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Center for Manufacturing Excellence Capstone Project: SEC Rivals Checkers

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CENTER FOR MANUFACTURING EXCELLENCE CAPSTONE PROJECT: SEC RIVALS CHECKERS

By

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A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

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DEDICATION

This thesis is dedicated to everyone that has impacted my experience as an undergraduate student at the University of Mississippi.

ACKNOWLEDGEMENTS

I appreciate the combined effort of the CME faculty and staff in preparing and guiding the senior capstone teams through our projects. Special thanks to Mark McAnally, our technical advisor; Andy Gossett, the manufacturing facilities manager; Dr. Jack McClurg, my thesis advisor; Mike Gill, CME capstone instructor and my second reader; and Dr. Scott Kilpatrick, my third reader. I would also like to thank my other capstone team members: Grant Andres, Miller Grissinger, Lacey Loft, Nick Walrod, and Justin Zosel.

ABSTRACT

Each year, the seniors in the Haley Barbour Center for Manufacturing Excellence complete a capstone project. A team comprised of seniors in varying disciplines work to develop a business model focused on producing a specific product. This team, SEC Rivals Checkers, chose to produce wooden checker boards where each half of a board is custom to a specific SEC school. These halves were designed to be interchangeable, so a variety of different combination could be created when utilizing the product. Through initial marketing analysis, cost estimation, prototyping, and process development, the original SEC Rivals Checkers idea was developed into a finished product backed by a robust manufacturing process. After evaluating the final cost estimates of potentially making the checkerboards as products for sale, it was determined that the product would be financially feasible and profitable.

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LIST OF ABBREVIATIONS

CME	Center for Manufacturing Excellence
SEC	Southeastern Conference
CAD	Computer Aided Design
SWOT	Strengths Weaknesses Opportunities Threats
PMBOK	Project Management Body of Knowledge

Chapter 1: INTRODUCTION

The Haley Barbour Center for Manufacturing Excellence (CME) program requires all students to perform a senior capstone project. A capstone project team consists of a group of students from various disciplines. Typically, the project team creates a business around a product designed by one of the members on the team. Some teams work on outside projects hosted by companies or other university departments. Before groups are assigned, each senior proposes a business idea primarily based on a design for a project. The faculty then select a few of these designs to become projects for the year.

During the fall semester, each team is to focus on creating a strategy for the business and a quality prototype of the product. Before any work can be accomplished, a rough schedule for the project is created. To understand how the product would do in a competitive industry, market analysis techniques are implemented. To develop the quality prototype, the team creates drawings and other models to convert the concept into a design. These designs are then vetted through the production of initial prototypes, leading to the final prototype produced with similar materials that will be used in the final form of the product.

The spring semester is when the team begins to create the manufacturing process that will be used to make the product. Although the design may be finalized after the fall semester, best methods for processing the product are typically not realized early in the project. In preparation for a final production run, the teams use principles and techniques learned throughout their time within the program. This could include implementing lean principles to remove waste, line balancing through time studies to evenly distribute work throughout the process, or problem-solving methodologies to determine the root cause of any issues that occur during the project. When the final production is complete, final accounting estimates are generated to determine if the product would be profitable, and a final report is created and presented to the CME faculty.

Chapter 2: INITIAL PROJECT SETUP

Idea Creation

SEC Rivals was created to produce wooden checkerboard halves, each with a laser-engraved top with designs ranging from the various colleges within the SEC. Although the design was straightforward, its simplicity was multipurpose. Each board would be made from the same exact materials and produced with the exact same process, but each half board would be differentiated by lasering the specific college's design onto the top of the board. Not only does this streamline the production process while providing a large portfolio of products, it also allows for major common processes to become automatic in the future. For example, using the Universal Robots available in the CME, the process step where each board is loaded and unloaded into the laser engraver could be automated, an equipment utilization that was never used by previous capstone teams. The design for this project was proposed to the faculty and other seniors via PowerPoint and video presentation created by Ward Winstead.

Team Organization

The capstone team consisted of six seniors in the Haley Barbour Center for Manufacturing Excellence program. As the CME intended, the team members represented various disciplines: two mechanical engineering, two accounting, one finance, and one marketing major.

Ward Winstead, a mechanical engineering major, was the project leader for the duration of the senior capstone project. He was responsible for managing the team's communications, internally among members and externally with the technical advisor and capstone instructor. He also created the overall project schedule and monitored the team's performance. Ward also worked on the Production Team to prepare the manufacturing line for final production, which included designing fixtures and studying the possibility of automating various processes.

Justin Zosel, a mechanical engineering major, was the lead product designer and production expert. During the early stages of the project, he was responsible for the CAD modeling of the components and the initial creation of the prototype. Preparing for production runs, Justin was in charge of detailing the line layout, and modeling any fixtures necessary to facilitate proper assembly of the final product.

Grant Andres, a finance major, was the lead Corel designer. He was responsible for creating the various designs necessary to produce the product versions the team chose to offer.

Nick Walrod, a marketing major, was the marketing expert. Nick performed various marketing analysis techniques to predict the validity of the ideas and estimate a reasonable product cost. He also greatly assisted the production team as necessary when preparing for the production run.

Miller Grissinger, an accounting major, was the lead buyer and accounting expert. He was responsible for working with the manufacturing facilities manager to purchase the various parts necessary to create a prototype and materials needed to produce the final components during the production run. Miller also monitored the team's budget and evaluated the cost of the final product, assessing the options when considering renting or purchasing the necessary equipment for production.

Lacey Loft, an accounting major, was an accounting expert and the reporting expert. She assisted Miller in the creation and monitoring of the team's budget. As the reporting expert, she managed the documentation requested at various milestones by the capstone instructor.

Project Management

Manf 460, Introduction to Project Management, is a CME elective that discusses project management best practices through the PMBOK (Project Management Body of Knowledge). The PMBOK categorizes these best practices into 5 groups based on their chronological use in a project: Initiating, Planning, Executing, Monitoring and Controlling, and Closing. To ensure the success of this project, the team applied these 5 basic process groups discussed in Manf 460 to categorize the functions that were to be implemented throughout the project.

Initiating **-** Team was founded by the sponsor. The team assigned roles, responsibilities, and expectations to team members. A GroupMe and a Google Drive were created.

Planning - There were weekly meetings on Wednesdays from 12:00-1:00 PM to plan the next week's schedule in regards to nearest milestones. Initial designs, marketing analysis, and cost calculations were executed. Factory floor times were weekly on Tuesdays at 2:30-4:00 PM and Fridays at 11:00 AM-1:00 PM. These times were modified as necessary.

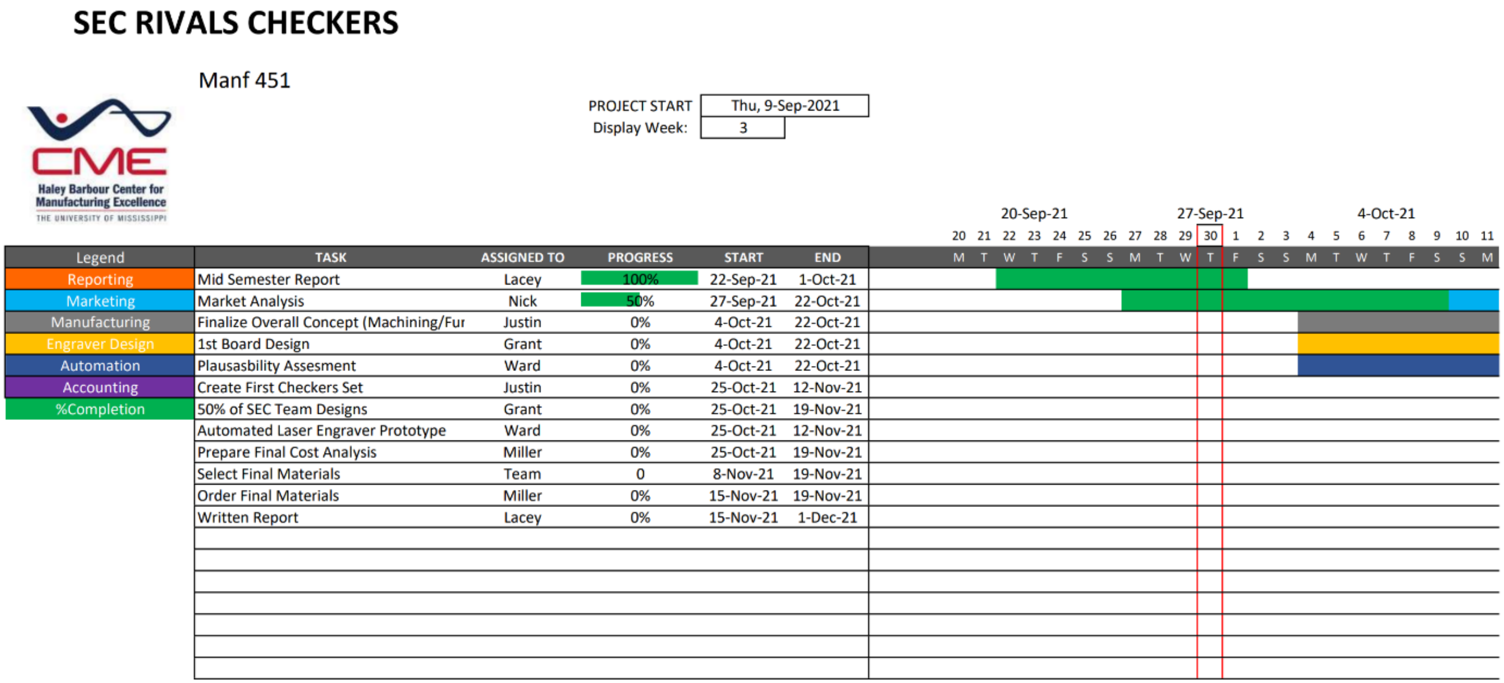
Executing - After planning the work during weekly meetings, team members worked on designated tasks. Members worked on tasks individually or with assistance from other team members.

Monitoring and Controlling - Weekly meetings were used to review current progress in comparison to the schedule. Adjustments were made to ensure risks were controlled and milestones were accomplished on time. Notes were taken at each meeting to provide records and information used to generate the written report.

Closing - The work for each semester was concluded with a written report. This report summarized the work completed and the lessons learned by the team members [1].

Scheduling

The SEC Rivals Checkers team chose to approach achieving project milestones through a parallel path methodology. This allowed the team to accomplish most tasks independently of the completion of other tasks, decreasing overall schedule risk from delayed completions. This also increased the responsibility of each team member, ensuring the entire team was invested in the project. A Gantt Chart, as shown in Figure 1, was created to review the major tasks for the fall semester. The tasks are broken into six categories: Reporting, Marketing, Manufacturing, Engraver Design, Automation, and Accounting/Purchasing. On this chart, team members were assigned to tasks, but this designation did not exclude other team members for assisting the assigned individuals. Although the individual tasks were across multi-week spans, the team had weekly meetings to discuss progress, and the schedule was reviewed and adjusted accordingly.



SEC RIVALS CHECKERS

Manf 451

PROJECT START: Thu, 9-Sep-2021
Display Week: 3

Legend	TASK	ASSIGNED TO	PROGRESS	START	END
Reporting	Mid Semester Report	Lacey	100%	22-Sep-21	1-Oct-21
Marketing	Market Analysis	Nick	50%	27-Sep-21	22-Oct-21
Manufacturing	Finalize Overall Concept (Machining/Fur	Justin	0%	4-Oct-21	22-Oct-21
Engraver Design	1st Board Design	Grant	0%	4-Oct-21	22-Oct-21
Automation	Plausasbility Assesment	Ward	0%	4-Oct-21	22-Oct-21
Accounting	Create First Checkers Set	Justin	0%	25-Oct-21	12-Nov-21
%Completion	50% of SEC Team Designs	Grant	0%	25-Oct-21	19-Nov-21
	Automated Laser Engraver Prototype	Ward	0%	25-Oct-21	12-Nov-21
	Prepare Final Cost Analysis	Miller	0%	25-Oct-21	19-Nov-21
	Select Final Materials	Team	0	8-Nov-21	19-Nov-21
	Order Final Materials	Miller	0%	15-Nov-21	19-Nov-21
	Written Report	Lacey	0%	15-Nov-21	1-Dec-21

Figure 1: Gantt Chart Excerpt

Chapter 3: MARKET ANALYSIS

At the beginning of the semester, a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was completed to understand potential risks if this product was sold and competed in the market. See the appropriate sections below from the team's fall semester report for this analysis.

Strengths

- Internal resources - Our team strengths included the internal resources that we had available for use. The CME floor has state of the art equipment that we have access to. The main equipment that we utilized includes, but is certainly not limited to laser engraver, sheet router, and table saw.
- Internal skill set - Our six-person Capstone team consisted of 6 individuals coming from various backgrounds. This gave us a well-diversified team with a separation of majors contributing to a broad range of knowledge and industry exposure. We had accounting, finance, engineering, and marketing majors on our team. By designating tasks to specific individuals, our project's assignments were curated to the person with the most expertise.
- Tangible assets - The most important tangible asset that gave our group a competitive advantage was the opportunity to use technologies that the CME has available. The main technology that benefited our group in product development and creation was access to the software needed. SolidWorks was used to render a model of our initial design. The next software that was implemented was a CNC

program that allowed us to automate the laser engraver portion of our manufacturing process. Corel Draw was also used to create the designs that were laser engraved on the product.

Weaknesses

- Resource limitations regarding funding - Resource limitations were very possible. We were capped at an initial investment of $1000. If our team continuously changed designs it would have led to a great increase in material and machining cost. This extra cost would have to been absorbed in our selling cost of the product or it would have driven our total profits down.
- Things our competitors do better - Our competitors in the checkerboard industry are more experienced than us. Many of which have been in the industry for years creating custom boards. Our group does not have the sales volume to take advantage of scale and drive down the marginal cost per board. This sales volume will have to be increased by marketing for our business to succeed in the long term.
- Things our group lacked - Our group lacked a member who is very knowledgeable about woodworking. This was something our group had to overcome, for wood material and design played a huge part in our product's development.
- Unfamiliar machinery - Disregarding the help we received from floor technicians, our group had few years of experience using the laser engraver and other CNC machines.

Opportunities

- Few competitors in our area - There are few competitors in Oxford that offer custom board games. Our product would fit in well at small stores around the square.
- Underserved markets or niche market for product - The checkers board market is a very competitive and over saturated market, but the custom checkerboard market is not as populated. SEC football fans are a dedicated breed of people and are willing to spend more money for something that is of quality and represents their favorite team.
- Potential media coverage of our product - We could have gotten media exposure of our product not only during the manufacturing process but also at completion. Our team could promote this product as being an Ole Miss student project. This could have helped influence local attention from Oxford natives as well as garner attention from alumni all over the nation.
- External profit increasing opportunities - The cost of material following the ongoing pandemic has risen to new highs. Wood is especially expensive in the current environment. The price of materials should steadily go down as companies and manufacturers continually solve problems within their supply chain. If the price of materials does go down, we might have an opportunity to increase our profit margin as well as decrease the price of our final product.
- Timeline acceleration - As stated in the previous bullet, supply chains of all things have been a mess, with many companies backlogged on orders still. This backlog of material and supplies could have affected the timeline of our project. If the lead

times of our material became shorter, it would benefit our team by allowing us to manufacture more products at a faster rate.

- Help from floor technicians - The floor technicians are very qualified and played an important role in assisting our team in the physical creation of our product. This was a great opportunity that our team utilized.

Threats

- Emerging competitors - As stated in previous sections, there is not a lot of competition in the custom checkerboard market. This could change overnight if other companies see opportunity within this market. Our team would have to have a sustainable competitive advantage to continually hold market share. Patents or copyrights on our products would help diminish this concern.
- Negative media coverage - This risk of negative media coverage was very minimal for our product. The game of checkers has been around for a long time and is a very simple game. The only concern would be maintaining proper expression of each team and showing respect to all the schools.
- Changing customer attitude toward product - Customer attitude towards the product could potentially be an issue. This would only occur if household income greatly decreased. Our product sits in the luxury goods section of the market. This increases consumers' price sensitivity if income becomes an issue.
- External profit absorbing elements - Material cost increase was a potential harm to our products' success. If materials continued to increase in price and demand our product would continuously become more expensive and less profitable.
- Timeline deceleration - Our goal of completing design and manufacturing was dependent on materials being available when we need them with current lead

times. This lead time could change for the worse and could have affect our set execution timeline.

- Industry requirements / standards - The industry does not have any set standards on checker boards. Our team needed to research risks associated with the individual checker pieces, as there could be a risk for choking hazards in young children. The greatest risk our product had was copyright issues surrounding the SEC teams and their designated mascots. Our team would have to talk to lawyers before and/or get permission from the teams to profit off of their intellectual property rights. For this capstone project, however, the CME does have permission to use Ole Miss trademarks.

Chapter 4: INITIAL DESIGN AND PROTOTYPING

During the early team meetings, further details were discussed regarding the initial design of the product. One of the first design choices made was to use magnets to connect one board half to another during use on a table, which allows for any combination of board halves when enjoying the product. Magnets would also be used to connect the boards together when not in use. It was also decided that each board half would be hollow and exposed on the bottom, so the game pieces could be stored inside the boards while not in use. To make each board hollow, a large top face would act as the playing surface of the board, as well as the trim surrounding the board. Walls would be mounted underneath the board to provide the desired piece storage space. An early CAD model of a board can be seen in Figure 2. Lastly, the team decided to also laser team logos on the face of each piece.

Figure 2:Initial Design CAD Mode

With initial design ideas, the team then began to construct early prototypes. While producing the first board top, the team quickly realized that adding walls beneath the boards would be difficult. Our solution to this issue was using pieces that connect to the sides of the playing board surface. These pieces would act as both the walls of the underneath storage and the trim around the board. This solution also made the overall production of the product easier by reducing the required machining of the board surface. See Figure 3 for this assembly method.

Figure 3:Example of Early Prototype Wall Assembly Method

Through this early prototyping, the team also realized that it would be difficult make checker pieces out of wooden dowels. After communicating with other faculty and students in the CME, we decided the best method to produce these pieces was through lasering acrylic. It was already decided that the pieces would have laser engraved logos, so using the laser to engrave and shape the pieces reduced the overall production time and necessary equipment in creating the checker pieces.

After weeks of further prototyping, other design decisions were vetted, resulting in final design considerations that would be implemented in our final prototype, which can be seen in Figure 4.

Figure 4:Final Prototype

With the final prototype complete, plans for the production-ready design were outlined. A quarter inch piece of birch plywood would be used for the top of the board The walls would be made from red grandis wooden planks. Slots in the walls would hold the birch top in place. Dowels would be used to hold the front wall to the two side walls. Forty-five-degree ends would be placed on both ends of the back wall, as well as on the corresponding ends of the side walls. Magnets would be placed on the bottom of the back and front walls to hold two board halves together in storage, while two additional magnets placed in the front of the front wall would be used to connect two board halves while the user is playing a game of checkers. See Figures 5-10 for final drawings of the product. With these designs complete, materials were ordered to be ready for production setup at the beginning of the spring semester.

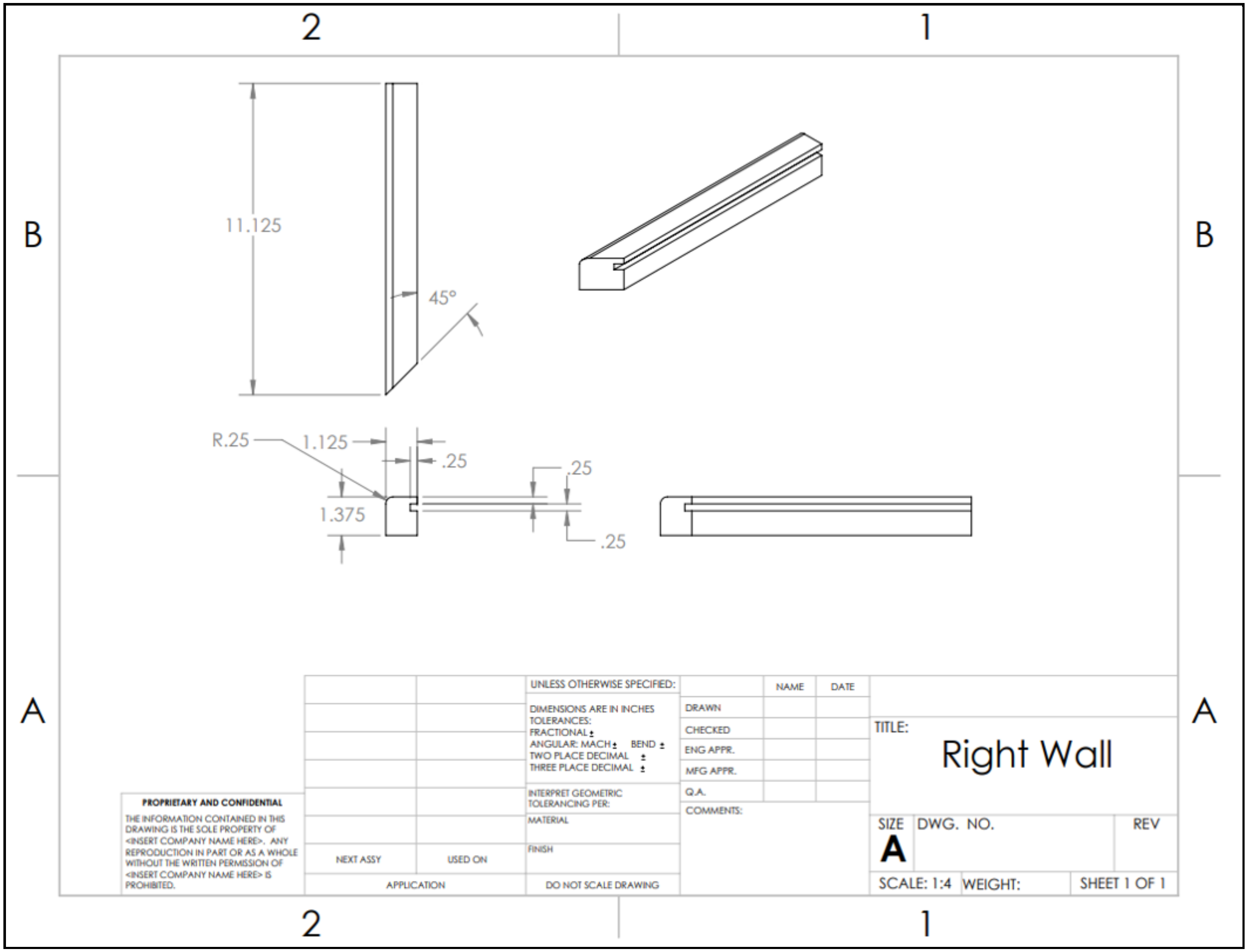


Figure 5:Right Wall Final Drawing

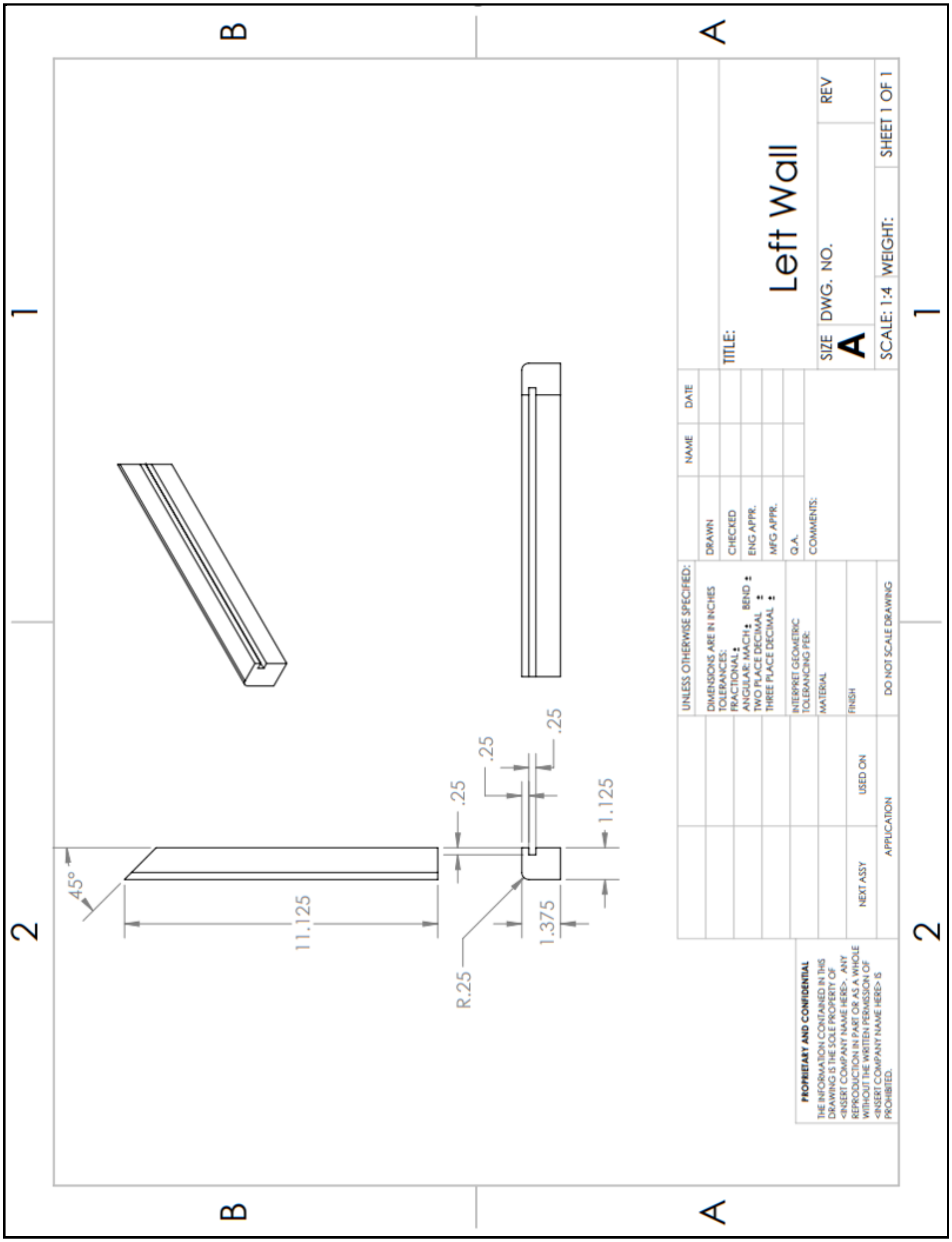


Figure 6:Left Wall Final Drawing

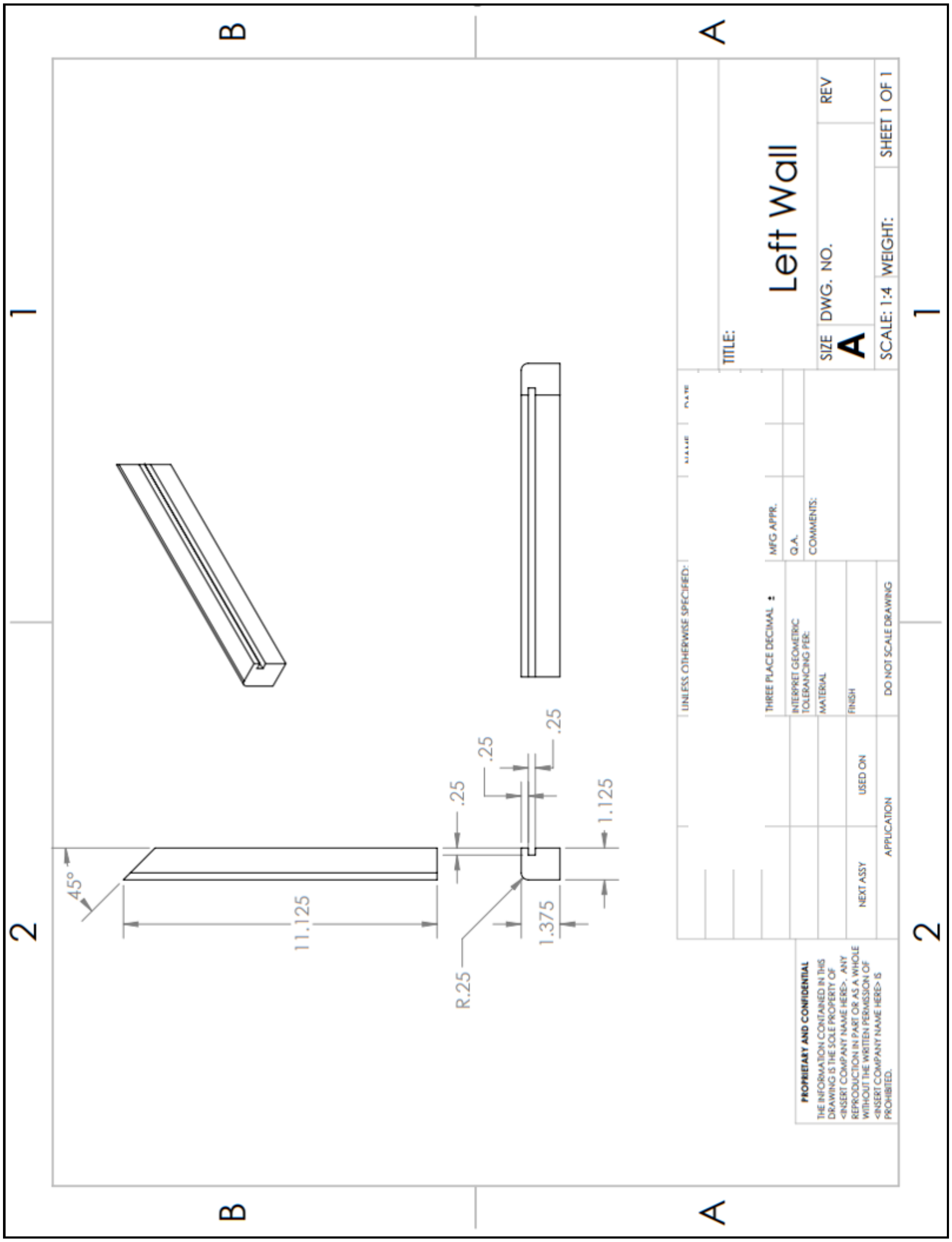


Figure 7:Back Wall Final Drawing

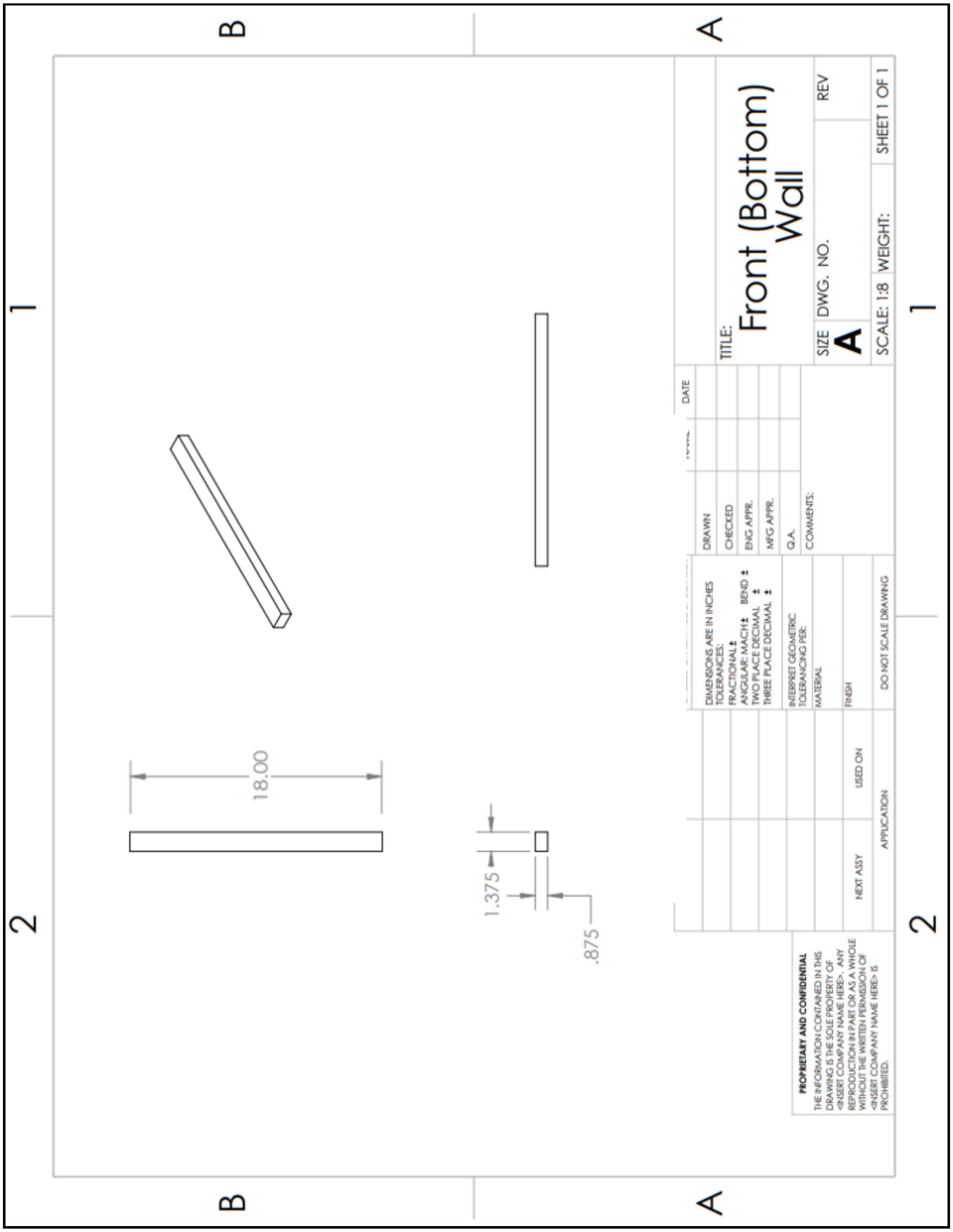


Figure 8:Front Wall Final Drawing

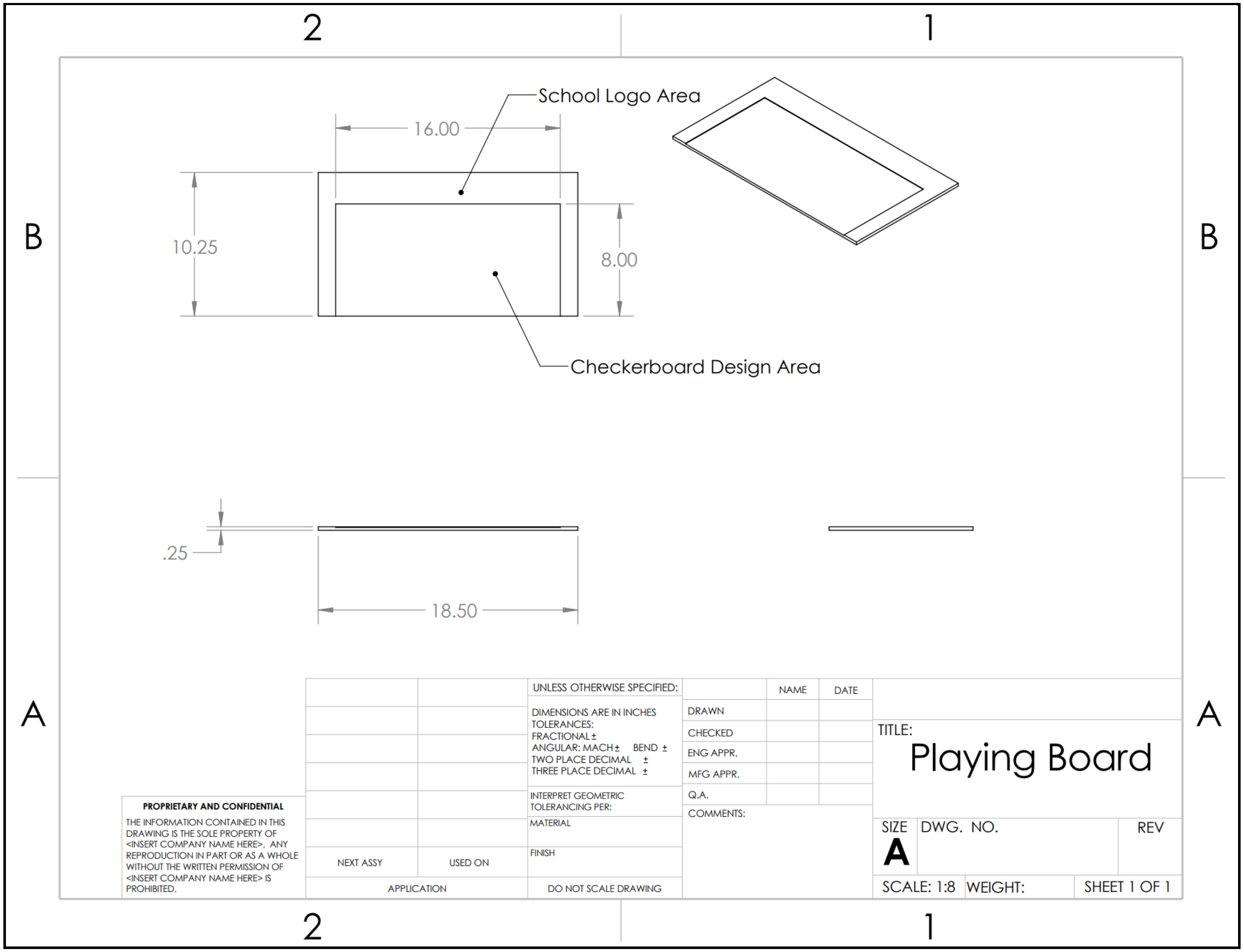
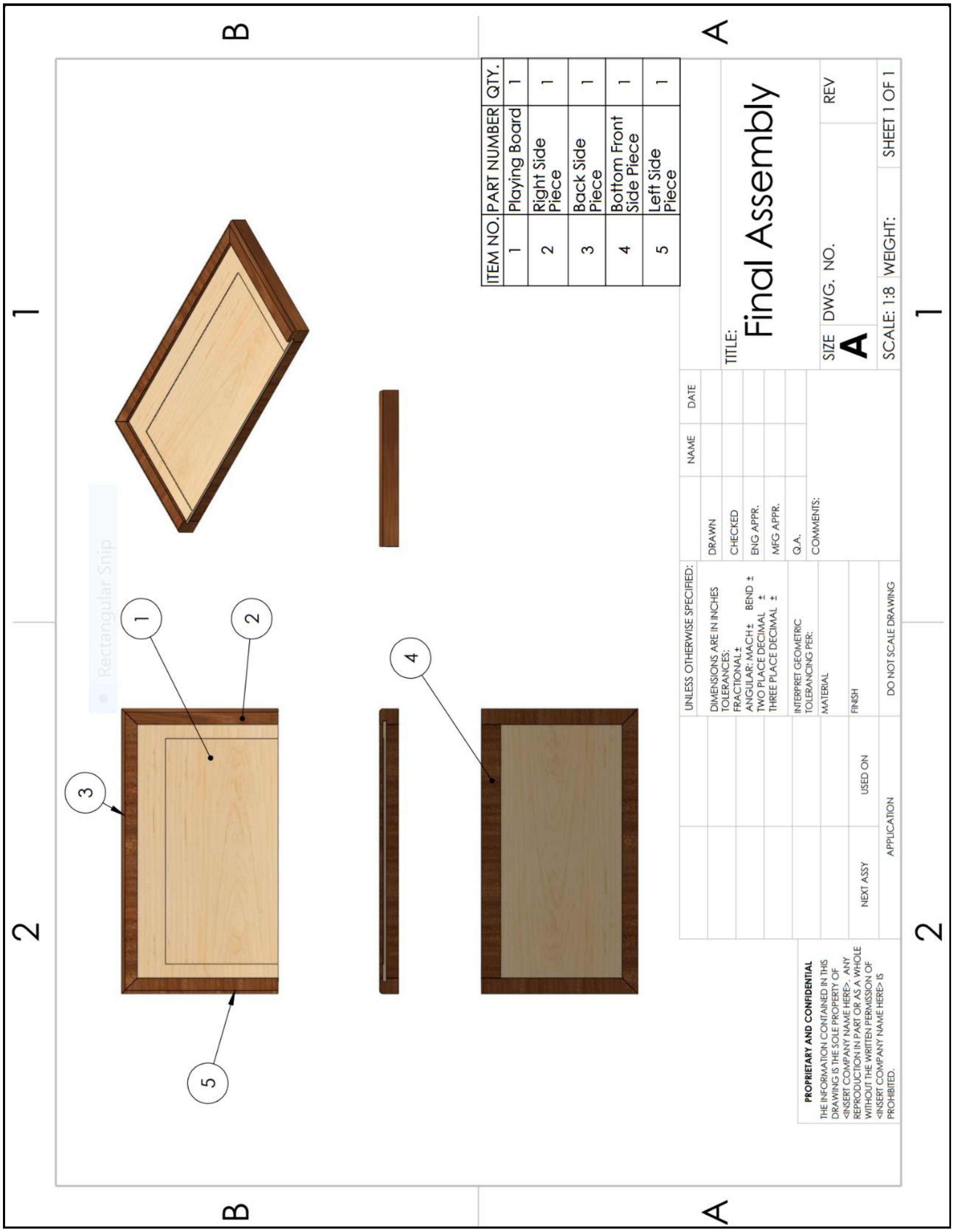


Figure 9:Playing Board Drawing



ITEM NO.	PART NUMBER	QTY.
1	Playing Board	1
2	Right Side Piece	1
3	Back Side Piece	1
4	Bottom Front Side Piece	1
5	Left Side Piece	1

Figure 10: Final Assembly Drawing

Chapter 5: PROCESS SETUP

Initial Findings

Preparing for the final production run roughly a month after the spring semester started, the team quickly began building units with the final materials to better understand the process requirements. One of the first issues we discovered was that the birch plywood we purchased was quarter inch nominal (three-sixteenths), and not exactly a quarter of an inch. Although it took time to update the wall designs with smaller slots, we did not have a routing bit to create a three-sixteenths slot, further delaying our process testing. Another issue that occurred in this initial testing was that the magnets we purchased were not strong enough to reliably hold two boards together. Though we could have accepted using these magnets, we decided to test magnets available at the local Home Depot. After trying these stronger magnets, the team was satisfied with how the boards connected together. With these changes implemented, boards were made from final production materials, helping the team identify what machines would be needed in the assembly process. The list of these machines is located in Table 1.

Table 1: Necessary Equipment for Production

Equipment	Quantity	Effected Parts/Process
Table Saw	1	Playing Board, Front Wall
Miter Saw	2	Front, Back, and Side Walls
Table Router	2	Back, and Side Walls
Drill Press	2	Front, Back, and Side Walls
Hand Drill	1	Front Wall
Laser Engraver	1	Playing Board, Game Pieces
Table	1	Final Assembly

Assembly Line Construction

With the necessary equipment identified and a takt time determined, we began designing an assembly line layout to use for our production run. With a takt time of roughly thirty minutes, we believed two operators, instead of the estimated three, could perform all the processes within that time. One operator would be responsible for machining all of the walls, while the other would machine the playing board, laser the board and the pieces, and complete the final assembly. Using information we have learned in previous CME classes, we decided to use a U-shape design for the layout of the equipment. This would reduce the amount of needed floor space and reduce transportation waste with equipment being placed closer together [2]. An AutoCAD drawing was made of this floor layout, as seen in Figure 11.

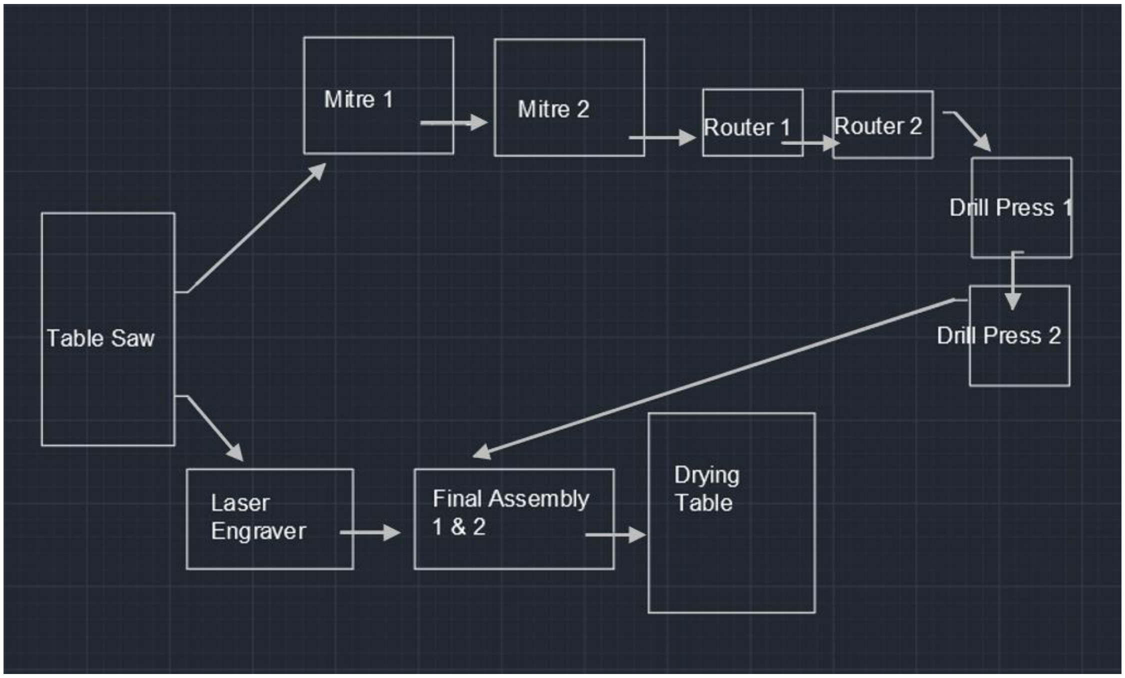


Figure 11: Line Layout CAD

Fixture Design

To ensure the necessary machining operations could be completed within the desired takt time, the team decided fixtures would be useful to add to the production process. One benefit to modeling production parts in CAD is the ability to use models to simulate fixtures created in a similar CAD software. To take these 3D models from digital components to usable fixtures, we utilized the 3D printers in the CME Makerspace. Using the printers allowed us to quickly create and test the fixtures. One of the primary applications we wanted to apply fixturing was drill bit alignment and part locating when drilling holes for the magnets and dowels. 3D-printed fixtures alone would not be suitable for this process, because the drill bit would erode the walls of the fixture very quickly, reducing its reliability. To solve this issue, steel drill guides were purchased and integrated into the design. See Figures 12 - 13 for examples of these fixtures.

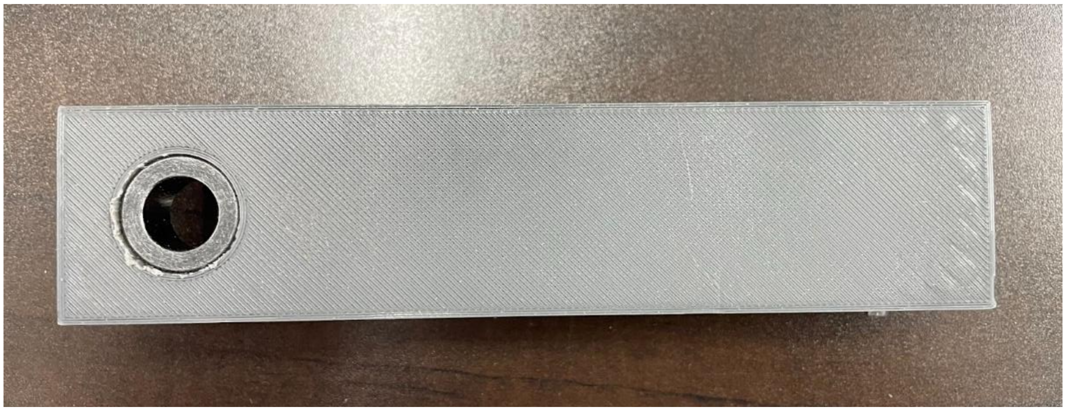


Figure 12: Example Machining Fixture

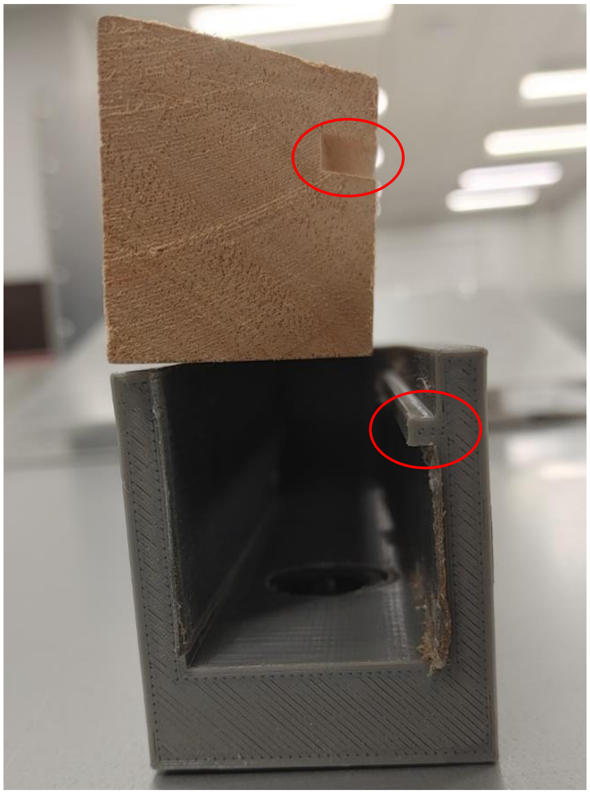
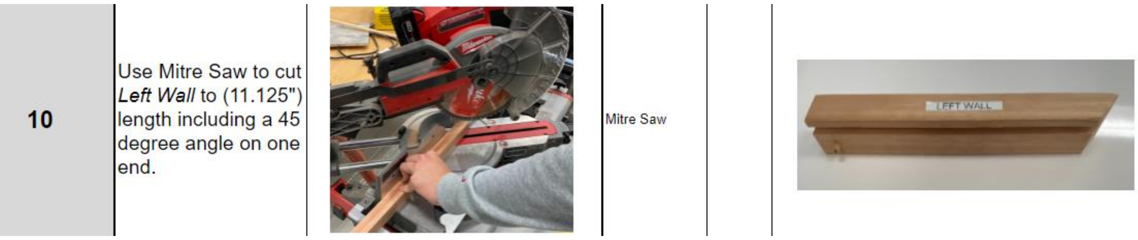


Figure 13: Holding Fixture used to Locate Component

Work Instructions

To ease the manufacturability of our designs, we created and implemented work instructions at each respective station. A standard work sheet shows clear instruction on each subsequent procedure within the floor manufacturing steps. We included pictures of each component or sub assembly for each step in the process. Along with the pictures, there are also machinery specifications that should be used as well as measurements or jig assignments that are specific to that particular process step. These work instructions act as an additional control for the production process and intend to lower the risk of defective parts. They are very crucial for steps that do not have a "poka-yoke" system in place. Work instructions are meant to be a continuous improvement vehicle as they can be easily edited in excel, and improvement steps, when found, can be applied upon proper approval. See Figure 14 for an excerpt from one of the work instructions used in this project.



10	Use Mitre Saw to cut *Left Wall* to (11.125") length including a 45 degree angle on one end.	Mitre Saw		

Figure 14: Work Instruction Excerpt

Autonomous Process Setup

One of the objectives for the project was to add an automated section to the production process. The CME has two collaborative robots, a UR3e and a UR5e, which are both produced by Universal Robots. The team decided that using the UR5e to automatically load and unload the laser engraver would be the most practical application. By using a OnRobot VG10 Electric Vacuum Gripper, the robot would be able to grab a board or sheet of acrylic, place it in the engraver, communicate to the laser to laser the piece, and then remove the lasered component. During the fall semester, it was discovered that the required cable necessary to connect the VG10 to the robot was not provided to the CME when the gripper was purchased, so programming the robot for the desired task was delayed to the beginning of the spring semester.

Once spring semester began and the missing cable was purchased, we began working on connecting the gripper to the robot. Although the cable was connected, the required software was not available on any device located within the CME. Further working with the supplier of the gripper via email, we were able to download the correct software necessary. However, the current firmware on the robot was out of date, forcing the team to spend time updating the firmware to the latest version. Once the firmware was updated to the version specified by the supplier, the gripper was usable, allowing for initial testing of the system. After a few minutes of use, however, the gripper was not being recognized by the robot. This led to numerous gripper software and robot firmware updates, which took multiple days to complete. Unfortunately, these updates did not solve the issue, but further communications with the OnRobot support engineer from Denmark, who was recommended to us by the local supplier, led the team to a solution.

By deleting another company’s gripper software from the robot, the gripper began to function properly.

The team was excited to have the robot functional, but at this point in the semester, the production run was scheduled within the same week. Although the team was able to show the robot’s movements with the laser loading process, it was not possible to complete the fully automated process as desired.

Figure 15: Collaborative Robot VG10 Gripper Setup

Production Run

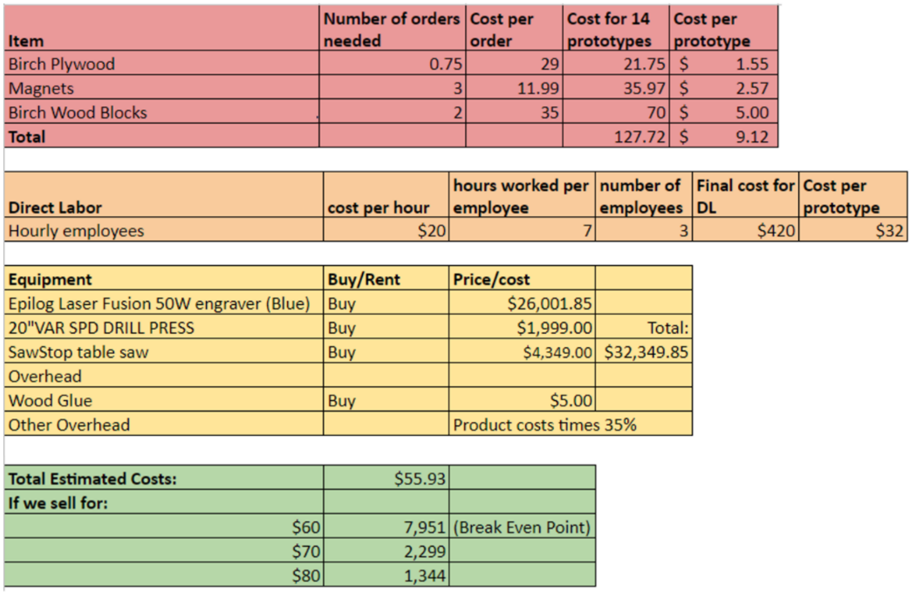
Through our final production run, we were able to see the improvements we made to our production process greatly benefit the overall efficiency of the cell. By implementing our line layout and using the newly designed fixtures, we were able to reduce our predicted headcount from three operators to two. This was a major labor rate reduction that would lower our overall cost and increase our margins. During the final assembly steps, we realized some areas where processes could be done incorrectly, so further implementation of fixtures could be performed. Although we were not able to implement the automated laser engraver process, we discussed how automated the process would be necessary to keep the output from the laser engraver in sync with the rest of production. Overall, the CME faculty members who observed our final production run were impressed with our development of our product and process. One version of our final product can be seen in Figure 16 below.

Figure 16: Final Product

Chapter 6: ACCOUNTING METRICS

After completing plans for the final design at the end of the fall semester, the accounting majors worked with the rest of the team to make early estimates for the overall cost and profit metrics for our product. See Table 2 below and the following information from the fall semester report.

Table 2: Initial Accounting Estimates



Item	**Number of orders needed**	**Cost per order**	**Cost for 14 prototypes**	**Cost per prototype**
Birch Plywood	0.75	29	21.75	$ 1.55
Magnets	3	11.99	35.97	$ 2.57
Birch Wood Blocks	2	35	70	$ 5.00
Total			127.72	$ 9.12

Direct Labor	**cost per hour**	**hours worked per employee**	**number of employees**	**Final cost for DL**	**Cost per prototype**
Hourly employees	$20	7	3	$420	$32

Equipment	**Buy/Rent**	**Price/cost**	
Epilog Laser Fusion 50W engraver (Blue)	Buy	$26,001.85	
20"VAR SPD DRILL PRESS	Buy	$1,999.00	Total:
SawStop table saw	Buy	$4,349.00	$32,349.85
Overhead			
Wood Glue	Buy	$5.00	
Other Overhead		Product costs times 35%	

Total Estimated Costs:	$55.93	
If we sell for:		
$60	7,951	(Break Even Point)
$70	2,299	
$80	1,344	

We expect to sell around 33,000 of our individual half boards, or 16,000 whole boards in total. We arrived at 33,000 by taking the population of the states that are more obsessed with the Southeastern Conference. We included Mississippi, Tennessee, Georgia, Alabama, Louisiana, and Arkansas in this calculation, because there are no other major universities in those states. We added the population of those states together and divided it by 1,000, to reach a target market of .1% of individuals in those states. We decided to spread the production number of 33,000 over 10 years, which led to two major conclusions. First, it is less expensive to buy all the machines that we need for production rather than renting them. Secondly, if we sell each half board for $70, then we will be making a profit within the first year of production.

Determining the direct material and labor costs is significantly easier than determining the overhead costs and sales. The direct materials can be determined by multiplying the number of orders for each material and dividing it by the cost of each order. We reached an estimate of 13 half boards per day by taking the 3,300 half boards per year and dividing it by the number of workdays in a year, 261. This gave us a takt time of 33 minutes, which was calculated by dividing the 13 halves per day by 7 hours. We chose to use 7 hours instead of 8 to account for breaks and expected inefficiencies. To get direct labor cost, we estimated that we would need 21 man-hours of work during the day to produce our goal of 13 half boards a day. Thus, we decided to have 3 employees work 7 hours a day at $20/hour, which is the industry average in Mississippi.

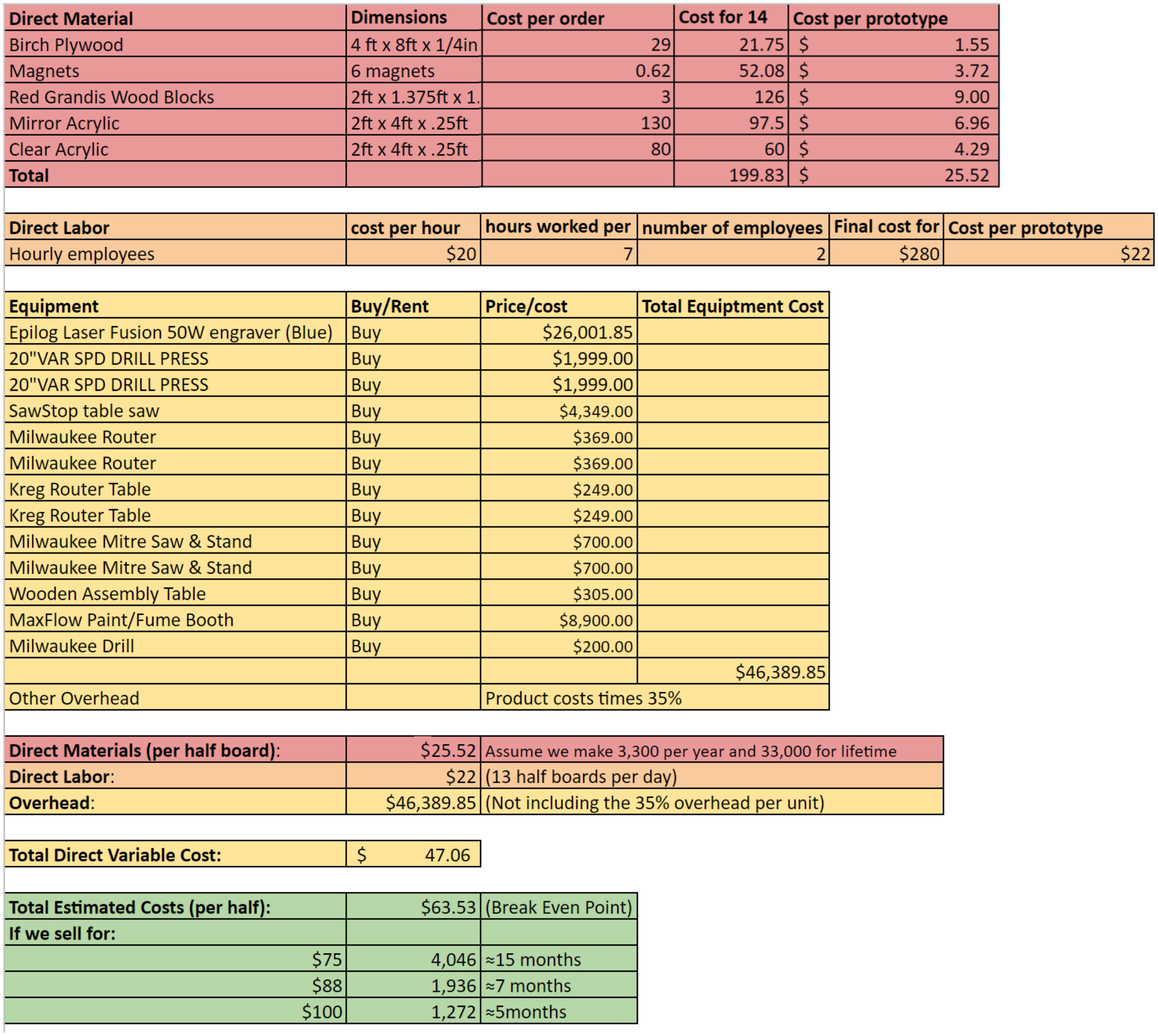
In terms of overhead costs, research was conducted to determine what percentage to use for manufacturing companies overhead in relation to their production costs. When dealing with manufacturing companies based in the US, overhead averages 35% of production costs. While 35% might seem low, we do not have much fixed overhead, which gives us a lot of flexibility when dealing with the overhead percentage.

After completing improvements to our design and production process, along with further cost analysis, some modifications were made to our initial accounting estimates.

One major change to our original estimates is the overall labor cost. To get direct labor cost, we estimated that we would need 14 man-hours of work during the day to produce our goal of 13 half boards a day. Thus, we decided to have 2 employees work 7 hours a day at $20/hour, which is the industry average in Mississippi. This differs from last semester's 21 man-hours per day to manufacture 13 half boards per day. Through improvements made with the line layout, fixtures, and overall production processes, we were able to reduce our labor hours by thirty-three percent.

Our overhead percentage was reevaluated, but not changed after further analysis. To prove that 35% was a very reasonable overhead percentage estimate, we assumed that the boards would sell for $75 per half board. This meant that we would reach the break-even point after selling 4,046 units. If you were to remove the overhead percentage estimate, $66,637.62 would remain to cover all overhead costs. The purchasing costs for all of the necessary equipment was $46,389.85, which leaves around $20,000 to cover any remaining overhead costs. We decided this was a reasonable amount, because the only costs that would be considered material are rent, air conditioning, and any advertisement costs. There is no need for a line manager or a project manager, because there are only two employees. The head of the project would be able to cover the advertisement costs because they collect 100% of the profits. With these estimated evaluated, we still believe that this product, if launched as an actual product, would be fiscally viable.

Table 3: Final Accounting Metrics



Direct Material	**Dimensions**	**Cost per order**	**Cost for 14**	**Cost per prototype**
Birch Plywood	4 ft x 8ft x 1/4in	29	21.75	$ 1.55
Magnets	6 magnets	0.62	52.08	$ 3.72
Red Grandis Wood Blocks	2ft x 1.375ft x 1.	3	126	$ 9.00
Mirror Acrylic	2ft x 4ft x .25ft	130	97.5	$ 6.96
Clear Acrylic	2ft x 4ft x .25ft	80	60	$ 4.29
Total			199.83	$ 25.52

Direct Labor	**cost per hour**	**hours worked per**	**number of employees**	**Final cost for**	**Cost per prototype**
Hourly employees	$20	7	2	$280	$22

Equipment	**Buy/Rent**	**Price/cost**	**Total Equiptment Cost**
Epilog Laser Fusion 50W engraver (Blue)	Buy	$26,001.85	
20"VAR SPD DRILL PRESS	Buy	$1,999.00	
20"VAR SPD DRILL PRESS	Buy	$1,999.00	
SawStop table saw	Buy	$4,349.00	
Milwaukee Router	Buy	$369.00	
Milwaukee Router	Buy	$369.00	
Kreg Router Table	Buy	$249.00	
Kreg Router Table	Buy	$249.00	
Milwaukee Mitre Saw & Stand	Buy	$700.00	
Milwaukee Mitre Saw & Stand	Buy	$700.00	
Wooden Assembly Table	Buy	$305.00	
MaxFlow Paint/Fume Booth	Buy	$8,900.00	
Milwaukee Drill	Buy	$200.00	
			$46,389.85
Other Overhead		Product costs times 35%	

Direct Materials (per half board):	$25.52	Assume we make 3,300 per year and 33,000 for lifetime
Direct Labor:	$22	(13 half boards per day)
Overhead:	$46,389.85	(Not including the 35% overhead per unit)

Total Direct Variable Cost:	$ 47.06

Total Estimated Costs (per half):	$63.53	(Break Even Point)
If we sell for:		
$75	4,046	≈15 months
$88	1,936	≈7 months
$100	1,272	≈5months

Chapter 7: CONCLUSION

Through prototyping, cost and market analysis, process creations, and continuous improvement, the SEC Rivals Checkers team successfully took an idea and formed a viable business model for a finished product built through a robust process. Since the capstone class is the final course requirement for CME students, this project gave the team the ability to apply what we have learned over the past four years and develop an actual production process. Throughout this team project, each member further developed his or her teamwork skills, another key learning objective of the CME.

As the original idea creator and project leader, I have learned leadership skills that I believe will apply to my career in the future. Separating and assigning tasks to specific individuals distributes responsibility throughout the team. However, assigning these goals too early could result in a team where some members do not provide their fullest amount of effort, because they may not believe their assigned responsibility showcases what they are most capable of doing. At the beginning of this project, I realized some of the team members contributed more in areas that were not their original assignment. Therefore, although structure and proper responsibility allocation is important, a more fluid approach to completing tasks on a project may be more beneficial.

BIBLIOGRAPHY

[1] A Guide to the Project Management Body of Knowledge: (PMBOK® Guide). Sixth ed., Project Management Institute, Inc., 2017.

[2] "U Shaped Layout," https://operationsinsider.com/the-language-of-lean/u-shape-layout#:~:text=The%20U%2Dshaped%20layout%20provides,is%20done%20from%20the%20outside. 4/01/22