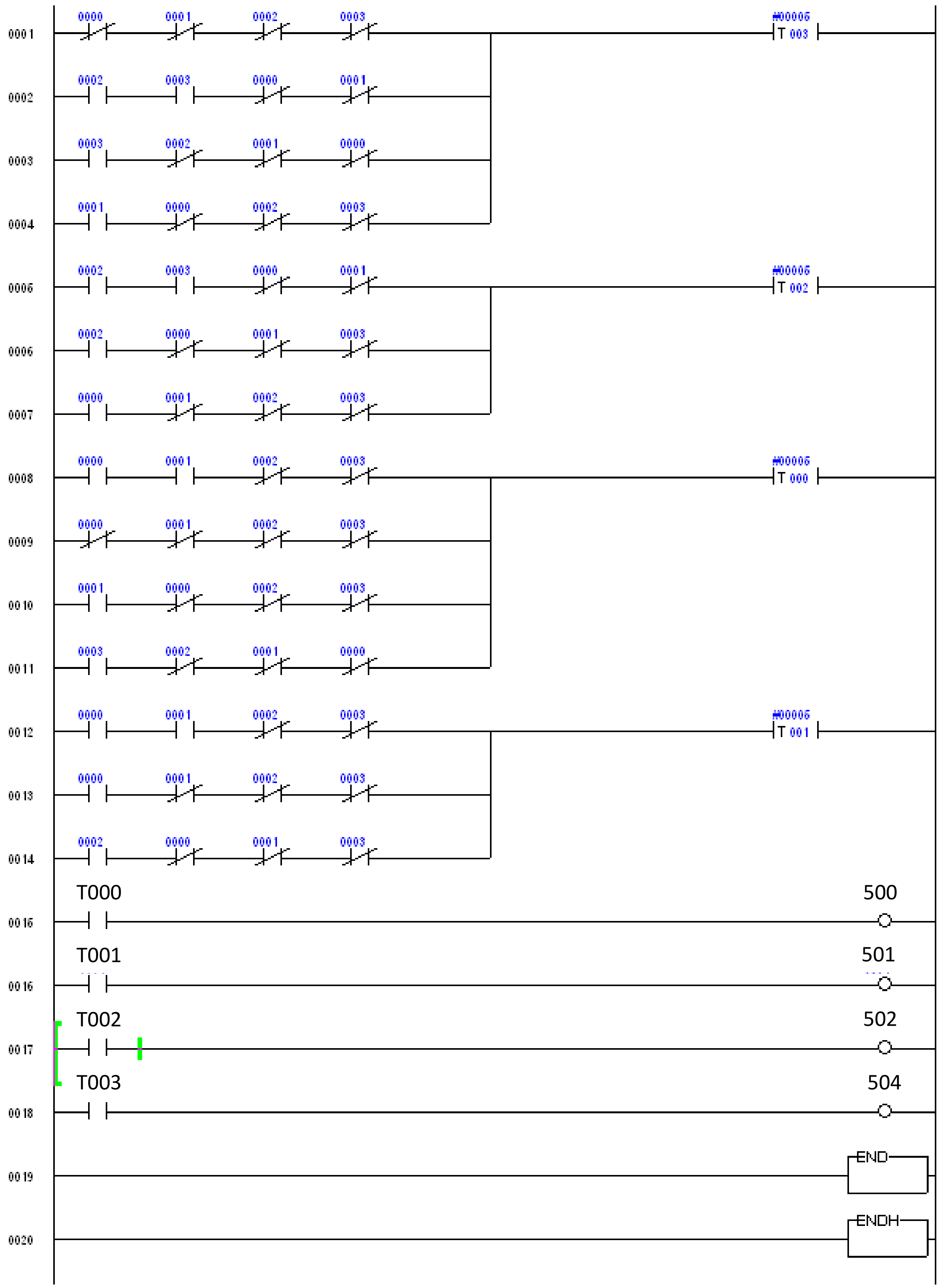
Appendix VI – Robot Diagram



Appendix VII – Electrical Diagram



Appendix VIII – Final Program



Appendix IX – Competition Results

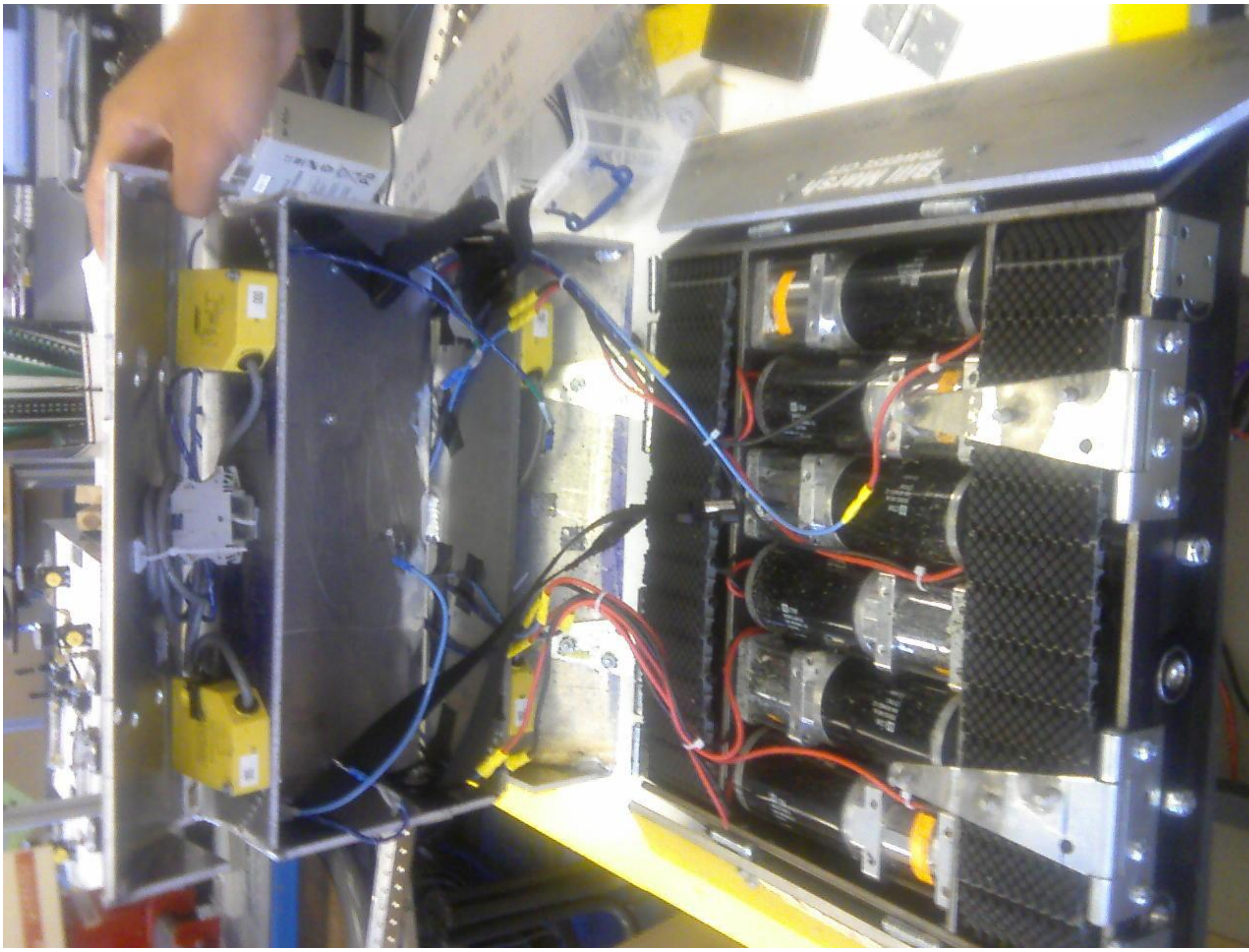
Results

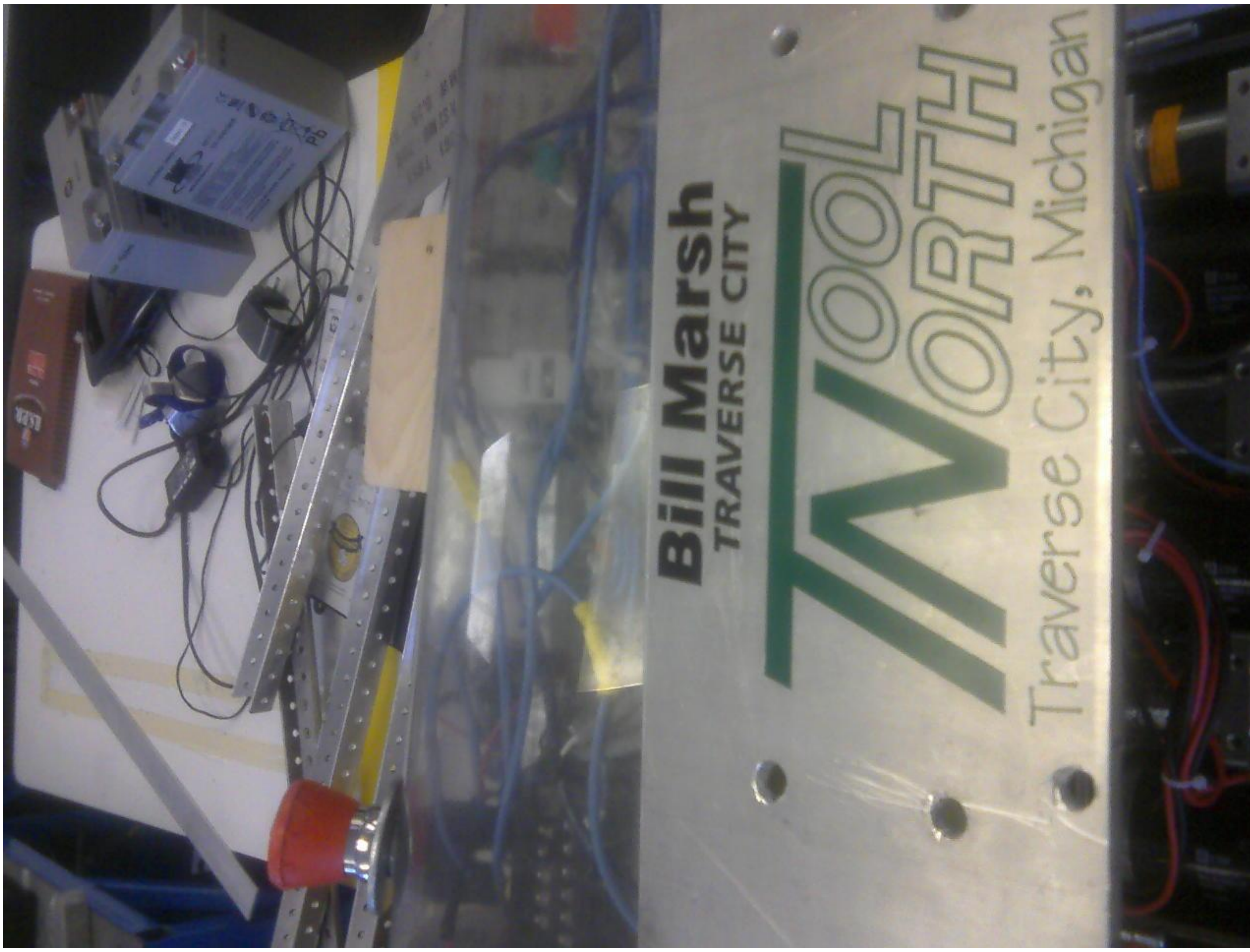
Friday April 16th, 2010		
Match 1	Win	Sensors locked on and we drove them right off the mat.
Match 2	Loss	They defeated us due to more speed and torque.
Match 3	Win	Due to opponent withdrawal.
Match 4	Win	It took two tries. First try theirs was smoking and they stopped the match. The second match we pushed their robot around in circles and ended up pushing them out. Their robot was too high for our sensors to sense properly.
Saturday April 17th, 2010		
Match 1	Win	Pushed to edge of mat where they backed out under their own power. Our circuit breaker blew due to unknown reasons.
Match 2	Loss	Our sensors didn't pick up their robot because their profile was too low. This was the same team that defeated us on Friday due to more speed and torque. Their robot began to rise up our flaps but caught a side flap using it against us as a hold to push us out.
Exhibition Matches		
Modifications		We took off the side flaps only leaving front and back flaps on. Matches were against the team that beat us.
Match 1	Draw	They caught us sideways, which made the robots turn in a wide circle. Their tires burned quite a bit of rubber.
Match 2	Win	We caught them head on and held them off until their wheels burned right through the mat. This would have resulted in disqualification on their part.

If we would have had additional time, we could have filed down the edges better as well as cut off the over lapping parts of the side flaps which would have given us the edge we needed to beat the robot that beat us twice. None of the other robots were able to beat us.

Appendix X – Photographs

Modifications to allow the base's sides to be removed.

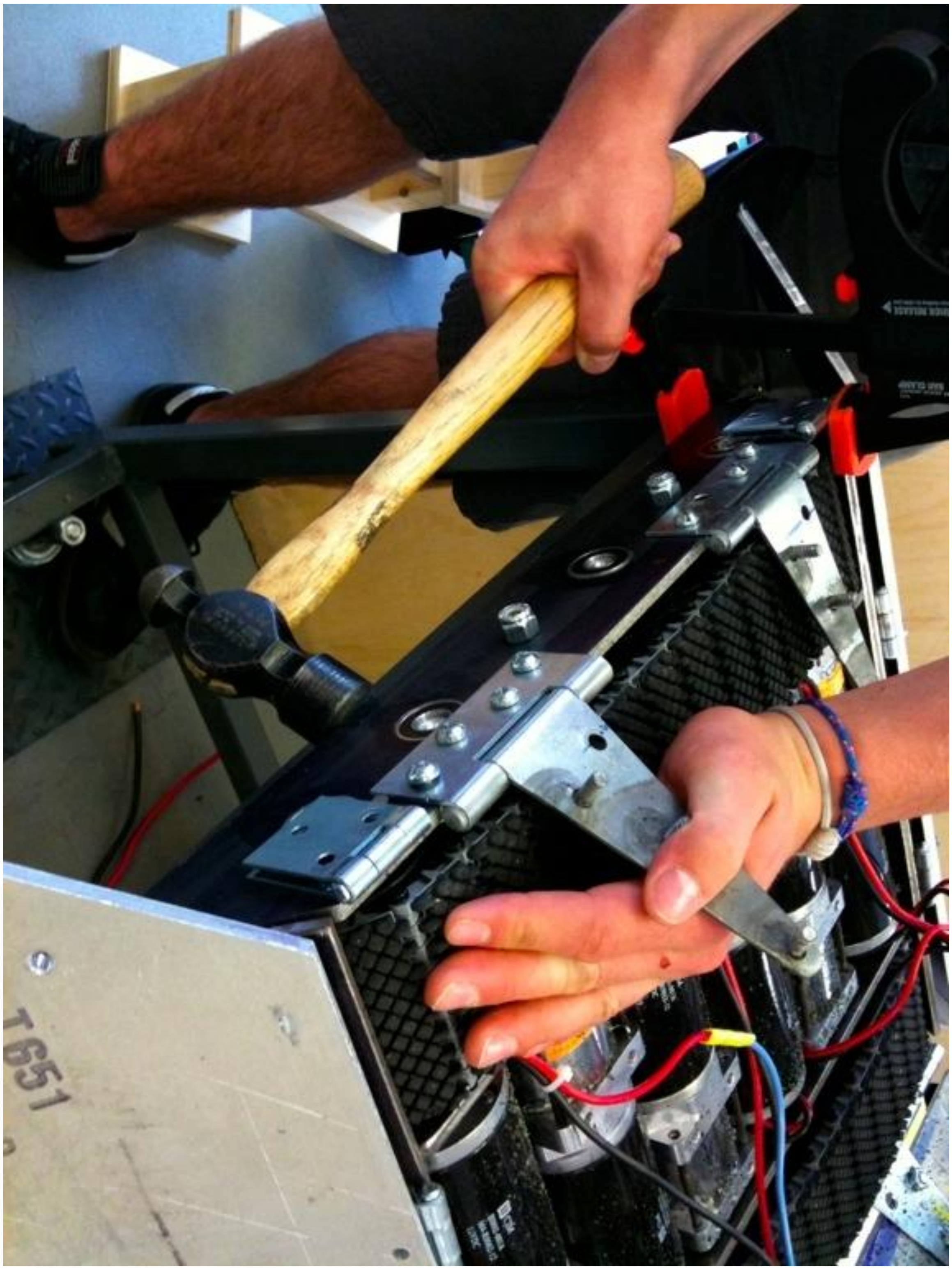

The assembled top and base, with sensors, motors and wiring in place. Batteries did not fit at this point.



The top of the robot with the electrical components fitted in.

Re-welded housing for the batteries, adjusted to allow them to fit.

Bolts for the Axels, before modification (below), and after (above).



Adjusting the alignment of the axles to allow them to rotate freely.

Assembled robot with all parts fitting properly.

Flaps attached by hinges.

Modified edges on the side flaps: the one on the left has been filed to a razor’s edge.

The hinge assembly: bolts welded into the hinges are inserted through the holes to secure the top.

The hinges elevate the top to allow for heat dissipation and tread clearance.

The Lexan Top.

Appendix XI—Weighting Data

Component			
	Weight	Amount	Total
CIM motor	5	6	30
Gearbox	2	6	12
Treads and cogs (1 track)	2	2	4
Aluminum Axles	0.5	8	4
1/4 inch Aluminum Plate (1 in^3)	0.059043	303.34	17.91
1/4 inch Steel Plate (1 in^3)	0.283898	111.66	31.7
Keyence PLC	2	1	2
Battery	12	2	24
Other Components	2	1	2
Estimated Total Weight			127.61
Weight After Initial Build			129
Aluminum Top			-5
Lexan top			0.5
Approximated New Weight			124.5
First Competition Weigh In			126.5
2 Aluminum Side Flaps			-3
Approximated New Weight			123.5
Second Competition Weigh In			120
2 Aluminum Side Flaps			3
Third Competition Weigh In			124.25
Fourth Competition Weigh In			125.75
Fifth Competition Weigh In			124.75