**Team 1A: Firearms Disposal**

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## EXECUTIVE SUMMARY

### Design Problem

There are many ways that an individual can come into possession of a firearm. For those who possess firearms they no longer want, there are few options available to dispose of them. This project aims to create a safe and publicly accessible product that completely destroys unwanted firearms to prevent any firearm components from going back into circulation.

### Customer Requirements and Engineering Specifications

Since safety is our highest priority, the product needs to meet the NIJ 0108.01 Standard level IV bullet proof requirements and the destruction component must be far away from the user at all times. The product must be able to accept firearms of all sizes and must be able to store the waste product of the destroyed firearms. The product must destroy firearms according to the ATF guidelines using one of the following methods of destruction: shredding, melting, crushing. In order for the product to be mobile, it must fit within the footprint of a shipping container and should be within the allowable weight that can be transported by a semi-truck. The product must be modular and have readily available replaceable parts.

### Concept Selection

After compiling all of the team's generated concepts into a table, the team categorized and sorted each concept by its method of destruction. We then selected the best concept out of the different categories and then compared them side by side to see which one is ideal for our project.

### Presentation of Final Concept

Our final design concept accepts a firearm through the kiosk opening, prompts the user to close the kiosk door, then transports the firearm to an industrial shredder where it is shredded and turned into scrap. Figure 1 below shows a picture of the build design.

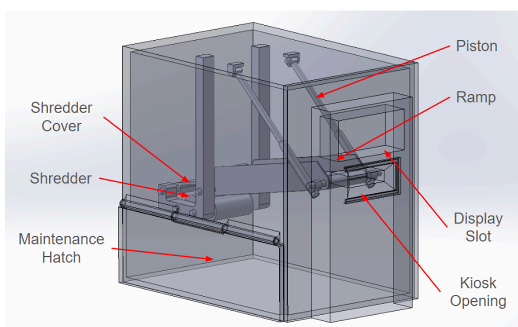



**Figure 1.** Above shows prototype design with adjusted transparent level on the outer shell.

### Engineering Analysis

We analyzed possible destruction methods (shredding, crushing, melting), shredder selection, maximum overall size, firearm size acceptance, waste container, maximum weight requirement, safety distance, and bullet proof standard. Method of shredding was chosen for destruction from analysis due to the smaller and easily managed waste produced and a lower chance of error occurring.

### Expected Deliverables

Our team presented two different models. The first model is the prototype CAD model and a 1:10 size scale model to show people physically what happens to an object when going through our prototype design.

**TABLE OF CONTENTS**

**INTRODUCTION**

There are limited options available for individuals to dispose of unwanted firearms. The current disposal options include turning the firearm into your local police station, selling it at a police gun buyback event, selling it to a gun enthusiast or gun shop, and destroying the firearm yourself (DIY).

Many individuals do not want their firearms to be put back into circulation or resold with the potential of causing harm. Aside from the DIY method, none of these options guarantee that the firearm will be completely destroyed and left unuseable.

The DIY method is up to the user's discretion and could pose the risk of the gun being restored or reconstructed. The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) has a set of guidelines that detail how to destroy your own firearm. These guidelines allow the use of the following destruction methods: cutting with oxy-acetylene torch, melting (smelting), crushing, or shredding the firearm [2]. The average individual most likely does not have access to such equipment or machinery. As for police gun buyback events, individuals are informed that their firearm will be destroyed, but they are sent out to a third-party destruction service where destruction cannot be guaranteed. This project aims to create a safe and publicly accessible product that completely destroys unwanted firearms to prevent any firearm components from going back into circulation.

**Benchmarking**

There are few gun disposal options that offer complete destruction of the firearm. Firearms that are obtained during police gun buyback events are sent to third-party companies that advertise firearm destruction. One of these third-party companies, GunBusters, offers firearm disposal for law enforcement agencies only. They do not offer disposal for civilian firearms. Firearms that are obtained during gun buyback programs are picked up from the law enforcement agency by GunBusters and are taken to their facilities for destruction, they are not destroyed on the spot. Once at the GunBusters facility, the firearms are stripped of any components that can be resold, which is a concern for many people who would like their firearms to be fully destroyed and unable to cause harm [3]. The remaining components are then destroyed using their patented firearms pulverizer system [4]. This system utilizes cameras within the machine to document the firearm serial number, make, model and record a video of its destruction. This documentation is then sent to the law enforcement agency to be maintained in their database and to be sent to the National Firearm Registry.

GunBusters is only required to destroy the receiver of the firearm. Every other usable component is resold and can be used in other firearms. Figure 2 shows an exploded-view of a common firearm, a Sig Sauer P320, with the receiver highlighted in yellow. All other components could potentially be resold.

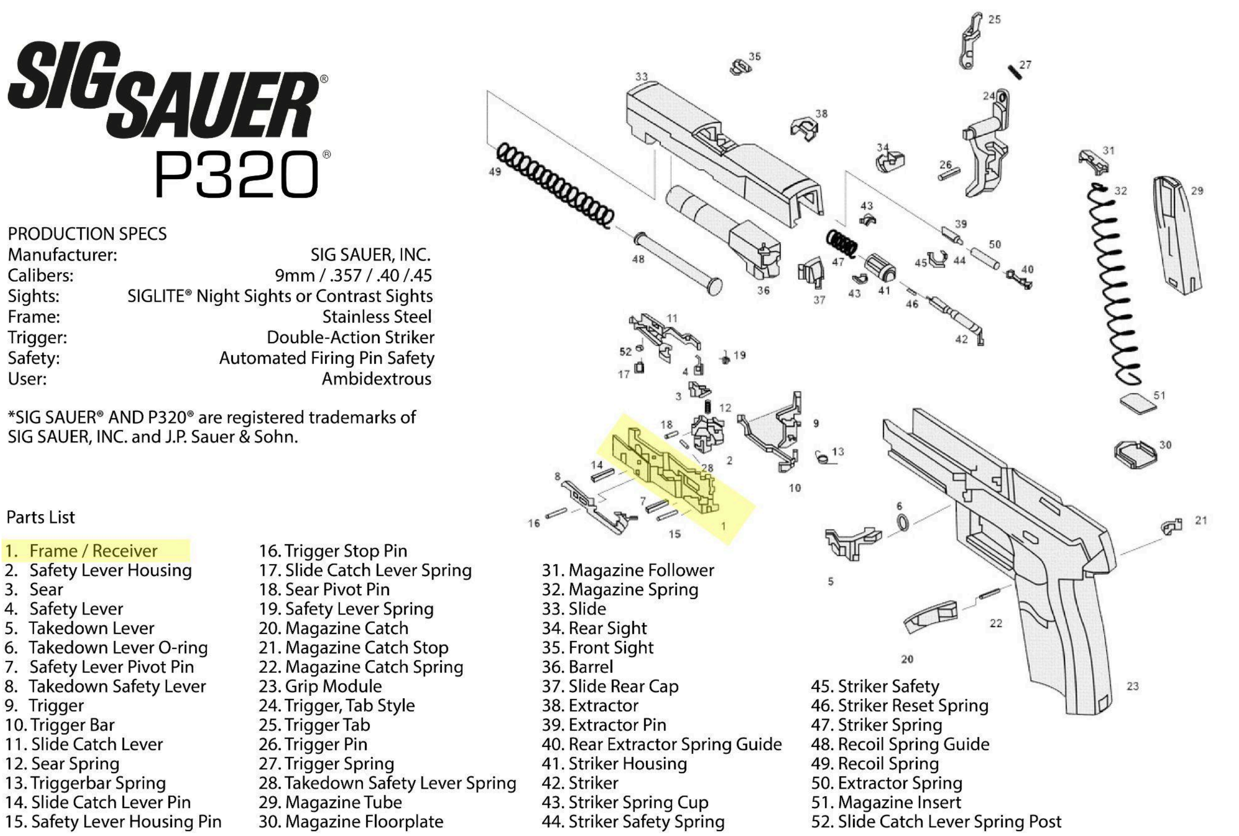



**Figure 2.** an exploded-view of a common firearm, a Sig Sauer P320, with the receiver highlighted in yellow. All other components could potentially be resold [5].

Do it yourself, DIY, is accessible to anyone with access to proper tools to dispose of their firearms. According to the ATF guidelines, if an individual wants to properly destroy their firearms, they will need access to equipment for the following methods of destruction: cutting with an oxy-acetylene torch, melting, shredding, or crushing [2]. The DIY method of disposal offers guaranteed destruction because the user will be the person executing the destruction. There is no documentation for this method unless the user records the firearm serial number and destruction evidence and submits it to the Nation Firearm Registry (NFR) themselves.

Table 1 below shows the current options for firearm disposal that have the possibility of complete destruction of the firearm. We have excluded disposal options that do not offer destruction, such as resale. We have organized the disposal options in the following table to compare their aspects of accessibility, if destruction is guaranteed, if documentation is sent to the National Firearm Registry, and whether or not the destruction happens on the spot.

**Table 1.** Benchmarking of current firearm disposal options.

| | **Police Gun Buyback Event** | **Gun Busters [3]** | **DIY [2]** |
|---|---|---|---|
| **Accessibility** | Only to registered owner of firearm | Only law enforcement | Anyone with access to proper tools |
| **Destruction Guaranteed** | No | No | Yes |
| **Documentation Sent to National Firearm Registry** | Yes | Yes | No |
| **On the Spot Destruction** | No | No | Yes |

These disposal options described above have a gap in accessibility. We are aiming to design a product that can allow anyone to deposit their unwanted firearm to be completely destroyed. This product should not request for any identities from the user or document any information such as the firearm's serial number, make or models, so users can remain anonymous while disposing of their unwanted firearm.

There is also a gap in the destruction aspect of the disposal. Police gun buyback events and third-party services, like GunBusters, do not destroy firearms on the spot, so destruction cannot be verified. The DIY method allows for verified destruction, but individuals are limited in using this method due to expensive equipment and machinery which can be unsafe to operate. Our design will allow the individual to verify that their firearm was destroyed on the spot without purchasing any equipment or endangering themselves or their community.

**Stakeholders Analysis**

Our team grouped the stakeholders into five different groups - customers and beneficiaries, resource providers, opponents and problem makers, bystanders and potential allies, and complementary organizations and allies. The stakeholders map is shown on the following page in Table 2.

**Table 2.** Stakeholders map

| Customers & Beneficiaries | Resource Providers | Opponents & Problem Makers | Bystanders & Potential Allies | Complementary Organizations & Allies |
|---|---|---|---|---|
| Community Residents | Sponsor | Gun Manufacturers | Media Outlets | Community Groups |
| Schools | | Gun Supporters | | Schools |
| | | | | Medical Providers |

Our project's customers and beneficiaries are any individuals with unwanted firearms. Their needs are important because we require them to trust this project to destroy their firearms if we want them to use our product. One example of this group is Shane Hooper, a 31 year old unwanted gun owner. He stated he is wary of gun buyback programs specifically because he does not trust police departments to destroy firearms [6].

Community residents and local business owners are also important beneficiaries because they benefit from less risk of gun violence in their communities. Their needs are important because they may advocate their local government either for or against this project if their needs are met or not met, respectively.

The important resource provider is our sponsor, David Humphreys, who will be providing the funding necessary to conduct necessary testings and create this product to put in communities.

Gun law repeal activists could be an important opponent or problem maker. There is a high chance that they are against a product that removes firearms from circulation. Their needs are important because we need to appeal to their concerns to avoid them opposing this project in their communities. It is extremely important that we emphasize the fact that we are only asking for unwanted firearms to be turned in. We are not, in any way, attempting to get people to give up their firearms or their rights to own firearms.

An important bystanders and potential allies would be media outlets. They are not affected by the outcome of this project, but they have influence over communities that may either support or oppose us. An example of a supporting media outlet is the Huffington Post with their article "It's Way Too Hard To Dispose Of Unwanted Guns In The U.S." [7]. Articles such as this that call out the lack of gun disposal options have the potential to inform the public about our product.

Gun control advocates could be important complementary organizations and allies. They believe in reducing the number of guns in communities and agree with our cause. Their needs are important because their support is crucial in informing the community about our product. An example of gun control advocates is Moms Demand Action, an organization fighting for public safety measures to protect people from gun violence incidents [8]. Having a large organization like them as an ally not only gives our product a strong support but may also help inform the public about the product's existence.

Out of the mentioned stakeholders, community members, business owners, and schools will be affected positively because they will see a reduction in firearms in their community, so less accidental injuries and hopefully less gun violence. However, immediate neighbors to the resting place of our design may be affected negatively if the unit produces lots of noise or waste, so we will need to keep them in consideration.

**Intellectual Property**

There are already patents for some methods of firearm destruction. GunBusters owns a patent for their firearms pulverizer machine which documents the firearms serial number, make, and model and then provides this information to law enforcement [3]. There is another U.S. patent for a "Destruction unit and firearm with said destruction unit and method for rendering a firearm inoperative" in which a molten filler material is poured into the barrel of the firearm to render it inoperative [9]. We have also found a World patent that utilizes the crushing method for destroying a firearm, "Weapon demilitarization system and process" [10]. Like GunBusters, we could potentially patent our destruction process combined with unique safety and mobility features. We will own the intellectual property that is created in this project, since we were not required to sign an intellectual property agreement with our project sponsor or the University of Michigan.

**Design Process**

We followed the ME450 design process, shown below in Figure 3. The ME450 design process is well-structured and provides guidance to novice designers, making the process less time-consuming and more productive during the semester. As the team consists entirely of ME450 students, we found the ME450 design process to be the most useful for our project for the presented reasons.

A model based on Design Build and Test was considered. However, while this model provided a perspective, it offered few guidelines and was test-based. In our case, a test-based design process would not be cost-effective and could expose team members to danger due to the nature of the project we are working on.

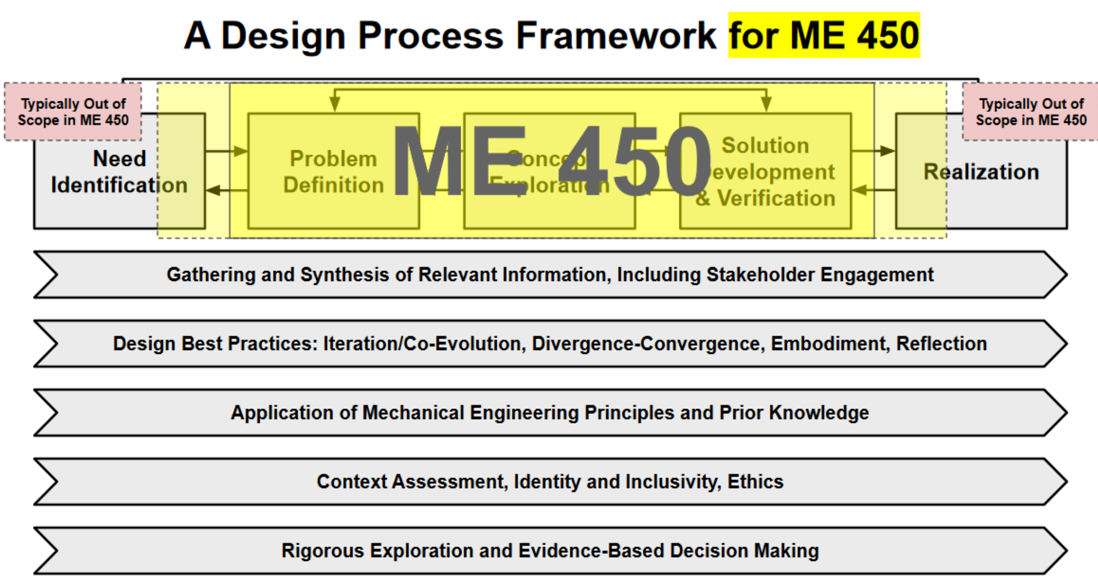



**Figure 3.** Standard ME450 design process model

After deciding on the ME450 design process, we made use of the Tools box in every stage of the model, which helped in the formation of the problem definition and the concept exploration. To generate concepts, we have utilized different tools like brainstorming, TRIZ, and Design Heuristics. Our team tried not to dwell much on the need for identification as it is slightly outside the scope of ME450. In the meantime, we focused on the problem definition, concept generation, and solution development and verification.

**Information Sources**

A key information source that has guided our work is the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) [2], which provided the guidelines for proper firearm destruction, firearms safety and regulatory compliance. Additionally, Michigan firearm disposal records [11] supplied information on the procedures that the Michigan State Police follow for the disposal of firearms, such as legal requirements, internal policies and methods of disposal. They also provide a list of weapons slated to be destroyed in the next 60 days. Our sponsor, Dr. Humphreys, provided a memo from the Philadelphia DA's Office [12] which details the legality of gun disposal. It was difficult to find information on current firearm destruction specifications, such as the force required to crush or shred a firearm, so we were required to do a first principle's analysis for each destruction method. In order to complete these analyses, we gathered common firearm material specifications and properties from AZOM and MatWeb.

**USER REQUIREMENTS AND ENGINEERING SPECIFICATIONS**

To determine our project's engineering targets, we first created a list of the stakeholder's requirements. We then assigned one of the following categories to each condition: engineering requirement, project constraint, or wish. Below in Table 3, we have listed the stakeholder's requirements with their assigned category and justification.

**Table 3.** Stakeholders requirements with their assigned category and justification

| Condition | Category | Justification |
|---|---|---|
| **Anonymous** | Project Constraint | Will not restrict anyone from turning in an unwanted firearm; identification is not required.<br><br>Firearms will not be investigated for possible involvement in crimes. |
| **Accessible** | Project Constraint | Ideally, the project will be placed within the community to collect firearms, so it must be usable by all community residents. |
| **Accepts all firearms** | Engineering Requirement | Firearms come in many different sizes, we must be able to accept all firearms, no matter the size. |
| **Safe to the community** | Engineering Requirement | The community needs to be protected from accidental discharge of a firearm inside of the disposal unit. The unit should follow bulletproofing guidelines. |
| **Destroy firearms** | Engineering Requirement | Firearms will be completely destroyed and cannot be restored to firing condition. |

It is important to our sponsor that our solution be anonymous for those who are looking to dispose of unwanted firearms. Current firearm disposal options require the person submitting the firearm for disposal to identify themselves and they must be the registered owner of the firearm [6]. As we have found in our research, there are many reasons for a person to come into the possession of a firearm that is not registered to them. For example, Gregory Bloom inherited a pistol and he noticed that its serial number was altered, which is a federal crime. He reached out to at least three different police departments and none of them was able to take it away from him. This experience led Bloom into thinking he is stuck with the illegal firearm with no clear way of disposing [13].

One of the current firearm disposal options, Gun Busters, uses their patented firearms pulverizer machine to document the firearm's serial number, make, and model and then provides this information to law enforcement [3]. In contrast, our product will not require identification from the user or the firearm submitted for disposal. This will offer anyone who possesses an unwanted firearm an option to properly dispose (meaning completely destroy) the firearm without fear of legal consequences.

One of the most important requirements of our project is being safe to the user and community. Since our project will be placed and operated in public spaces within the community, safety is of extreme importance. To determine the necessary requirements of safety, we will be using the Ballistic Resistance of Body Armor NIJ Standard 0101.06 and 0108.01 [14][15] and other engineering standards for the different levels of bulletproofing. Another important requirement to our project is that the product must destroy firearms. We followed the ATF guidelines and research on properties of materials used to manufacture firearms to aid us in finding the appropriate destruction specifications.

We believe our team's engineering specifications are reasonable. We were able to find standards from online sources detailing the different levels of bulletproofing and we utilized the specifications listed on our desired level and incorporated them into our engineering specifications. However, not all the requirements were able to be translated into engineering specifications. For example, it is difficult to quantify the requirement of "anonymous". For this reason, we have categorized this requirement as a project constraint rather than an engineering requirement.

**Requirements and Specifications for Subfunctions**

Our team has divided the project into three different subfunctions. The first subfunction applies to the overall project. The next subfunction is storage, which is responsible for storing the waste of surrendered firearms after destruction. The third and final subfunction is destruction, which is responsible for destroying the surrendered firearms.

**Requirements for the Overall Project**

Below in Table 4, our team has listed requirements and specifications for the overall project. The requirements in this section apply to all other subfunctions. Our product needs to have modular and replaceable parts to help reduce repair time and increase ease of maintenance. This is due to the fact that the project is non-profit, having the product be easier to repair would be highly beneficial. The modular parts also need to be readily available. We also want the product to be portable, so its maximum dimensions need to be just smaller than a shipping container footprint to allow easy transportation of our firearms disposal unit. The product must also be within the allowable weight that can be transported by a semi-truck.

**Table 4.** Requirements and specifications for the overall project.

| Requirement | Specifications | Justification |
|---|---|---|
| **Must be modular** | The product must have > 2 modular and readily available replacement parts | Easier to replace broken components [16], sponsor requirement [1]. |
| **Must be safe to the users and community** | Level IV bullet-proof material (NIJ Standard 0101.06, 0108.01)<br><br>User should be > 60" away from the destruction part at all time | To prevent any accidental harm to the user or the people around it [14][15][17][18].<br><br>Separating the user away from the destruction part of the unit at all times avoids injury, based on the average arm length of an adult [19]. |
| **Must fit inside footprint of shipping container** | The product must have the following dimensions:<br>Width ≤ 8'<br>Length ≤ 40'<br>Overall height ≤ 13' 6" | The standard size of a shipping container is 8' x 40', using this size as a maximum will allow for easier transportation of the firearms disposal unit [20][21].<br><br>The maximum height of a vehicle in Michigan must not exceed 13' 6" [22]. |
| **Must be light enough to be transported by semi-truck** | The product must weigh < 45,000 lbs | Largest amount a semi truck can haul legally is 80,000 lbs [23].<br><br>Unloaded 18-wheeler semi-truck weighs approximately 35,000 lbs [24]. |

The first requirement our team has for the project is that the product must be modular and have readily available replacement parts. Our team specified that the product must have more than two modular and replaceable parts, for example shredder blades. Having more modular and replaceable parts in our design means that the product can be quickly repaired by swapping out parts that are damaged with brand new functioning parts that are readily available. Having modular parts can also prevent fatal damage to the product [16]. This is crucial to our product design since the project is non-profit and having a method to reduce repair and maintenance cost can help the sustainability of this project.

The next requirement for the overall project subfunction is that the product must be safe to the user and the community. For specification, our team decided the material used to create the product has to be level IV bulletproof according to the NIJ Standard 0101.06 and 0108.01[14][15]. This is to prevent any accidental harm done to the user or people around it if a firearm discharge occurs inside the storage component of the product.

Our team has also specified that the firearm deposit opening of our design, which is the location where the user inserts their firearm, must be more than 60” away from the destruction part of the product. This is to prevent people from reaching inside the product and injuring themselves. To determine the value of 60”, our team researched and found the average human arm lengths – 27 inches. We also performed empirical testing by measuring our own arm reach through a 4” x 16” cardboard cutout, which we created to simulate the firearm deposit opening. This is demonstrated below in figure 4. In the end, we found an average distance of arm reach that was similar to our previous research, and rounded the number up to 30 inches. We doubled the value to increase the factor of safety to ensure no one can reach the destruction part of the product, which gives us the safety distance of 60”.

**Figure 4.** Empirical testing of measuring our own arm through the cardboard cutout.

The next requirement for the overall project subfunction is the product must be able to fit inside the footprint of a shipping container. Our team wants the product to be able to be hauled by a semi-truck, so that it can be easily transported to different locations. We have found that the standard size of a shipping container is 8’ x 40’ [20][21]. We have also found that in the state of Michigan, the maximum height of a vehicle must not exceed over 13’6” [22]. Therefore, the specification of this requirement is that the product itself cannot go over the dimensions of 8’ x 40’ x 13’6”.

The last requirement for the overall project subfunction is that the product must be light enough to be put on and moved by a semi-truck. Our team has found that the largest weight a semi-truck can legally haul is 80,000 lbs [23]. This 80,000 lbs of weight consists of the truck and trailer also, which means that our team needs to take account of the weight of the truck, trailer, our product, and even the firearm waste within the product. Since the weight of an unloaded 18-wheeler semi-truck is approximately 35,000 lbs, we temporarily specified the product should not exceed the weight of 45,000 lbs.

**Requirements for Storage Subfunction**

In Table 5 below, we have listed the requirements and specifications related to the storage of firearms collected. Our goal is to ultimately destroy all firearms collected, no matter the size. It is also necessary for our product to store the waste of destroyed firearms, so we have added a requirement of the minimum amount of waste our product will store.

**Table 5.** Requirements and specifications related to the storage of disposed firearms.

| Requirement | Specifications | Justification |
|---|---|---|
| **Must be able to accept firearms of any size** | Length of the unit intake must be between 45" and 150",<br><br>Width of firearm deposit opening must be between 16" and 72",<br><br>Height of the firearm deposit opening must be between 4" and 4.5". | Project requirement [1]<br><br>Based on the sizes of common firearms [24][26][27] |
| **Must store firearm waste** | Must be able to store waste of > 150 firearms. | ULINE rigid bulk container can contain up to 2,000 lbs of weight [28]. Average rifles weighs around 8.5 lbs [29]<br><br>Container can carry > 200 rifles on average based on average weight. |

The first requirement that we have for the storage subfunction is that the product must accept firearms of any size. To do so, our team has researched firearm thickness, length, and other dimensions, and determined that the product has to at least be able to take in firearms of the largest dimensions we found. We have determined the largest possible dimensions are 45" x 16" x 4", which means that our product must be able to accept firearms of at least that size. Using these dimensions, we are able to specify the size of the opening of our product, which is the location where the user will insert their firearm. The opening should have dimensions of at least 4" x 16". This dimension will ensure any firearm can be inserted with its barrel pointing into the opening, as demonstrated in Figure 5 shown below. Our team also specified the length of the unit intake must be greater than 45", to ensure the product is able to contain firearms of any length. The intake is the space where the firearm is placed after insertion through the opening, and right before firearm destruction.

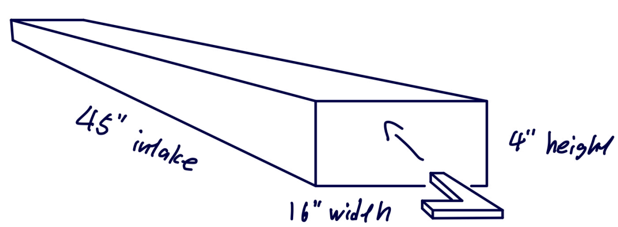



**Figure 5.** Above drawing demonstrates how the firearms should be turned into the product according to our dimension specifications.

The second requirement for the storage subfunction is that the product must be able to contain the waste of at least 150 firearms (approximately 1,300 lbs). We have found an off-the-shelf product, a rigid bulk container, from ULINE that we think is suitable for our waste container. It can hold up to 2,000 lbs of waste [28]. We have also found that the average weight of a standard rifle is around 8.5 lbs [29]. After doing some calculations, we came to the conclusion that the rigid bulk container can carry the weight of more than 235 standard rifles. To account for variance in the average firearm weight calculation, we have applied a safety factor of 35%, which reduces the minimum amount of firearm waste required to be contained from 235 standard rifles down to 150 standard rifles.

**Requirement for Destruction Subfunction**

In Table 6 below, we have listed the requirements and specifications related to the destruction of surrendered firearms collected. The table specifically focuses on the destruction subfunction.

**Table 6.** Requirement and specifications related to destruction of firearms. It should be noted that only one method of destruction must be met to satisfy the requirement.

| Requirement | Specifications | Justification |
|---|---|---|
| **Must destroy firearms per ATF guidelines** | **Shredding:** must exert shear force of > 719 MPa<br><br>**Crushing:** must apply > 830 of force on to the firearms<br><br>**Melting:** must apply consistent heat > 2919 ºF to the firearm | The ATF requires firearms to be destroyed in a specific way to guarantee it cannot be used, resold or remanufactured into another firearm [2].<br><br>Sponsor wants firearms to be destroyed [1]. |

To destroy firearms, we decided to follow the ATF guidelines to properly destroy any surrendered firearms. We have compiled Table 7 in the "Engineering Analysis" section that includes the physical properties of commonly used materials used to manufacture firearms, specifically yield strength, shear stress, and melting point. This data helped us determine the specific values needed for each method of destruction.

For the method of shredding, we specified that the product must be able to shred firearms by applying a shear force that is greater than 719 MPa. We found that grade 5 titanium requires the highest shear force of over 479 MPa to shear. We have applied a safety factor of 1.5 and to obtain the final value of 719 MPa. For this reason, we are requiring the shredding device to apply a shear force greater than 719 MPa to be able to shred any firearm.

For the method of crushing, our team specified that the product will be applying 830 of force on the firearm to crush it. Using Table 7 from our "Engineering Analysis" section, our team had done research and found out that the material on a firearm that requires the highest crushing force is 830. By specifying that the product should exert at least 830 of force of the firearm when crushing, we want the product to be able to crush any kind of firearm.

For the method of melting, we want to make sure that every component of the surrendered firearm is completely melted after going through the destruction process. Again, utilizing the data compiled in Table 7 from the "Engineering Analysis" section, we have found the highest melting temperature of the common materials used in firearm manufacturing, which is 2919 ºF. In order to completely melt every firearm, the temperature must be greater than this value.

Note that only one of the destruction methods specifications described has to be met, not all. Our concept generations have considered each method and the final destruction method was selected after analysis was conducted.

## CONCEPT GENERATION

Our team's concepts were first generated using a mixture of the TRIZ method and brainstorming. We used the TRIZ method to strip away the details and generalize our problem down to simply how to destroy solids. Then, we used the effects database from Oxford Creativity to access a list of effects to our problem, shown below in figure 6 [30].

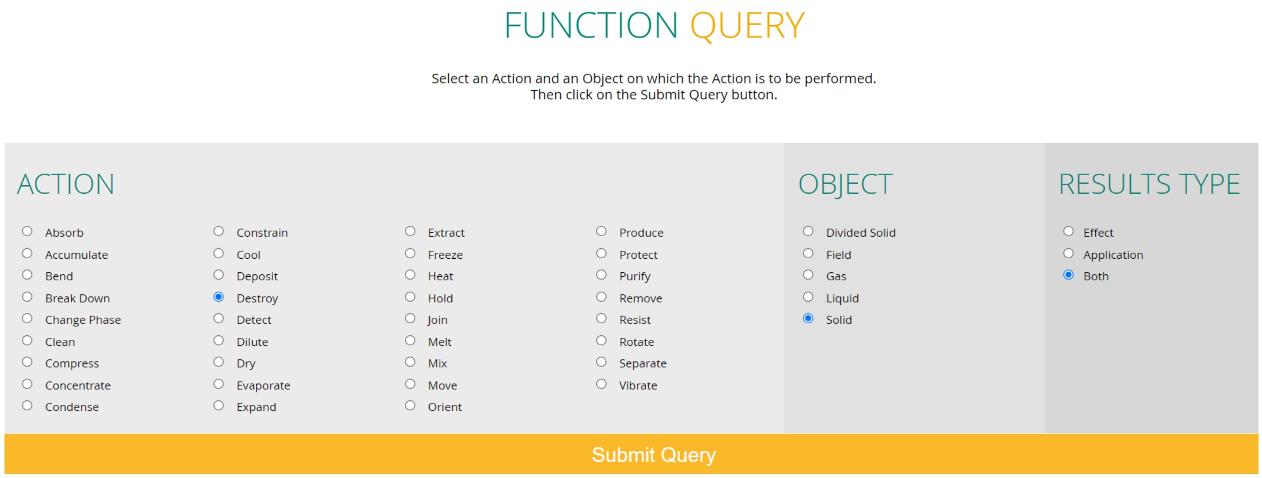



**Figure 6.** Effects Database from Oxford Creativity

After submitting the query, we received 109 suggestions for ways to destroy solids. From this list of suggestions, our team took inspiration from methods such as combustion, deformation, detonation, heating, hydraulic press, and more. Each member of our team then came up with twenty unique concepts using these suggestions. Some of the concepts generated were also paired with simple sketches to help us better explain the concepts. At this phase of concept generation, we wanted many different concepts and encouraged wild ideas as well, since they often help inspire good solutions. Afterward, each team member also used Design Heuristics to look back at our generated ideas and see if we could tweak them to generate even more concepts. Figure 7 shows the seventy-seven heuristics. In the end, our team ended up with an abundance of generated concepts to work with.

| | | |
|---|---|---|
| 1. Add levels<br>2. Add motion<br>3. Add natural features<br>4. Add to existing product<br>5. Adjust function through movement<br>6. Adjust functions for specific users<br>7. Align components around center<br>8. Allow user to assemble<br>9. Allow user to customize<br>10. Allow user to rearrange<br>11. Allow user to reorient<br>12. Animate<br>13. Apply existing mechanism in new way<br>14. Attach independent functional components<br>15. Attach product to user<br>16. Bend<br>17. Build user community<br>18. Change direction of access<br>19. Change flexibility<br>20. Change geometry<br>21. Change product lifetime<br>22. Change surface properties<br>23. Compartmentalize<br>24. Contextualize<br>25. Convert 2D material to 3D object | 26. Convert for second function<br>27. Cover or wrap<br>28. Create service<br>29. Create system<br>30. Divide continuous surface<br>31. Elevate or lower<br>32. Expand or collapse<br>33. Expose interior<br>34. Extend surface<br>35. Flatten<br>36. Fold<br>37. Hollow out<br>38. Impose hierarchy on functions<br>39. Incorporate environment<br>40. Incorporate user input<br>41. Layer<br>42. Make components attachable/ detachable<br>43. Make multifunctional<br>44. Make product recyclable<br>45. Merge surfaces<br>46. Mimic natural mechanisms<br>47. Mirror or array<br>48. Nest<br>49. Offer optional components<br>50. Provide sensory feedback<br>51. Reconfigure<br>52. Redefine joints<br>53. Reduce material | 54. Repeat<br>55. Repurpose packaging<br>56. Roll<br>57. Rotate<br>58. Scale up or down<br>59. Separate functions<br>60. Simplify<br>61. Slide<br>62. Stack<br>63. Substitute way of achieving function<br>64. Synthesize functions<br>65. Telescope<br>66. Twist<br>67. Unify<br>68. Use common base to hold components<br>69. Use continuous material<br>70. Use different energy source<br>71. Use human-generated power<br>72. Use multiple components for one function<br>73. Use packaging as functional component<br>74. Use repurposed or recycled materials<br>75. Utilize inner space<br>76. Utilize opposite surface<br>77. Visually distinguish functions |

**Figure 7.** Design Heuristics table [31].

Our team then classified the concepts that were generated by their method of destruction – cutting, deforming, melting, upcycling / preservation, entertainment, and unrealistic. Our classified concept table can be found in appendix A.  The concepts were not really distinct from one another when inspected by category. For example, in the cutting category, most if not all of the concepts generated utilized a shredder.

**Examples of Generated Concepts**

The first example of our generated concepts is the shredder in an "ATM" like machine. Like the name of the concept, the front end of the solution would be like an ATM kiosk. However, instead of retrieving money from the unit, users would be turning in their unwanted firearms to the opening. The opening would have a long tunnel that leads to the container in the back. This long tunnel is to prevent people from reaching inside the waste container. At the opening of the container in the back of the kiosk, shredders are mounted to break down the firearms that slide down the tunnel, and the waste will be dropped down to the waste container. The waste container should be secured and portable, to protect the public from accidental discharge from within, and people from breaking into the container to take away its contents. The concept drawing is shown below in figure 8.

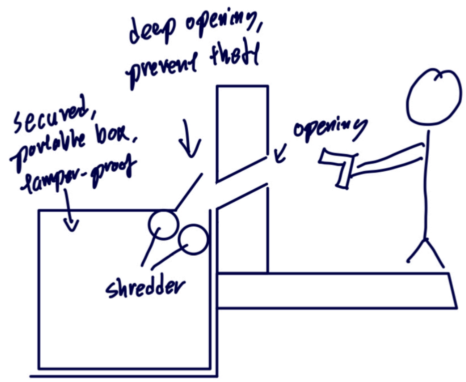



**Figure 8.** Shredder in "ATM" like machine

The second example of our generated concepts is the firearms cremation service. Similar to cremations, users are able to insert their unwanted firearm into this unit, and the firearm will slide into the product, and start melting it down. Users can inspect the destruction process from the small windows on the opening of this unit. After the firearms are melted down, the users are able to bring back the "ashes" of their unwanted firearms. The concept drawing is shown below in figure 9.

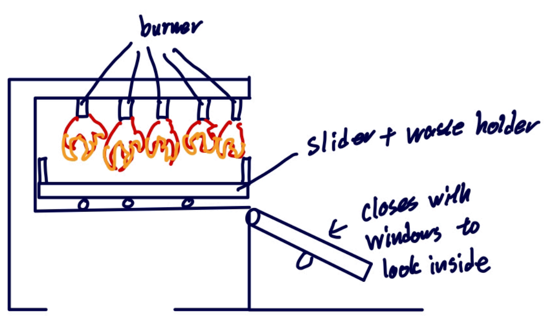



**Figure 9.** Cremation for firearms

The third example of our generated concepts is the easy press unit. This would be a small unit placed in a public setting with an easy process. People can bring their unwanted firearms to this unit, insert it, and the press in the machine is able to crush the part of the firearm that was inserted. People then can walk away with their non-functional firearm and keep it as a souvenir. The concept drawing is shown below in figure 10.

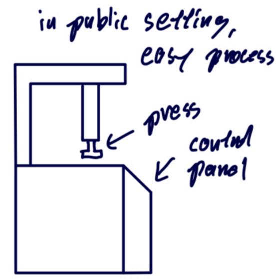



**Figure 10.** Easy press unit

The fourth example of our generated concepts is the specialized van unit for mobile firearm destruction. This is a specialized modified van containing a shredder and waste container inside. This unit is like a mobile blood drive, but for people to dispose of their unwanted firearms. The concept drawing is shown below in figure 11.

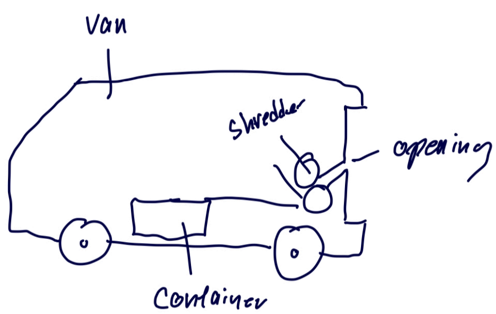



**Figure 11.** Specialized van unit for mobile firearm destruction

The fifth example of our generated concepts is the firearm compactor. This concept is similar to a trash compactor, but for firearms. People are able to turn in their unwanted firearms to a portable container at a public location, then after the container is full, it will be transported to the compactor. The container will be placed on top of the compactor, and then release all of its contents down to the compactor below. The compactor then will compress the firearms with strong hydraulic presses. The compacted firearm block will be removed after the process and transported away to a scrap yard for recycling. The concept drawing is shown below in figure 12.

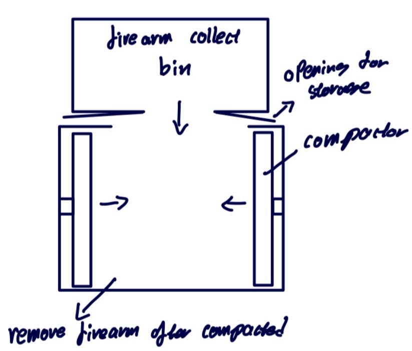



**Figure 12.** Firearm compactor

**CONCEPT SELECTION PROCESS**

After compiling all of the team's generated concepts into a table, the team categorized and sorted each concept by its method of destruction – cutting, deforming, melting, upcycling / preservation, entertainment, and unrealistic. The table is shown below in figure 13. It was necessary to narrow our focus by eliminating concepts that are not plausible or are unrealistic, such as "sending the firearms to space" or "sacrificing them to the local volcano". We also eliminated categories that did not align with our project goal of destroying unwanted firearms, such as entertainment and upcycling / preservation. We then selected the best concepts from the remaining categories – deformation, cutting, and melting.

| Cutting | Deformation | Melting | Storing | Irresponsible | Upcycling / Preservation | Entertainment | Unrealistic |
|---|---|---|---|---|---|---|---|
| Cut guns with bandsaw blades | Use a press to wedge the firearm in half | Send guns to metal manufacturer to melt and recycle | Garbage truck goes door to door in community to collect guns | Use the gun so much, the barrel melts off | Pouring molten metal into the barrel | Host world record competition to break guns | Send to sun |
| Cut guns with plasma cutter | Crushing machine | Weld the trigger mechanism | Gun dropbox (like Blockbuster) | Have two firearms facing each other, fire them at the same time | Make art and furniture out of unwanted guns | Have firearm gambling -- where will the gun break in half? | Send firearms to space |
| Cut guns with EDM | Coil the firearm around a cylinder | Garbage truck with incinerator | Portable bin, to be collected every period | Use for testing military weapons, how metal withstands explosives | | Live stream gun destruction | |
| Shredder in "ATM-like" machine | Run firearms over with a tank | Blast furnace | Time vault | Throw in trash | | Tournament to break guns | |
| Collected in container then blow them up | Food truck with hydraulic press | Melt via induction | An emergency station that can call first responders and can be used to destroy guns | Throw in lake | | Create a TV show of people breaking guns in many different ways | |
| Metal shredder | Insert the firearm into a container that then crushed the firearm | Clamp with electrodes and melt | Storage container disguised as a recycling bin | | | | |
| Cut guns with a saw | Crush with hydraulic press | Incinerator | Portable, secured storage box | | | | |
| Shred the guns | Trash compacter | Attendent places the firearm onto a conveyor that leads to a furnace to melt it | New section in trash yard | | | | |
| Cut guns using a high speed mill | | Put firearms in acid | Gun "jail" and public destruction | | | | |
| Cut guns using a waterjet | | User loads firearm onto conveyor that leads to a furnace to melt it | Special mail-in box | | | | |
| Cut guns using a laser | | Sacrifice guns to a volcano | | | | | |
| User inserts the firearm into a container that drops the firearm into a metal shredder | | | | | | | |
| Attendent accepts firearm and uses a torch to cut firearm into pieces | | | | | | | |
| A van has an opening on the side for inserting the firearm and mechanism inside shreds the firearm | | | | | | | |

**Figure 13.** Above shows a table of generated concepts organized in categories in different columns.

**First Concept**

Our first concept, shown below in Figure 14, utilizes melting as the destruction method. The concept allows the user to insert the firearm into an opening on one side of the concept unit and the firearm drops directly into a furnace below. The furnace heats the firearm until the metal reaches its melting and becomes molten. The molten metal is then poured from the furnace into ingot molds in the waste container below the furnace. The waste container is removable so solidified metal ingots can be removed from the unit. The concept unit has a viewing window that allows the user to watch their firearm go into the furnace. The window would be made from bulletproof glass. An advantage of this concept is that it is physically smaller compared to other destruction methods. There are many disadvantages of this concept, the first being that it will require a large amount of energy and time in order to melt the firearms. The waste created by this concept is also not ideal, as it will create large ingots of metal that will be heavy and difficult to remove from the unit.

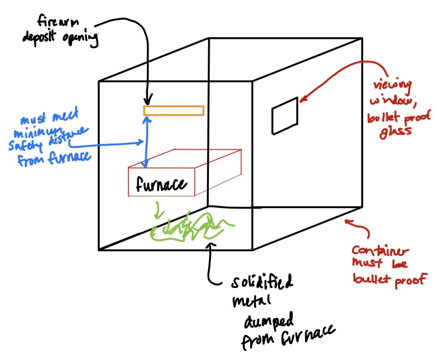



**Figure 14.** Shown above is a top concept featuring the destruction method of melting. This concept is not ideal due to the increased energy and time required to melt the firearms. This concept also produces a larger waste product than other methods.

This concept has the potential to meet some of our requirements of the shell subfunction. The concept is not able to meet the requirement of being modular, as it will not have many modular parts since the major component of the furnace would not be easily replaceable. The requirement of fitting inside the footprint of a shipping container could be met by this concept since the dimensions of this design are not constrained by any elements and can be modified if necessary. Depending on the material of the exterior shell and the weight of the solidified ingots in the waste container, the concept unit could exceed our maximum weight requirement of 45,000 lbs.

The material of the concept unit can also affect its ability to meet the safety requirements of the storage subfunction. If the proper material is selected, the concept unit could meet the level IV bulletproof requirements per the NIJ Standard 0101.06 and 0108.01[14][15]. The deposit opening is greater than the required safety distance of 60” from the stored firearm waste. The concept unit should be able to accept firearms of any size since the design dimensions are not constrained by any elements other than the safety distance.

This concept somewhat aligns with half of our requirements for the destruction subfunction. Using melting as the method of destruction not only uses more energy, but also takes more time to complete the destruction process. However, the deposit opening is positioned greater than the minimum required safety distance of 60” from the destruction unit.

This concept is consistent with some of our requirements and specifications, but it has issues regarding the safety of the user and community. For instance, the deposit opening drops the firearm directly into the furnace, which restricts the ability to reject an item that is not a firearm. The melting destruction method also requires more time and energy to complete the destruction process than other methods, such as shredding or deforming.

**Second Concept**

The second top concept is shown below in figure 15. The concept unit features the method of deformation with hydraulic press to destroy firearms. It has an opening in the front for users to turn in their unwanted firearms. The design has a display that shows the user instructions and more information. This design utilizes a hydraulic press to deform the firearms and make them non-functional. Once the firearm is inserted into the concept unit, the opening should be closed, and the press inside will start compressing the firearm to deform it. The press will then follow a track built on the top of the intake of the concept unit and stop incrementally to compress the entire length of the firearm. After the press has gone through an entire cycle, the firearm resting in the intake of the unit will be deformed and non-functional. After this, the intake floor will open, dropping the non-functional firearm down to the waste container. The waste container can be removed and would be emptied when full. One advantage that this design has over the others is that the size is compact. However, firearms destroyed with the method of hydraulic press produce a larger waste product than firearms destroyed with the method of shredding. Utilizing the destruction method of hydraulic press will fill the waste container more quickly, which will require a higher frequency of emptying the waste container.

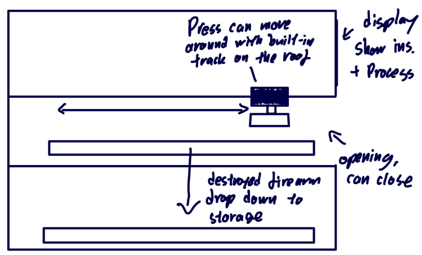



**Figure 15.** A top concept featuring the method of deformation with hydraulic press. This method was not able to compete with other concepts due to inconsistencies with our requirements and specifications and the larger waste product that would require more frequent maintenance.

This concept can meet some of the shell subfunction requirements. It has a solid design that is hard to implement with many modular and replaceable parts. However, it should be able to fit inside the footprint of a shipping container easily because the biggest component in the concept unit would be the intake that houses firearms before destruction. Our requirement for the minimum intake length is 45" which easily fits in the footprint of a shipping container. For the weight requirement, further research may need to be done to be sure if the product can weigh less than 45,000 lbs.

For the storage subfunction, the concept unit should be able to accept firearms of any size. If the team used proper materials, the storage could achieve level IV bulletproof requirements per NIJ Standard 0101.06 and 0108.01 [14][15]. However, the storage is located close to the opening of the design, so users may be able to reach inside the container and remove firearms.

This concept is inconsistent with the requirements from the destruction subfunction. Utilizing the method of shredding produces much smaller waste that can be easily maintained in the waste container, whereas when using the destruction method of hydraulic press, the firearm waste would be much larger and will fill up the waste container more quickly. The mobile press in the concept unit can also come in close contact with the user which could cause injuries if the user somehow found a way to sneak a limb inside.

Overall, this design is inconsistent with our engineering requirements and customer specifications. The design's major flaw of producing large wastes that quickly fill up the waste container, which then requires a high frequency of emptying the waste container, overshadows its advantage of its compact size.

**Third Concept**

Our third concept, shown below in Figure 16, utilizes a metal shredder as the destruction method. The concept allows the user to insert the firearm into an opening on one side of the concept unit and then moves the firearm to the shredder using a ramp with rollers. Once the firearm reaches the shredder, the shredder will turn on, shred the firearm, and then the waste will be deposited into a waste container below the shredder. The waste container is removable so it can be easily emptied and serviced. The concept unit has a viewing window that allows the user to watch their firearm go through the shredder. The window would be made from bulletproof glass. This concept unit also has a retractable top, which allows maintenance on the shredding device. An advantage of this concept is that it creates a smaller waste product compared to other destruction methods. This would allow the device to accept a greater number of firearms before needing to be serviced or emptied. This concept is purely mechanical and does not have any safety features to prevent non-firearm items from being inserted in the device, which is a major disadvantage.

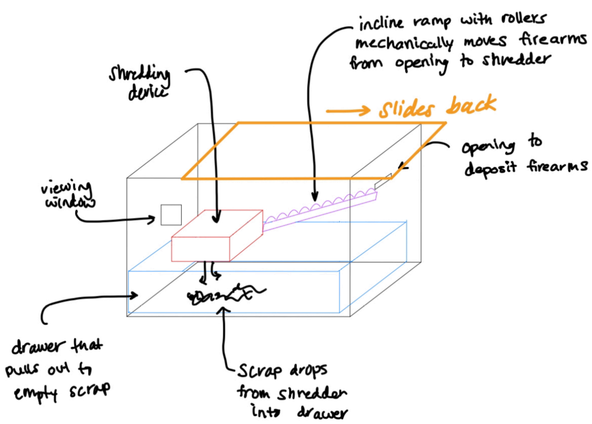



**Figure 16.** Shown above is a top concept featuring the destruction method of shredding. This concept meets most of our requirements, but it lacks critical safety features, like the ability to reject an item if it is not a firearm.

This concept could meet the requirements of the shell subfunction. The concept will be able to have numerous modular parts since many sections of the design are already removable, such as the top slider and the waste container. The size of the concept unit should be able to fit within the footprint of a shipping container. Depending on the material of the exterior shell, the concept unit could exceed our maximum weight requirement of 45,000 lbs.

The material of the concept unit will also affect its ability to meet the requirements of the storage subfunction. If the proper material is selected, the concept unit could meet the level IV bulletproof requirements. The concept unit should be able to accept firearms of any size, and the ramp with rollers will move the inserted firearms more than 60” away from the user which meets our requirements for the storage subfunction.

This concept could meet the requirements for the destruction subfunction if the proper shredding device is selected. Per our requirement for shredding, the shredding device must be able to apply a shear force of at least 800 MPa.

Even though this concept is consistent with the majority of our requirements and specifications, it has issues regarding the safety of the user and community. For instance, the ramp with rollers declines directly into the shredder, which restricts the ability to reject an item that is not a firearm. Our concern is that trash could be inserted into the concept unit which could damage or reduce the effectiveness of the shredder, or an animal or a user’s limb could be inserted into the concept unit.

**Fourth Concept**

Last of our team's top four generated concepts is shown below in figure 17. The concept design utilizes shredding as its method of destruction for firearms. The concept has an ATM-like design kiosk in the front, with a display to show instructions and other information to the users. The kiosk also has a control panel for the user to navigate around the product, and an opening for users to turn in their firearms when instructed by the display. The opening should be closed unless the user is in the process of surrendering their firearms to the inside. After the firearm is turned into the product, the opening will close, and the turned in firearm will be resting on a set of trapdoor. After users confirm the destruction of their unwanted firearm, the trap door will open, dropping the firearm down to the shredder right below. The waste produced will then be dropped below to a removable container that will be emptied periodically. The advantage of this design is that there are many different steps of function to ensure user safety, such as blocking the user away from the shredder with a gate that closes on the kiosk. However, the design has a major flaw which is it requires such a big shredder design. Shredders with such long dimensions are not only difficult to find but also take up a lot more space and energy.

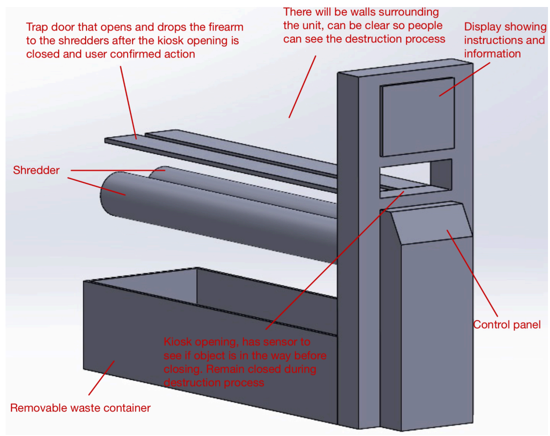



**Figure 17.** Another top concept featuring the destruction method of shredding. This concept was able to match with many of our requirements and can easily match with more refinements.

This concept can meet most of the shell subfunction requirements. The concept can easily have more than five modular and replaceable parts, and be smaller than the footprint of a shipping container. However, the weight requirement may need further research to confirm if the design can be light enough to be put on and moved by a semi-truck.

This concept can meet all of the requirements from the storage subfunction. The design should be able to accept firearms of any size. The design can be assembled with proper materials to achieve level IV bulletproof NIJ Standard 0101.06 and 0108.01 [14][15] and the opening of the kiosk can be easily designed to be more than 60" away from the stored firearm wastes.

For the destruction subfunction requirements, the shear force that the shredders can exert depends on the shredder that we purchase, so this requirement could be satisfied if the proper shredding device is used. However, for the safety requirement, the current design may not be able to satisfy the specification of "user should be > 60" away from the destruction part at all time." The design has a long shredder design, extending from one end of the concept to the other. This puts the shredder very close to the user.

Overall, this design is consistent with our engineering requirements and customer specifications, and this design's advantage of utilizing a shredder and having different safety functions for the user make it a competent choice for our team

After testing with our design and thinking of ways of putting together the designs, our team determined that the concepts cannot be combined into a system in an efficient way. This is because all the concepts are aiming toward the destruction of unwanted firearms with different methods. The selected concept in the end should be the most efficient and matches the most requirements that we have listed in the previous requirements and specifications section.

One of the first concepts that our team came up with in the beginning was using the method of deformation with hydraulic press to destroy the unwanted firearms. We considered  designing a conveyor belt like system with numerous mid-size presses along its length to deform the firearms. However, after some research, our team discovered that this exact method is patented by David Boland, Inc. [10]. We liked the idea of deformation, so we attempted to generate other deformation concepts that would not infringe on the patent. Most of our ideas were not efficient. For example, we thought of using a large hydraulic press that would  completely deform the firearm in one press, which eliminates the need for a conveyor belt system. However, this would require having an extremely large press to account for firearms of any size, and the waste produced would be difficult to store.

These troubles led our team to other methods of destruction. In the end, we favored the method of shredding. This is because the shredding method can completely destroy a firearm, and the waste produced can be easily stored since they are much smaller pieces. With this decision, the biggest difference between our first generated concepts and the current concept is the method of destruction, and implementing safety elements into the design. All of the concepts presented have a similar outer shell component which protects the user and community from accidental discharge and any equipment malfunction. The outer shell is a critical component of each concept because safety is our most important requirement.

**SELECTED CONCEPT DESCRIPTION**
After the concept selection process, our team decided to use concept 4 as a starting point. A low fidelity prototype is shown below in figure 18. We have updated the design of the trapdoor (green) to allow the inserted firearms to slide into the shredder in a vertical orientation. This change allows us to significantly reduce the size of shredder needed in the unit, since previously the firearms could be dropped into the shredder in any position which would require a much larger shredder. This design choice also positions the shredder much farther away from the user.

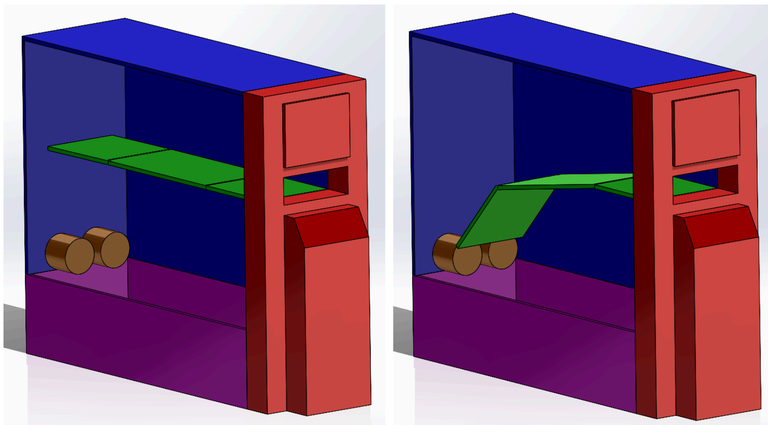


**Figure 18.** Shown above is the low fidelity prototype of our selected concept. Assembly on the left shows the starting position of the design and assembly on the right shows the position of the design that is sliding the inserted firearm down to the shredder. The blue part shown above is the outer shell that covers every component of the concept unit. For the purpose of demonstrating the inside of the design, it is half open here.

Figure 19 shows the kiosk of the unit, which is the part of our concept unit that the users will interact with. The kiosk has a display on the top to provide users with instructions and other information. The opening of the kiosk stays closed until the user is instructed by the kiosk to insert their  unwanted firearms into the opening. The opening will close once the firearm is inserted.  The control panel is the component that the users interact with  to control the product.

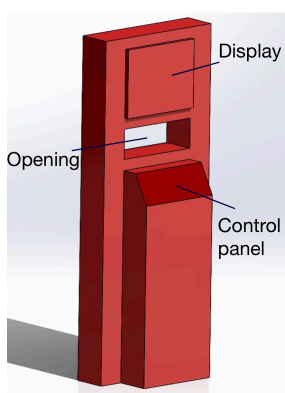



**Figure 19.** Low fidelity prototype of kiosk

Figure 20 shows the outer shell of the product, which will completely cover the entire product. The shell may have small windows that users may look in to observe the destruction process. The shell should be bulletproof according to the NIJ Standard 0106.01 and 0108.01 [14][15] to protect the community against accidental discharge during the destruction process.

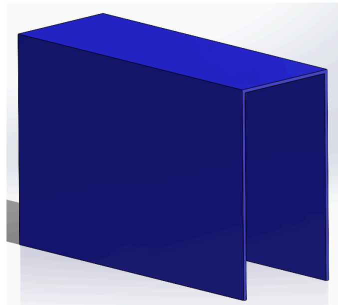


**Figure 20.** Low fidelity prototype of the outer shell. The model shown here is the full model that will completely cover the components inside the design, unlike the part shown previously in figure 18.

Figure 21 shows the articulating trapdoor. The trapdoor tilts down by segments to slide the inserted firearm to the shredder. The trap door has a long design because it will need to be able to accommodate any size of firearm. This long design also helps to keep the user far away from the shredder. There will also be small rollers on top of the trapdoor to ensure the firearm on top will slide down to the shredder without getting stuck. The trapdoor will only start tilting downward once the opening on the kiosk is closed and the user has confirmed to destroy their unwanted firearm. The trapdoor is also separated into three segments. This is to better position firearms of different sizes and ensure the firearm will be sliding into the shredder in a vertical orientation.

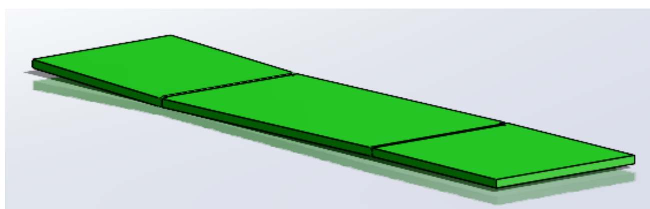


**Figure 21.** Low fidelity prototype of the articulating trapdoor. Divided into three segments, with a shorter panel on the side and the longer panel in the middle. The trapdoor tilts down one segment at a time to position the firearm in a vertical orientation when it is sliding into the shredder.

Figure 22 shows the shredder. Our team will not be reinventing the wheel and designing our own shredder. We will be looking for shredders available on the market that best match the dimensions and power necessary for our design. The shredder should only operate once the opening on the kiosk is closed and the user has confirmed to destroy the surrendered firearm inside the concept unit.

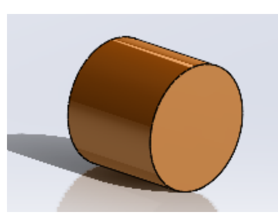


**Figure 22.** Low fidelity prototype of shredder.

Figure 23 shows the waste container. This is the container that catches the shredded firearm waste after the firearm goes through the shredder. The container is removable which means that it can be periodically transported away to a recycling facility or the scrap yard to empty its contents.

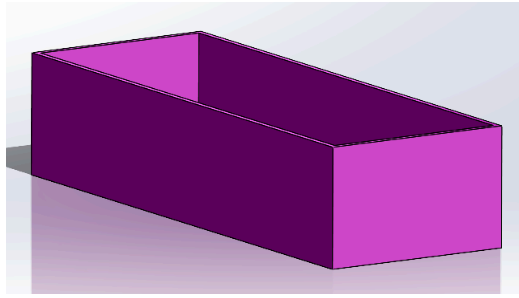


**Figure 23.** Low fidelity prototype of the waste container.

The selected concept that our team has chosen was not because of heavy sponsor influence, but in a more objective way. The design was first chosen because it met the majority of  requirements that we have listed in our requirements and specifications table. This design can also be easily adjusted to ensure all requirements are met. Our team reviewed our top generated concepts with our sponsor, David Humphreys, and he thought all of the concepts were acceptable, but he especially liked our current selected concept.

The selected concept is well enough defined to be analyzed rigorously using engineering concepts. Though our team has not yet determined its final dimensions, we were able to test different sizes of the deposit opening by creating a cardboard cutout and performing empirical testing on our team's average arm reach into the unit. Having the low fidelity prototype with clearly marked placement of subfunction systems allows our team to further refine the model to match with the requirements and specifications closely. This project would be difficult to achieve within the constraints of ME 450, especially the budget constraint. Our team has done research, and found out that the cheapest shredder that we could find on the market costs around $250, which is more than half of our team's $400 budget. It is impossible to finish building the rest of the components of our team's design using the remaining budget. Our team would also require more resources to help with designing specific dimensions of certain components and knowledge in other fields of expertise to make the design functionable.

Thus, our team decided to create a scale model that is mostly 3D printed. The components of the model are articulated so that the process of turning in firearms, feeding firearms to shredder, and removing firearm waste from containers can be demonstrated to audiences.

**ENGINEERING ANALYSIS**

In this section, we have analyzed possible destruction methods (shredding, crushing, melting), shredder selection, maximum overall size, firearm size acceptance, waste container, maximum weight requirement, safety distance, and bullet proof standard.

**Destruction Method Analysis**

A primary requirement of our design is that it must destroy firearms according to the ATF guidelines for properly destroying a firearm. The ATF guidelines allow destruction via shredding, melting, or crushing in order to permanently disable the firearm [2]. We have evaluated each method of destruction in order to select the appropriate destruction method for our design. In our evaluation of each destruction method we have considered the initial cost of equipment, cost of operation, maintenance, and the waste produced from destruction. The analysis on the three different destruction methods helped inform our decision to go with the method of shredding to destroy the firearms.

After researching common materials used in firearm construction, we have compiled Table 7 below listing the yield strength, calculated shear yield stress, and melting point of each material. We have calculated the shear yield stress based on the Von Mises Criterion using Eq 1:

$$k = \frac{\sigma_y}{\sqrt{3}} \quad (1)[32]$$

where $k$ is the shear yield stress, and $\sigma_y$ is the yield strength of the material. We have incorporated the material properties in our evaluation of each destruction method to determine if the method will be able to successfully destroy a firearm.

**Table 7.** Common materials used in firearm construction and their respective yield strengths, shear stress, and melting points. Note that grade 5 titanium (the highest strength material) is not a common material used to manufacture firearms. Instead, it is used to manufacture firearm suppressors. We want our product to still be able to destroy firearm components made from such material, so we will be using grade 5 titanium as our baseline. We have also included a safety factor (SF) of 1.5 to the shear yield stress values.

| | 4140 Steel [33] | 4150 Steel [34] | 1020 Steel [35] | 416 Stainless Steel[36] | Grade 5 Titanium[37] | 7075-T6 Aluminum[38] | 6061-T6 Aluminum[39] |
|---|---|---|---|---|---|---|---|
| **Yield Strength** | 415 MPa 60,200 psi | 380 MPa 55,100 psi | 350 MPa 50,800 psi | 275 MPa 39,900 psi | 830 MPa 120,000 psi | 503 MPa 73,000 psi | 276 MPa 40,000 psi |
| **Shear Yield Stress** | 240 MPa 34,756 psi | 220 MPa 31,812 psi | 202 MPa 29,330 psi | 159 MPa 23,036 psi | 479 MPa 69,282 psi | 291 MPa 42,147 psi | 160 MPa 23,094 psi |
| **Shear Yield Stress + 1.5 SF** | 360 MPa 52,134 psi | 330 MPa 47,718 psi | 303 MPa 43,995 psi | 238.5 MPa 34,554 psi | 719 MPa 103,923 psi | 437 MPa 63,221 psi | 240 MPa 34,641 psi |
| **Melting Point** | 1,416 °C 2,580 °F | 1,427 °C 2,600 °F | 1,516 °C 2,760 °F | 1,480 °C 2,696 °F | 1,604 °C 2,919 °F | 477 °C 890 °F | 582 °C 1,079 °F |

**Shredding**

The first method of destruction that we have evaluated for our design is the method of shredding, in which the firearm is placed into a shredding machine and the sharp teeth of the shredding blades will grab the firearm and pull it through the machile while shearing it into small pieces. This method of destruction requires the shredding machine to be able to apply a minimum shear yield stress of 479 MPa or 69,282 psi to the firearm in order to cut it into pieces. These values are based on our material analysis of common firearm materials, as shown in Table 6. We have decided to use the values of the highest strength material (grade 5 titanium) used in firearm construction since our device must be able to destroy any firearm. Shredding machines can have a lower initial cost than other destruction method equipment, such as high temperature furnaces. Shredding blades can be serviced or replaced with readily available components, making maintenance easier. This method of destruction also produces easily managed waste since the device shreds the firearm into small metal fragments.

**Crushing**

The next method of destruction that we have evaluated for our design is the method of crushing. This method of destruction would potentially utilize a hydraulic press to crush the firearm and deem it permanently inoperable. Since firearms come in many different sizes, it would be difficult to select a size of hydraulic press that could crush every firearm in one pass, so we have made the assumption that it would be necessary to crush each firearm in many passes using a smaller hydraulic press. This would increase the time it takes to complete the destruction of the firearm, and the waste product of crushing the firearm is approximately the same size as the initial firearm, which will take up a lot of space and will not easily stack. For this reason, we have eliminated the destruction method of crushing and have not completed any further analysis on the method.

**Melting**

The last method of destruction that we have evaluated for our design is the method of melting, which is also known as smelting, where the firearm would be heated until it is completely melted. This method of destruction requires the use of a furnace that is capable of heating a firearm above its melting point to ensure that the firearm is completely melted. Based on the melting points of common firearm materials above in Table X, the furnace would need to reach a minimum of 1604 °C or 2919 °F in order to melt the most common firearms. A furnace capable of heating to these temperatures would be very expensive initially, would require a large amount of energy, and an increased cycle time per firearm over other destruction methods. The waste product of melting the firearms may also be difficult to contain and move due to its weight and size. Due to the increased cycle time and inconvenient waste product, we have eliminated this method of destruction.

**Shredder Analysis**

Shredding metal is a common practice in many industries (such as metal recycling) and there are many different types of shredding machines. Since our design must be able to shred high strength metals we will be focusing our analysis on dual-shaft shredding machines that can offer a high torque output with low operating RPM.

To reduce initial cost and production lead time, we have made the decision to use an "off-the-shelf" shredding device rather than designing a custom shredder. Utilizing an "off-the-shelf" shredding device allows for less expensive maintenance and readily available replacement parts, such as shredder blades. The maximum overall size specification we have set for our design could be a limiting factor in shredder selection, but we must first consider the shredding capabilities of each device. In order to select the appropriate shredding device for our design, it is necessary to understand the amount of force a shredder is able to apply based on the technical specifications provided by the shredder manufacturer. Common technical specifications provided by the manufacturer are: power output (usually a minimum and maximum value, in kW or HP), operating RPM (usually a minimum and maximum value), shredding blade diameter or radius, shredding blade tooth length, shredding blade tooth width, and shredding blade thickness. Using these technical specifications, we are able to calculate the minimum and maximum amount of shear stress the shredding device can apply to a firearm. These calculations can be found in Appendix B.

We have compiled Table 8 below, which lists the provided technical specifications and the calculated minimum/maximum applied shear stress for each shredder. We have included both metric and imperial units for easier comparison between shredders.

**Table 8.** Technical specifications of specific shredder models and applied shear force values shown for each shredder model. Note that the Taskmaster® TM1600 has two options for blade thickness and the blade thickness has a significant impact on the applied shear force.

| | **Taskmaster® TM1600 [40]** | | **FTS-500 [41]** |
|---|---|---|---|
| **Power (min / max)** | 10 HP / 20 HP<br>7.5kW / 14 kW | | 10 HP<br>7.5kW |
| **Torque (min / max)** | 42724 N-m / 94943 N-m<br>378144 in-lb / 840320 in-lb | | 79752 N-m<br>705869 in-lb |
| **Operating RPM (min / max)** | 18 / 20 | | 15 |
| **Blade Radius** | 89 mm<br>3.50 in | | 100 mm<br>3.93 in |
| **Blade Thickness** | 13 mm<br>0.50 in | 19 mm<br>0.75 in | 20 mm<br>0.787 in |
| **Tooth Length** | 51 mm<br>2.00 in | | 25 mm<br>1.00 in |
| **Contact Area of Tooth** | 663 $mm^2$<br>1.00 $in^2$ | 969 $mm^2$<br>1.50 $in^2$ | 500 $mm^2$<br>0.787 $in^2$ |
| **Applied Shear Force (min / max)** | 744 MPa / 1655 MPa<br>108041 psi / 240091 psi | 496 MPa / 1103 MPa<br>72027 psi / 160061 psi | 1571 MPa<br>227932 psi |

It is important to note that the applied shear force from the shredder tooth is calculated with one tooth being in contact with the firearm at a time per shaft. If more than one tooth is in contact, the amount of power required to maintain the same shear stress applied to the firearm would need to be multiplied by the number of teeth in contact at the same time. To ensure no decrease in applied shear force while shredding, we will stagger the tooth orientation on the shredder's shaft, as seen in Figure 24.

**Figure 24.** Above shows the staggered shredding blade orientation on a dual-shaft shredding machine. This orientation ensures that no more than one tooth is in contact with the firearm at the same time, which allows the shredder to maintain the applied shear stress on the firearm [42].

**Maximum Overall Size Analysis**
Since our device is not intended to remain within any community permanently, it is necessary that the device can be transported easily to different locations. Considering storage containers and semi-trailers are easily transported via semi-truck, we have determined that the entirety of our device must fit within the footprint of a shipping container. The standard size of a shipping container is 8’ x 40’ [20][21], so we will use these dimensions as our maximum length and width. In the state of Michigan, the maximum height of a vehicle cannot exceed 13’6”. To determine the maximum height of our device, we used Eq 2:

$$H_{req} = H_{MI,\,max} - H_{trailer} \tag{2}$$

Where $H_{req}$ is the maximum allowable height of our device, $H_{MI,\,max}$ is the maximum vehicle height allowed in the state of Michigan, and $H_{trailer}$ is the average height of a semi-trailer. Using the average height of a semi-trailer of 5’ [43], we have determined that our maximum allowable height of our device is 8’6”.

**Firearm Waste Container Analysis**
The waste container could become too heavy for manual removal since the average weight of a standard rifle is around 8.5 lbs [29]. In order to increase the ease of waste removal from our device, we wanted to include forklift lift points on the bottom of the container. We have found a purchasable component that can be used for our waste container which includes the forklift lift points. This container can hold up to 2,000 lbs of waste, so it can hold an estimated 235 shredded firearms [28]. We will reduce the maximum weight by 35% to ensure a margin of error for our estimation of firearm weight, which changes our maximum firearm weight to 1,300 lbs. The container is 48” x 45” x 19”, which is shown in Figure 33.

**Maximum Weight Requirement Analysis**
After researching transportation regulations for the state of Michigan, we have found that the maximum weight a semi-truck can legally haul on a public road is 80,000 lbs [23]. This maximum weight value is the gross vehicle weight, meaning that we must take into account the weight of the truck, trailer, our product and the firearm waste that could potentially be transported inside our product. Using Eq 3, we can estimate the maximum unloaded weight of our product:

$$W_{disposal\ unit} = W_{total} - W_{semi,\ unloaded} - W_{firearm\ waste} \tag{3}$$

Where $W_{disposal\ unit}$ is the unloaded weight of our product, $W_{total}$ is the maximum allowable weight that can be hauled on a public road, $W_{semi,\ unloaded}$ is the weight of an unloaded 18-wheeler semi-truck, and $W_{firearm\ waste}$ is the weight of the destroyed firearms that are held within our product. Since the weight of an unloaded 18-wheeler semi-truck is approximately 35,000 lbs [24], and we have estimated the firearm waste to be approximately 1,300 lbs, we have determined that the unloaded weight of our product must be less than 43,700 lbs.

**Safety Distance Analysis**
It is important for the user to not be able to reach into the device and potentially injure themselves, so we needed to determine the appropriate distance between the destruction device and the user. We created a cardboard cut out to simulate the firearm deposit opening, which is 4” x 16”. Using the cutout, we measured the length each team member was able to achieve when putting their arm through the opening (shown in Figure 4). The average length was approximately 30” and applying a safety factor of 2, we have determined that the destruction device must be 60” away from the user.

**Bulletproof Analysis**

In order to protect users from accidental discharge of a firearm inside our product, we have set a requirement for its exterior shell to be bulletproof according to NIJ Standard 0108.01 Level IV, which is the highest level of bulletproofing. Since we do not know what types of firearms will be disposed of in our device, we wanted to offer the most protection possible. The NIJ Standard 0108.01 requires a material to stop a minimum of one shot of a 30.06 caliber steel core armor piercing round at a measured velocity of 868 ± 15 m/s [14]. To be deemed bulletproof by NIJ Standard 0108.01, the material must be fired at by the specified ammunition without a bullet penetrating the material. We do not have the ability to physically test materials to determine if they are bulletproof according to this standard, so we have researched products currently available that offer any level of bulletproofing.

We first found personal body armor plates that could offer NIJ Standard 0108.01 level IV bulletproofing, which was constructed from ceramic, ultra high molecular weight polyethylene (UHMWPE), and layered synthetic fibers like Aramid [44]. These plates offered the bulletproof protection that we were looking for, but they are very small and could not be integrated into our device due to its round-shaped design to fit on a human body. Figure 25 below shows the round-shaped bullet protection plate.


**Figure 25.** Above shows the bullet proof protection plates. They are small and round-shaped specifically to fit on human bodies, which makes it extremely difficult to apply on the product's shell [45].

We also cannot design our own plate using these materials due to our inability to physically test its ability to stop bullets. This led to us searching for materials that are used in protected facilities, like banks and government facilities. Unfortunately, we were unable to find a NIJ Standard 0108.01 level IV bulletproof material that could be purchased for our specific requirement. However, we did find the Armorcore Level 8 Bullet Resistant Fiberglass Wall Panel [46], which is a UL752 Standard level 8 bulletproof and also NIJ 0108.01 level III bulletproof. The Underwriters Laboratory UL 752 Ballistic Standard requires a material to protect against multiple shots from military assault rifles with a muzzle energy between 2519-3048 ft-lbs [47]. The NIJ Standard 0108.01 level III requires the material to stop a minimum of five rounds from a high powered rifle at a measured velocity of 838 ± 15 m/s [15]. Since the NIJ Standard 0108.01 level IV protects against military grade firearms and these are not likely to be turned in for disposal in our device, we have made the decision to use the lesser NIJ Standard 0108.01 level III bulletproofing in our device. The Armorcore Level 8 Bullet Resistant Panel is shown in Figure 26 on the following page.

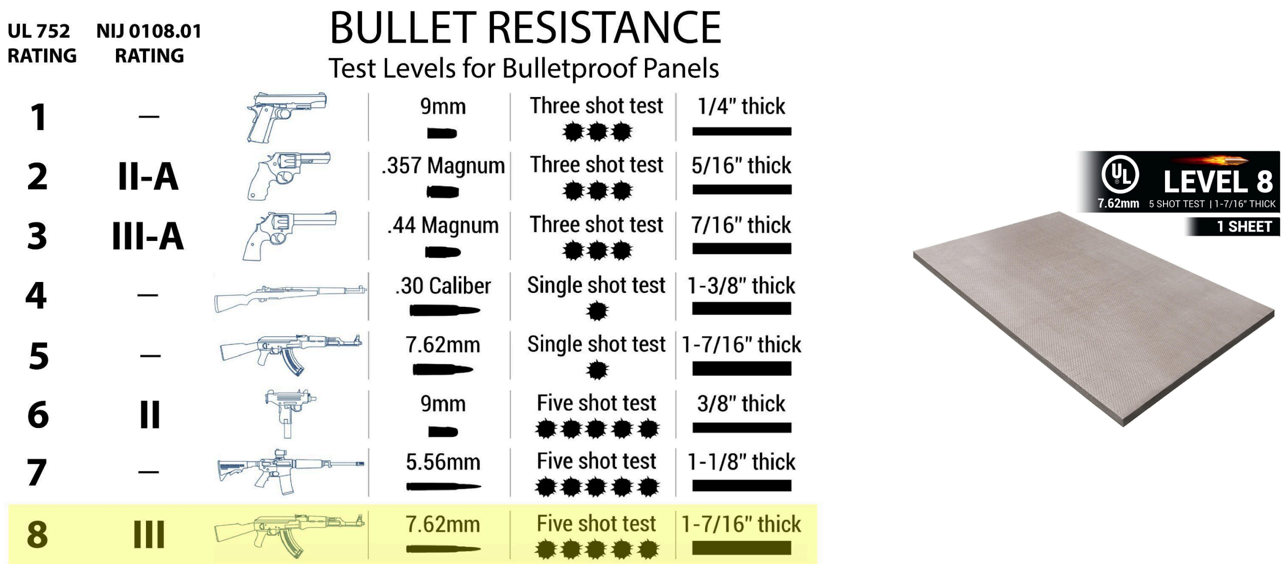



**Figure 26.** Above shows the Armorcore Level 8 Bullet Resistant Fiberglass Wall Panel[46][47].

**FINAL DESIGN DESCRIPTION**
Since it would be extremely difficult for our team to manufacture and build out our prototype design, we have decided to create a CAD model of the design with the proper dimensions for analysis and verification. We also created a scale model prototype to demonstrate the process of surrendering unwanted firearms, the destruction of firearms, and emptying the wastes from the product. Figure 27 below shows isometric views of the prototype design with different transparency levels and markings on the important components of the prototype design. We have included the prototype unit's technical drawings in Appendix C, manufacturing plans in Appendix D, and the bill of materials in Appendix D. More details regarding dimensions will be discussed in the analysis and verifications section.

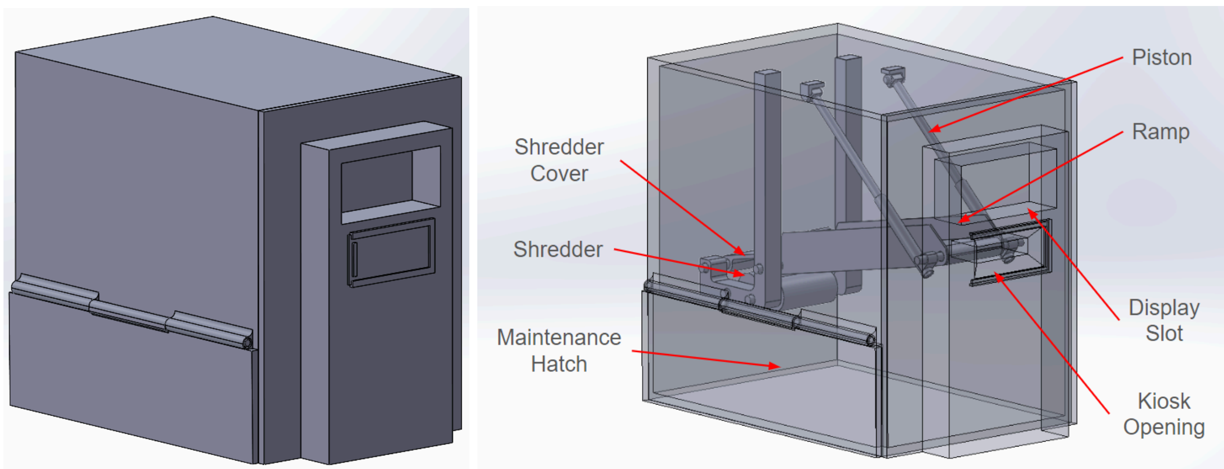



**Figure 27.** Above shows isometric views of the prototype design that we have created. On the left is a normal view of the design unit and on the right we have adjusted the transparency of the shell of the design to reveal the inside components. The view on the right also has markings on the important components of the assembly.

The prototype design has seven important components - display slot, kiosk opening, ramp, piston, shredder cover, shredder, and maintenance hatch. This list may be changed as the project progresses.

On the kiosk of the prototype unit, there are two important features - display slot and opening. The display slot is the place where an interactive display will be inserted to the unit. The display interacts with the users by showing instructions and live streaming the destruction process. The kiosk opening (also referred to as the firearm deposit opening) is where the users insert their firearm to surrender it. Here we have implemented a safety feature. The shredders within the unit will not function as long as the kiosk door is open. The shredders can only function if the sensors on the kiosk detect that the kiosk door is closed. We have decided that there is a need for multiple sensors for detection to ensure safety of users and the local community, but we need to do more research in order to decide on specific sensors.

After the user inserts their unwanted firearm into the unit, the firearm would be rested on the intake, which is the ramp component. The ramp has two side walls to prevent the firearm from falling directly into the waste container without being destroyed. The ramp also has a conveyor belt system to transport the firearm down to the destruction part or transport the firearm back out to the opening (just in case the user regrets their decision and wants their firearm back).

The unit also has a piston system that is responsible for lifting the ramp up and down with the help of metal motors (not modeled)  at the ramp's hinges. This is an important component to the design because the piston system helps the ramp to orient the inserted firearm in a vertical position for feeding into the shredder. We want the firearms to be fed into the shredder in a vertical orientation because it will decrease the cross-sectional area of the firearm which means a smaller shredder can be used.

The next important component is the shredder cover. It is responsible for covering up the shredder. The cover will only be raised up with a motor when the kiosk opening is confirmed closed by the sensors and the user has confirmed to continue the destruction of their firearm. This is so the inserted firearm would not have a chance to reach the shredders without confirmation, and also separate the users completely from the shredder.

The shredder is another important component of the prototype unit. It is responsible for destroying the surrendered firearms. For the current stage of this project, our team has decided that we will not be designing and manufacturing our own shredder design. Instead, we will be finding a shredder on the market that not only has the appropriate dimensions to fit into our prototype unit, but also enough applied shear force to destroy any firearms in the unit.

Lastly, we come to the maintenance hatch. This is where maintenance crew can access the inside of the prototype unit for maintenance and periodically empty the waste container within the prototype unit that holds the waste resulting from the shredder destroying the firearms.

**Why Will It Work?**
Below in Figure 28, we have presented the starting position on the left and the ending position of the prototype unit on the right. Note the final design would have chamfered or smoothed out edges for further safety measurements.

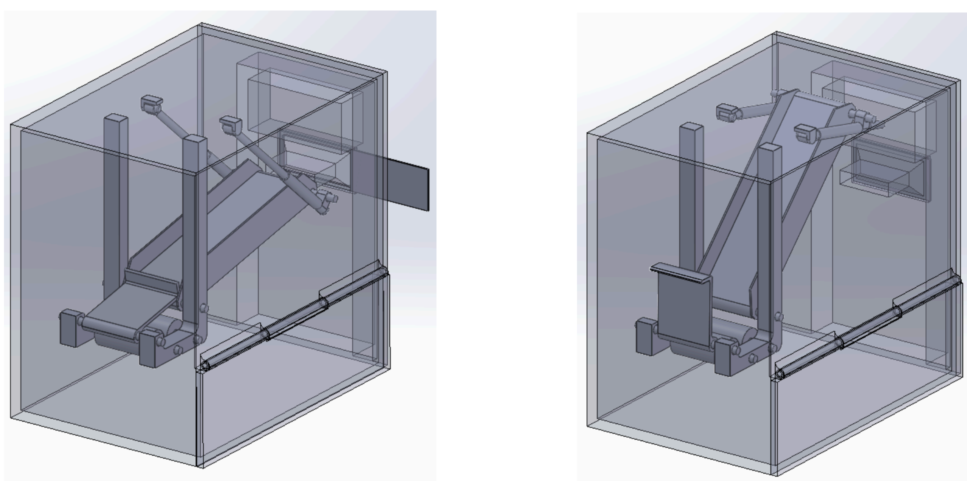


**Figure 28.** Above shows the isometric view of the prototype unit CAD from the CAD. The left view shows the prototype unit at its starting position. The right view shows the prototype unit at its ending position.

In the starting position, the ramp is aligned with the kiosk opening. The shredder cover is also in the lowered position, covering up the shredder. In this position, the end of the shredder cover that is closer to the opening serves as a support for the inserted firearm lying on the intake (ramp) to lean against so that the firearm would not move outside the intake.

The kiosk opening starts out closed and locked. The opening will unlock itself and open once a user interacts with the kiosk. With the kiosk door opened, the user can insert their unwanted firearm into the unit, on the intake (ramp). When the user performs such action, the display on the kiosk will ask the user to confirm destruction and close the kiosk opening by sliding the door back to its closing position. The inside components should not function without the kiosk opening being closed. The prototype unit will know the opening closed by having different sensors observing the position of the kiosk door.

Once the firearm is inserted to the unit and resting on the ramp. The user can either choose to "regret decision" or confirm destruction. If the user regrets their decision of destroying the firearm, they can interact with the kiosk, and the conveyor belt system on the ramp that is holding onto the inserted firearm can then transport the firearm back to the opening, where the user can pick it up. Figure 29 shows the step described.

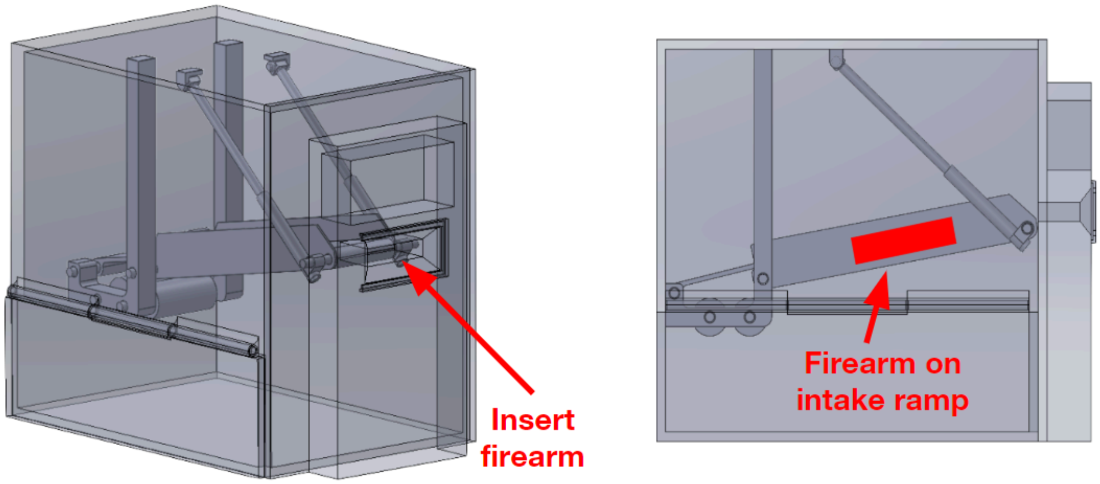



**Figure 29.** Diagrams showing where to insert the firearm to the unit and where the firearm will be rested after insertion.

If the user confirms destruction, the unit will first make sure the kiosk is closed with the process mentioned previously, then the shredder cover inside will lift up and reveal the shredders below. The end of the ramp that is near the opening will also lift up with help of motors and the piston system on the inside ceiling of the prototype unit's shell. This will allow the unit to orient the inserted firearm in a vertical position when feeding to the shredder. This is important because feeding the firearm vertically to the shredder allows us to have a smaller dimension shredder within the unit. Figure 30 below shows the ramp lifting up by the piston system.

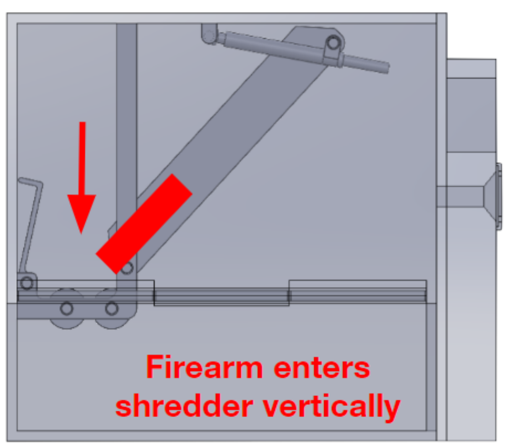



**Figure 30.** Side view showing ramp raised up by piston system to drop off firearm in vertical orientation.

Figure 31 below shows the ramp assembly within the prototype CAD at its ending position when it is orienting the firearm vertically while feeding the firearm to the shredder.

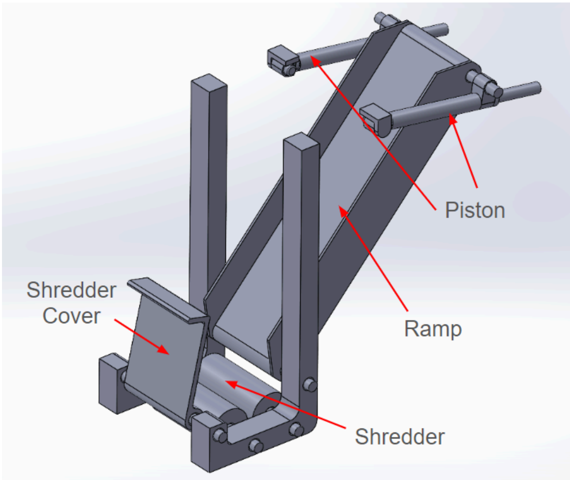



**Figure 31.** Above shows the ramp assembly at the ending position, consisting of the shredder cover, shredder, ramp, and pistons.

After the firearm goes through the shredder, the after waste will then be dropped down to a rigid bulk container. The side of the prototype shell has a maintenance hatch that can open up for a maintenance crew to access the inside of the unit to maintain the machine or periodically empty the container. The maintenance hatch should be locked at all times and only authorized personnel are able to open it. Figure 32 shows the maintenance hatch opening.

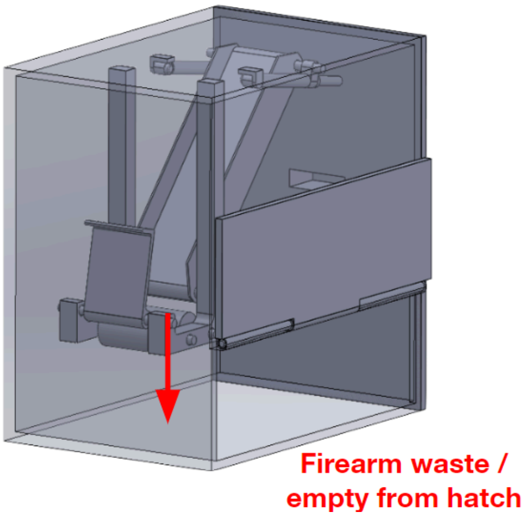



**Figure 32.** Maintenance hatch opening, allowing access to the inside. The hatch is locked at all times and only authorized personnel will have access.

The rigid bulk container from ULINE, shown below in Figure 33, can contain 2,000 lbs of contents (an average rifle weighs around 8.5 lbs, which means that the container can contain the waste of more than 235 rifles on average). This container also has 4-way forklift access, which allows it to be easily moved with a forklift.

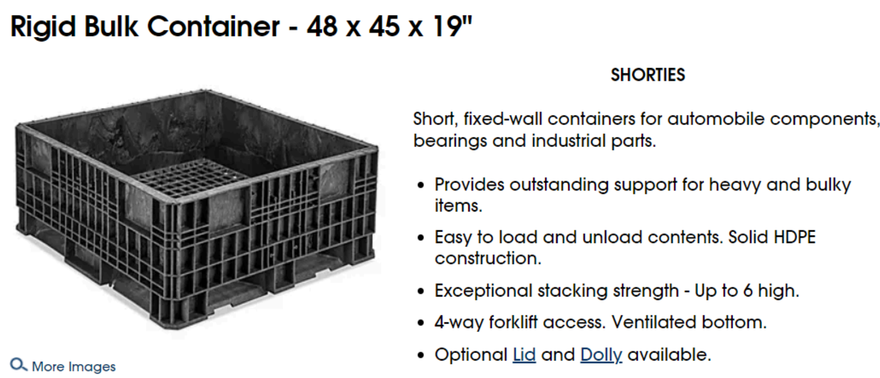



**Figure 33.** Rigid bulk container from ULINE showing the 4-way forklift access[28].

**BUILD DESIGN DESCRIPTION**

We have constructed a 1:10 scale model prototype, which is our team's build design. Figure 34 shows the build design assembled and built with 3D printed components and laser cut acrylic outer shell.


**Figure 34.** Build design scale model.

**How Does It Differ From the Final Design?**

This build design is a simplified version of the final design, which means that some parts were omitted, such as the motors, fasteners, and maintenance hatch. The scale model is purely for demonstrating the process of firearms going through the unit so that people can better understand how it works. Due to these reasons, the scale model will not be able to actually shred anything; it is purely for demonstration of the destruction process.

For the scale model prototype, our team utilized a 3D printer to manufacture most of the components. However, we also used  clear acrylic, as suggested by Don Wirkner to create the outer shell of the scale model. Having a clear shell allowed us to demonstrate the interior components and how they function.

**How will it prove the most important aspect of the final design?**

The scale model prototype helped our team to visualize the volume each subsystem should take up. This allowed us leeway to modify each of the subsystem's dimensions, just in case something unexpected happened. For example, needing more space to place a bigger shredder in the unit.

The scale model prototype has also given us ideas of how and where to implement safety features. Our team came up with different safety features while designing and assembling. For example, having the shredder cover to physically separate the user from the shredder, and the unit not functioning without the kiosk opening being closed.

Having the prototype also gave our team ideas on which part of the design can be modular. Through modeling each component of the prototype in Solidworks, we gained a better understanding on the overall structure of the design and found how many different parts can be modular to make maintenance easier. For example, our team would not be designing and manufacturing our own shredders or waste containers, instead they would be purchased components. This makes those components easily interchangeable and they will be readily available for purchase. Also, while we are creating the model, we purposefully created more small parts to form an assembly, instead of having a large singular part. This is so that when a small component on the assembly broke, we could just swap out that one part on the assembly, instead of replacing the entire one large part.

Creating the prototype model also sets a direction for the process and mechanism of feeding, destroying, and storing unwanted firearms. Before we created the prototype, we had a general idea of how the unit should function. However, we were not sure how exactly each process would work. After creating the model, we gained more knowledge on how to make certain processes happen more smoothly. For example, implementing the piston system to help with the ramp lifting up and down to orient the inserted firearm. Before the model, our team knew we wanted the machine to drop the firearm into the shredder vertically to allow a smaller dimensioned shredder, but we were not sure. By experimenting with different designs and placements of the intake (which later evolved into the ramp), we have come to the idea of using piston and motors to lift the ramp up as the optimal method.

**VERIFICATION AND VALIDATION PLANS**

We have outlined our verification plans for our requirement specifications below in Table 9. We were able to perform most of our verifications and validation using our CAD model and visual inspection.

**Table 9.** Verification plans for requirement specifications.

| Requirement | Specification | Verification | Result |
|---|---|---|---|
| **Must be modular** | More than 2 modular and readily available replacement parts | Shredder blade, container, and more are modular and readily available for replacement | Pass |
| **Must be safe to the users and community** | Must achieve level IV bullet-proof by NIJ 0108.01 Standard | NIJ Standard 0108.01 Level III and UL752 Level 8 testing has been performed by panel manufacturer, does not meet Level IV requirements | Fail |
| | Minimum distance 60" between the user interface and the destruction part | Visual Inspection, Measurements performed on CAD model | Pass |
| **Must fit inside footprint of shipping container** | Required dimensions:<br>Width ≤ 8'<br>Length ≤ 40'<br>Overall height ≤ 13' 6" | Visual Inspection, Measurements performed on CAD model | Pass |
| **Must be light enough to be transported by semi-truck** | Must weigh less than 45,000 lbs | Weight analysis performed on CAD model | Incomplete |
| **Must be able to accept firearms of any size** | Intake ramp must be a minimum of 45" in length | Visual Inspection, Measurements performed on CAD model | Pass |
| | Firearm deposit opening must be at least 16" in width and 4" in height | Visual Inspection, Measurements performed on CAD model | Pass |
| **Must store firearm waste** | Must store waste of more than 150 firearms | Analysis of average firearm weight and container weight capacity | Pass |
| **Must destroy firearms per ATF guidelines** | Must exert shear force of more than 719 MPa | Analysis of firearm material and shredding machine technical specifications | Pass |

**Must Be Modular**

Our modular requirement for our project specifies that we have more than two modular / replaceable components in our product. We have specifically selected shredding machines that have readily available and replaceable shredding blades. We have also selected an off-the-shelf container to be used for the waste container in our product, which can be easily removed and replaced if it needs to be emptied or is damaged. Our final design concept passed the verification for modularity since it has more than two components that are modular / replaceable.

**Must be Safe to User and Community**

To ensure safety to the user of our device, we are requiring a minimum distance 60" between the user interface and the destruction part. To verify our requirement of the minimum distance between the user and destruction part of our design, we have created a prototype model in CAD and have completed verification by visual inspection. As shown below, in Figure 35, the user interface is 77" from the destruction part, which passes our verification.

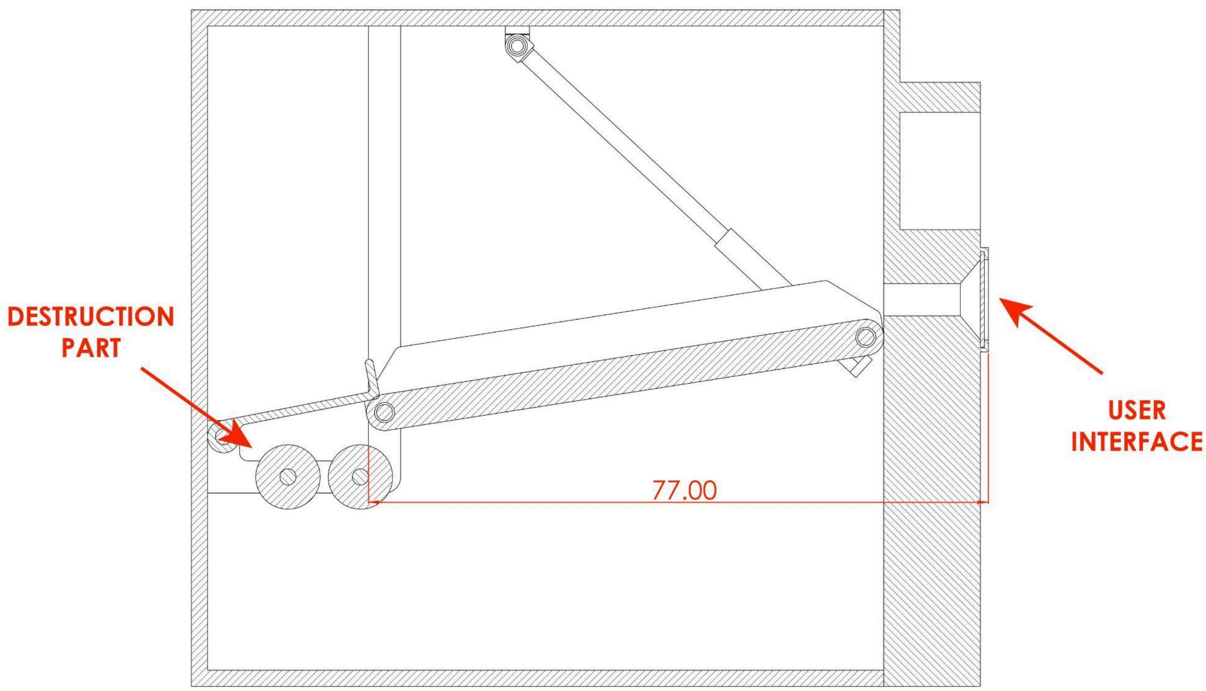



**Figure 35.** Above shows the distance between the user interface and the destruction part of our prototype model.

**Must meet NIJ Standard 0108.01 Level IV Bulletproof Specifications**

We were not able to specify a material that could meet the NIJ Standard 0108.01 Level IV bulletproofing specifications at this time since it must be physically tested by firing ammunition at the material. We have found an alternative option, Armorcore Fiberglass Wall Panel, which is a large drywall-like panel that can be affixed to the interior walls of our product. The Armorcore Fiberglass Wall Panel has been tested under the guidelines for both the NIJ Standard 0108.01 Level III and UL752 Level 8 bulletproofing specifications and meets the requirements. Our final design concept did not pass the verification for NIJ Standard 0108.01 Level IV bulletproofing, it was only able to meet NIJ Standard 0108.01 Level III bulletproofing specifications. Table 10 on the next page, shows the required testing specifications for each standard compared with our selected material, Armorcore Fiberglass Wall Panel.

**Table 10.** Requirements for NIJ Standard 0108.01 Level III and UL752 Level 8 bulletproofing compared with actual tested ammunition on the Armorcore Fiberglass Wall Panel.[46][47]

| | Required Test Ammunition | Required Nominal Bullet Mass | Required Bullet Velocity | Required Hits per Armor Specimen |
|---|---|---|---|---|
| **NIJ 0108.01 Level III [14]** | 7.62 mm<br>308 Winchester | 9.7 g<br>150 gr | 838 ± 15 m/s<br>2750 ± 50 ft/s | 5 |
| **UL752 Level 8 [46]** | 7.62 mm rifle<br>lead core full metal copper jacket, military ball | 9.7 g<br>150 gr | 2750 ft/s – 3025 ft/s | 5 |
| **Armorcore Fiberglass Wall Panel Testing [47]** | 7.62 mm rifle<br>lead core full metal copper jacket, military ball | 9.7 g<br>150 gr | minimum 2750 ft/s | 5 |

**Must Fit Inside Footprint of Shipping Container**

To ensure our product can be easily transported, it must fit within the footprint of a shipping container. To verify our dimensional requirement, we have created a prototype model in CAD and have completed verification by visual inspection. As shown below, in Figure 36, our product is 60” wide x 86” long x 84” tall. These dimensions fit within the footprint of a shipping container, so it does pass our verification.

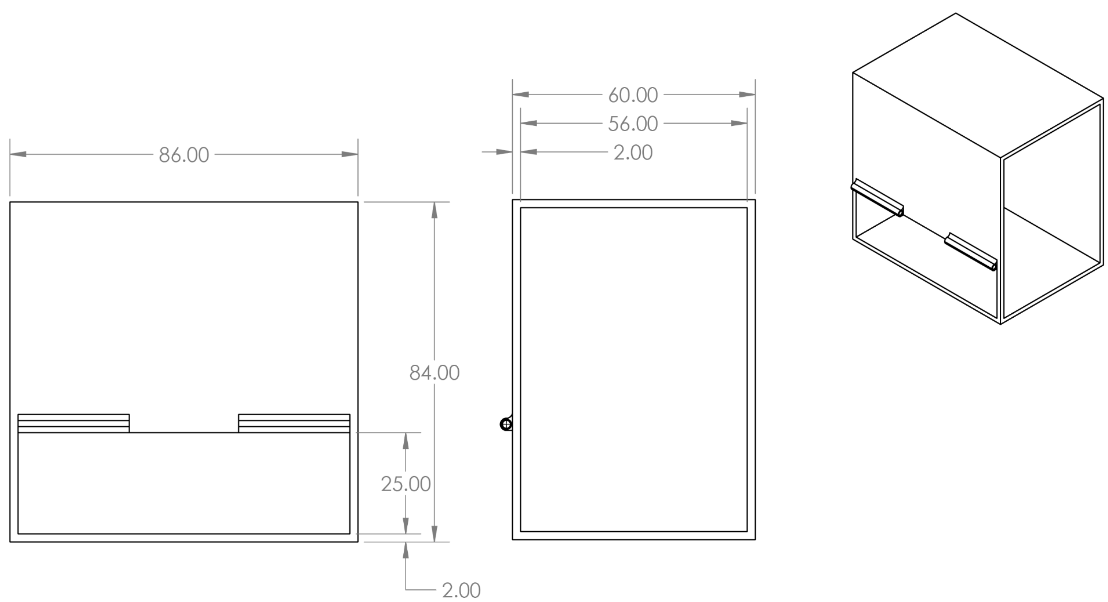



**Figure 36.** Above shows the overall dimensions of our product: 60” wide x 86” long x 84” tall. These dimensions fit within the footprint of a shipping container of 8’ wide x 40’ long x 13' 6" tall.

**Must be Light Enough to Transported by Semi-Truck**
Our plans to verify our specification for overall weight of our product are to apply material properties to our CAD model to get an estimate of the shell's weight. We will then need to calculate the required amount of bulletproofing material and calculate the additional weight. Our CAD model is not yet complete enough to make this determination.

**Must Accept Any Size Firearm**
To ensure our device is able to accept firearms of any size, we are requiring the firearm intake ramp be a minimum of 45" in length, and the firearm deposit opening must be at least 16" in width and 4" in height. To verify our requirement of the firearm intake ramp length and firearm deposit opening dimensions, we have created a prototype model in CAD and have completed verification by visual inspection. As shown below, in Figure 37 panel a, the firearm intake ramp is 60.5" in length, which passes our verification. Figure 37 panel b, shows the width of the firearm deposit opening is 16" and the height is 4", which also passes our verification.

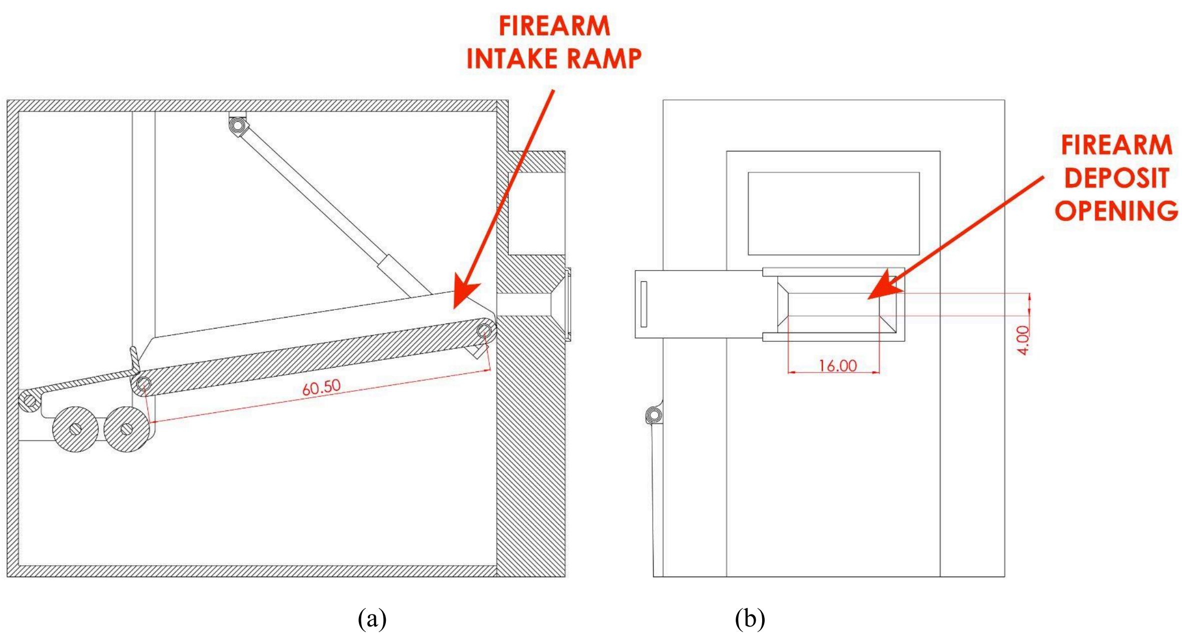



**Figure 37.** Above in panel a, the length of the firearm intake ramp is shown, while the firearm deposit opening dimensions are shown in panel b.

**Must Store Firearm Waste**
Using the average weight of a standard rifle of around 8.5 lbs [29], we have calculated the approximate weight of 150 firearms to ensure our device is able to store the minimum specified number of firearms. The calculated weight of 150 firearms is approximately 1,275 lbs and our selected waste container can hold up to 2,000 lbs of waste, so it does pass the verification for storing the minimum waste of 150 firearms.

**Must Destroy Firearms Per ATF Guidelines**

To verify that a given shredding machine could destroy a firearm, we have compiled Table 11 below, which shows the minimum force that must be applied by the shredding device to the firearm in order to shear the material compared with the forces the given shredding machines are able to apply. All shredding devices were able to meet the requirements to shred the firearm material, so our final design concept passes the verification.

**Table 11.** Comparison of specific shredding machine's applied shear stress with required shear stress for grade 5 aluminum. Verification is based on the shear force with a safety factor of 1.5. All shredding devices are able to apply the shear force required to shear the firearm material.

| | **Taskmaster® TM1600 [40]** | | **FTS-500 [41]** |
|---|---|---|---|
| **Blade Thickness** | 13 mm<br>0.5 in | 19 mm<br>0.75 in | 20 mm<br>0.787 in |
| **Applied Shear Force (min / max)** | 744 MPa / 1655 MPa<br>108041 psi / 240091 psi | 496 MPa / 1103 MPa<br>72027 psi / 160061 psi | 1571 MPa<br>227932 psi |
| **Required Shear Force (grade 5 titanium)** | | 479 MPa<br>69,282 psi | |
| **Required Shear Force (grade 5 titanium) + 1.5 SF** | | 719 MPa<br>103,923 psi | |
| **Pass Verification?** | Pass | Pass - within range | Pass |

## DISCUSSION

### Problem Definition

We have not considered that due to the total weight of our design concept, it may not be able to be unloaded from a semi-truck. The maximum weight of 45,000 lbs, would require an extremely heavy-duty forklift and it is likely not available locally. If we had more time, our team would research alternate construction materials to reduce the overall weight of the unit.

If we had more time, our team would have liked to explore user interface options. We considered having a display in our product to allow user interaction, and show instructions. However, we did not consider how to properly apply those features. If given more time and resources, we would like to dive deeper and research what functionality the display should possess.

We also did not consider the power source. The unit is designed to be mobile. However, we did not spend too much time researching the batteries and power generators we could use to properly make our design plausible.

### Design Critique

For this project, we have created a CAD model that is able to demonstrate the general process of accepting unwanted firearms, destroying them, and emptying the firearm waste. This physical prototype model is simplified due to high cost, lack of resources, and time constraints. Our design does not select a specific shredder, and we do not know if the shredding devices will physically fit into the space we have allotted. The dimensions of the shell will likely need to be expanded to ensure the shredding device fits within the interior of the shell.

### Risks

A potential problem that our team might be facing in the very near future is completing a more accurate bill of materials for the full scale, final build of the prototype design. The unit will require many fasteners, motors, electronic components, and other parts that we have yet to consider. For example, it would be difficult for our team to determine the specific number of fasteners needed to assemble the unit.

Due to the high cost of the material and shredding device, we will not be able to create a functional prototype. Instead, we have created a scale model of the unit with clear acrylic walls in order to showcase the inside of our selected concept. The inside components were 3D printed and the assembly is  articulated. The scale model demonstrated the firearm deposit opening and the path the firearm traveled to the shredding device.

Our current solution for preventing non-firearm items from being put into the concept unit is to limit the size of the deposit opening, but it will not be enough to prevent small items from being put into the concept unit, such as animals or trash. We have considered adding an x-ray device that could scan the item placed in the concept unit before it is sent to the shredder to ensure the shape and material are consistent with a firearm. Alternatively, we have also considered implementing a camera on the interior of the concept unit that is viewed remotely by a person that can determine if the item placed inside is a firearm. In both cases, if the item is not a firearm, it would be rejected and would not be sent to the shredder.

We are also considering that this device could be very loud in a public space and could possibly exceed legal allowable noise levels. One possible solution is to add a rubber lining to the interior of the shell to help reduce the amount of noise that can be heard outside of our device.

In the future, we would like to obtain community feedback on our potential design solution. After gaining community approval, more verification and validation testing will need to be done to ensure community safety, such as NIJ Standard 0108.01 Level IV bulletproof testing. It is also unknown if our solution will be accepted by communities, since this concept is new and has not yet been demonstrated.

## REFLECTION

### Social Aspect

The driving social aspect of this project, beyond the interest of the sponsor, is firearm injury prevention. The main concern is unwanted firearms owners will dispose of their guns in an unsafe manner that could cause the firearm to discharge during the process. Our project sponsor Dr. Humphreys is a social scientist, so he highly ranks this project's social impact over other priorities. He does, however, also value the environmental impact and has challenged us to think of environmentally friendly solutions that could offer the possibility of recycling the waste material produced.

Our product will be used by the general public, so safety is our highest priority. We implemented crucial safety features, like the bullet-proof shell, and we have made our design user friendly by adding an interactive screen to the kiosk. The product will have a positive social impact because the goal of this project is to keep people and communities safe.

The use of our product involves the transportation of disposed firearms waste and requires energy to completely destroy firearms, so it will consume many finite resources and emit pollutants. The product will be expensive to manufacture, but it is not going to be mass produced because it will be a mobile service, stopping for a period of time in different communities.

There are not many ways that the manufacture, use, or disposal of this design will be sustainable, so we can take actions that will make them more sustainable. We could reduce the size of our product to make our design more sustainable, but a consequence of this size reduction could also be a reduction in the number or type of firearms accepted. We could also attempt to recycle the firearm waste product. In order to recycle the firearm waste product, it would need to be sorted by material which requires time and costly equipment, but would be more environmentally sustainable.

### Ethics

One dilemma we faced during the design process is how to address the fact that criminals may use our product to destroy the evidence of a firearm used in a crime. After some consideration, we believe if a criminal has the intent to destroy or dispose of their firearm, they would do so regardless of our unit being in their community. While we do not condone their actions, we would rather their firearms be disposed of in a safe way than to remain in circulation and potentially hurt themselves or others. Another issue is how to address stolen firearms. Similarly, if a thief wanted to dispose of a stolen firearm they would just do so, so we would rather they dispose of it in a safe way.

It may be the understanding of some individuals that we are aiming to encourage people to give up their firearms. The intent of this project is only to destroy firearms that are already unwanted, not to convince people to give them up.

### Inclusion and Equity

Our product aims to allow any person who wishes to dispose of their unwanted firearms to do so. We have considered that users may not have firearm experience. It is important to be inclusive of users without firearms experience because most people are not experts. A strategy to address user experience is to frequently perform usability tests on new users with no prior knowledge of our product. This assures our product is intuitive to anyone and not just ourselves or people with prior firearm experience. It is also important to be inclusive of users who do not want to be identified, as requiring identification could deter them from using our product and lead them to dispose of their firearms in an unsafe way. A strategy to address identification concerns is to not document the individual turning in a firearm for destruction. This ensures all users feel comfortable using our product and are never dissuaded from turning in an unwanted firearm. Our product will also be compliant with the Americans with

Disabilities Act (ADA) requirements to ensure individuals with disabilities can still use our product without issue. This includes wheelchair users and people with hearing and visual impairments.

There is a power dynamic between the sponsor and ourselves because the sponsor is funding the project and has much more background knowledge than us. However, we do have more expertise in the field of engineering compared to our sponsor,

Another power dynamic to consider is between ourselves and the users. We have the most influence over the design of the product, so we might have ideas that do not align with the end user's needs. We were conscious of this power imbalance, and worked hard to take account of user experience.

We also considered the power dynamic between team members. We have established roles and responsibilities for each team member, but no one of us has more power over another. We never made decisions without the consent of the rest of the group and we communicated with each other promptly throughout the project. We also considered how experience level and age differences might be a power dynamic. It is possible that team members with more experience or are older will garner more respect and have more power over other members. To address this, we are balancing the workload based on time commitment and stakes in the project. We are balancing based on work assignment because this ensures no team member is burdened with more work than another.

**RECOMMENDATIONS**

We recommend looking into materials used in NIJ Standard 0108.01 Level IV personal body armor plates to line the interior walls of the shell. These armor plates are made from ceramic, ultra high molecular weight polyethylene (UHMWPE), and layered synthetic fibers like Aramid [43], which look promising, but testing would be required to verify they meet the NIJ Standard 0108.01 Level IV for bulletproofing.

We recommend that the sponsor should first show the concept to different communities for advice and approvals. Then, make appropriate changes based on feedback received. Another recommendation would be to add an inner door to the firearm deposit opening. This would increase safety factor and strengthen the deposit opening, which is currently the weakest part of the design.

**CONCLUSION**

There are many different ways that an individual may come in the possession of an unwanted firearm. These individuals often feel stuck since the process of disposing of a firearm is so complicated. Our team has designed a product that completely destroys firearms, which is accessible to the public and safe to use. Further steps need to be taken in the immediate future, such as gaining community approval, so that the project can become a reality.

**ACKNOWLEDGEMENTS**

Team 1A would like to acknowledge Dr. Shanna Daly for her help in assisting with the overall design process, and Dr. David Humphrey for sponsoring the project and precious knowledge in the field of firearms disposal.

**REFERENCES**


[1] Humphreys, D., “Sponsor Interview.”

[2] Bureau of Alcohol, Tobacco, Firearms and Explosives, “How to Properly Destroy Firearms” [Online]. Available: https://www.atf.gov/firearms/how-properly-destroy-firearms.

[3] GunBusters LLC, “GunBusters Firearms Destruction” [Online]. Available: https://gunbustersusa.com/.

[4] Reynolds, R. W., “Firearms Pulverizer System and Method.”

[5] TekMat Gun Accessories, *Sig Sauer P320 Schematic*.

[6] Mcintire, M., 2023, “The Guns Were Said to Be Destroyed. They Were Just Reborn.” [Online]. Available: https://www.nytimes.com/2023/12/10/us/guns-disposal-recycling.html.

[7] Wing, N., 2018, “It’s Way Too Hard To Dispose Of Unwanted Guns In The U.S.” [Online]. Available: https://www.huffpost.com/entry/gun-disposal-buyback-us_n_5bb64d69e4b028e1fe3bd152#.

[8] Moms Demand Action, “Moms Demand Action for Gun Sense in America” [Online]. Available: https://momsdemandaction.org/

[9] Giebel, K.-F., Mauch, E., and Dietel, B., “Destruction Unit and Firearm with Said Destruction Unit and Method for Rendering a Firearm Inoperative.”

[10] Crum, P. D., Hildebrandt, C. K., Harne, G. K., and Boland, D. A., “Weapon demilitarization system and process.”

[11] Michigan State Police, “Public Notice of Intent to Dispose of Firearms” [Online]. Available: https://www.michigan.gov/msp/services/ccw/public-notice-of-intent-to-dispose-of-firearms.

[12] Philadelphia DA Memo

[13] Wing, N., 2018, “Some Americans Want To Give Up Their Guns — But It’s Complicated,” huffpost.com [Online]. Available: https://www.huffpost.com/entry/gun-disposal-destruction_n_5ba01f1ee4b013b0977debe1?qe.

[14] 2008, “Ballistic Resistance of Body Armor NIJ Standard-0101.06.”

[15] 1985, “Ballistic Resistance of Body Armor NIJ Standard-0108.01.”

[16] D Ernawati et al, 2018, “Modularity Design Approach for Preventive Machine Maintenance,” J. Phys.: Conf. Ser. 953 012232.

[17] architecturalarmour.com/, “Armoured Steel” [Online]. Available: https://www.architecturalarmour.com/security-products/bullet-boards/armoured-steel.

[18] “Consumer Product Safety Commission (CPSC)” [Online]. Available: https://www.usa.gov/agencies/consumer-product-safety-commission.

[19] Lieng, E., and Park, J., 2024, “Empirical Test for Arm Reach.”

[20] International Van Lines, “Container Sizes” [Online]. Available: https://internationalvanlines.com/container-sizes/.

[21] Morin, M., 2021, “Everything You Need to Know About Shipping Container Trailers” [Online]. Available: 19. https://www.falconstructures.com/blog/shipping-container-trailer.

[22] *MICHIGAN VEHICLE CODE 257.719*.

[23] Salinas, G., “MAXIMUM WEIGHT LIMIT OF AN 18-WHEELER” [Online]. Available: https://www.salinastriallaw.com/san-antonio-truck-accident-lawyer/what-is-the-maximum-weight-limit-of-an-18-wheeler/.

[24] ONSITE TRUCK and & EQUIPMENT REPAIR, "HOW MUCH DOES A SEMI TRUCK WEIGH" [Online]. Available: https://www.onsitetruckaz.com/post/how-much-does-a-semi-truck-weigh-ultimate-guide-2022.
[25] Salvatore, 2019, "How Pistol Dimensions Influence Concealability," https://www.usacarry.com/ [Online]. Available: https://www.usacarry.com/pistol-dimensions-influence-concealability/.
[26] McShan, A., 2023, "A Guide to Pistol Sizes: Full-Sized to Compact Options" [Online]. Available: https://www.academy.com/expert-advice/pistol-sizes.
[27] Gunbuilders.com, 2023, "AR 15 Size - Gun Case Sizing Guide" [Online]. Available: https://www.gunbuilders.com/blog/ar-15-size-gun-case-sizing-guide/.
[28] ULINE, "Rigid Bulk Container - 48 x 45 x 19""" [Online]. Available: https://www.uline.com/Product/Detail/H-8927/Bulk-Containers/Rigid-Bulk-Container-48-x-45-x-19.
[29] Brooks, B., "Lightweight Rifles and Mountain Hunting" [Online]. Available: https://argalioutdoors.com/advice/lightweight-rifles-and-mountain-hunting.
[30] "EFFECTS DATABASE" [Online]. Available: https://wbam2244.dns-systems.net/EDB/.
[31] Canvas slides, heuristics table
[32] Ashby, M. F., and Jones, D. R. H., 2012, *Engineering Materials 1: An Introduction to Properties, Applications, and Design*, Butterworth-Heinemann, Amsterdam ; Boston.
[33] Azom, "AISI 4140 Alloy Steel (UNS G41400)" [Online]. Available: https://www.azom.com/article.aspx?ArticleID=6769.
[34] Azom, "AISI 4150 Alloy Steel (UNS G41500)" [Online]. Available: https://www.azom.com/article.aspx?ArticleID=6770.[1]
[35] metalsuppliersonline.com, "Carbon Steels 1020" [Online]. Available: https://www.metalsuppliersonline.com/propertypages/1020.asp.
[36] MatWeb, "416 Stainless Steel" [Online]. Available: https://www.matweb.com/search/datasheet.aspx?matguid=2d05275df2a841a1b7ddffa503f41fa1&ckck=1.
[37] MatWeb, "Titanium Ti-6Al-4V (Grade 5)" [Online]. Available: https://www.matweb.com/search/DataSheet.aspx?MatGUID=10d463eb3d3d4ff48fc57e0ad1037434.
[38] MatWeb, "Aluminum 7075-T6" [Online]. Available: https://www.matweb.com/search/DataSheet.aspx?MatGUID=4f19a42be94546b686bbf43f79c51b7d.
[39] MatWeb, "Aluminum 6061-T6; 6061-T651" [Online]. Available: https://asm.matweb.com/search/SpecificMaterial.asp?bassnum=ma6061t6.
[40] Shred-Tech, "Shred-Tech ST-400 Industrial Shredder" [Online]. Available: https://shred-tech.com/shred-tech-st-400-industrial-shredder/.
[41] Fante, "FTS Mini Single Motor Shredder" [Online]. Available: https://fanterecycling.com/product/fts-mini-double-shredder/.
[42] OXRD, *Double Shaft Plastic Shredder Blades and Knives*.
[43] Schneider, "Semi-Truck and Trailer Dimensions: A Guide to Standards" [Online]. Available: https://schneiderjobs.com/blog/semi-truck-trailer-dimensions.
[44] BLOCKER, R., 2021, "Level IV Body Armor - What Is It Made of and Other Things You Need to Know" [Online]. Available: https://bulletproofzone.com/blogs/bullet-proof-blog/what-is-level-iv-body-armor.
[45] Bulletproof Zone, "DFNDR LEVEL IV ARMOR PLATE" [Online]. Available: https://bulletproofzone.com/collections/level-iv-body-armor/products/dfndr-level-iv-armor-plate.

[46] Covenant Security Equipment, “Armorcore Level 8 Bullet Resistant Fiberglass Wall Panel UL 752 Rated” [Online]. Available: https://covenantsecurityequipment.com/collections/all/products/armorcore-level-8-bullet-resistant-fiberglass-wall-panel-ul-752-rated.
[47] “UL 752 SPECIFICATIONS AND AMMUNITION.”
[48] Covenant Security Equipment, “Armorcore Level 8 Bullet Resistant Fiberglass Wall Panel UL 752 Rated Spec Sheet” [Online]. Available: https://drawings.covenantsecurityequipment.com/pdf/CSE_Product_Data_Sheets_Levels_1-8.pdf.
[49] Meriam, J. L., Kraige, L. G., and Bolton, J. N., 2015, *Dynamics*, John Wiley & Sons, Inc, Hoboken, NJ.
[50] Hibbeler, R. C., 2017, *Statics and Mechanics of Materials*, Pearson, Hoboken.

## APPENDIX A: Concept Generation

Figure A.1 below shows our team's concept generation table. Each column shown on the table is a different category, characterized by different methods of firearm disposal - cutting, deforming, melting, storing, irresponsible, upcycling / preservation, entertainment, and unrealistic.

| Cutting | Deformation | Melting | Storing | Irresponsible | Upcycling / Preservation | Entertainment | Unrealistic |
|---|---|---|---|---|---|---|---|
| Cut guns with bandsaw blades | Use a press to wedge the firearm in half | Send guns to metal manufacturer to melt and recycle | Garbage truck goes door to door in community to collect guns | Use the gun so much, the barrel melts off | Pouring molten metal into the barrel | Host world record competition to break guns | Send to sun |
| Cut guns with plasma cutter | Crushing machine | Weld the trigger mechanism | Gun dropbox (like Blockbuster) | Have two firearms facing each other, fire them at the same time | Make art and furniture out of unwanted guns | Have firearm gambling -- where will the gun break in half? | Send firearms to space |
| Cut guns with EDM | Coil the firearm around a cylinder | Garbage truck with incinerator | Portable bin, to be collected every period | Use for testing military weapons, how metal withstands explosives | | Live stream gun destruction | |
| Shredder in "ATM-like" machine | Run firearms over with a tank | Blast furnace | Time vault | Throw in trash | | Tournament to break guns | |
| Collected in container then blow them up | Food truck with hydraulic press | Melt via induction | An emergency station that can call first responders and can be used to destroy guns | Throw in lake | | Create a TV show of people breaking guns in many different ways | |
| Metal shredder | Insert the firearm into a container that then crushed the firearm | Clamp with electrodes and melt | Storage container disguised as a recycling bin | | | | |
| Cut guns with a saw | Crush with hydraulic press | Incinerator | Portable, secured storage box | | | | |
| Shred the guns | Trash compacter | Attendent places the firearm onto a conveyor that leads to a furnace to melt it | New section in trash yard | | | | |
| Cut guns using a high speed mill | | Put firearms in acid | Gun "jail" and public destruction | | | | |
| Cut guns using a waterjet | | User loads firearm onto conveyor that leads to a furnace to melt it | Special mail-in box | | | | |
| Cut guns using a laser | | Sacrifice guns to a volcano | | | | | |
| User inserts the firearm into a container that drops the firearm into a metal shredder | | | | | | | |
| Attendent accepts firearm and uses a torch to cut firearm into pieces | | | | | | | |
| A van has an opening on the side for inserting the firearm and mechanism inside shreds the firearm | | | | | | | |

**Figure A.1.** Above shows a table with listed concepts generated during our team's concept generation process.

**APPENDIX B: Engineering Analysis**
**Shredder Selection Analysis Calculations**

Starting with the power output and operating RPM range, we are able to calculate the shredder's output torque using Eq B.1:

$$P = T * \omega \qquad \text{(B.1)[49]}$$

where $P$ is the power out of the shredder, $T$ is the output torque of the shredder, and ω is its angular velocity. Replacing ω with $\frac{RPM * 2\pi}{60}$ and solving Eq X1 for $T$, we can calculate the shredder's minimum and maximum torque output using Eq B.2 and Eq B.3:

$$T_{min} = \frac{P_{min}}{RPM_{max}} * \frac{60}{2\pi}, \quad T_{max} = \frac{P_{max}}{RPM_{min}} * \frac{60}{2\pi} \qquad \text{(B.2, B.3)}$$

where $T_{min/max}$ is the minimum/maximum torque output of the shredder, $P_{min/max}$ is the minimum/maximum power output of the shredder, and $RPM_{min/max}$ is the minimum/maximum operating speed of the shredder.

After determining the minimum/maximum torque output, we can then calculate the minimum and maximum force that can be exerted by the shredder using Eq B.4:

$$T = F * d \qquad \text{(B.4)[50]}$$

where $T$ is the torque output of the shredder, $F$ is the force exerted by the shredder, and $d$ is distance from the axis of rotation to the contact point of the shredder blade on the firearm.

Replacing $d$ with the radius of the shredding blade and solving for $F$, we can calculate the minimum and maximum force the shredder is able to apply using Eq B.5 and Eq B.6:

$$F_{min} = \frac{T_{min}}{r_{blade}}, \quad F_{max} = \frac{T_{max}}{r_{blade}} \qquad \text{(B.5, B.6)}$$

where $F_{min/max}$ is the minimum/maximum force exerted by the shredder, $T_{min/max}$ is the minimum/maximum torque output values from Eq B.2 and Eq B.3, and $r_{blade}$ is the radius of the shredding blade.

We must take into account the geometry of the shredding blade tooth since the force exerted by the shredder is distributed over the contact area of the shredding blade tooth. We can calculate the contact area of a single tooth using Eq B.7 or Eq B.8:

$$A_{rec} = l_{tooth} * w_{tooth}, \quad A_{tri} = \frac{l_{tooth} * w_{tooth}}{2} \qquad \text{(B.7, B.8)}$$

where $A_{rec}$ is the contact area of a rectangular tooth on the shredding blade, $A_{tri}$ is the contact area of a triangular tooth on the shredding blade, $l_{tooth}$ is tooth length, and $w_{tooth}$ is the tooth width.

We can calculate the minimum and maximum shear stress that can be applied to the firearm using Eq B.9:

$$\tau = \frac{F}{A} \qquad \text{(B.9)[50]}$$

where $\tau$ is the shear stress applied to the firearm, $F$ is the force exerted by the shredder, and $A$ is the contact area of a tooth on the shredding blade.

It is important to note that the tooth geometry has a large impact on the shear stress applied to the firearm – a triangular tooth essentially doubles the force applied by the shredder.

Substituting the calculated contact area of the tooth for the appropriate tooth geometry, $A_{rec}$ *or* $A_{tri}$, and the $F_{min/max}$ values calculated from Eq B.5 and Eq B.6 into Eq B.9, we can calculate the minimum and maximum shear stress applied to the the firearms using Eq B.10 and Eq B.11:

$$\tau_{min} = \frac{F_{min}}{A}, \quad \tau_{max} = \frac{F_{max}}{A} \qquad \text{(B.10, B.11)}$$

where $\tau_{min}/\tau_{max}$ is the minimum/maximum shear stress applied to the firearm, $F_{min/max}$ is the minimum/maximum force exerted by the shredder, and $A$ is the contact area of a shredding blade tooth.

**APPENDIX C: Bill of Material of Design Concept**

Below in figure C.1, our team has presented our bill of materials for the design concept. Most of the items are unknown at this stage of the project and require further research to obtain more accurate information. The parts that we have listed below are known parts with information gathered.

**Table C.1.** Bill of materials for the final design concept. Require further research to obtain more accurate information.

| Part # | Description | Material | Method | Seller | Quantity | Mass of Material | Unit Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|
| 1 | Bullet-Proof Panel [46] | UHMWPE, ceramic, Aramid | Purchased Component | Covenant Security Equipment | 8 | 364.8 lbs /sheet | $2,100 | $16,800 |
| 2 | Taskmaster® TM1600 Shredder [40] | | Purchased Component | Shred Tech | 1 | | Unknown, Estimated $10,000+ | $10,000+ |
| 3 | Waste Container [28] | Polyethylene | Purchased Component | ULINE | 1 | 104 lbs | $340 | $340 |
| | | | | | | | **Total Cost** | **$27,140+** |

**APPENDIX D: Bill of Material of Scale Prototype Model**

Below in figure D.1, our team has presented our bill of materials for the 1:10 scale prototype model. We 3D-printed most of the components, and laser cut clear acrylic sheet from to create the shell.

**Table D.1.** Bill of materials for the scale prototype model.

| Part # | Description | Material | Method | Seller | Quantity | Mass of Material | Unit Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|
| 1 | Kiosk | PLA Filament | 3D-Printing | MakerBot | 1 | 93.54g | $8.42 | $8.42 |
| 2 | Kiosk Door | PLA Filament | 3D-Printing | MakerBot | 1 | 6.64g | $0.60 | $0.60 |
| 3-A | Shell Top | Clear Acrylic | Laser cut | McMaster-Carr Part #8560K357 | 1 | 51.6 $in^2$ | $5.16 | $5.16 |
| 3-B | Shell Bottom | Clear Acrylic | Laser cut | McMaster-Carr Part #8560K357 | 1 | 51.6 $in^2$ | $5.16 | $5.16 |
| 3-C | Shell Side Wall | Clear Acrylic | Laser cut | McMaster-Carr Part #8560K357 | 2 | 72.24 $in^2$ | $7.23 | $14.46 |
| 3-D | Shell Front Wall | Clear Acrylic | Laser cut | McMaster-Carr Part #8560K357 | 1 | 50.4 $in^2$ | $5.04 | $5.04 |
| 3-E | Shell Back Wall | Clear Acrylic | Laser cut | McMaster-Carr Part #8560K357 | 1 | 50.4 $in^2$ | $5.04 | $5.04 |
| 4-A | Ramp | PLA Filament | 3D-Printing | MakerBot | 1 | 33.82g | $3.04 | $3.04 |
| 4-B | Ramp Side Wall | PLA Filament | 3D-Printing | MakerBot | 2 | 13.68g | $1.23 | $2.46 |
| 5 | Shredder Cover | PLA Filament | 3D-Printing | MakerBot | 1 | 8.73g | $0.79 | $0.79 |
| 6-A | Shredder Blade | PLA Filament | 3D-Printing | MakerBot | 32 | 1.64g | $0.15 | $4.80 |
| 6-B | Shredder Axle | PLA Filament | 3D-Printing | MakerBot | 2 | 1.79g | $0.16 | $0.32 |
| 7 | Ceiling Hanger | PLA Filament | 3D-Printing | MakerBot | 2 | 18.79g | $1.69 | $3.38 |
| 8 | Axle | PLA Filament | 3D-Printing | MakerBot | 3 | 1.4g | $0.13 | $0.39 |
| 9 | Waste Container | PLA Filament | 3D-Printing | MakerBot | 1 | 75.42g | $6.79 | $6.79 |
| 10-A | Piston Secure | PLA Filament | 3D-Printing | MakerBot | 2 | 0.94g | $0.08 | $0.16 |
| 10-B | Piston Head | PLA Filament | 3D-Printing | MakerBot | 2 | 3.84g | $0.35 | $0.70 |
| 10-C | Piston Base | PLA Filament | 3D-Printing | MakerBot | 2 | 3.1g | $0.28 | $0.56 |
| | Acrylic Glue | | | Amazon | 1 | | | $8.99 |
| | | | | | | | **Total Cost** | **$76.26** |

**APPENDIX E: Technical Drawings**

Figures E.1 through E.18 below show the engineering drawing of parts that were 3D-printed. Note, all dimensions on drawings will be scaled by a factor of 10 for the prototype model.

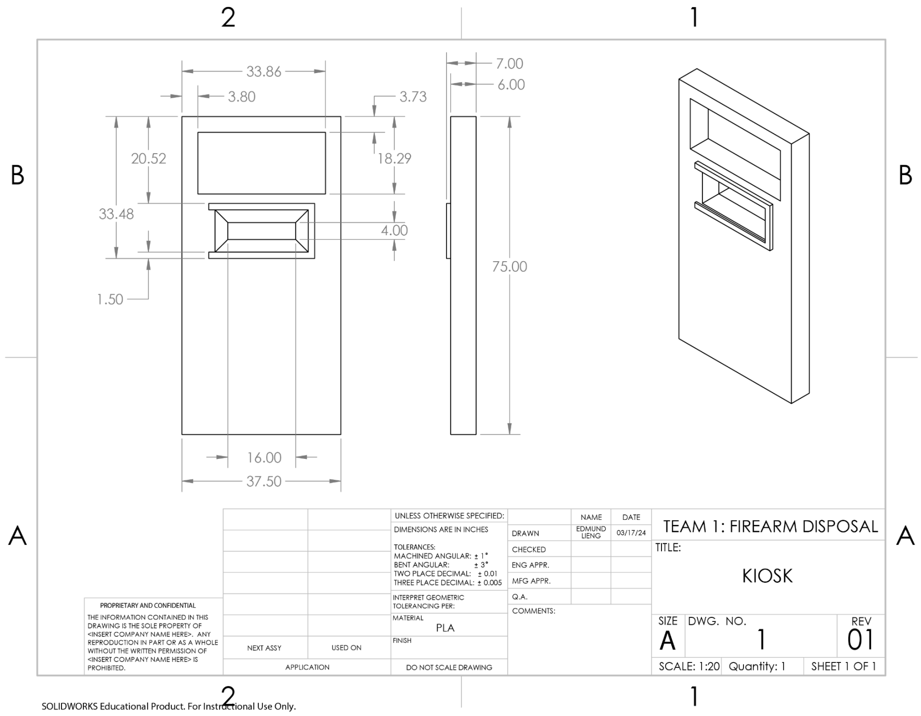



**Figure E.1.** Technical drawing of the kiosk.

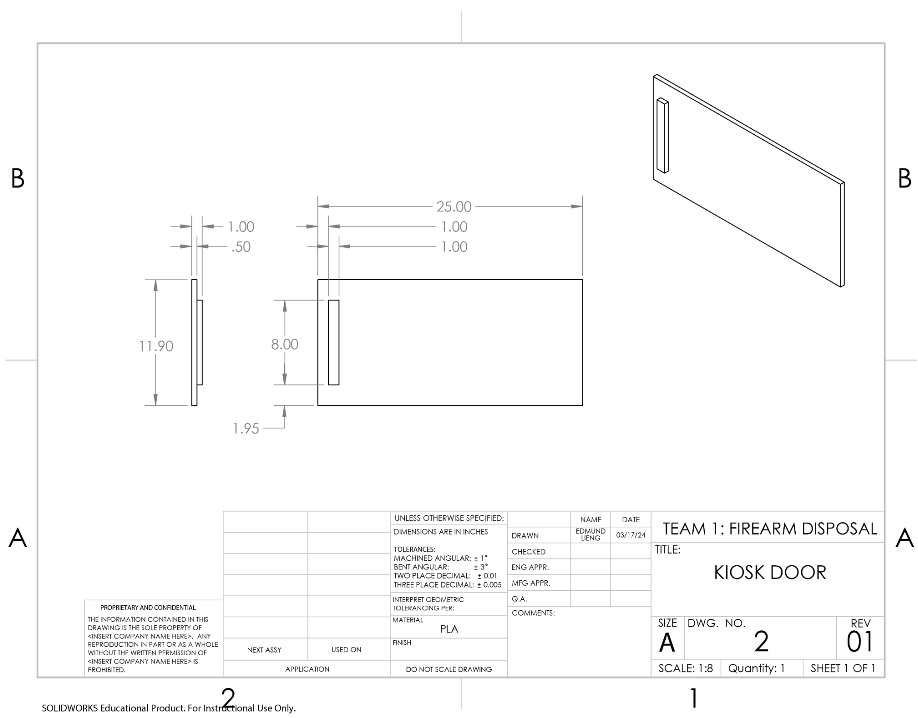



**Figure E.2.** Technical drawing of the kiosk door.

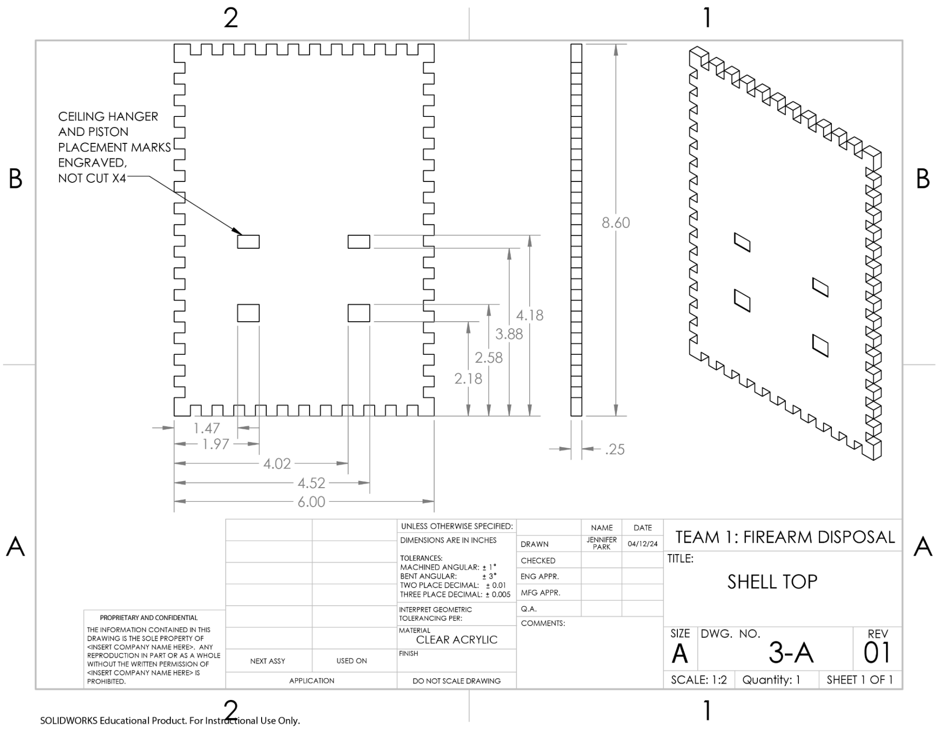



**Figure E.3.** Technical drawing of the shell top.

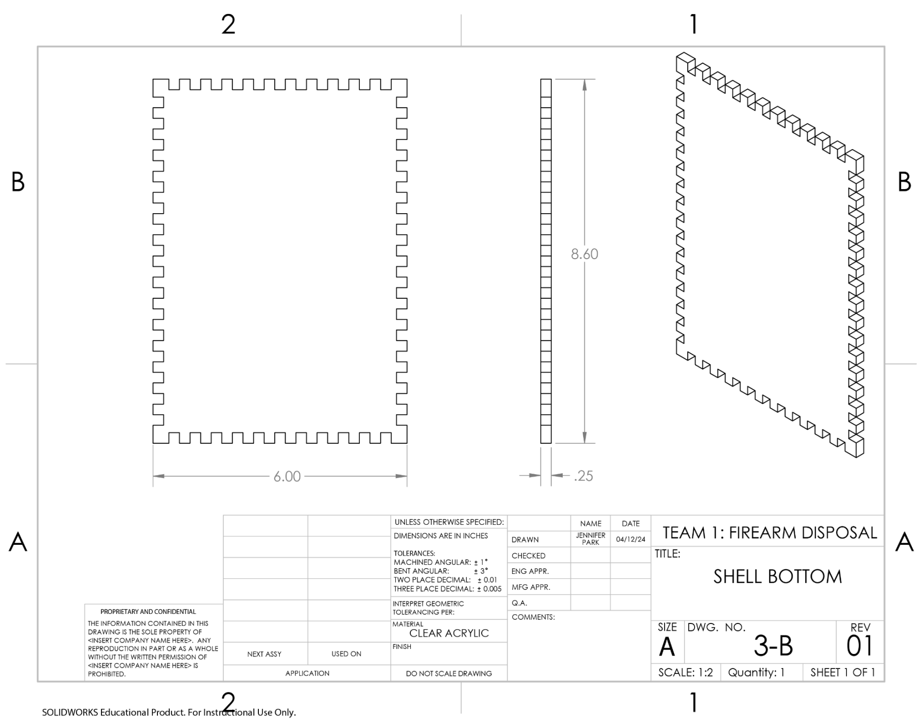



**Figure E.4.** Technical drawing of the shell bottom.

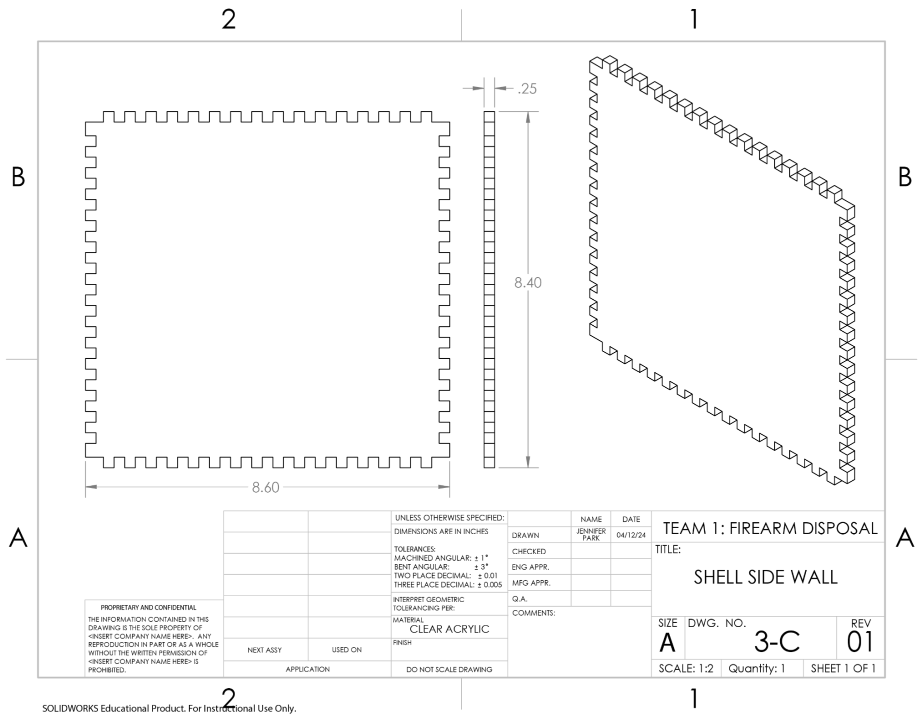



**Figure E.5.** Technical drawing of the shell side wall.

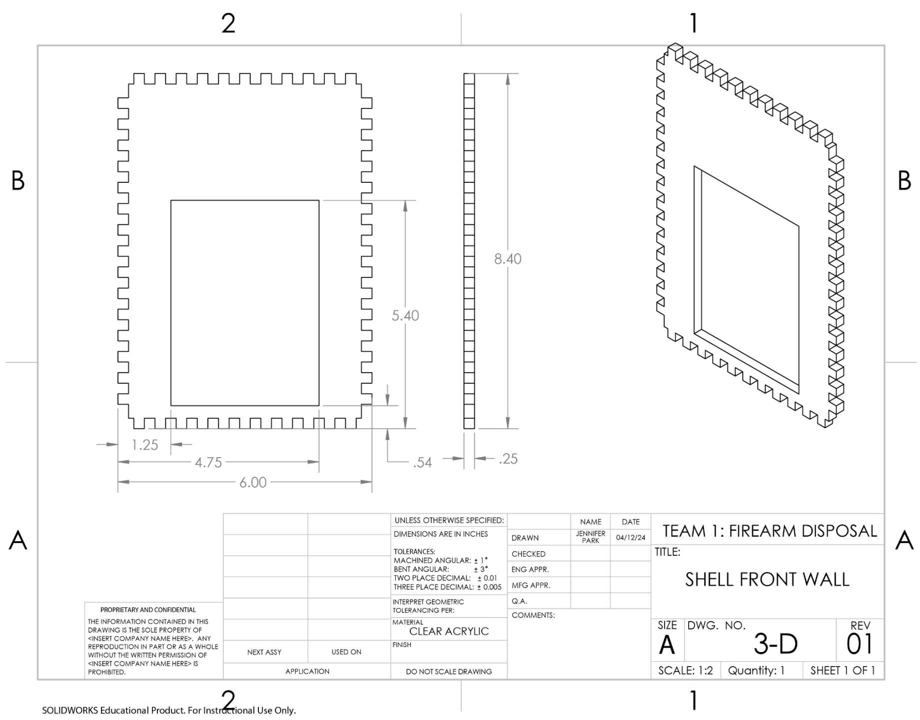



**Figure E.6.** Technical drawing of the shell front wall.

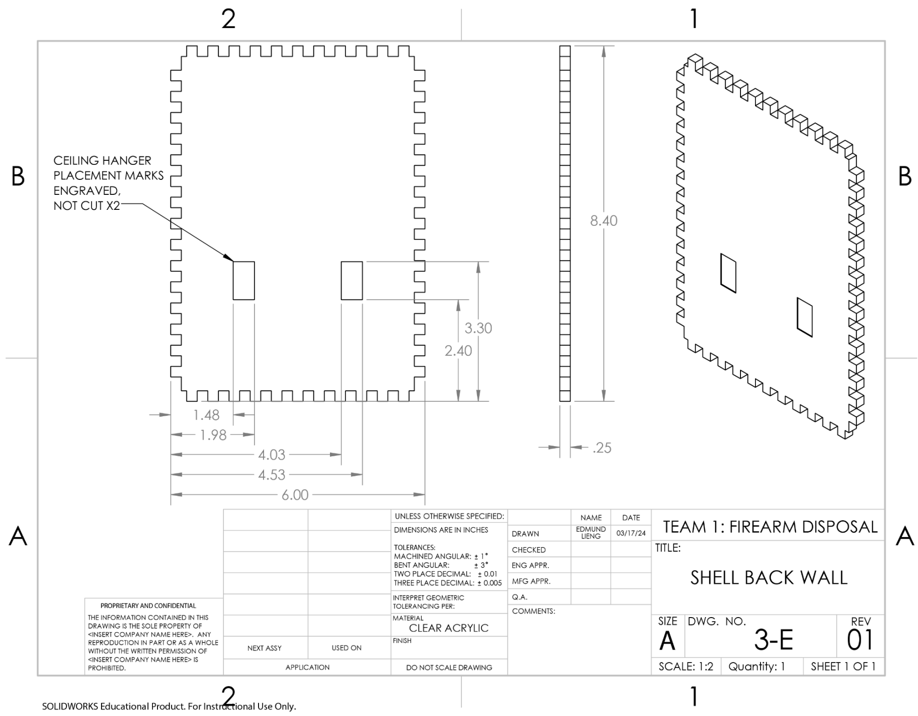



**Figure E.7.** Technical drawing of the shell back wall.

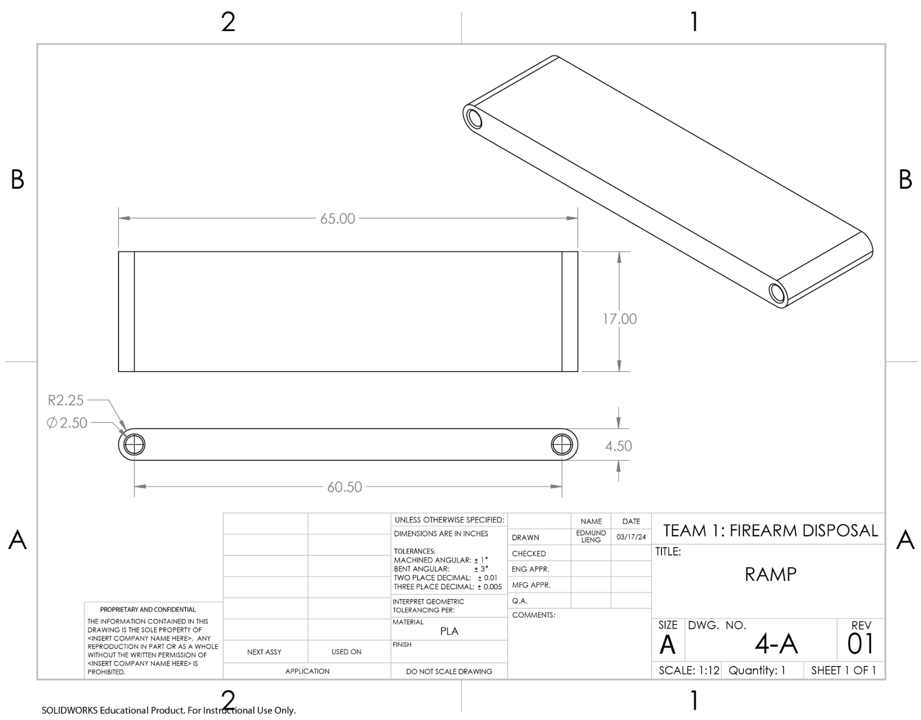



**Figure E.8.** Technical drawing of the ramp.

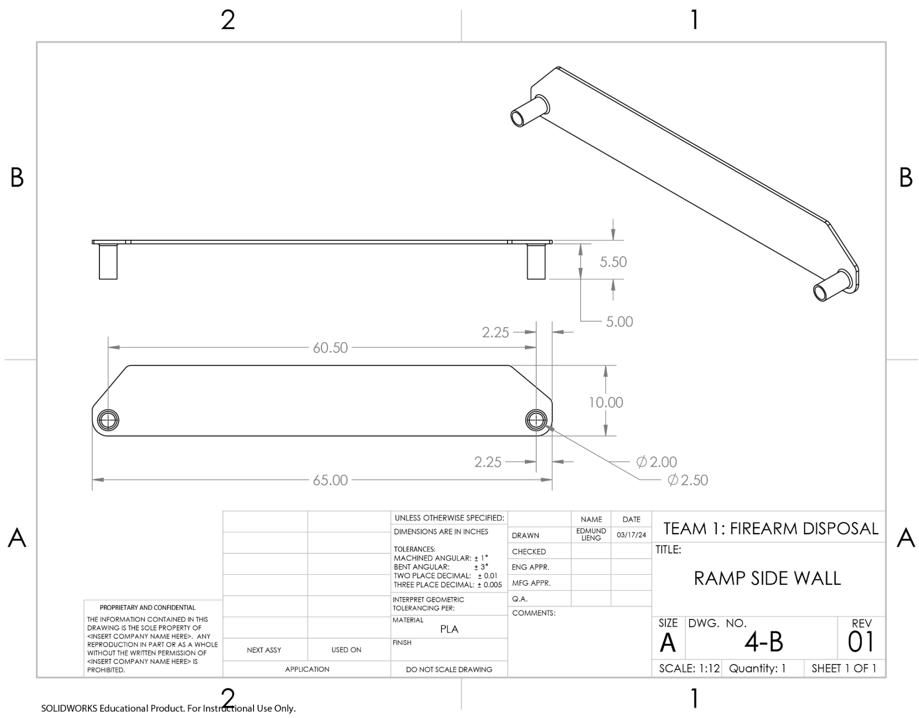



**Figure E.9.** Technical drawing of the ramp side wall.

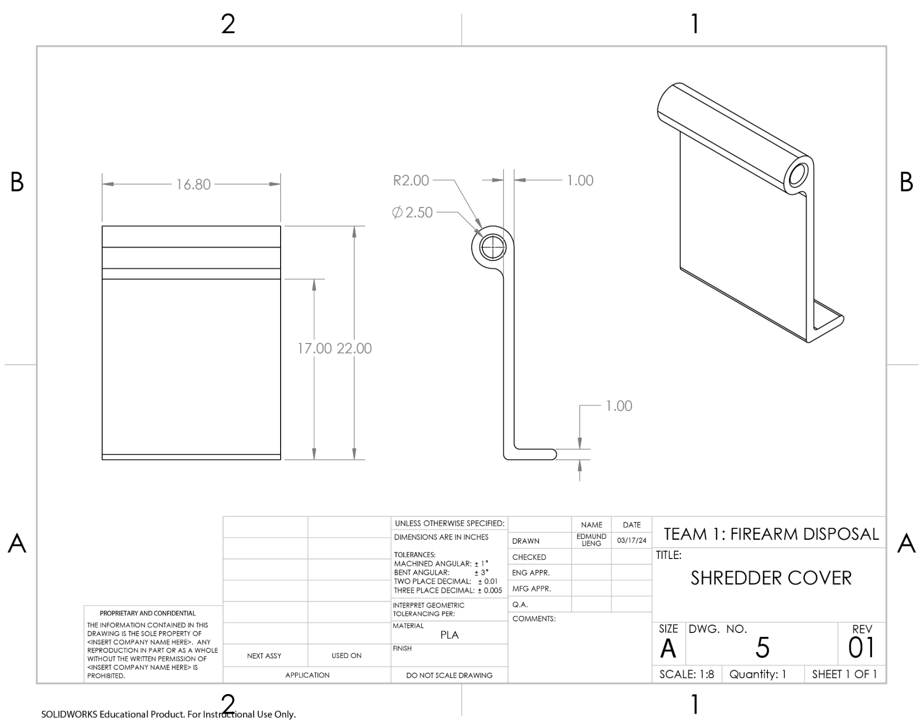



**Figure E.10.** Technical drawing of the shredder cover.

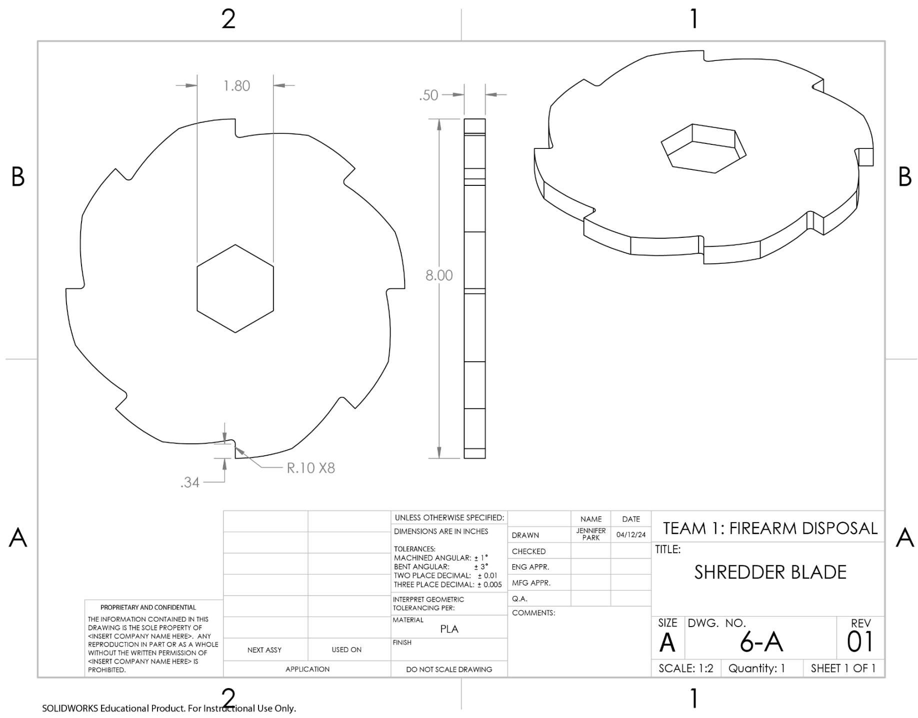



**Figure E.11.** Technical drawing of the shredder blade.

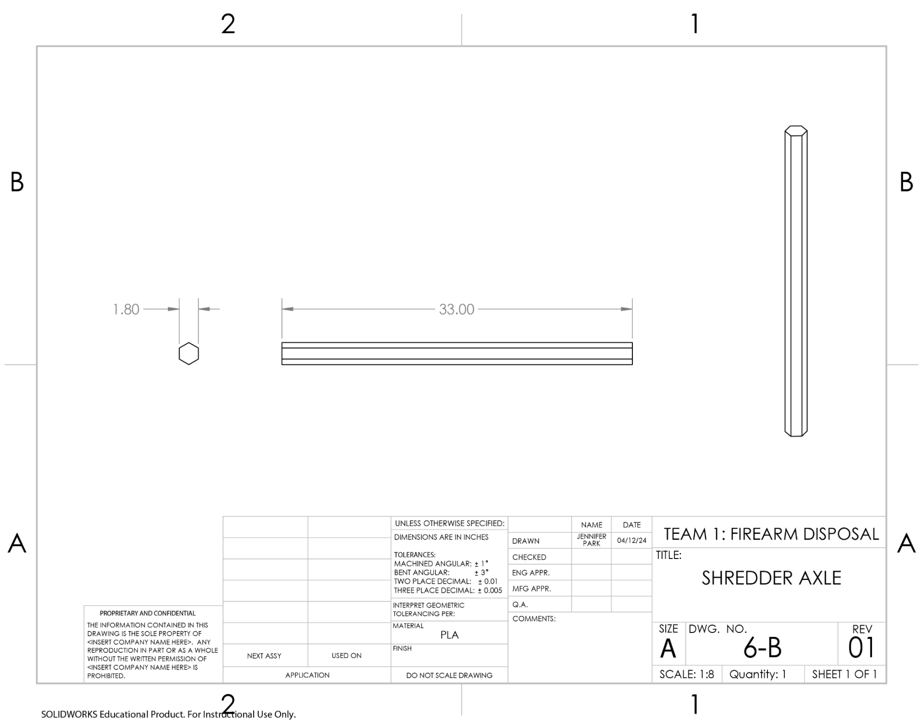



**Figure E.12.** Technical drawing of the shredder axle.

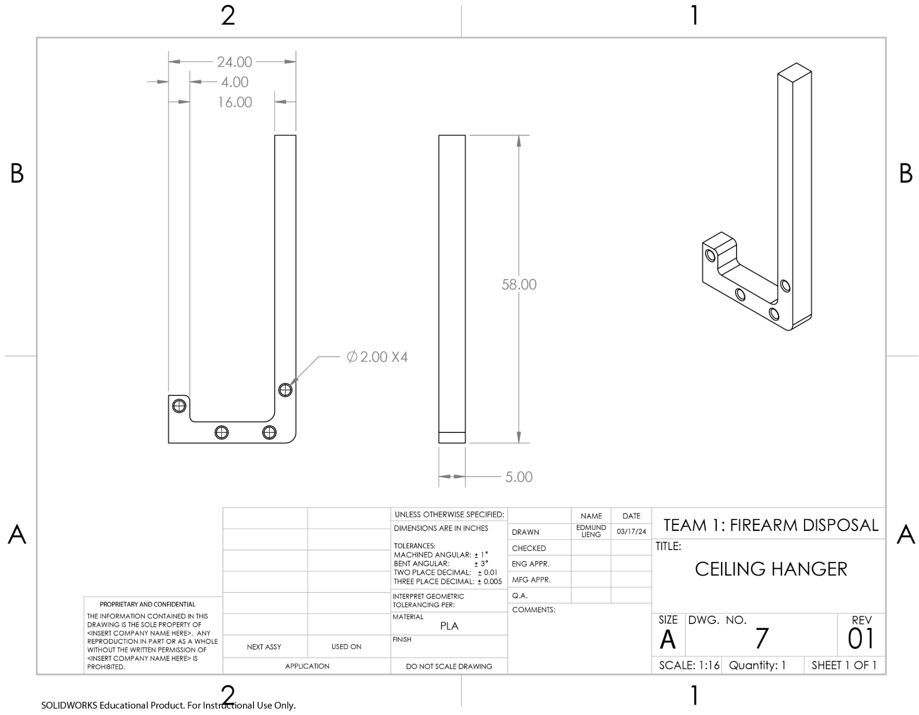



**Figure E.13.** Technical drawing of the ceiling hanger.

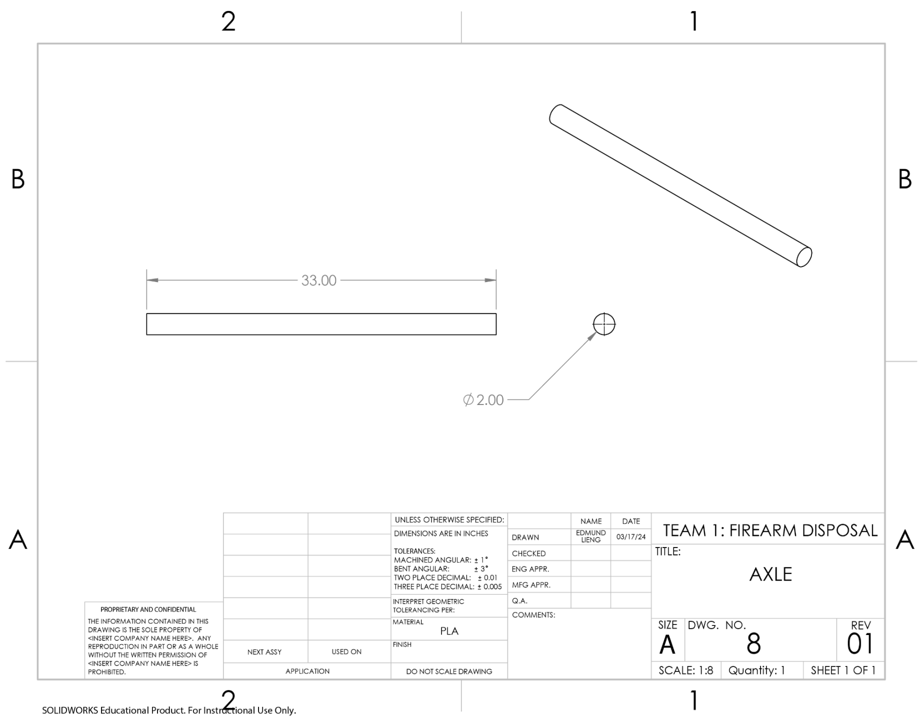



**Figure E.14.** Technical drawing of the axle.

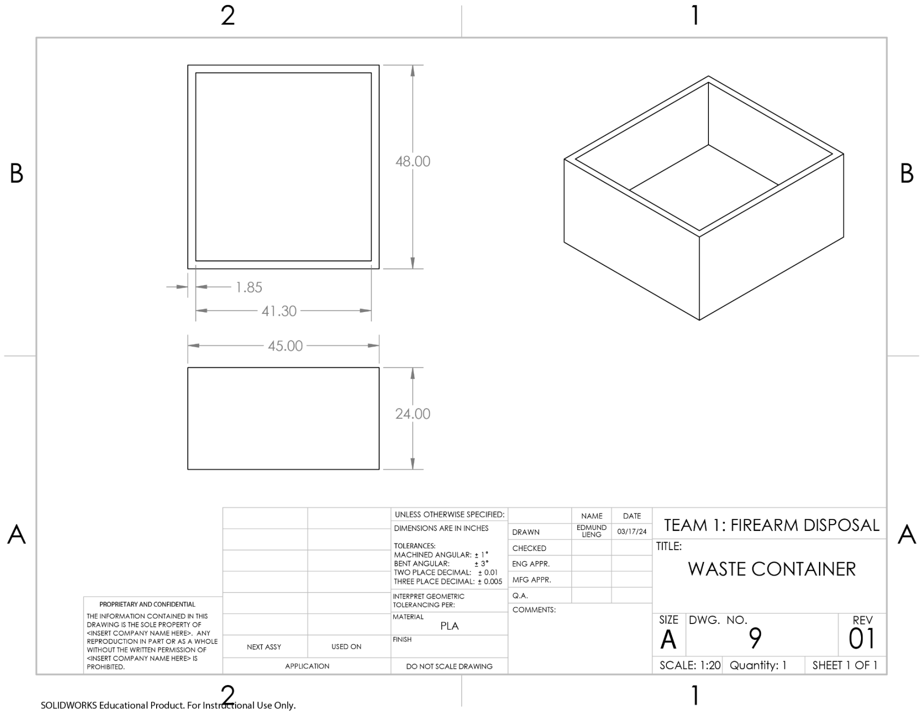



**Figure E.15.** Technical drawing of the waste container.

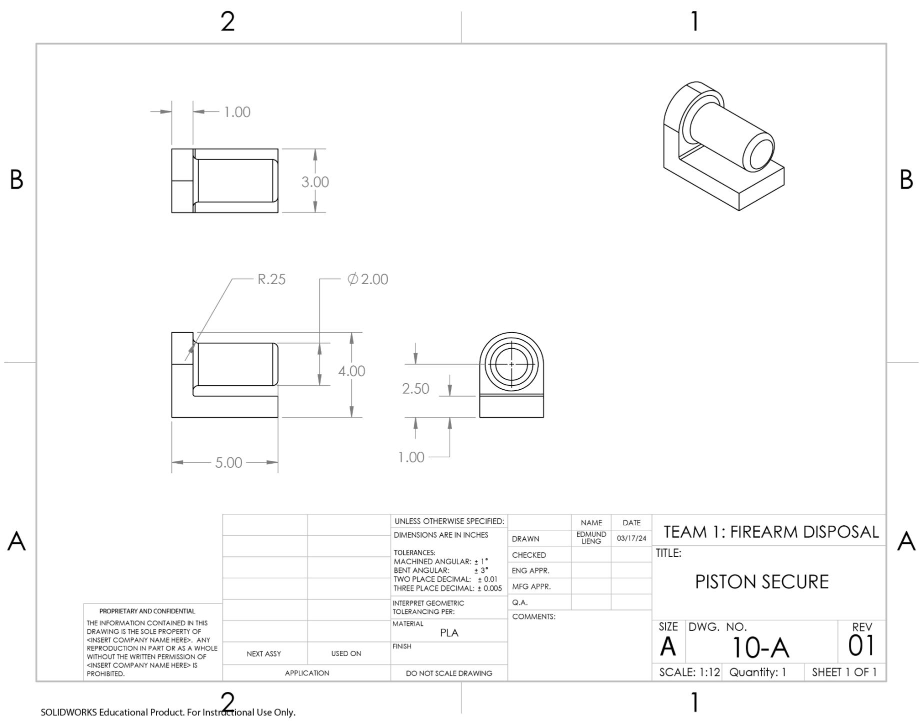



**Figure E.16.** Technical drawing of the piston secure.

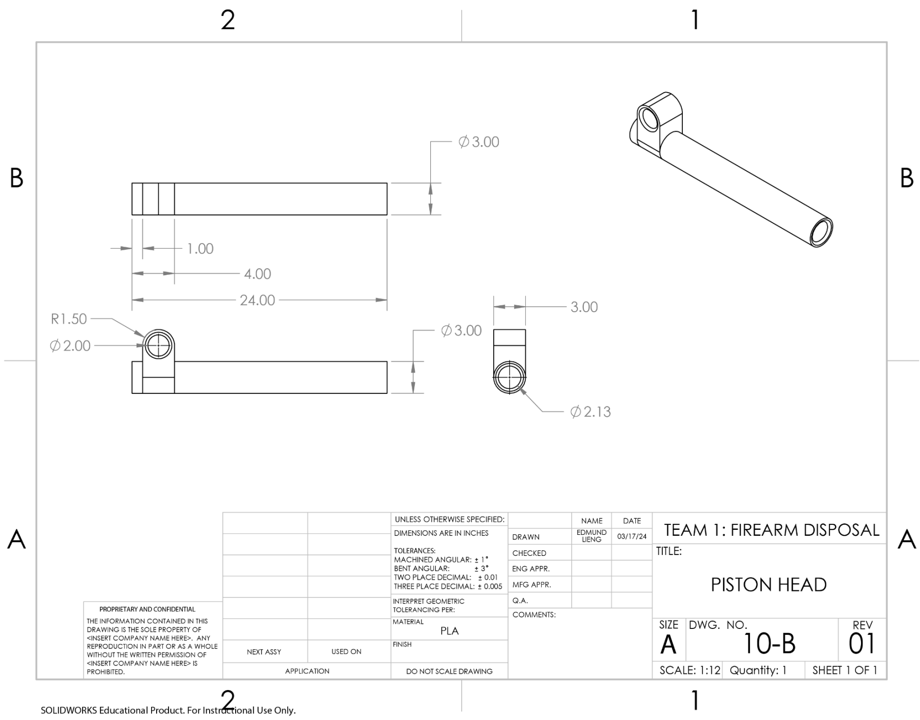



**Figure E.17.** Technical drawing of the piston head.

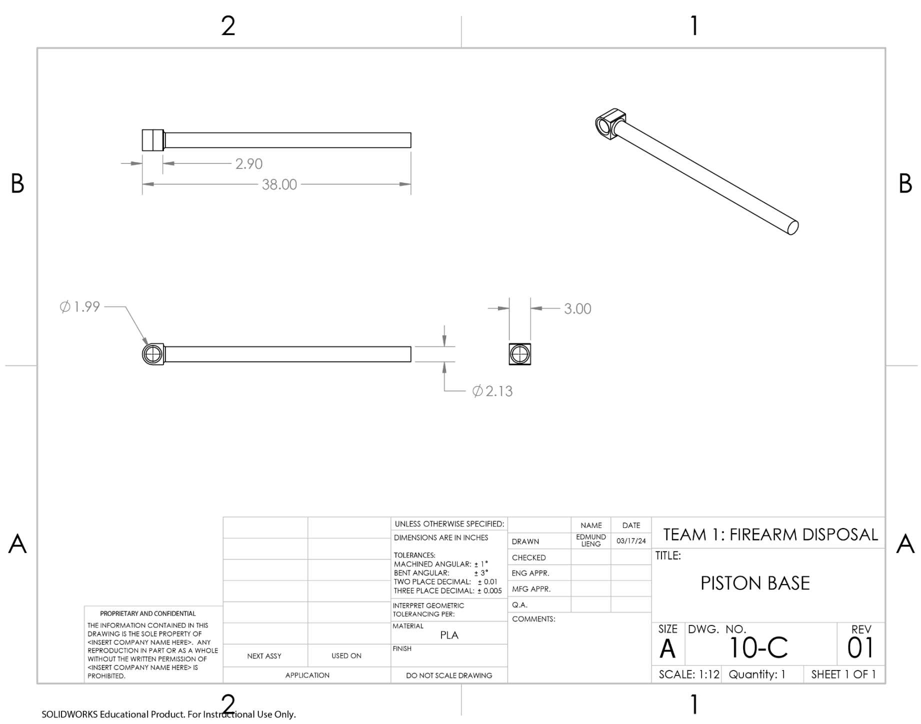



**Figure E.18.** Technical drawing of the piston base.

**APPENDIX F: Manufacturing Plan**

Table F.1 below shows the manufacturing plan of parts that we have created and used to assemble our scale model.

**Table F.1.** Manufacturing plan of components that are included in the scale model.

| Part # | Description | QTY | Process Description | Machine / Fixture | Material |
|---|---|---|---|---|---|
| 1 | Kiosk | 1 | 3D- Printed | MakerBot 3D Printer | PLA |
| 2 | Kiosk door | 1 | 3D- Printed | MakerBot 3D Printer | PLA |
| 3-A | Shell Top | 1 | Laser Cut / Engrave | EPILOG Legend 36EXT 50W CO2 Laser | Clear Acrylic |
| *3-A Process 1* | *Exterior Profile* | | *Laser Cut Mode* | *Speed: 4% Power: 100%: Frequency: 1%* | |
| *3-A Process 2* | *Component Placement Marks* | | *Laser Engrave Mode* | *Speed: 40% Power: 100%: Frequency: 1%* | |
| 3-B | Shell Bottom | 1 | Laser Cut | EPILOG Legend 36EXT 50W CO2 Laser | Clear Acrylic |
| 3-C | Shell Side Wall | 2 | Laser Cut | EPILOG Legend 36EXT 50W CO2 Laser | Clear Acrylic |
| 3-D | Shell Front Wall | 1 | Laser Cut | EPILOG Legend 36EXT 50W CO2 Laser | Clear Acrylic |
| 3-E | Shell Back Wall | 1 | Laser Cut / Engrave | EPILOG Legend 36EXT 50W CO2 Laser | Clear Acrylic |
| *3-E Process 1* | *Exterior Profile* | | *Laser Cut Mode* | *Speed: 4% Power: 100%: Frequency: 1%* | |
| *3-E Process 2* | *Component Placement Marks* | | *Laser Engrave Mode* | *Speed: 40% Power: 100%: Frequency: 1%* | |
| 4-A | Ramp | 1 | 3D- Printed | MakerBot 3D Printer | PLA |
| 4-B | Ramp Side Wall | 2 | 3D- Printed | MakerBot 3D Printer | PLA |
| 5 | Shredder Cover | 1 | 3D- Printed | MakerBot 3D Printer | PLA |
| 6-A | Shredder Blade | 2 | 3D- Printed | MakerBot 3D Printer | PLA |
| 6-B | Shredder Axle | 2 | 3D- Printed | MakerBot 3D Printer | PLA |
| 7 | Ceiling hanger | 2 | 3D- Printed | MakerBot 3D Printer | PLA |
| 8 | Axle | 3 | 3D- Printed | MakerBot 3D Printer | PLA |
| 9 | Waste container | 1 | 3D- Printed | MakerBot 3D Printer | PLA |
| 10-A | Piston Secure | 2 | 3D- Printed | MakerBot 3D Printer | PLA |
| 10-B | Piston Head | 2 | 3D- Printed | MakerBot 3D Printer | PLA |
| 10-C | Piston Base | 2 | 3D- Printed | MakerBot 3D Printer | PLA |

Figure F.1 - F.10 below show the step by step assembly plan of our prototype scale model.

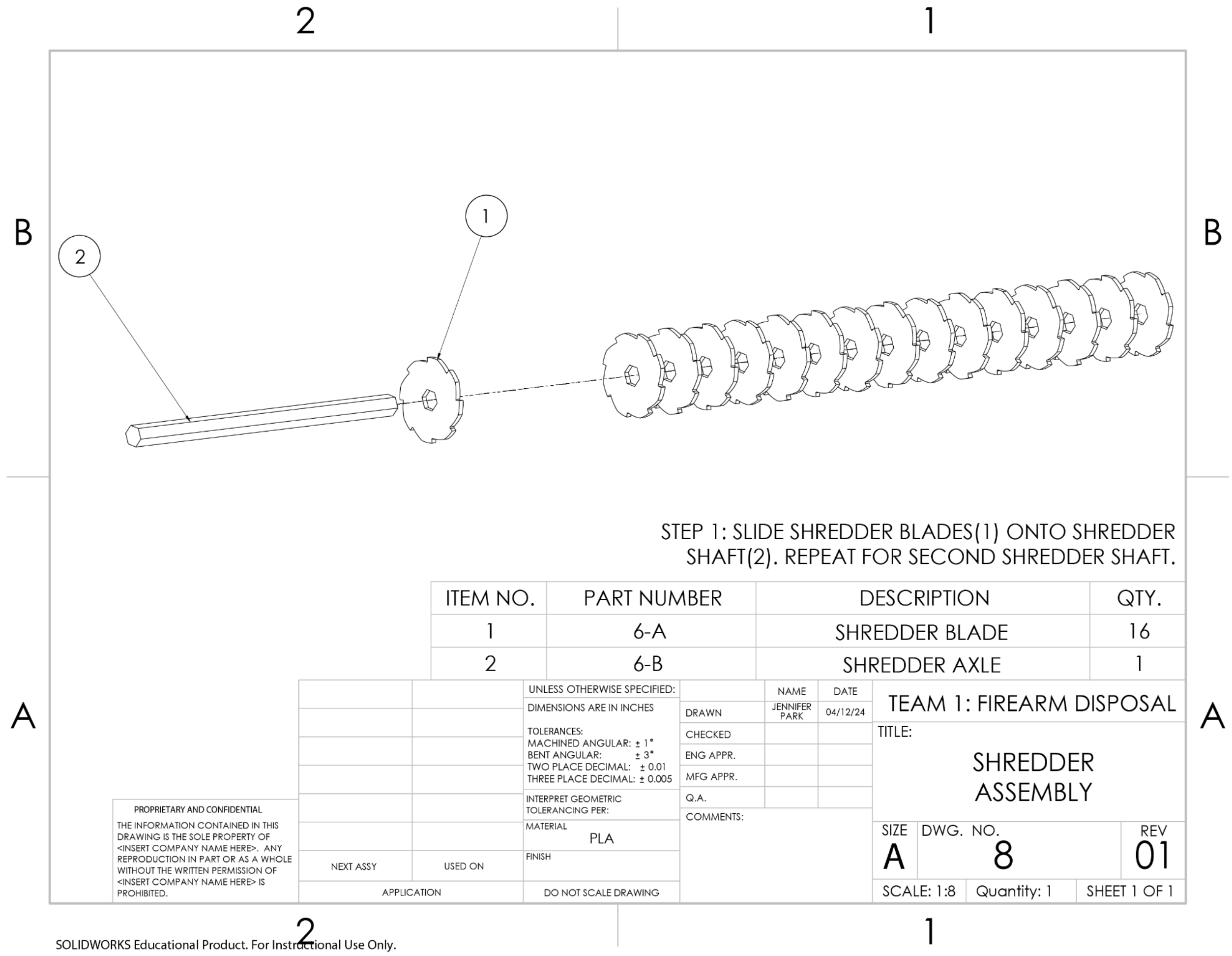



**Figure F.1:** Assembling the shredder blades onto the shredder shaft.

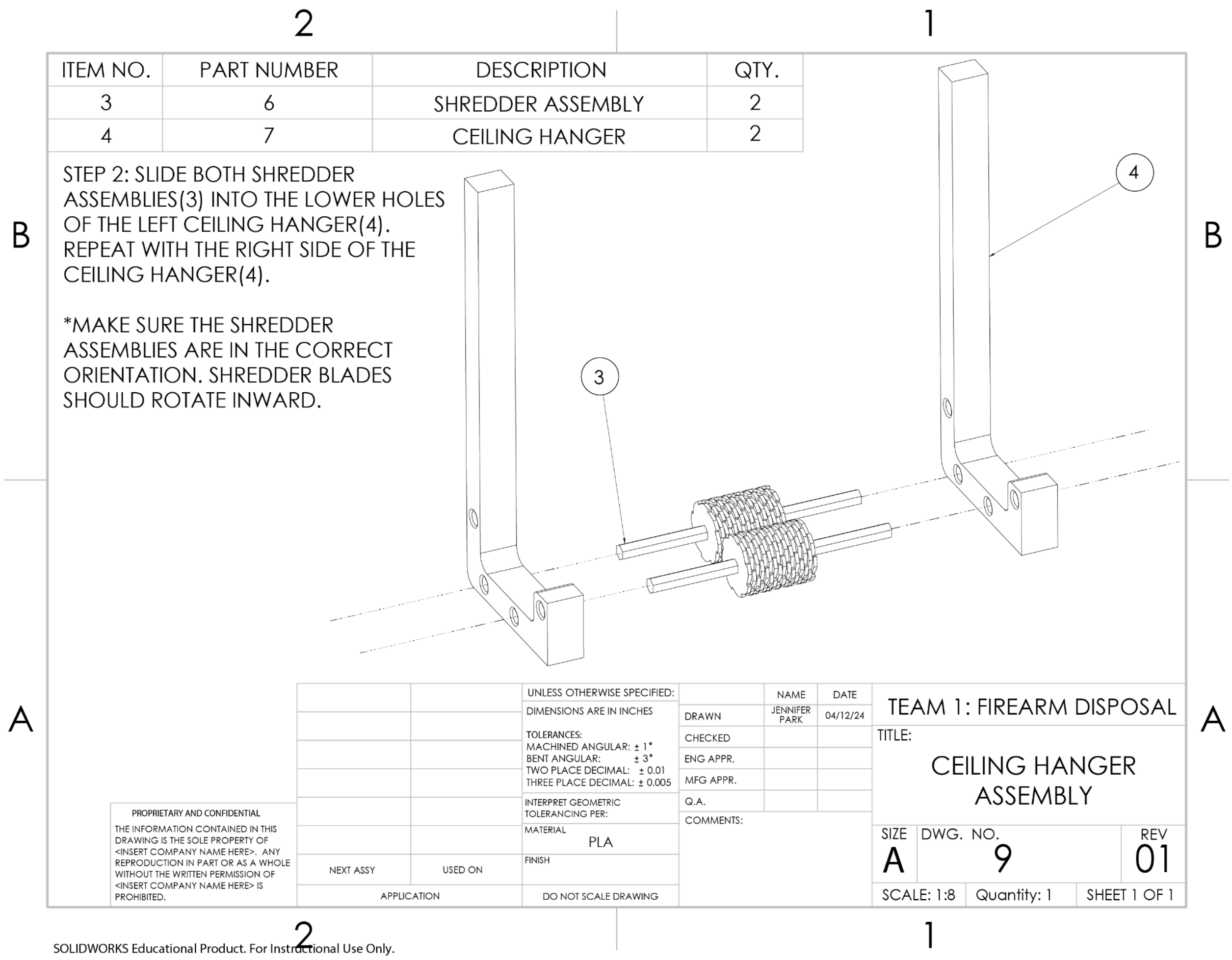



**Figure F.2:** Assembling the ceiling hangers and shredder shaft assemblies.

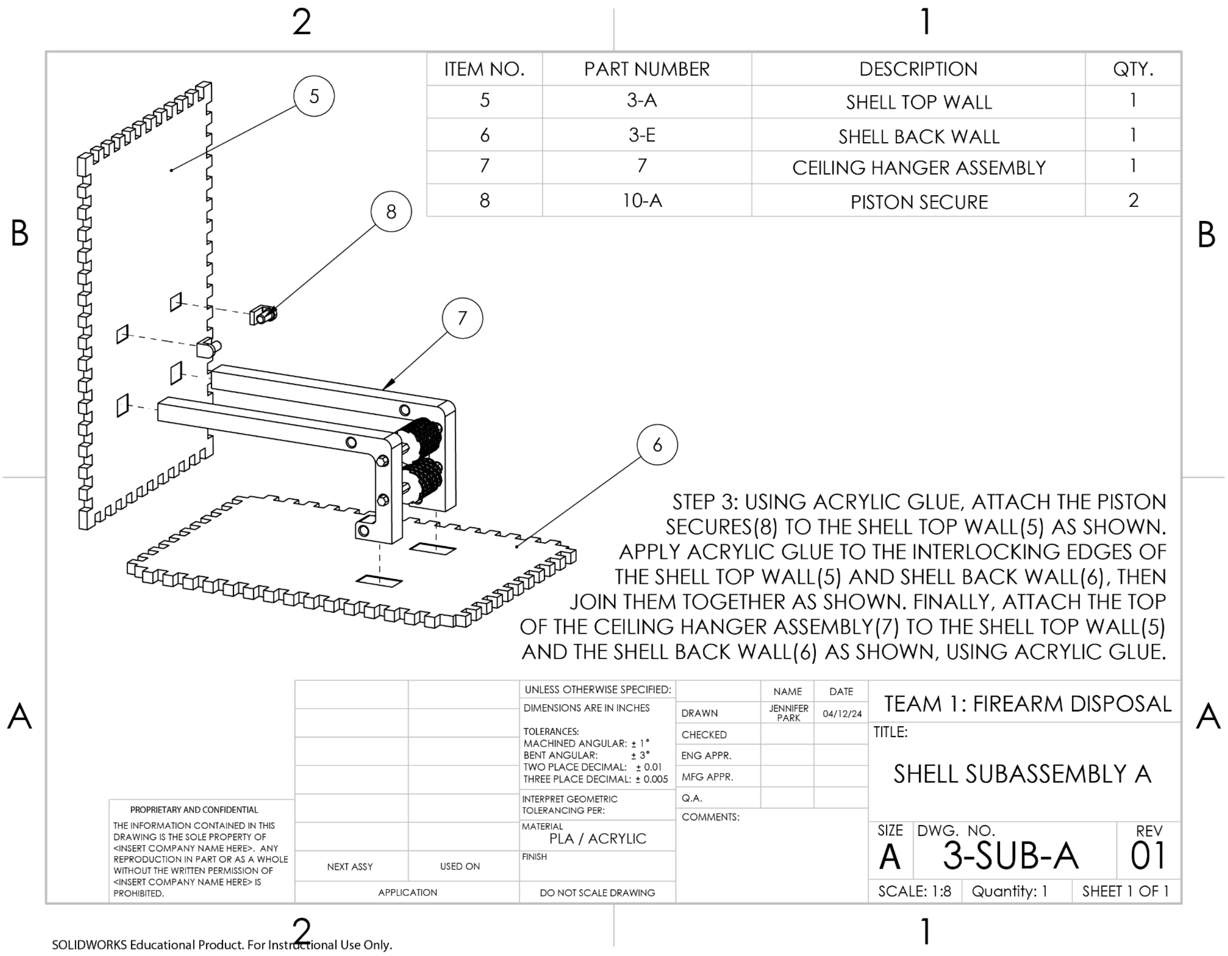



**Figure F.3:** Assembling the ceiling hanger assembly to the outer shell pieces.

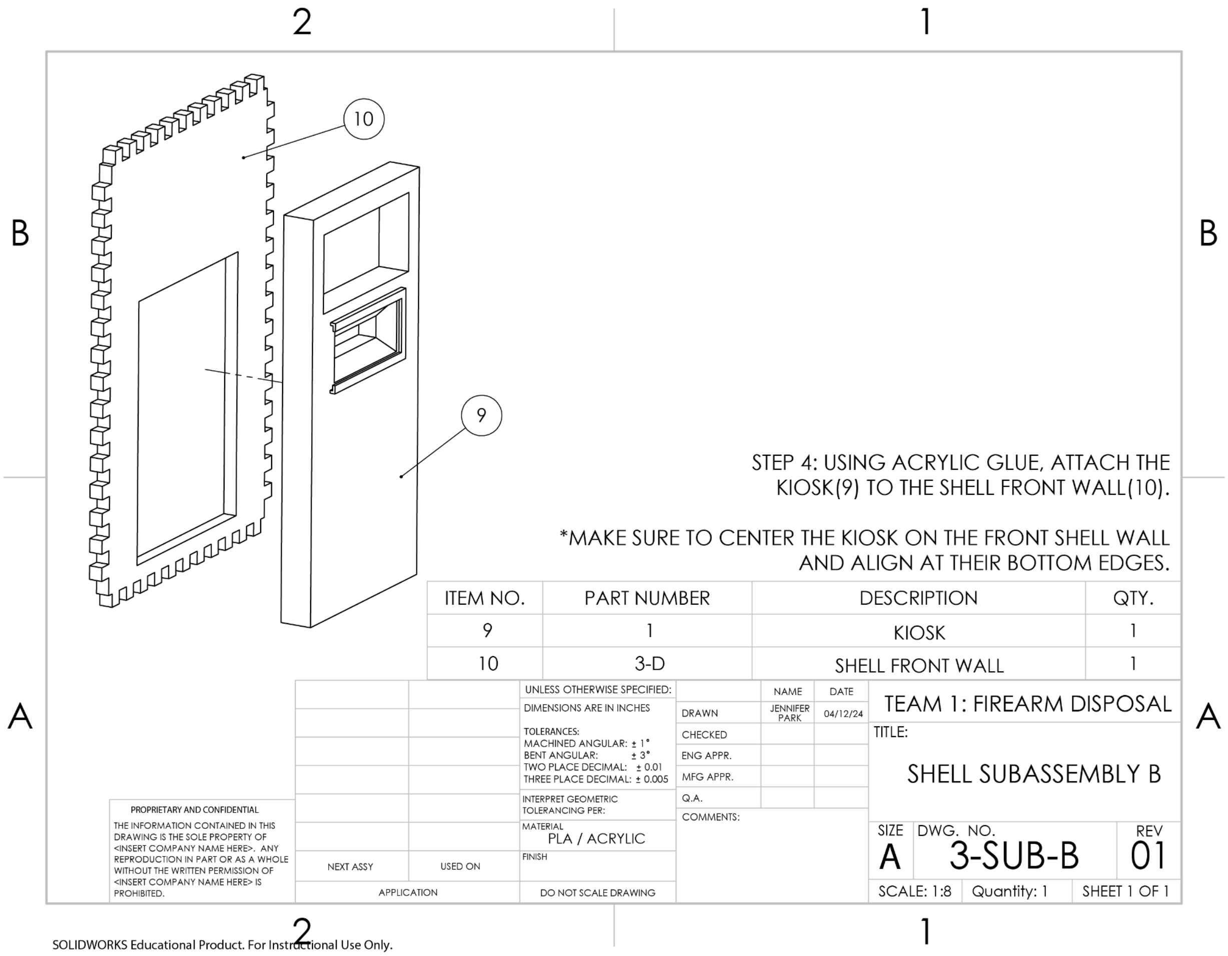



**Figure F.4:** Attaching the kiosk part to one of the outer shell pieces.

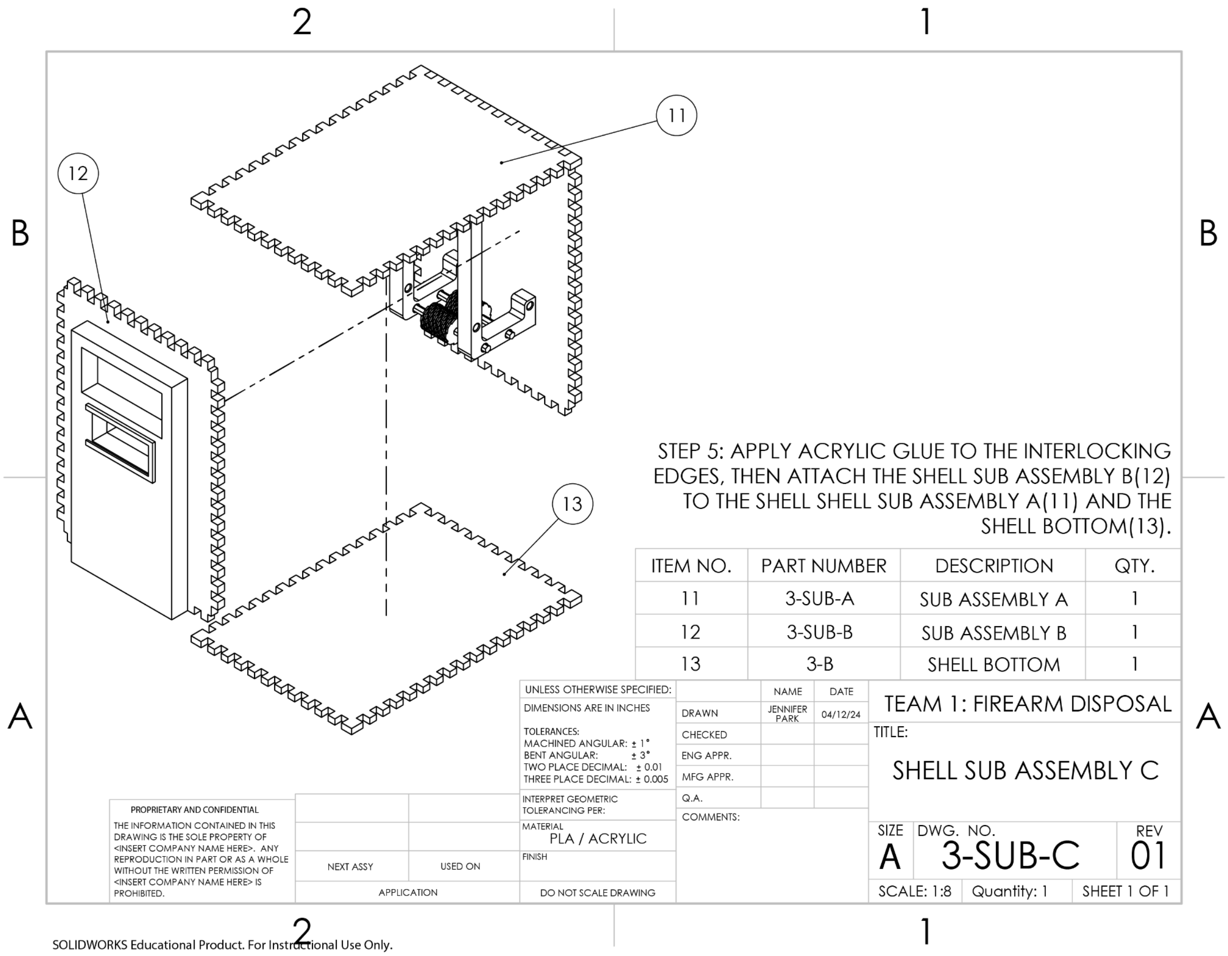



**Figure F.5:** Assembling the outer shell pieces.

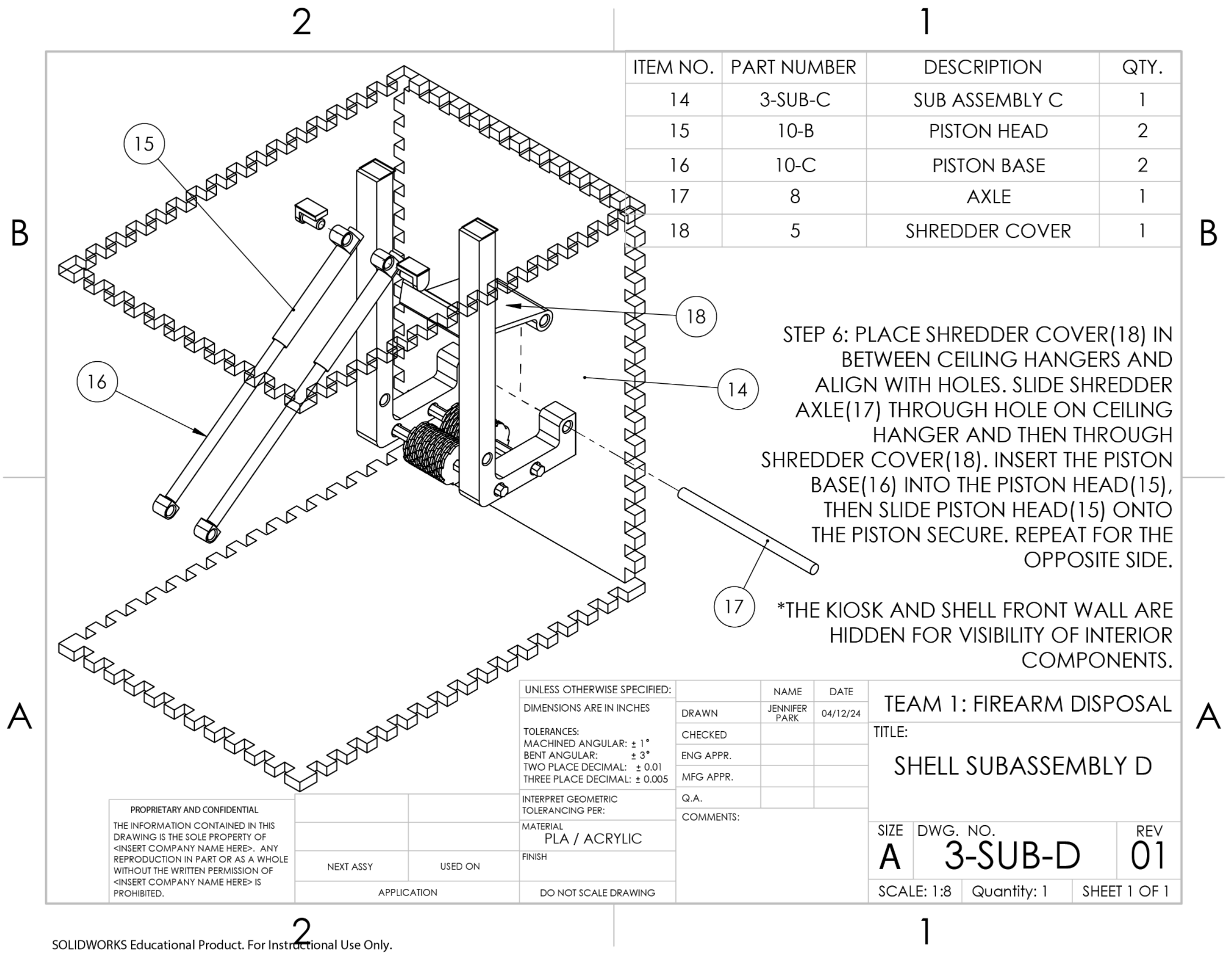



**Figure F.6:** Assembling the shredder cover and the piston system onto the main assembly.

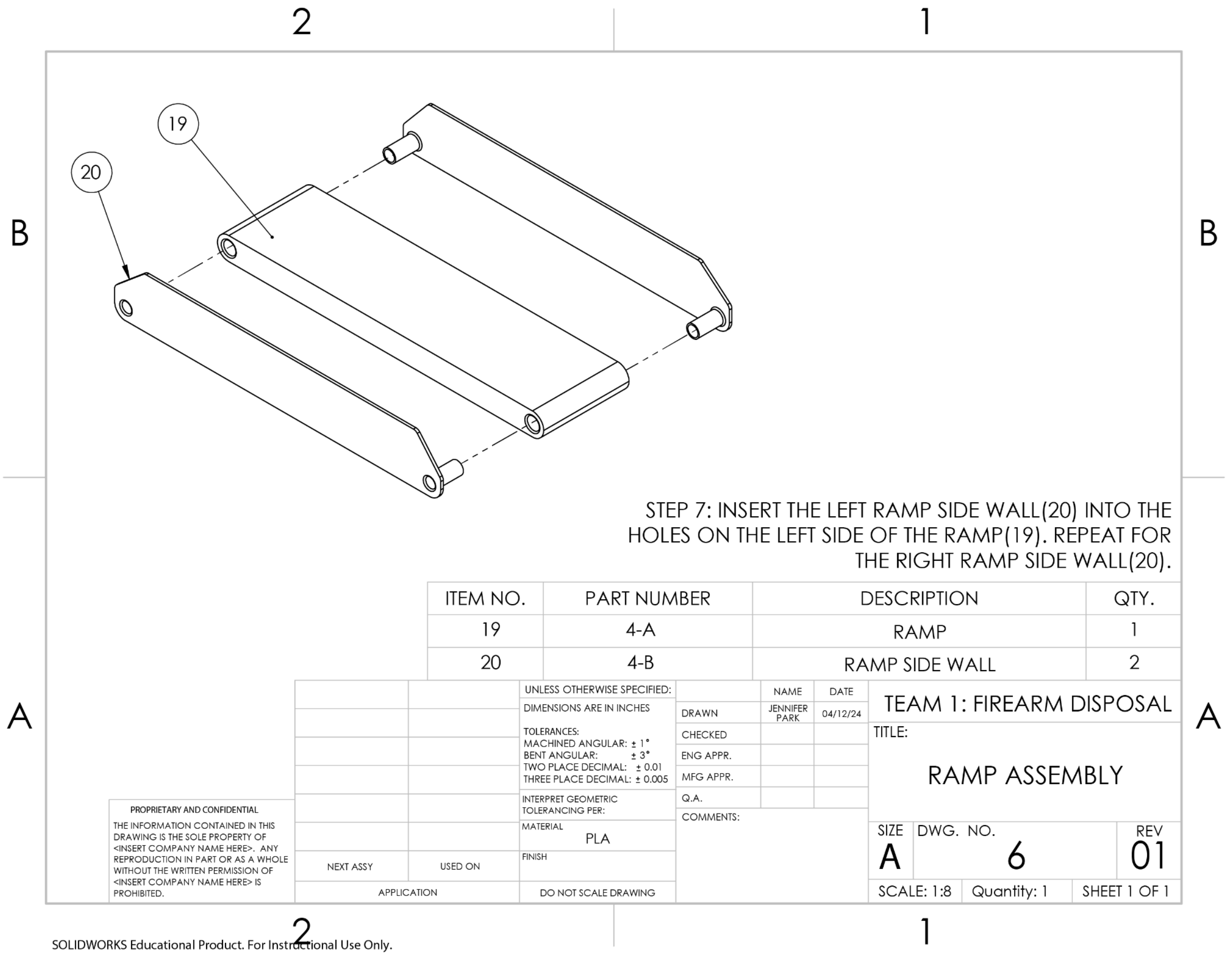



**Figure F.7:** Assembling the ramp and ramp side walls.

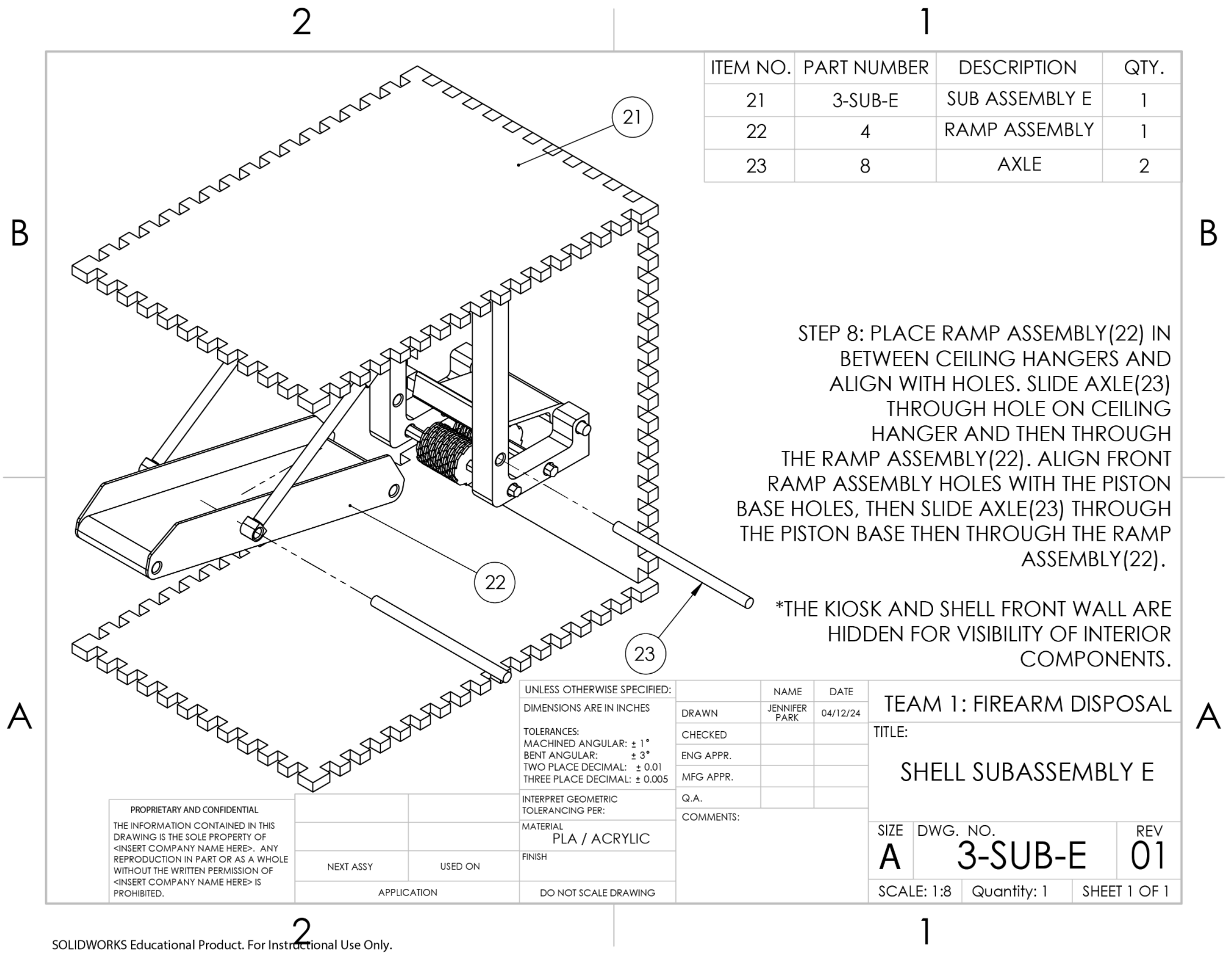
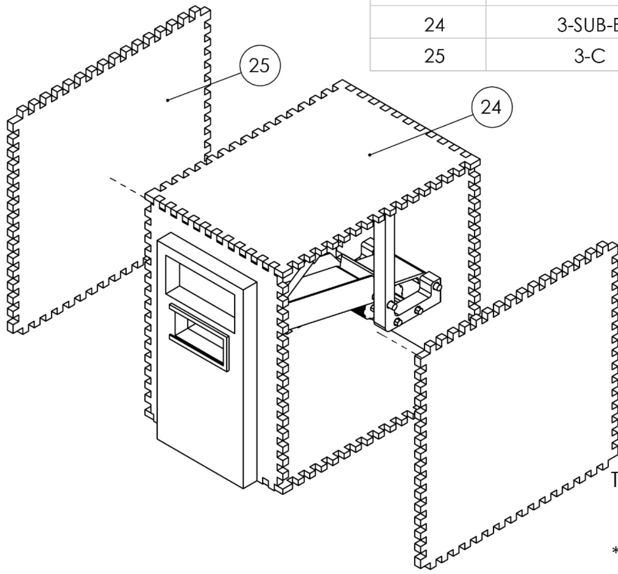



**Figure F.8:** Install ramp assembly and axles.

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 24 | 3-SUB-E | SUB ASSEMBLY E | 1 |
| 25 | 3-C | SHELL SIDE WALL | 2 |




STEP 9: ATTACH THE LEFT SHELL SIDE WALL(25) TO THE INTERLOCKING EDGES OF SUB ASSEMBLY E(24). REPEAT WITH THE RIGHT SHELL SIDE WALL(25).

*DO NOT GLUE SHELL SIDE WALLS. THEY SHOULD BE REMOVABLE TO ACCESS INTERIOR COMPONENTS.

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NEXT ASSY | USED ON | APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
MACHINED ANGULAR: ± 1°
BENT ANGULAR: ± 3°
TWO PLACE DECIMAL: ± 0.01
THREE PLACE DECIMAL: ± 0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL: PLA / ACRYLIC
FINISH
DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | JENNIFER PARK | 04/12/24 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TEAM 1: FIREARM DISPOSAL

TITLE: FULL ASSEMBLY

SIZE: A | DWG. NO.: 11 | REV: 01

SCALE: 1:8 | Quantity: 1 | SHEET 1 OF 1

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**Figure F.9:** Install ramp assembly and axles.

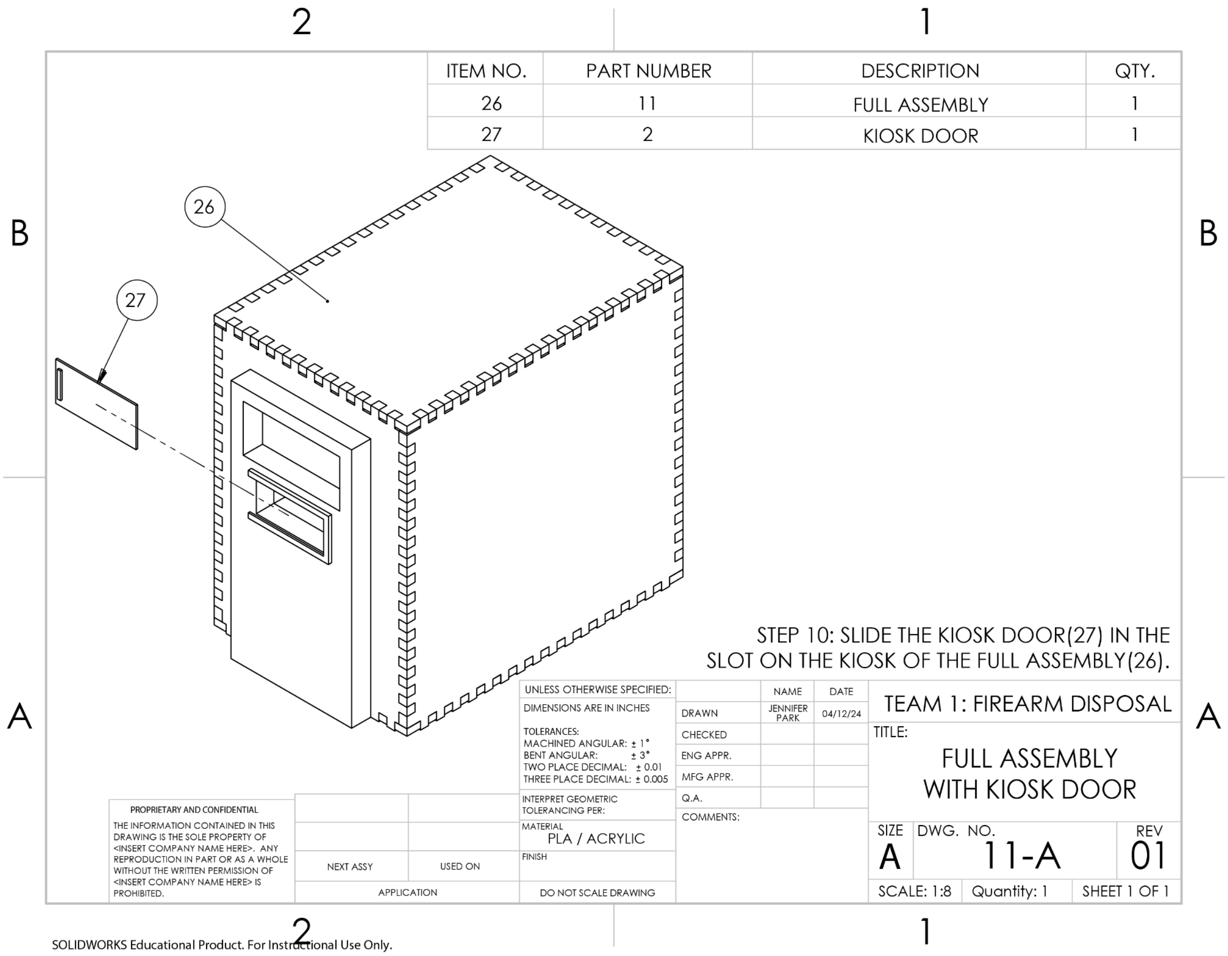


**Figure F.10:** Install kiosk door.