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Customized Sidearm Case: Leading a CME Capstone Team from Concept to Production

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CUSTOMIZED SIDEARM CASE: LEADING A CME CAPSTONE TEAM FROM CONCEPT TO PRODUCTION

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DEDICATION

This thesis is dedicated to my mother, father, and sister. They have encouraged and pushed me throughout my academic career, and I would not be where I am today without them.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank two of my fellow team members, Jordan Davis and Taner Douell, without whom this product idea could have never left the prototyping phase or had a successful production run. Mason Koons, Mitchell Boulanger, and Patrick Phillips were also key in developing the marketing and financial side of the project. Next, I would like to acknowledge Dr. Jack McClurg who was a guiding figure and helping hand as the team advisor throughout the duration of the capstone experience. Mr. Andy Gossett was an essential part of the entire production process as the team's factory floor liaison and a constant source of encouragement and support. Furthermore, I am extremely grateful for Mr. Mike Gill and the rest of the Center for Manufacturing Excellence faculty and staff for their consistent backing and positive feedback as the production process came to a conclusion. Last but not least, I could not have persevered through both the production process and the writing of this thesis without the continued support of Catherine Page, whose words of motivation and comfort will mean more than she could ever know.

ABSTRACT

The goal behind this thesis is to document and analyze my performance as the project manager for the Customized Sidearm Case capstone team during the Center for Manufacturing Excellence's senior capstone experience. The capstone experience begins the fall of students senior year where a select number of product ideas submitted by the students are chosen, and teams are built around these projects. The objective of the project is to walk a product from the concept phase through the entire design process resulting in a full-scale production run during the spring semester. My product pitch of a wooden sidearm case, customized to any of the six branches of the military, was one of the products selected by the CME faculty. I was selected as the team captain and assigned five other CME students to work with. Over the course of the design process the team focused on creating an initial prototype, conducting market research, building a business model, and setting up a final production run where the team's processes and performance would be graded by the CME faculty. As the project manager I experienced several hurdles including design changes, budget expenses, and low team morale. However, I faced these challenges head-on and finished the capstone experience with a high-quality product delivered on-time and admired by several members of the CME faculty and staff. Over the course of the project, I learned several valuable lessons about project management I will be able to apply to my future career as a Marine Corps Officer and eventually as an engineer.

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CHAPTER 1: PROJECT BASE

CME CAPSTONE EXPERIENCE

The Toyota-Haley Barbour Center for Manufacturing Excellence is a program at the University of Mississippi comprised of approximately 200 students working towards their emphasis in manufacturing. The Center for Manufacturing Excellence (CME) contains students from all different majors and teaches them "accountancy, business, and engineering principles through the lens of manufacturing" [1]. To satisfy the graduation requirements for the prestigious program, senior students are required to participate in and complete the CME Capstone Experience. The capstone experience is a combination of two different academic classes students take in the fall and spring of their senior year (Manf 451 and Manf 452), which is a culmination and application of all the knowledge they have collected over their four years of learning. Students are required to "ideate a product and take that product through conceptual design, initial marketing, and production processing. The course(s) will address aspects of finance, advertising, marketing, and business development. It will also introduce project management/operation in a manufacturing business and prototype development" [2].

The summer before senior year begins, every student is required to propose a product idea that follows a specific set of guidelines: the product must have four or more components that are either manufactured or assembled, the product cannot be similar to

products created in earlier CME lab classes, and students should attempt to create a product that encompasses several types of manufacturing. After all project ideas are submitted, the top 7-10 projects are chosen, and students are assigned to teams based around those product ideas with a budget of $1000. Each team is assigned a technical advisor from the CME staff and a team captain. The technical advisor assists each team with bringing their product to life and the team captain for each team is simply the "owner" of the proposed product. The team captains then begin working with their teams through the design process from initial concept all the way through an observed production run, while conducting market research, creating proposed business models, observing safety precautions, and refining the manufacturing process. Teams are graded on a series of reports that update the status of the project in conjunction with a final production run observed by several members of the CME faculty and the team's advisor.

INITIAL PRODUCT CONCEPT

Fall semester, senior year for me began only three days after departing Brown Field on United States Marine Corps Base Quantico in Virginia. I had just completed 10 weeks of grueling training to earn the title of United States Marine and have the privilege to commission as a Second Lieutenant upon earning my bachelor's degree. Therefore, when I had to create an idea for a product for my senior capstone, I decided to create a product that I felt could be used as a tribute to all the service men and women who came before me and all those still yet to take up the call. My original product concept was for a customizable, hand-crafted, wooden sidearm display case which would be engraved with any seal of the six current U.S. military branches on the inside of the lid and have the

name of the branch on the outside. Figures 1 A and B below show the two different slides submitted at the beginning of the semester to be reviewed by the CME faculty.

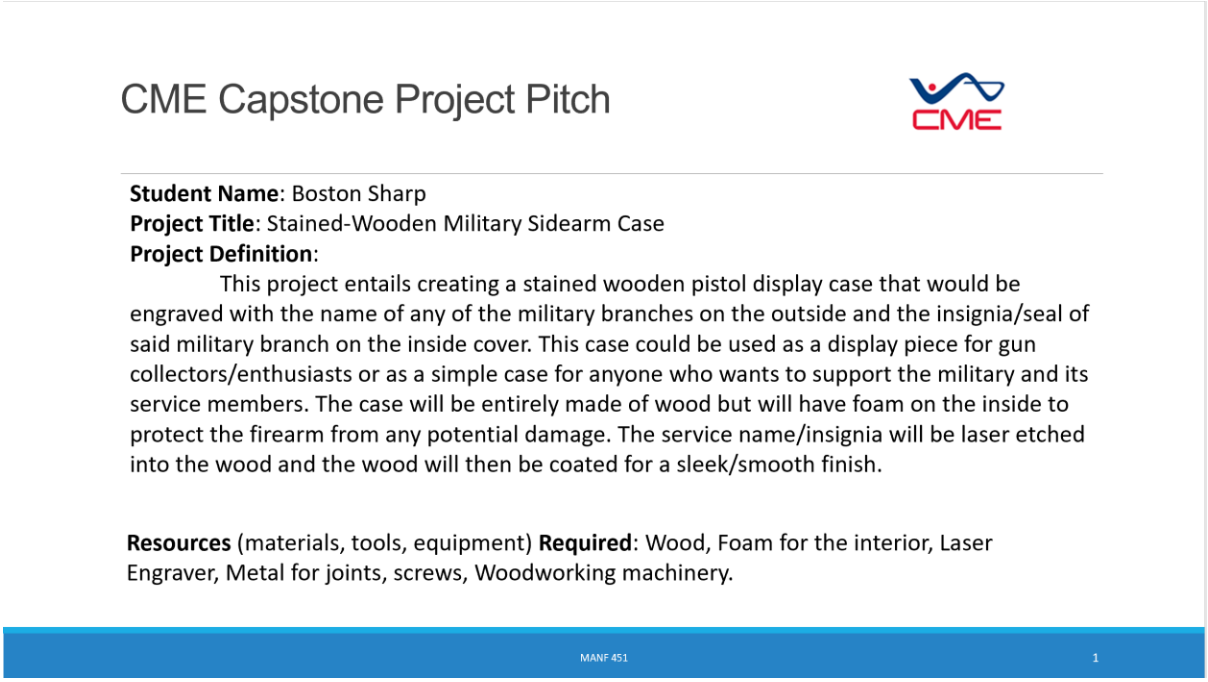


Figure 1A: Project Definition and Title

Figure 1B: Project Pitch Slide

The first slide simply contains the proposed project title, a brief product description, and an estimate of the resources and materials that might be needed on order to manufacture and assemble the product. The second slide consists of a project pitch that, if the project was selected by the CME faculty for production, would be used to recruit remaining CME senior students to work on my capstone team. Both slides show the basis for my product idea, an attractive case where firearms could be kept/displayed which promoted support for members of the United States armed forces.

CHAPTER 2: ASSEMBLING THE TEAM

Project management is the use of strategic, technical, and leadership skills to complete a project; “a temporary endeavor undertaken to create a unique product, service, or result” [3]. While this concept may sound simple in theory, it is a complex undertaking that requires skillful balance of a number of operations and is often only enhanced through experience. A project manager (PM) must balance what is known as the iron triangle: scope, cost, and time, while also being cognizant of the quality of the project. Scope can be defined as the “what” of the project; what all does this specific project entail, and sometimes more importantly, what does it not. The cost of the project is the budget a project manager has to work with, and the time portion of the triangle simply represents the schedule or how long before the project must be completed. According to the *Project Management Body of Knowledge (PMBOK)*, a project manager utilizes 10 different primary knowledge areas to assist in completing a given project while controlling the aforementioned iron triangle. The 10 knowledge areas include: integration management, scope management, time management, cost management, quality management, human resources management, communications management, risk management, procurement management, and stakeholder management. All three phases of the iron triangle and most of the 10 knowledge areas were experienced over the course of the capstone project; however, at the beginning of the project, the human resources management knowledge area became the most essential.

SIDEARM CASE IDEA CHOSEN

The Customized Sidearm Case Project began when I received an email from Mr. Mike Gill, the instructor of Manf 451 and 452. CME faculty and staff had reviewed the approximately fifty different product ideas submitted by CME seniors and whittled down the list until the top 10 remained. The selection of the Customized Sidearm Case as a capstone project meant that I would become the team captain of the project by default. My next step as team captain was to create a 60-90 second video to be watched by the remaining seniors whose projects were not chosen. The remaining students would view each team captain's video and then rate every project from their least to most favorite. Students would then be placed on teams based on their preference, major, and at the discretion of Mr. Gill in order to balance the teams evenly. Project preference would play a role in being placed on a given team, but a student rating a specific project as their favorite did not guarantee their selection for that team. As the project manager, it became my job to acquire and assemble the best possible team to complete the task that lay before me. Therefore, I had to create a video that would catch the eye of the best students and encourage them to join my team. Since my project was focused primarily on a way to represent and honor the men and woman who have served this country, I decided to create a video designed to further that theme. I decided to dress up in my woodland MARPAT (Marine Pattern) camouflage uniform and record myself discussing the fundamental aspects of my product and why I believed it would be successful. I was confident that I had created a video that would inspire others to join my project and be enthusiastic about turning this idea into its physical form.

TAKING THE INITIATIVE

I felt that my video was alluring and believed that it would attract other students to join my project. Nevertheless, I also knew that having students who were eager to work on my project did not guarantee success. Only students with the right skillsets would be able to assist me in delivering a quality product at the end of this project. Thus, I was determined to be proactive rather than reactive. Negotiation is one the primary tools listed in the *PMBOK* when acquiring resources, but rather than negotiating a salary or other incentive, I was negotiating and selling an idea to several of the students I thought could benefit by project. My initial plan was to recruit a student whom I had worked with throughout my collegiate career on previous projects, homework, etc. However, his product was also chosen as capstone project making him unavailable. My next stop was Taner Douell, a mechanical engineering student I knew had extensive experience with both CAD drawings and wood working, both of which would be essential in the production of the sidearm case. I convinced him that my product would allow him to use his artisan woodworking skills compared to most of the other products and that he would have some creative license in how the box was "brought to life." He agreed that my project was a notably interesting concept and assured me my project would be at the top of his list. The next student I sought help from was Jordan Davis, another mechanical engineering student I had worked with who was extremely organized and guaranteed to keep the team on task and efficient. Unknown to me at the time, I discovered that her father engaged in cabinet making as a hobby, and she was drawn to my project from the beginning. I relayed to her that she would be an excellent addition to my team and that she could help in adding to the overall quality of the project and she also assured me that

she would mark the sidearm case as her preferred project. Although I knew that both of them placing me first on their sheet did not guarantee them placement on my team, hope abounded that I could acquire at least one of their services and by doing so lighten the burden of success that seemed to be resting solely on my shoulders for the moment.

TEAM MEMBERS ASSIGNED

After the deadline for students to submit their project preferences had passed, teams were assigned in an email by Mr. Gill. In industry, it is rare that a project manager receives exactly what they request. Most of the time there is a heavy amount of bargaining and compromise in what resources a project manager is actually allowed to use for their specific project. However, I was lucky enough to receive both of the main students I pursued. According to the email, my team would consist of me (mechanical engineer), Taner Douell (mechanical engineer), Jordan Davis (mechanical engineer), Mason Koons (accounting), Mitchell Boulanger (accounting), and Patrick Phillips (accounting). I was assigned three mechanical engineers and three accountants; allowing me a very well-balanced team for this type of endeavor. Our first task was to set up the initial team meeting to outline expectations of the project and initial team member roles.

Before we met, I had a brief meeting with Mr. Gill about my team and learned that not all of my team members had filled out project preference forms. Several students had neglected to complete the form and were placed on different teams by Mr. Gill on the basis of where he thought they could be most helpful. As a project manager, it is important to keep morale of a team high and workers motivated. Learning this new information signified that I would need to work extra hard in order to ensure that all of

my team members felt that they had a stake in the project in order to get the best out of the team. Upon reflection, the project manager's role as a motivator is one I could have improved upon.

INITIAL MEETING

After introductions, the first task before the capstone team was to finalize the product idea. Although I created the initial product concept that was selected, I wanted to gather input from the team on how they envisioned bringing this sidearm case to life. I wanted to know what they had envisioned as I described my product in my video and through my PowerPoint slides. Upon much discussion, we determined that there would be slight differences between my original product proposal and the prototype that we would begin working on. The team decided that the outside of the sidearm case could be a display piece but that the box should secure and protect the firearm inside. The selected military seal would now be laser engraved on the top of the lid rather than the inside, and protective foam would be placed on both the inside of the lid and in the bottom of box to encapsulate/safeguard the user's firearm. An American Flag image would also be added to the laser engraving options as a neutral choice for those who still want to support the military but have no personal ties to a specific branch. Due to the primary purpose of the case switching from display to protection, a radio frequency identification (RFID) locking device was added as a possible enhancement to the design. During this meeting a rough CAD model was created by Taner and is displayed below in Figure 2.

Figure 2: Initial CAD Model

During the initial meeting, roles were also given to each team member that best suited their skill sets. As the project manager I decided there would be two primary teams with each team member having a secondary role for the project as whole. The accountants (Mitchell, Mason, and Patrick) and the engineers (Taner, Jordan, and I) would constitute the two teams. As these teams had similar or identical schedules it would be easier for them to meet and accomplish given tasks without too many obstacles. The accountant team would primarily be in charge of the marketing, business, and monetary aspects of the project, whereas the engineers would be primarily in charge of design, prototyping, and the eventual production run. Ultimately, as the project progressed, it became apparent that as the project manager I did not balance the workload properly between the two teams. The engineering team would spend significantly more time working towards the final goal of the project compared to the accounting team.

Furthermore, working as distinct units also prevented the integration of both team's responsibilities. The engineering team needed to still have an understanding of the monetary aspect of the project to correctly limit expenses during the prototyping process, and the accounting team needed to be aware of the decisions being made on the factory floor to help build the business model around the product the team was constructing. In industry, a lack of communication/coordination can cause projects to completely fail, as engineers create designs that are too expensive to compete in a given product market and accountants/businessmen pitch products to customers that are physically impossible to create. Although the Customized Sidearm Case capstone was ultimately a success, this lack of cohesion would be the root cause of significant overspending later during the project.

Secondary roles given to the different team members included: Taner held the posistion as primary CAD modeler, Jordan became the buyer coordinating the purchase of materials, Mitchell took over the role of recording meeting agendas and minutes; Mason became the marketing lead of the group, and Patrick was in charge of the budget. Although team members had differing responsibilities, I decided that due to the small size of the team, any decision critical to the outcome of the project (design, reports, etc.) would still be discussed between the group as a whole. I felt that this would keep all team members fully committed to the success of the project and increase buy in.

CHAPTER 3: PROTOTYPING

EARLY DESIGN

The prototyping process essentially began during the first team meeting discussed previously. Mr. Gill ordered all teams to have their first materials ordered within about a week of team assignments to begin the prototyping process as soon as possible. This meant that the team had to put together a list of materials during that first meeting in order to meet this deadline. As mentioned previously, the "iron triangle" of a project involves balancing the scope, cost, and time of an enterprise. Normally in a given industry project, the scope is determined in tandem between the business and a customer. This allows the two entities to create an initial idea of how much a customer is willing to spend and how much of the customer's "dream" the business can accomplish for this set amount of money and still be profitable. However, the CME capstone project more closely resembles a research and development venture where the scope is created entirely by the design team. I decided that in order to experiment with the size of the scope throughout the project; it would be essential to cut costs anywhere possible. With a budget of only $1000, the team decided to use wood provided by the CME factory floor to build the prototype and cut down on the cost of the initial material order.

The capstone team decided to increase the functionality of the sidearm case by adding security features and creating a more protective environment inside the box. Nevertheless, I still wanted the case to have a handmade and artisan aspect that allowed

the customer to display the case proudly and promote the primary ideology behind the original design, honoring the veterans and current service member of the United States Armed Forces. To bolster this blueprint, the team decided to use SOSS 100 Satin Brass Concealed Hinges purchased from grainger.com. Although expensive, these hinges would be hidden from the outside of the sidearm case when it was closed and create a purely wooden pretense to the box. A wooden dovetail interlocking system was chosen to piece the sides of the box together add to the decorative appearance. Dovetail woodworking requires a special metal fixture to accurately cut the wood in order to ensure the sides of the box fit perfectly together. Fortunately for the team, the factory floor already owned such a fixture and therefore did not require the team to place the purchase of this equipment against the budget. It should also be noted that a few different equipment accessories purchased by the team over the course of the capstone project were also not required to count against the team's budget. At the beginning of the semester, team captains were instructed that specific equipment necessary to the success of a project could be purchased outside the initial $1000 budget if the equipment could be utilized on the CME's manufacturing floor for future capstone projects. Accessories to the dovetail fixture purchased on subsequent material orders fell under this category.

Aside from the concealed hinges, a number of other items deemed necessary by the team to begin the prototyping process were purchased in the team's initial material order: wood glue used to enhance the strength of the dovetail joint; foam inserts for protecting the firearm placed inside the case; sand paper to smooth the surface of the wood; polyurethane capable of giving the wood a more glossy and smooth finish; and a relatively inexpensive partially programmed RFID locking device discovered on Amazon

that could increase the value and "wow" factor of the final product. A fairly expensive item that was also purchased during the initial material order was epoxy resin and accompanying pigment. The idea behind this purchase was to create a deeper laser engraved image on the surface of the box which could be filled with a colored resin to augment visual appeal. However, this was eventually deemed unworthy of further pursuit due to the scope and time constraints placed on the project. This had a negative impact on the budget as it was purchased but added no value to the final product. This assists in highlighting the difference between a known scope negotiated between a business and a customer versus an R&D scope that is created and modified over the course of the project. By the end of the project, the team was significantly over budget. Discussed later, aspects of the project such as the failed resin experiment help to explain the causation behind this misstep. Furthermore, in industry, the project manager has more authority over when and how the budget is spent. The initial material order deadline was difficult to hit and caused the team to employ more guesswork as to what items/equipment would be needed for the project. An ideal scenario would allow the team to purchase items as they are needed in an attempt prevent as little monetary waste as possible.

GETTING OUT ON THE MANUFACTURING FLOOR

After the initial materials arrived, the immediate task before the engineering team was to create a 90% working prototype by the end of the fall semester; this was the deadline set for the team by "upper management" (Mr. Gill). The first step was to figure out how to operate the dovetail jig. The jig required the use of a hand-router with several different cutting bits. The jig can be seen below in Figure 3.

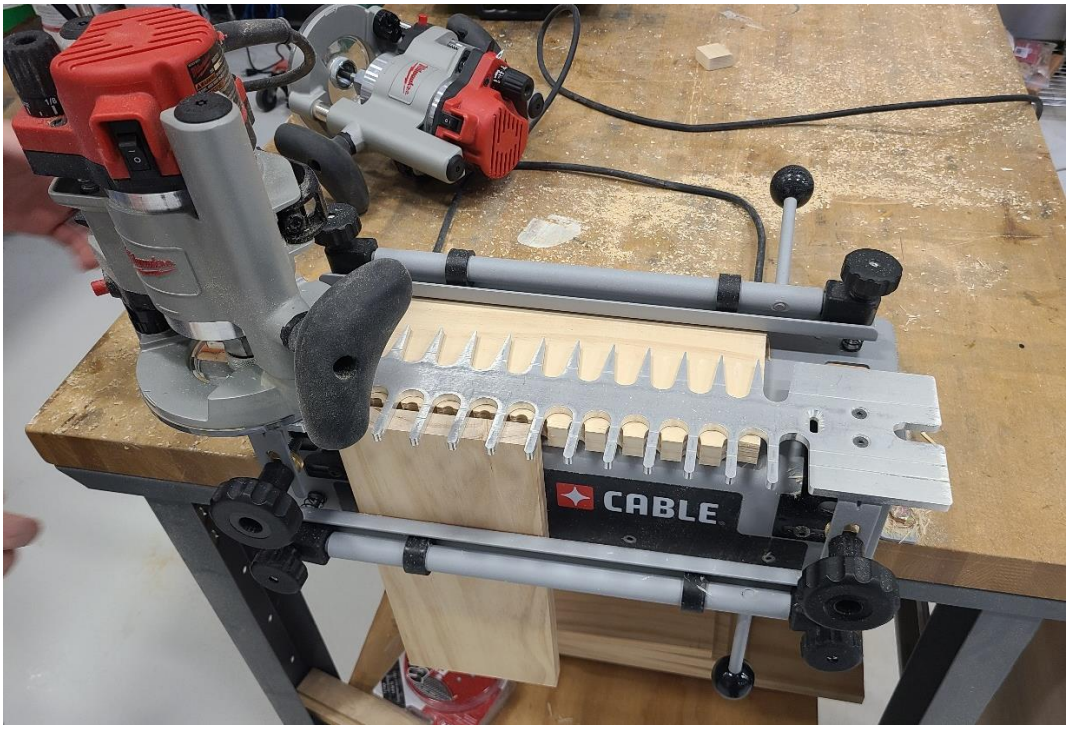


Figure 3: Dovetail Jig with Hand-Router

To operate this jig properly the team watched countless YouTube tutorials, utilized trial and error, sought help from the team's advisor Dr. McClurg, and were forced to order different parts not included with the CME factory floor's set. After over 3 weeks of working only on the dovetail joint, the team was able to learn the proper way to operate the jig without significant error while achieving repeatable results. An example of a finished dovetail joint is pictured below in Figure 4.

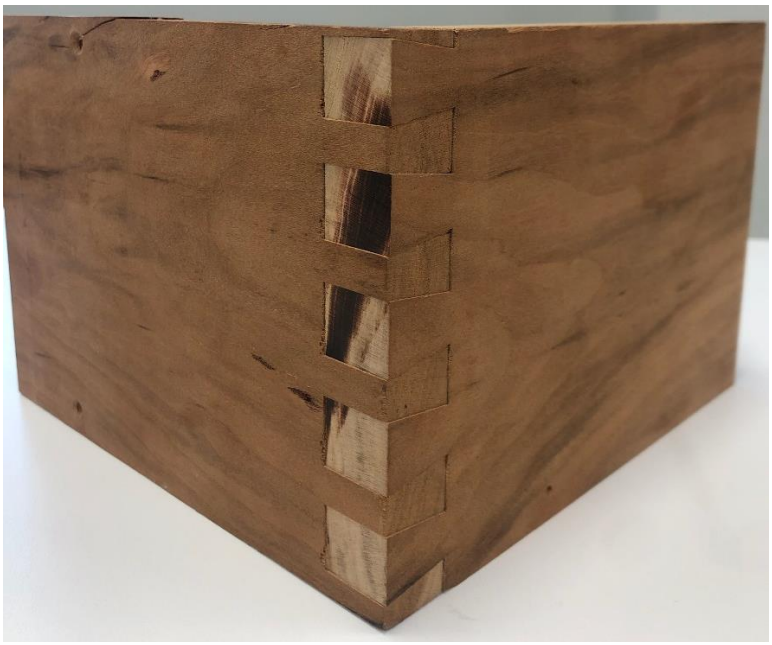


Figure 4: Completed Dovetail Joint

Although the dovetail joint does not inherently add to the functionality of the box and could have therefore been abandoned as an unworthy pursuit; the final result increases the artistry of the box significantly while adding value for minimal cost.

The next steps in the prototyping process were to determine how to create the bottom of the box and the lid. It is nearly impossible to perfectly dimension to the outer measurements of a four-sided box without using expensive computer-aided manufacturing. Therefore, to create the visually appealing aesthetic of the design, the team needed to eliminate any potential overhang or distinct edges on the lid and base. The team created two different solutions, one for the lid and one for the floor of the box. The bottom would be made out of ¼” thick plywood that would slot into the box about 3/8” from the bottom of the four dovetailed walls. The slots would be precut approximately halfway into the wood of each wall without cutting to each edge in order to hide the slots from the outside of the box. The top of the box or lid would be created

from the box itself. A piece of ¾” wood would be glued flat onto the top of the four sides with excess edge hanging over each side. The excess would be trimmed using a flush router bit and the lid would then be cut a certain distance from the top edge. This process guaranteed that the lid would fit perfectly onto the bottom of the case. Hand clamps were used to secure the lid to the rest of the box while the glue dried as shown in Figure 5.

Figure 5: Clamping the Lid

There were several other design selections that were worked on over the course of fall semester to ensure the first prototype was approximately 90% complete. Another special jig was ordered to cut the slots for the concealed hinges. This process also involved a hand router along with a new type of bit that did not count towards the team’s budget as it could be later utilized by the CME factory floor after the conclusion of the capstone projects. Learning to use this jig also took several hours of trial and error but did not require nearly the time commitment of the dovetail jig. A chamfer was selected for the top edges of the lid and was easy to include as it only required a special router bit already

owned by the CME floor. The team simply had to select the desired size that paired appropriately with the rest of the dimensions of the box. Next, the team practiced using the laser engraver to create the primary image on the lid of the box. Six different images were created using a special conversion software and are all displayed in Figure 6.

Figure 6: Laser Engraving Lid Options

Figure 6 shows the American Flag design chosen in addition to the seals of the five primary branches of the United States Armed Forces (the seal for the United States Space Force was added later in the prototyping process). Settings such as laser frequency, laser power, and laser speed were practiced and adjusted for the perfect appearance. It was while working with the laser engraver that it was decided pursuing the design idea of the epoxy resin pour was both too costly and too time consuming. The original intent was to laser engrave a deep enough image to allow for the resin to rest. However, the laser setting required to achieve this depth risked compromising the wood. I made the executive decision as the project manager to mark the resin as a potential concept to "explore in the future." In industry, a research and development project might allow for time after the prototype/product has been completed to return to a previous design concept for further analysis. However, the end of this project would involve the team members' graduation and prevented any future work due to the time constraints.

FINISHING THE ROUGH PROTOTYPES

Two different initial prototypes were created throughout the fall semester in order to practice different operations such as the dovetail joints and to assist in design choices like the chamfer angle or the laser engraving settings. As these sidearm cases were constructed, the team was able to make several design altering decisions that would (the team believed) improve both the aesthetic and overall design of the product. The original foam ordered for the boxes was a pick-and-pluck style foam that would allow the customer to remove sections of the foam to fit their specific style firearm perfectly. However, upon testing, it was decided the foam picking process was too cumbersome and did not generate the desired effect. Eggshell foam would be ordered for the final

prototype that would arrive over the Christmas holiday break and could not be tested until the beginning of the spring semester. This did not prevent the team from completing its original objectives as the initial prototypes were only required to be 90% complete at the end of the fall semester.

Wood was originally planned to be selected from the factory floor for the prototyping process before the team chose a different, likely more expensive wood, to use for the final prototype and the inevitable production run in the spring. However, most of the wood on the manufacturing floor was plywood and splintered to pieces during the dovetail operation. Therefore, the team was forced into ordering higher quality wood to create the initial prototypes. Cherry lumber was the first choice by the team and is modeled using the dovetail joints in Figure 4 above. This wood had a darker, visually pleasing color and was sturdy enough to survive the dovetail process. However, cherry proved to be exceedingly expensive and would increase the cost of the materials and decrease the potential profits. Eventually the team decided on a Select Kiln-Dried Square Edge Pine Board (HomeDepot.com) ordered from Home Depot. The pine was a significantly lighter shade than the cherry, but the original intention was to stain the wood darker towards the end of the production process. The boards were also 1" x 6" x 8' and a single board could produce 1 entire sidearm case for only around $25. Although the boards were listed as 1" thick, they were actually ¾" (the minimum width necessary to use the concealed hinges). The bottom of the case would be composed of ¼" birch plywood. Plywood was used for the slotted-in floor of the case because it did not require any additional processes that might split the wood.

The original cases were built to be 10” x 14” and approximately 6” tall. The initial prototypes are pictured in Figures 7A-C below. The size of these cases is significantly larger than that of the final design discussed later. The team decided these cases were both unnecessarily tall and wide.

Figure 7A: Both Initial Prototypes

Figure 7B: USMC Seal Prototype

Figure 7C: American Flag Prototype

With the initial prototypes completed, and the team satisfied with the current components (wood, hinges, RFID), an order was made at the end of the fall semester for all the materials necessary for the final production run in the spring semester. As the project manager, I knew the deadline for the production run was early in the semester so I wanted the materials ready so that the team could begin working immediately after we returned from the holiday. In hindsight, this would prove to be a rushed decision and would cause the team to fall short in one category of the iron triangle.

FINAL PROTOTYPE DESIGN

Once the engineering team returned for the spring semester, I wanted to create one final prototype immediately. Mr. Gill had given a deadline of mid-February to have all capstone teams' production runs completed. While this sidearm case would be labeled as the team's final prototype, it was essentially a first finished product. With this case, the team would select all final design preferences in order to prepare for the quickly approaching production run deadline. The first design change was to alter the dimensions

of the box to 9” x 13”. The team felt these dimensions would still fit almost any size sidearm without the large/clunky impression given by the initial prototypes. The next modification was to cut the box down to 4 3/8” after the four walls and bottom were glued together in order to decrease the height of the box. The walls were left uncut for the initial prototypes, therefore making the box as tall as the six-inch width of the board. The walls of the case were cut after the dovetail joints were assembled because it was determined that the dovetails had a better fit if cut at the full width of the board. The 4 3/8” height was used as this was the minimum height permitted to fit the RFID lock and allow for a clearance underneath the slots used to create the bottom of the case.

Once the final prototype was assembled to the point of the initial prototypes, the team needed to decide on the option of staining the wood. Most of the team members admired the darker shade of the cherry wood and wanted a similar color added to the bright pine; however, I proposed an alternative solution. I wanted to increase the overall artisan appearance of box; I proposed adding a process known as torching to the case followed by a thick coat of gloss polyurethane. Torching involves burning the wood along the different natural grains in the wood to create a light versus dark visual appeal. We torched the box by slowly passing a handheld butane torch along the entire sidearm case both inside and out. It was important not to hover over one spot too long and risk charring the wood. Torching is a delicate process that can quickly detract from the appearance of a product if the user is not careful. After the box had been torched, the team decided to add two full coats of a gloss polyurethane in order to give the entire case a smooth texture and protect the wood from scratching or moisture.

Before the end of the fall semester, eggshell crate foam was ordered to use for the inside of the sidearm case to protect the firearm. A 1-inch foam was ordered to fit into the lid of the box and 3-inch foam was used for the bottom of the case. The intent was to create an "excess of foam" that would squeeze the firearm between the two layers to prevent the weapon from sliding inside the box; this is similar to most modern rifle and sidearm cases. The foam was cut to dimension using the laser engraver with additional slots cutout for the RFID lock base in the 3-inch foam and for the latch in the 1-inch foam. Furthermore, the foam had an adhesive backing for attaching to the different parts of the case. Before the foam was attached to the base, a small hole was drilled into the base of the case to run a small cable attached to the lock base through the bottom of the box. The RFID locking mechanism was powered primarily by batteries; however, exposing this cable would allow the consumer to plug the lock (with an additional attachment) into an electrical outlet and power the device long enough to unlock the case and replace the batteries if or when they failed. This was an essential design feature as it guaranteed the customer would never be prevented from having access to their firearm. After the RFID lock and foam were attached to the inside of the sidearm case, the last feature added during the prototyping process was a small brass-colored metal chain attached inside the back left corner of the box to prop the lid up and prevent it from opening the full 180° allowed by the hinges. The finished prototype can be viewed in the different images of Figure 8.

Figure 8A: Front Closed View of Finished Prototype

Figure 8B: RFID Scanning Location

Figure 8C: Front Angled View of Finished Prototype

Figure 8D: Front Open View of Finished Prototype

Figure 8E: Inside Bottom View of Finished Prototype

CHAPTER 4: MARKET RESEARCH

GOOGLE FORM SURVEY

Another one of the primary responsibilities of a project manager is stakeholder management. This includes not only the stakeholders inside the company, but those outside as well, such as customers. Therefore, I wanted to create a way the team could receive feedback from potential customers in order to allow those that would be purchasing our product to have input into its design. The scope is always at least somewhat determined by the customer. If a company makes a product no one is willing to buy, they are wasting their own time and money. As our project resembled a research and development venture, we did not outline the product scope with the customer at the beginning and therefore needed to gather information while changes could still be made during the prototyping phase.

While the engineering team worked on the prototype during the fall semester, the accounting team created a Google form survey to gather information from potential customers of the Customized Sidearm Case. The purpose of this survey was to inform the team about features desired by possible consumers, potential price points, the demographics of people willing to purchase this product, etc. Once the survey was completed, I tasked each team member with sending out the survey to at least 10 different people to collect as much data as possible. While the primary focus would be on people associated with the military, I encouraged the team to also send the link to people not

connected to the military as it would allow the team to determine how large of a market the product could create. I decided to send the link to a groupchat of my fellow 1st Platoon graduates from Officer Candidate School, as well as a few family and friends. One of the other team members gave the link to a family member who was currently in the military and agreed to give the link to fellow active armed service members. In order to increase the likelihood of people filling out the survey, the team decided to add an incentive: a finished sidearm case would be given, free of charge, to one survey taker selected at random upon completion of the final production run.

The survey began with a brief introduction to the product, as well as a simple CAD model (Figure 2) and a picture of the dovetail joints used to hold the box together (Figure 4). Next, were 10 different questions, 9 of them multiple choice and the 10^{th} an open-ended question to encourage the survey taker to give any feedback not covered by the previous questions. The questions are pictured below in Figure 9A-D.

To accompany the Google form, the accounting team also created a Google sheets file that would collect the results from the survey and place them into both a bar chart and a pie chart. This would allow the team to understand the overall responses using two different visual mediums. In total the team received 54 responses to the survey. Of those that responded, approximately a quarter were not either retired, active, or future military. Several of the survey response graphs are pictured below in Figures 10A-F.

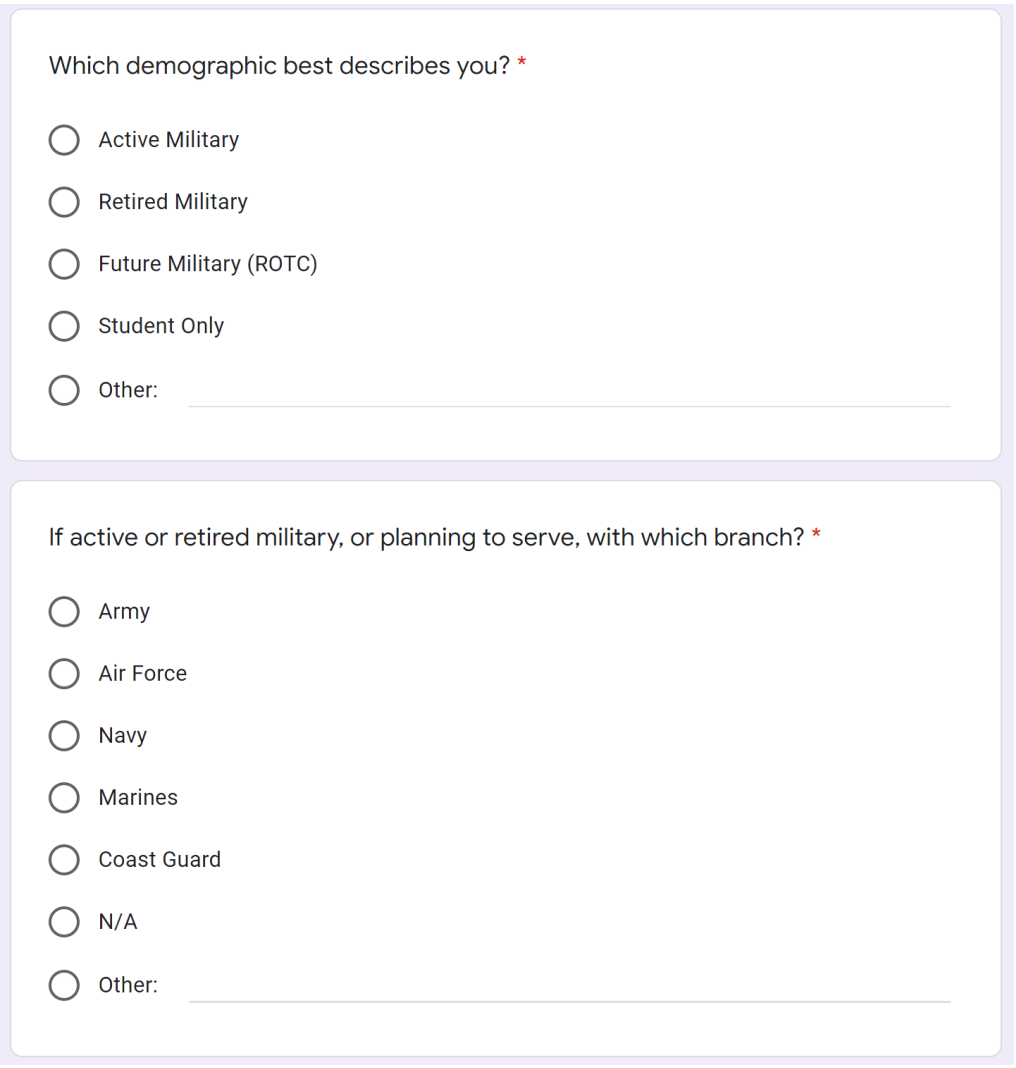


Figure 9A: Survey Questions 1 and 2

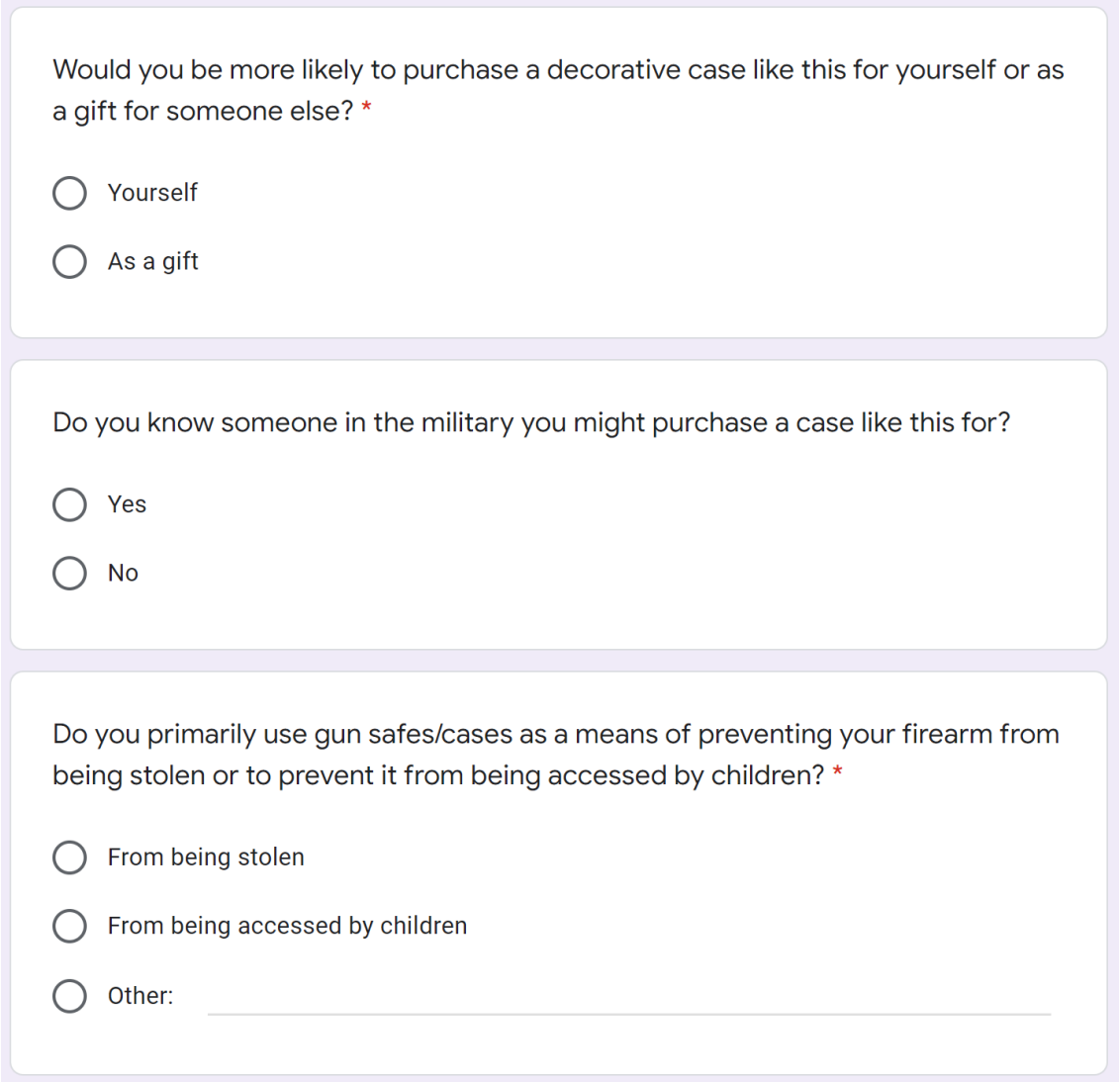


Figure 9B: Survey Question 3-5

Which aspect of the following do you consider the most important aspect of a gun safe/case? *

- ◯ Utility
- ◯ Mobility
- ◯ Appearance
- ◯ Security/Safety
- ◯ Ease of Access
- ◯ Other: _____

Which lock/entry method do you prefer for your gun safe? *

- ◯ Manual Key
- ◯ RFID (Keycard Scanner)
- ◯ Keypad
- ◯ Thumbprint
- ◯ Other: _____

Figure 9C: Survey Questions 6-7

If given the option of a laser designed foam insert for your specific firearm or a DIY customizable foam insert (pick n pluck) that could be fitted to any firearm and magazines, how much extra would you be willing to spend for the Customized option?

- ◯ Not Willing To Pay
- ◯ $20
- ◯ $30
- ◯ $40+

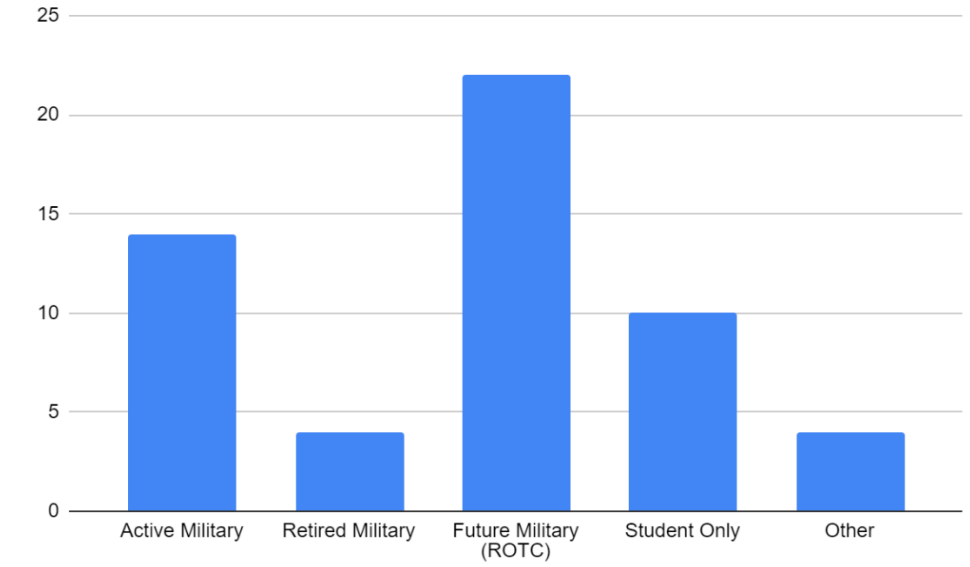
Assuming a decorative gun case like this had the majority of the features you want in a handgun case, what would you see as a fair price for the product? *

- ◯ $100-$150
- ◯ $151-$200
- ◯ $201-$250
- ◯ $250+

Are there any special features or designs you would like to see in a decorative case like this?

Your answer

Figure 9D: Survey Questions 8-10



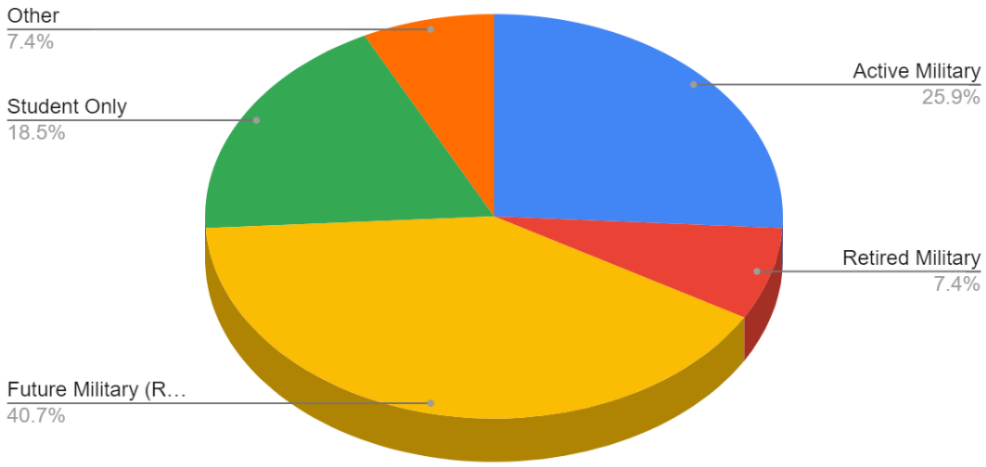


Figure 10A and 10B: Demographics Survey Response

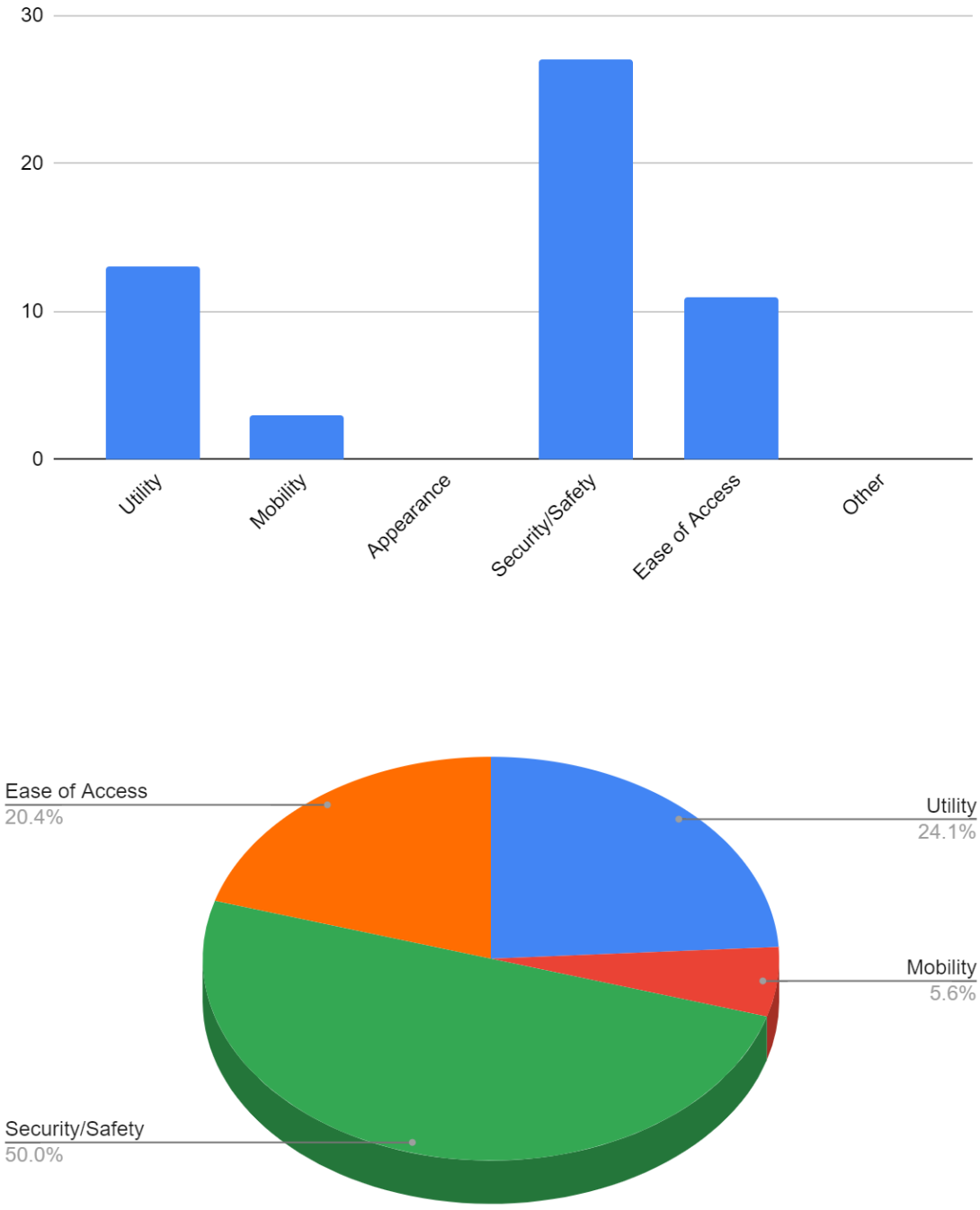
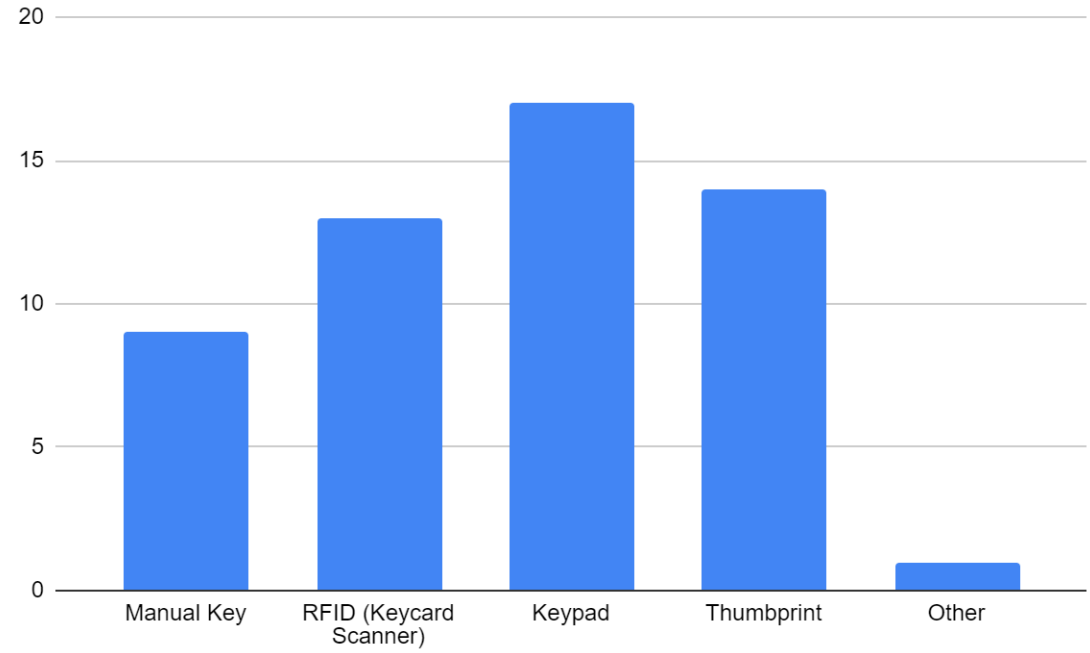


Figure 10C and 10D: Most Important Aspect Survey Response



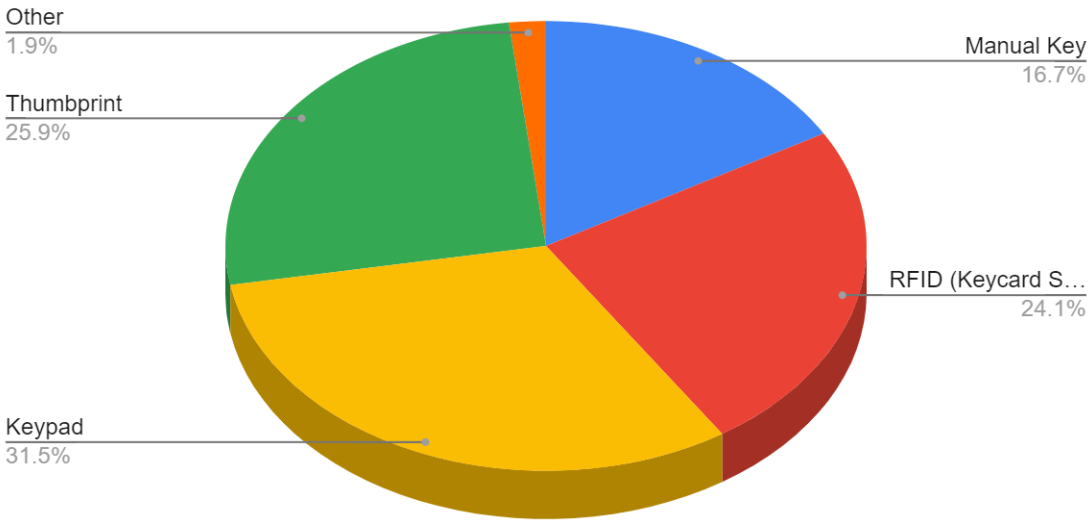
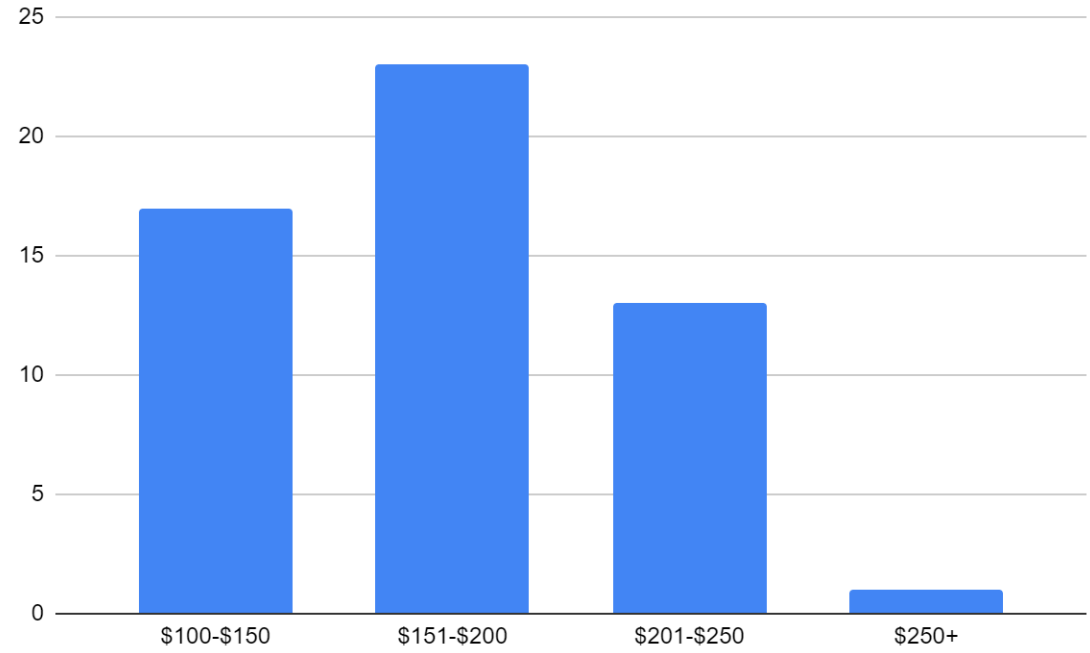


Figure 10E and 10F: Preferred Method of Security Survey Respone



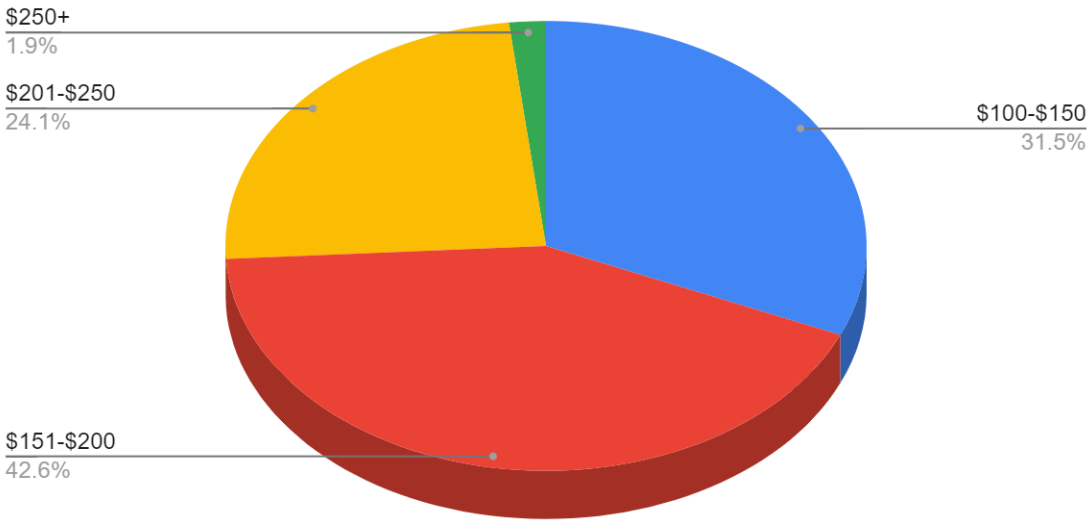


Figure 10G and 10H: Fair Price Survey Response

One of the main takeaways from the survey was that most consumers preferred a sidearm case that valued security over display ability. This helped the team to shift their focus during the prototyping solely towards safeguarding the firearm and settling on the idea of an RFID locking system. From the survey, the top security method was a thumbprint scanner; however, for the purposes of the capstone, the RFID was cheaper, easily acquired, and much simpler to install. Another design bonus resulting from the survey was for extra customization individualized for a specific customer. The team decided this could take the form of initials being laser engraved at the location where the RFID card could be scanned to open the box. A customer could input their initials during the ordering process and the initials could be engraved into the box with very little overall work time added to the process. The survey was ultimately an immense success that supplied the team with useful information and assisted in improving the final product created by the team.

CURRENT MARKET

The purpose of the CME capstone experience is to either create a product that has never been produced before, or to improve on the current design of an existing product. When I originally proposed my initial design, I did not know of any current products on the market similar to what I had imagined. Eventually, while researching the potential expected market for our new product, members of my team discovered that their were other hand-crafted wooden firearm cases on artisan sites such as etsy.com. However, none of these cases were exactly like the case we had created. A large number of the current designs did not have a locking mechanism and those that did possessed only a simple twisting key lock. Many of the products were engraved with some type of

patriotic or supportive imagery but none of them allowed for the customization our product was designed to include. The hidden hinges and dovetail joints were also somewhat rare. It appeared that while most sidearm cases had one or two of the features listed above, none of the current products contained all of them. These custom built cases ranged anywhere from $150-$300+. These prices would be the base point for the construction of the team's business model.

CHAPTER 5: BUSINESS MODEL

COST OF RAW MATERIALS

A considerable portion of the Center for Manufacturing Excellence Capstone Experience revolves not only around the building of a prototype/product but also in creating a sustainable business model around that product. It is essential to understand that in real-world manufacturing, companies cannot use whatever materials or machines they prefer to create their process. There are copious amounts of compromise in the design process in order to get the most profit out of a given product. This is why, in the capitalist economies of the United States, Western Europe, and elsewhere, companies exist ultimately, to turn a profit. These concepts led to some of the material/process decisions discussed during the prototyping analysis, such as utilizing the wood burning process on a cheaper piece of pine lumber compared to purchasing a more expensive wood such as cherry. In manufacturing, the final cost of a product is most easily manipulated during the design phase. Therefore, it is essential to understand the cost of raw materials being chosen to create the product.

Table 1 shows the price per part for every item in addition to the number of parts included in the final product. There are several items that have an amount used of less than one. This is due to the fact that a single sheet of foam for both the 1” and the 3” could produce enough foam for six different boxes. Therefore, the cost for a single sidearm case would be one-sixth the total cost of the sheet. It should be noted that the

butane tank necessary to work the torch was included at 1/20th the cost of a single canister because the team was able to torch the approximately 17 different boxes built over the course of the entire project with additional fuel still inside.

Table 1: Raw Material Breakdown for Sidearm Case

Raw Materials Price of Box			
Item	Cost	Quantity	Total
Hinges	$15.31	2.000	$30.62
Foam 1"	$28.13	0.167	$4.69
Foam 3"	$55.45	0.167	$9.24
RFID (2nd Order)	$19.99	1.000	$19.99
Wood 1"X6"X8'	$25.26	0.750	$18.95
1/4" x 4' x 8' Birch Plywood	$33.38	0.025	$0.83
Polyurethane	$19.98	0.0625	$1.25
Brass Colored Chain	$10.00	0.1	$1.00
Butane Torch	$23.98	0.050	$1.20
	Approx. Total:		**$87.77**

The total cost of the concealed hinges was approximately one-third the raw material cost of the box. However, the hidden hinges not only added to the desired aesthetic of the case, they also were not seen on any other case during the current market research done by the accounting team. This created a uniqueness to the case that might allow the team to capture a larger market share should this product become available for purchase. Another cost decision displayed in the above table was to cost the price of ¾ of an entire piece of wood towards a single box. There were approximately 2 feet of wood remaining once all the pieces necessary to build a single product had been cut off. This meant that 3 full length pine boards could be used to produce four total sidearm cases. Over the course of prototyping and in preparation for the eventual production run, the

team on occasion used the extra wood for correcting mistakes as they occurred. Jigs were created to eliminate as many of these mistakes as possible prior to the production run. Furthermore, a company that has refined the production process and trained workers to prevent common mistakes could cost the material without allocating the extra wood for corrections. This resulted in a cost saving of approximately five dollars per box. Overall, the total cost in raw materials was approximately $88.00. The addition of labor and manufacturing process costs would determine the total cost necessary for the team to create a selling price.

CHANGE IN BUSINESS PLAN

The production of a single Customized Sidearm Case required the use of a significant amount of equipment available to the capstone teams through the use of the CME's 12,000 sq ft. manufacturing floor. However, to create an accurate business model around the sidearm case, the accounting team assembled an approximate cost of the capital required to purchase the different tools and machines utilized throughout the production process. A breakdown of these costs and their sum are visible in Table 2.

Table 2: Breakdown of Equipment Costs

Tool/Direct Material:	Capital Costs:
Miter Saw	$420.00
PC Dovetail Jig and 2 Extended Hand Routers	$518.00
Hand Router and Kreg Table	$199.00
Table Saw	$4,349.00
Planer	$4,082.19
8 Medium Irwin Quick Grip Clamps	$52.72
Wet/Dry Vacuum	$199.00
Milwuakee Orbital Sander	$129.00
Router for Drill	$24.00
Hand Drill and Ratcheting Screwdriver	$216.00
Blowtorch	$27.88
Laser Engraver	$26,001.85
Total Capital Costs:	**$36,218.64**

It is also necessary to calculate the indirect costs associated with running a business, such as building space and utilities. These costs are estimated in Table 3; note that these costs are annual and must be paid every year as compared to the tooling which is a one-time purchase. The warehouse cost was approximated by "purchasing" 2000 square feet of warehouse space at an assumed monthly rate of $0.85 per square foot [4]. Next, the national average for utilities per year of $2.10 per square foot for a commercial building assisted in creating the utilities cost in Table 3 [5].

Table 3: Approximated Indirect Costs

Overhead/Indirect Costs:	Annual Cost:
Warehouse	$20,400.00
Utilities	$4,200.00
Total Annual Overhead:	**$24,600.00**

Initially, the team desired that the Customized Sidearm Case be able to function as a standalone business. However, a more fiscally feasible option would be to add the Customized Sidearm Case to the catalog of a previously established artisan woodworking business. This would eliminate the need to purchase all of the woodworking equipment listed in Table 2, potentially minus the laser engraver, as these are common pieces of machinery found in wood manufacturing operations. This idea was posed by one of the members of the team as their father owns a small cabinet making operation and possesses all of the equipment used to create the sidearm case minus the laser engraver. Furthermore, the price listed for the laser engraver in Table 2 matches the price of the engraver used by the team currently owned by the Center for Manufacturing Excellence. However, it would be possible to purchase a slightly smaller, less expensive laser engraver to cut down on the additional cost. Adding the Customized Sidearm Case to the product line of an established company would also significantly decrease the overhead cost accrued annually and allow any additional income created by the sale of these cases to count as pure profit for the company (minus the raw material and labor expenditures).

I decided to adjust the initial overall business model due to the specific product we were creating. The Customized Sidearm Case, unlike many products in the current market climate, is designed to last "forever" with the potential to be passed down through generations as a token of a military family's service to their country. Eventually, the product will saturate the market and the profit created by the sale of subsequent cases would have the potential to be unable to keep pace with the necessary overhead cost. New sidearm cases would only be purchased at a rate similar to that of the number of men and women joining the military each year. Another option would be to extend the

range of customization option beyond just the members of the United States armed forces. However, for the purposes of the capstone experience, I wanted the product to remain a memorialization of all those who have sacrificed everything to keep the United States free for democracy. Assuming the Customized Sidearm Case was not a standalone business also allowed the team to create a selling price point close to those outlined in the original marketing survey while still maximizing profits.

FINAL PRICE POINT

The last calculation necessary to create a selling price for the Customized Sidearm Case was labor cost. To estimate the labor cost, it was essential to determine the total time spent working to assemble one case. Every step was timed from the initial cutting of the wood to the inserting of the chain and recorded in Table 4. The individual tasks are measured in minutes, whereas the total is measured in hours.

From the table it can be determined that total assembly takes just under 1 hour and 45 minutes. It should be noted that this is purely time spent with a laborer's hands either on the box or moving it to the next process, i.e., this does not involve the different glue/polyurethane drying times or the total time spent in the laser engraver. The five-minute time allotment for the laser engraving process is simply the amount of time it would take a worker to setup and start the machine. The actual laser engraving process takes 30 minutes for the box and 15 minutes for the foam. During these "waiting periods," a worker could either begin setting up for the next process or start on a new order. Therefore, if an above average hourly rate of $25 per hour for a skilled woodworker is used to calculate the labor cost [6], it costs $43.75 to hire a worker to complete a single case.

Table 4: Time Estimate Breakdown

Finished Product Labor Time	
Process	Time (min)
Cut Side Wood	2
Cut Top Wood	2
Cut Dovetail	5
Router Bottom Slot	4
Cut Bottom Sheet	4
Glue Dovetails and Clamp	6
Cut Sides to Height	2
Plane Bottom of Box	2
Plane Top Piece	2
Glue Top to Bottom	2
Flush Cut Top	1
Sanding	10
Chamfer	5
Cut top off box	1.5
Laser Engrave Box	5
Laser Cut Foam	5
Torch Box	5
Polyurethane (Both coats)	14
Program RFID	3
Cut and Insert Hinges	10
Assembley (Foam, Chain, RFID, etc.)	12
Total Time (Hours)	**1.71**

In addition to the labor and raw materials cost, a $20 overhead cost would be added to each product in order to cover the previously mentioned cost of utilities, floor space, saw blades etc. Despite changing the business model to merge with a preexisting wood working enterprise, an overhead rate must still be accounted for in the final cost of each individual product. Therefore, the cost to produce a single box works out to approximately $152. With the previous research into the current market of artisan wooden sidearm cases considered, the team decided to set the base price for a single

Customized Sidearm Case at $250. This would include a full case assembled with hinges, RFID, foam, etc. and the primary laser engraved image on the top in addition to one image engraved on the front right of the box where the RFID lock is scanned to open the box. The image on the top of box would be selected from the six U.S. military branch seals or the American Flag design. The image at the RFID scanning location could be either a set of initials or a small image uploaded by the customer. Many of the boxes produced by the team during the production run included additional images, lettering, or mottos on both the front left of the box opposite the RFID lock engraving and the back of case (the laser engraver did not allow for images on the sides of the box due to case length). Additional engravings (up to five) could be added onto a customer's case at $10 per initialing/image and uploaded during the online ordering process necessary for this type of customizable product. However, these images would either need to be size restrictive or allow for variable prices. While initials may take only 2 minutes on the laser engraver, a full detailed image would take much longer and require more machining, increasing the cost. Thus, as a business producing these cases, an addendum on the online ordering site could be added stating that laser engraving prices are subject to change (with an email or similar messaging system confirmation). Customers could also contact the company about additional laser engraving customization either on the lip of the lid or on the bottom of the case for a negotiated cost. Lastly, the decision to burn the wood for a darker visual appearance was personal preference of the team and could be eliminated from the process at the request of any customer who favored a lighter wood look at no additional cost. With the numerous potential customization options, the Customized Sidearm Case would bring in a profit of roughly $100-$150+. In order to cover the cost

of the $26,000 laser engraver purchased by a previously established woodworking manufacturing operation, 208 sidearm cases at an average of $125 profit per case would need to be sold before any additional income sourced by the cases could be considered pure profit.

CHAPTER 6: PRODUCTION RUN

BUDGET OVERRUN

My primary failure as the project manager resulted from a rushed decision at the end of the fall semester. In preparation for the final production run that would take place in early February and be observed by several members of the CME faculty, I instructed the team buyer to place an order for the wood, RFID's, hinges, and foam necessary to construct 14 Customized Sidearm Cases. The goal of the final production run was to allow Mr. Gill and other CME faculty members the opportunity to watch the capstone teams run several products through the entire production process in order to make corrections, determine the viability of the fabrication process, and judge the team's performance over the course of both semesters. The final production run would serve primarily as the capstone experience's culminating event. I wanted to begin preparations immediately upon the completion of the team's final prototype. However, in doing so, I caused the team to run significantly over the original budget, compromising one side of the iron triangle. A complete breakdown of my capstone team's expenses is displayed in the Table 5.

Table 5: Customized Sidearm Case Team Expenses

Team Expense's Breakdown			
Item	Cost	Amount	Total
Wood Glue	11.99	1	11.99
Hinges	15.31	30	459.3
Foam Sheet	11.41	1	11.41
Sand Paper	5.99	1	5.99
Resin	40	1	40
Pigment	16.99	1	16.99
RFID	16.99	7	118.93
RFID (2nd Order)	19.99	7	139.93
Glue Scraper	26.48	1	26.48
Router Guide 101	28.74	1	28.74
Resin	70	1	70
Dove Tail Bit 17/32"	27.96	1	27.96
Router Guide 5/8"	7.12	1	7.12
Wood 1"X6"X8'	25.26	16	404.16
Router Guide 100	54.99	2	109.98
Foam 1"	28.13	3	84.39
Foam 3"	55.45	3	166.35
Aluminum Chain	9.99	1	9.99
1/4" x 4' x 8' Birch Plywood	33.38	1	33.38
#4 Gold 3/4" Screws (100-pack)	8.29	1	8.29
		Total:	**1781.38**
Paying for NOT using		**Final Budget:**	**1647.56**
CME paying for			

The items highlighted green in the above table show items that were purchased for use by the Customized Sidearm Case team but are being compensated by the CME as these items will be used by the manufacturing floor for future projects. The items in red highlight areas where the team ordered materials that did not make the final product design and are therefore provided no added value to the project. The final expense total for the team was calculated to be $1647.56, running over the initial $1000 budget by approximately 65%. This budget overrun was due to a lack of communication between

the accounting team and me as the project manager. A total of $1,133.16 of the final expenses were exhausted on the final material order alone.

The budget failure was an avoidable mistake for multiple reasons. The first solution would have been to order fewer materials and in turn not fabricate the original 14 sidearm cases desired by the team. The final production run would still have been successful without the need to produce a larger number of cases. However, the best solution would have been to approach Mr. Gill before the final material order and request an increase in budget. At the beginning of the capstone project, it was relayed to the teams that the $1000 initial budget was not an immovable number that teams were required to operate under. Additional funds could be requested through Mr. Gill and the CME in order to fill specific needs. Once the team realized its mistake, I made the immediate decision to report this misstep to Mr. Gill and accept full responsibility for the team's shortcomings. Mr. Gill explained that CME had the funds to cover this excessive spending and implored me and the team to use the situation as a learning opportunity. After all, the purpose of the CME capstone experience is to allow teams to succeed and fail in a learning environment where mistakes are less costly and can be studied for future prevention. In industry, a budget overrun of this magnitude could cost people their jobs. Therefore, it is essential to understand how this mistake occurred and what the team could have done differently. As the project manager, the most frustrating aspect of this shortcoming is that the entire situation could have been prevented with more communication and foresight. After calculating the raw material cost for a single case to be approximately $90, it is obvious that a material order for 14 boxes would not only overrun the budget when added to the previous team orders but surpass $1000 in this

specific order alone. Once the budget blunder had been addressed, it was time to begin preparations for the final production run.

PRODUCTION RUN PREP

Mr. Gill instructed all teams to have their production runs completed no later than February 11th. This gave our team four weeks to complete the final prototype as explained previously and to refine the entire production process to reduce error and increase repeatability. I scheduled the final production run for 12 PM on February 11th as this was the best time individual team members, Dr. McClurg (our advisor) and Mr. Gill, could all meet. It should be noted that two of the three accounting team members were participating in an internship and were not available during the build-up to the production run. It took two weeks to complete the final prototype, leaving two additional weeks to prepare for the final run. Over the course of these two weeks, Jordan Davis, Taner Douell, and I worked on the manufacturing floor for 2-6 hours per day every Monday through Friday, working tirelessly to have our project completed on schedule.

There are approximately five different drying processes that take place over the course of assembly for a single Customized Sidearm Case: gluing the dovetails together, gluing the pieces for the lid together, gluing the lid to the box, one coat of polyurethane, and a second coat of polyurethane. The dovetails and the lid can dry simultaneously, resulting in four different drying times lasting anywhere from 3 to 24 hours. Either way, it would be impossible for the team to assemble all 14 boxes from scratch on the day of production. Thus, the team decided to stage 2 cases at the end of every drying process, in order to walk Mr. Gill and additional CME faculty through the entire sidearm case fabrication process. The team would also have 4-5 already completed boxes on the day of

production. These boxes would serve as practice to perfect the production processes and would also be given to Mr. Gill, Dr. McClurg, and Mr. Andy Gossett (the CME's technical manufacturing floor advisor). These three people were instrumental in the success of the project and the team decided to gift them their own personalized sidearm cases as a memento of the team's capstone project.

As the team worked to complete and stage sidearm cases throughout the manufacturing process, jigs were created to prevent mistakes and ensure the tight tolerances necessary to create perfect-fitting case. These jigs are pictured below in Figures 11-15 and are followed by a brief description of their purpose.

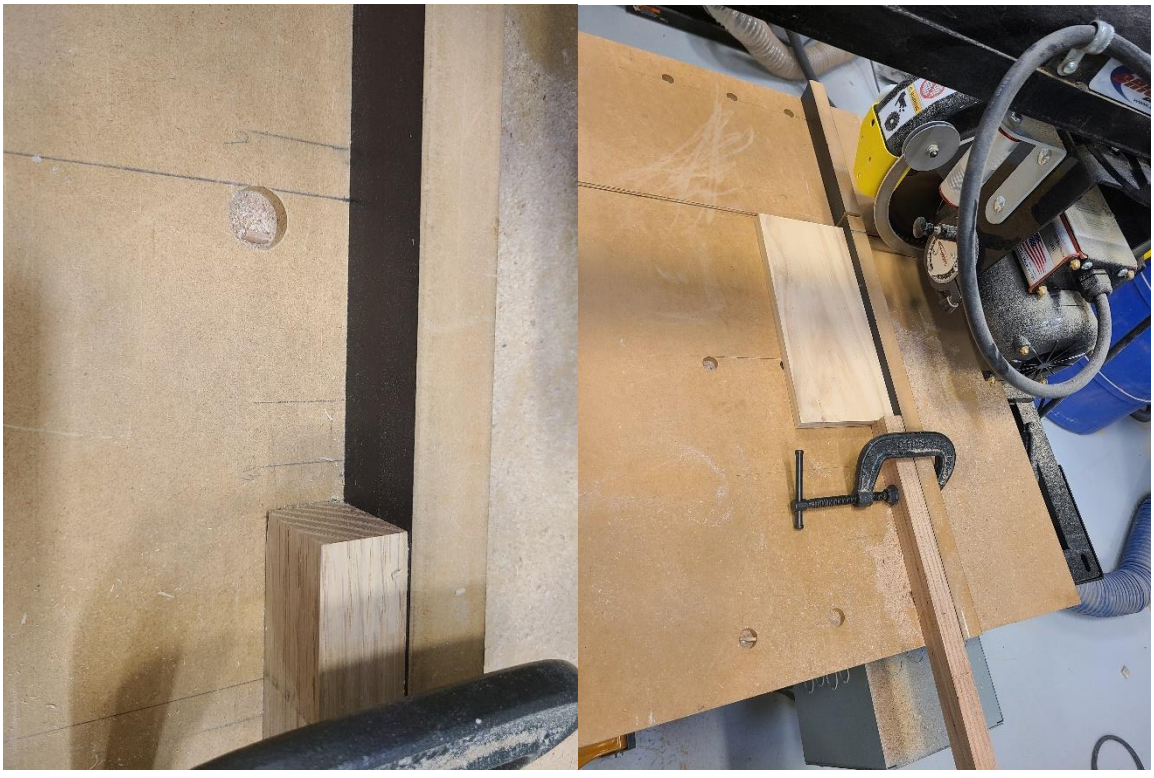


Figure 11A and 11B: Wooden Stops for Initial Cutting Process

Figures 11A and B display wooden stops used during the initial cutting of the pine boards. Figure 11A shows pencil markings at 9", 13", and 13.5". The piece of wood

would be lined up with the marking that correlated to the desired cut length and then clamped down. The pine board would then be slid along the table until contacting the stop and the cut made. During this process, ensuring that the side, front, and top boards were the same length as their counterparts was more important than ensuring they were exactly at the listed dimension. Thus, the stop was not moved until the next length of wood was set to be cut.

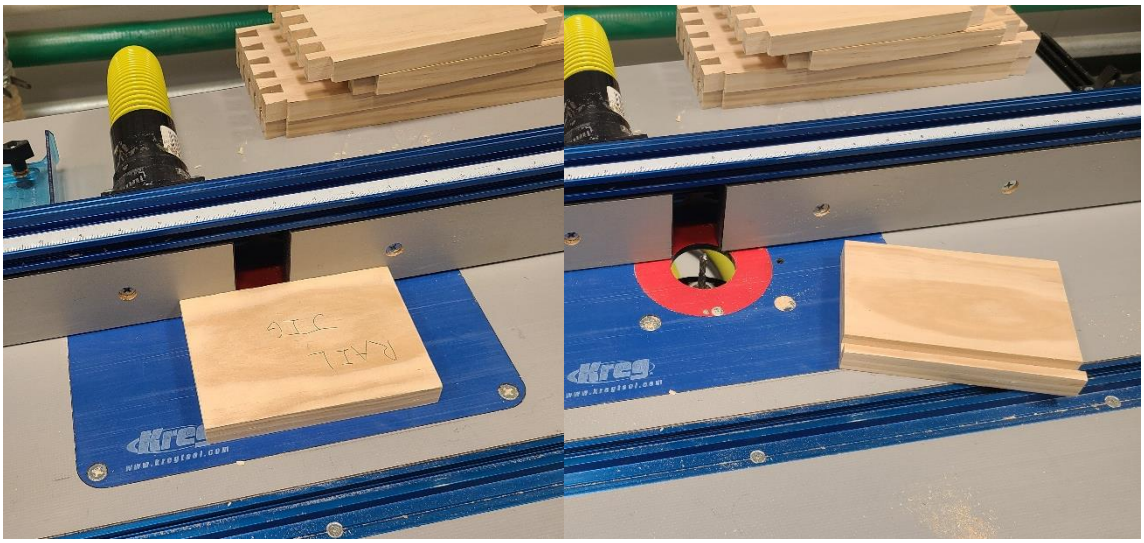


Figure 12A and 12B: Rail Positioning Jig

The rail positioning jig was used in conjunction with the table router to create the slot in the front and side boards of the sidearm case where the ¼” plywood would slide in to create the bottom of the case. The jig guaranteed the railing would be set the proper distance from the bottom of the box while also ensuring the router bit was set to the appropriate height for the depth of the cut.

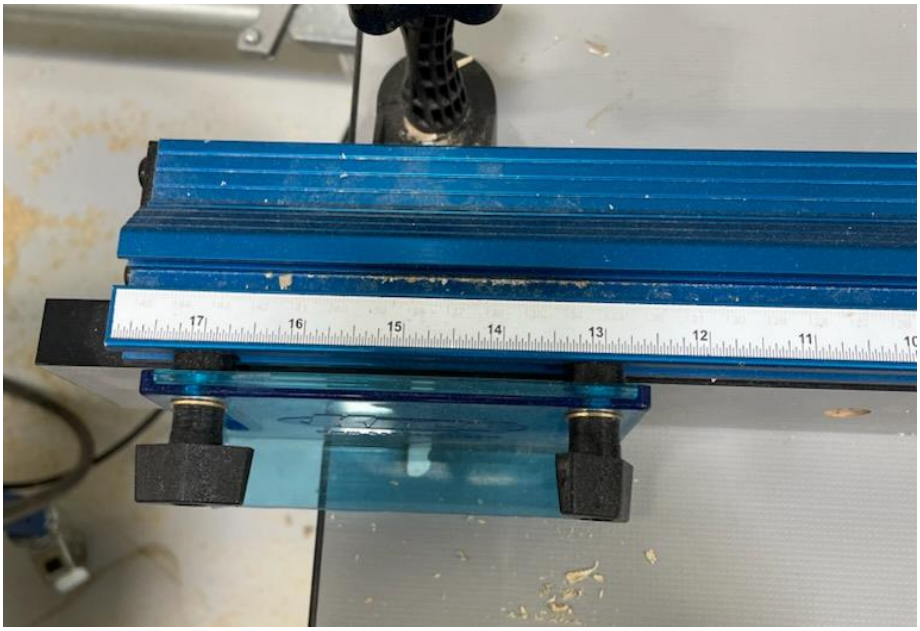


Figure 13: Lefthand Rail Stop

The jig displayed in Figure 13 was also used in the slot cutting process detailed in the previous paragraph. Figure 13 displays the lefthand rail stop used with the railing system on the table router. Stops were placed at both ends of the rail and used to ensure the slot did not cut farther than halfway through the dovetail on the longer front and back boards of the box to ensure the slot was not visible from the outside. These stops did not have to be moved for the smaller side boards because the slot could be cut all the way through without being visible once the sides were assembled.

Figure 14: RFID Cable Jig

The RFID cable jig was simply a piece of thin wood with a hole used to mark the proper location of the RFID cord that needed to be run through the bottom of the box. The piece of wood was simply placed up against the walls in the front right corner of the box and held there while a hole was drilled to make way for the cable.

Figure 15A and 15B: 1.5” Hinge Slot Measuring Block

The last jig created by the engineering team was the simplest of all. Figures 15A and B simply show a 1.5” wooden block used in tandem with the concealed hinge router guide to guarantee the hinge slots were exactly 1.5” from the outside of the box on both the lid and the box for perfect fit. The jigs were essential in preventing defects in the product and allowing for ease of assembly. Although the jigs solved several of the team’s inconsistencies in the production process, there were still a few more lessons learned over the course of the manufacturing and staging of the remaining sidearm cases.

An unexpected difficulty that arose in the build-up to the final production run revolved around the fit of the hinges. In the last 2-3 days leading up to the final production run, most if not all of the partially completed cases had been successfully staged throughout the fabrication process. The team had shifted primarily to finishing the five boxes to be distributed at the conclusion of the production run. However, the hinges

were suddenly no longer fitting into the slots cut using the proper router guide. The hinges had fit on the previous prototypes using the routing method. Not long after, the team realized that we had moved the hinge slotting process to after the polyurethane was applied. This created an extra layer of material that needed to be cut. Previously, the depth of the cut was set on the router by measuring the depth guide off of an actual hinge. To correct for the additional material, a slight offset was added to the depth gauge on the router to allow for a deeper cut and a more proper fit.

The next hurdle encountered was finding a quick method to cut the foam to the desired dimensions without burn marks. The team used the laser engraver to cut the foam during the prototyping process, however, this led to visually upsetting burn marks at the top of the foam. Nevertheless, the team needed to use the laser engraver in order to create precise dimensions for both the overall foam size and for the slots used to place the RFID locking mechanisms. The solution was to simply alter the orientation of the foam. The foam originally was cut with the peaks facing away from the laser engraver. Therefore, the team decided to rotate the foam and allow it to be cut with the peaks facing the laser. Although there was still slight scorching, it appeared towards the bottom of the foam where the customer would not be able to notice. Using the laser also allowed the team to cut up to six pieces of foam at once saving valuable labor time. In hindsight, the solutions to these problems should have been somewhat easily discernable. Yet, on multiple occasions in the days leading up to the final production run, morale dipped and frustrations abounded.

MANAGING MORALE

The role of a project manager requires not only the careful monitoring and supervision of tasks, money, and schedule, but also the management of people. As a project manager, people are often your most valuable resource. The workers (in this case students) assigned to your project will determine the level of success achieved for a given enterprise. If workers are invested and content with the work they are performing, then anything is possible. However, disgruntled or bitter employees can derail a project as quickly as any budget cuts or delayed shipments can. This management of my fellow teammates is one area I could have improved upon. I was not as successful at engaging the accounting team and ensuring they were producing both the quantity and the quality of work that was required. If a piece of work or writing was not what I anticipated, I would fix it myself rather than send it back and ask them to adjust it accordingly. Being in charge of your peers can be a difficult assignment and in order to prevent the work overload experienced by the engineering team I should have been more effective at delegating tasks both properly and evenly.

This unequal work distribution was part of the problem that led to frustration and irritation a few days before the final production run was set to take place. As problems such as the hinge complication arose with no solutions in sight, morale dropped. It was not this singular difficulty that caused problems but rather a multitude of factors that had finally reached a tipping point. The team had been working for hours every day outside of the time necessary to attend classes and complete homework in order to ensure the project stayed on schedule. All other capstone teams, besides one, had their production runs postponed because they were not at the standard desired by Mr. Gill. While this was

a compliment as it meant we were one of two teams on schedule and up to par, it was still disconcerting to see others have more time to work on their projects when they had not put in the necessary effort. Ultimately, problems were solved, irritation subsided, and the team had a very successful final production run. Nonetheless, it is still essential to understand that managing human emotions can play into the success of a project as much as having the right equipment to make a given product. By engaging your team and keeping them personally invested in the success of a project, it is possible to achieve amazing results.

PRODUCTION RUN DAY

The production run was set to take place Friday, February 11th at 12 PM. The engineering team and Mitchell from the accounting team arrived at the CME factory floor to make the final adjustments at 8 AM. The team moved some of the equipment used to more centralized locations in order to give the fabrication process more of an assembly line feel. Figure 16 shows the layout of machinery that would be utilized in a business setting where the Customized Sidearm Case was product being produced day after day.

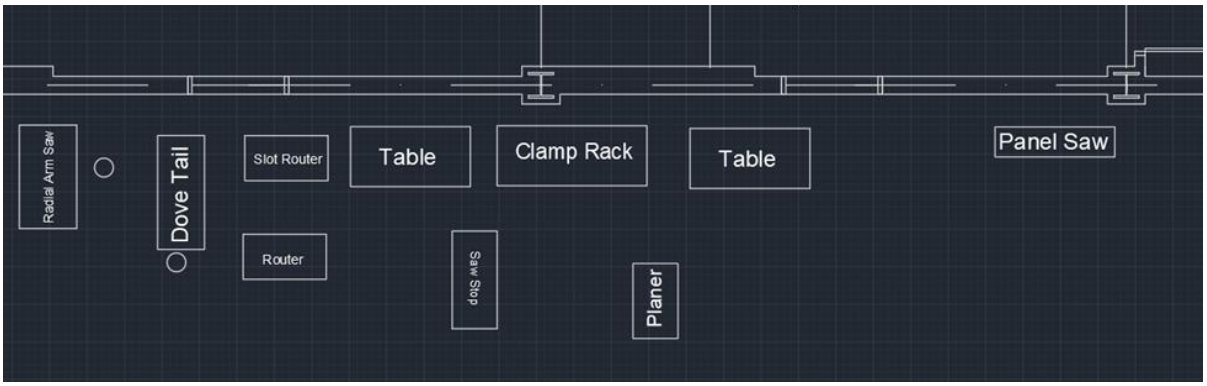


Figure 16: Ideal Manufacturing Floor Layout

The team moved some of the pieces of equipment to match the ideal setting, however some of the larger pieces of equipment could not be moved without the use of a crane system.

At 12 PM Mr. Gill, Dr. McClurg, Mr. Gossett, and several other CME faculty and staff members gathered for the team's presentation of the Customized Sidearm Case's production process. Each attending faculty member was given a brief two-page step-by-step guide to the production process created by the engineering team to assist the observers in accurately following the production process. Once everyone was assembled, the team began performing and explaining every single step of the production process to the accompanying onlookers. Figure 17 – 23 show several highlights of the final production run and are explained by the accompanying caption. The figures are organized in process order.

Figure 17: The Team Walks Through the Dovetail Joint Process

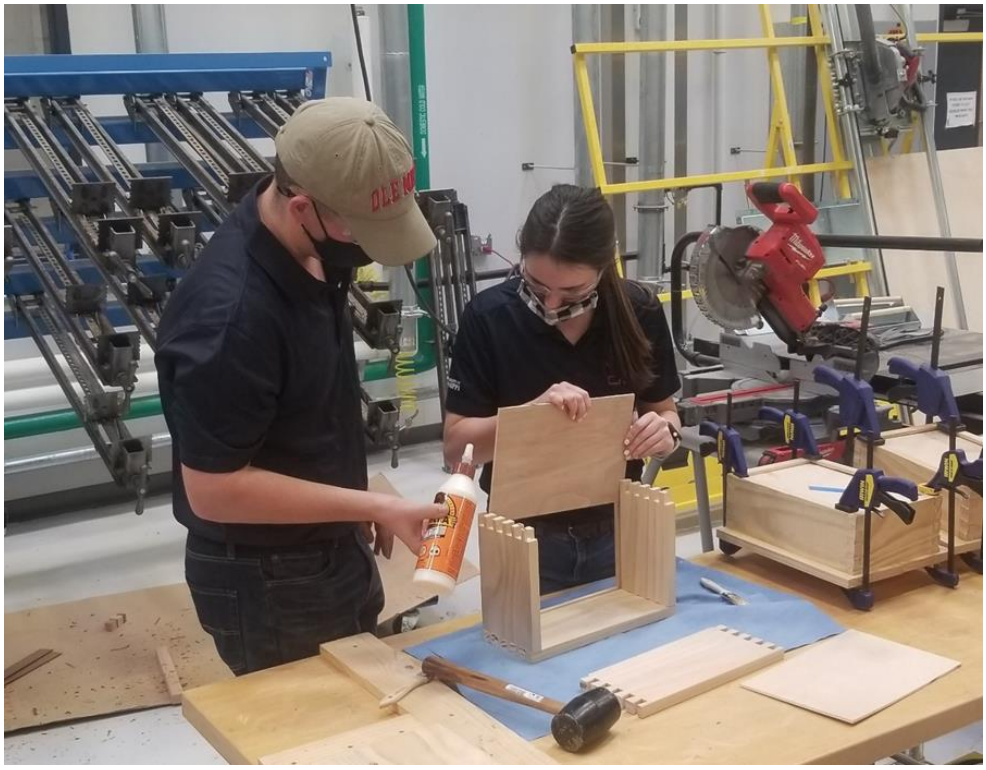


Figure 18: Team Members Assemble the Sides/Bottom of the Box

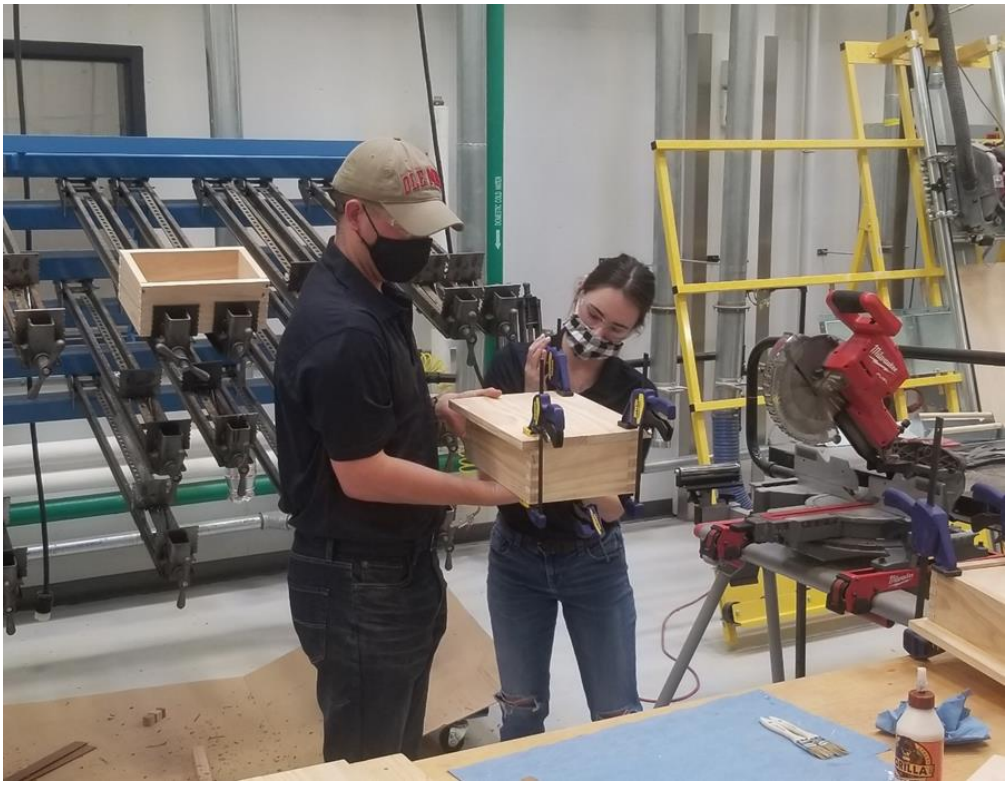


Figure 19: Team Demonstration on How the Lid is Glued and Clamped

Figure 20: Team Members Cut the Lid Off the Case

Figure 21: Explanation of the Laser Engraving Process

Figure 22: Torching the Case Demonstration

Figure 23: Capstone Team Demonstrates Final Assembly

The Customized Sidearm Case team's final production run was a resounding success. There were no major errors or mishaps over the course of demonstrating the process for Mr. Gill. The team answered all questions and explained any decision that was made with definitive reasoning. A suggestion was made from the audience that included removing the clamp rack from the equipment used by the team. This piece of equipment was originally necessary to ensure the box glued together correctly. However, as the team perfected the dovetail joint process, the clamp rack became obsolete, and the team heeded the advice and removed the clamp rack as a necessary piece of project equipment allowing for additional cost savings. Once the exhibition was concluded, the team received excellent feedback from Mr. Gill and others. The following comments were made to different team members by several different observers: "This project is definitely receiving an A;" "This is one of the best projects to come through the CME;" "Your team was the hardest working, and the product shows it." Comments such as these made all the stress, frustrations, and time spent on the factory floor worthwhile. Although not perfect, all the members of the team could now graduate with their heads held high, knowing they constructed a successful product from design to full production. Figure 24 displays the final product and Figure 25 is a photo of the team present on final production day, along with the team's advisor, Dr. McClurg.

Figure 24: Open-View of Finished Customized Sidearm Case

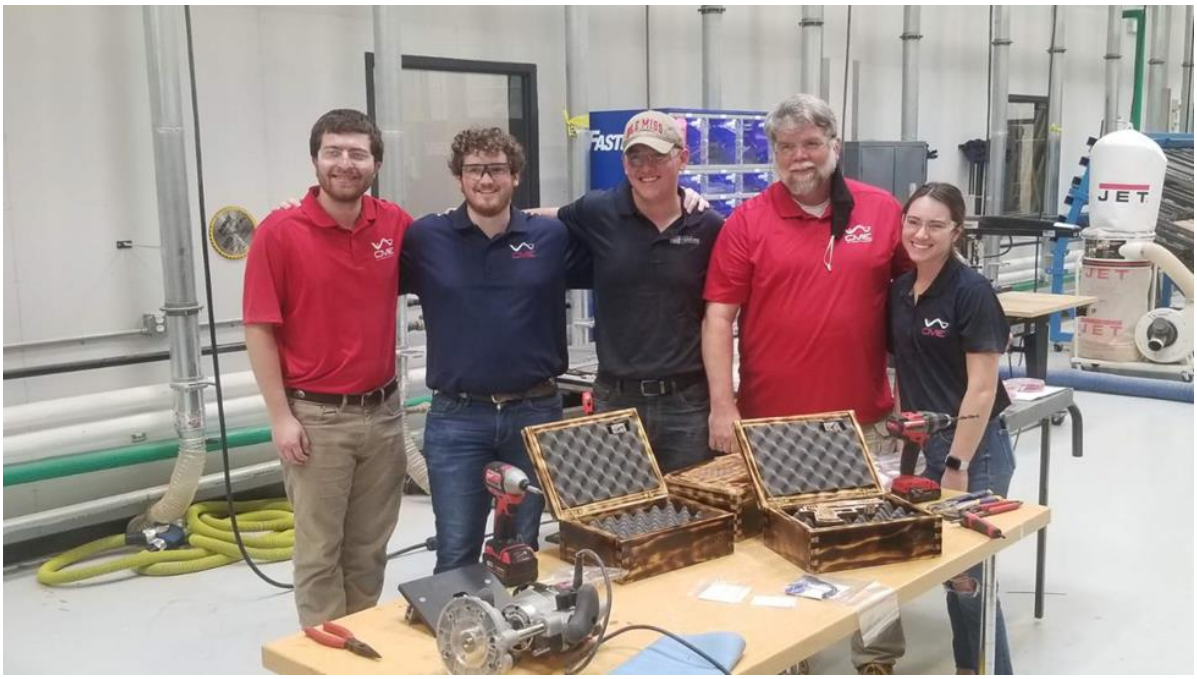


Figure 25: Production Day Team Photo
(From Right to Left) Mitchell Boulanger, Taner Douel, Boston Sharp, Dr. Jack McClurg, and Jordan Davis

CHAPTER 7: CONCLUSIONS

PROJECT MANAGER SELF-EVALUATION

Working as a project manager during the Center for Manufacturing Excellence's Capstone Experience taught me valuable lessons that I will be able to apply in the future both as an officer in the United States Marine Corps and post-military as I return to the world of engineering. It is important to analyze my performance as a project manager over the course of the project to improve in my shortcomings and strengthen my positives. As stated previously, the iron triangle is a favorable evaluation tool to measure both the project and the project manager. During the design process for the Customized Sidearm Case, I was able to gain a better understanding of the relationship between scope, schedule, and cost.

The obvious shortcomings of the project involved the cost portion of the iron triangle, as I allowed my team to overrun our initial budget by a significant portion. For the purposes of the capstone experience, I did not face any significant consequences. However, to overrun a project budget by greater than 60% can be detrimental to one's career, not only as a project manager but possibly with a company as a whole. It should also be noted that I was able to overrun the budget and still order the parts the team needed because there was no purchasing or accounting department to prevent the team from placing these orders. In industry, this type of order would probably not have been able to be placed and a solution would have to be created as to how to achieve the scope

of the product without the “necessary materials.” However, the argument can also be made that by following through with the final material order that caused the excess spending, the team was able to stay on schedule (unlike many of the other capstone teams) and create a more valuable product that appealed to the customer. The product effectiveness was demonstrated by the amount of people that complimented the final design of the sidearm case, with the team being asked on several occasions if they could make extra for students or faculty to purchase. This example shows the balance of the iron triangle and how a negative in cost developed into positives in both time and scope.

A project management area where I experienced both positives and negatives was my people management skills demonstrated during the course of the project. I recruited two excellent engineers and was able to invest them into the idea of the project that allowed me to turn the initial design concept proposed in my head into a successful tangible product. In contrast, I was not able to effectively manage some of the other team members who were assigned to the product at random and that created contention as a large chunk of the work fell to me and the two engineers I recruited. My tendency to want to do everything myself is not a quality trait desired in a project manager. A project manager must understand how to motivate even the people who were not originally enthusiastic about a given assignment, as any project manager understands there will be unmotivated people assigned to their project. In the future, I must be sure to improve how I distribute the workload to prevent the low morale of the team members I desperately needed to join my project.

Project Managers are judged primarily by the outcome of their project. In this regard, I believe my overall performance was a success. The Customized Sidearm Case

was labeled an excellent product by faculty, staff, students, friends and family, but most importantly by Mr. Gill acting in the role of upper management for the CME's capstone experience. The project was delivered on-time and well above the minimum quality necessary to successfully complete the capstone requirements for the Center for Manufacturing Excellence. The most important compliment that I received was given by the CME's manufacturing floor technical advisor, Mr. Andy Gossett. He told me that my team put in the most effort and was one of the hardest working capstone teams he had seen in years. He admired not only the effort but the care the team took to ensure we designed and produced a product truly worth creating a business around. These are the words that stick with me, and although I was not perfect as project manager, I believe my performance accurately reflects how I want others to view my professionalism and my commitment to success.

BIBLIOGRAPHY

[1] CME Website, https://cme.olemiss.edu/, 3/10/22

[2] Ole Miss Course Catalog, https://catalog.olemiss.edu/engineering/manf-451, 3/10/22

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

[4] "How Much Does it Cost to Rent a Warehouse" https://www.prologis.com/what-we-do/resources/how-much-does-it-cost-to-rent-warehouse#:~:text=Average%20base%20rental%20rate%3A%20%240.85, 4/3/22

[5] "What Is The Average Utility Cost Per Square Foot Of Commercial Property?" https://www.iotacommunications.com/blog/average-utility-cost-per-square-foot-commercial-property/#:~:text=The%20answer%3A%20The%20average%20cost, 4/3/22

[6] "Hourly Wage for Skilled Woodworking Carpenter Salary in the United States," https://www.salary.com/research/salary/alternate/skilled-woodworking-carpenter-hourly-wages, 4/10/22