

**UNWANTED FIREARMS DISPOSAL CONCEPT  
FOR COMMUNITIES**

Team 1B: Amon Green

Team 1: Amon Green, Edmund Lieng, Jennifer Park, Haazem Turaani

MECHENG 450: Design and Manufacturing III  
Winter 2024

## **TABLE OF CONTENTS**

<b>EXECUTIVE SUMMARY</b>	<b>4</b>
<b>INTRODUCTION</b>	<b>5</b>
Stakeholder Analysis	6
Design Process	7
Intellectual Property	8
Information Sources	8
<b>REQUIREMENTS AND ENGINEERING SPECIFICATIONS</b>	<b>9</b>
Must fit inside footprint of shipping container:	11
Must be light enough to be put on and moved by a semi truck:	11
Must be able to accept firearms of any size:	11
Must be safe to the users and community:	11
Must destroy firearms (via shredding):	12
<b>CONCEPT GENERATION</b>	<b>13</b>
Examples of Generated Concepts	14
<b>CONCEPT SELECTION PROCESS</b>	<b>16</b>
First Concept	16
Second Concept	17
Third Concept	18
Fourth Concept	19
<b>CONCEPT DESCRIPTION</b>	<b>20</b>
<b>ENGINEERING ANALYSIS</b>	<b>24</b>
<b>FINAL DESIGN DESCRIPTION</b>	<b>27</b>
Design Overview	27
Operation Overview	27
Steel Frame	28
Bulletproof Shell	29
Articulated Ramp	29
Kiosk	30
Bulletproof Door	30
Shredder	31
Axle	31
<b>VERIFICATION AND VALIDATION APPROACH</b>	<b>32</b>
Verification Test #1:	32
Verification Test #2:	33
Verification Test #3:	34
Verification Test #4:	35
Verification Test #5:	36
Verification Test #6:	36
<b>DISCUSSION</b>	<b>37</b>
Problem Definition	37
Design Critique	37
Risks	37

<b>REFLECTION</b>	<b>38</b>
Inclusion and Equity	38
Ethics	39
<b>RECOMMENDATIONS</b>	<b>39</b>
<b>CONCLUSION</b>	<b>39</b>
<b>ACKNOWLEDGEMENTS</b>	<b>40</b>
<b>BUILD DESIGN BILL OF MATERIALS</b>	<b>40</b>
<b>MANUFACTURING/FABRICATION PLAN</b>	<b>40</b>
<b>REFERENCES</b>	<b>41</b>
<b>APPENDIX</b>	<b>43</b>

## **EXECUTIVE SUMMARY**

The United States currently has the highest rate of gun ownership per citizen in the world, with 393 million firearms nationwide [1]. There are many ways that someone can come into possession of a firearm, like as a gift, an inheritance, or as something found on the street. For people who come into possession of firearms in these ways or similar, but do not want them, there are few options available to dispose of them [2].

We established this project needs to destroy firearms, or at least store them, if the community lacks the funding necessary. The product should accept any firearm, regardless of type, shape, or registration status. The product should be anonymous and able to be operated by any community member, without the help of an attendant. Before and after disposing of the collected firearms, the solution should store destroyed and intact firearms in a way that is secure from theft and protects the user from accidental discharge.

We chose shredding as the firearms destruction method. We generated many concepts that included shredding and our final design uses a shredder to destroy firearms.

The solution proposed in this project is a good option to start working with. The final design destroys firearms, does so safely, and can be deployed in a versatile set of communities. It is still recommended that other options be explored, however, given the setbacks that this project faced and the situations we were placed in. More research should be done on bulletproof materials as well as different shredder models, or different destruction methods entirely.

## **INTRODUCTION**

The Firearms Disposal project is sponsored by Dr. David Humphreys from the University of Oxford and the University of Michigan Institute for Firearm Injury Prevention [3]. He has worked with groups in Philadelphia since 2017 and the University of Michigan in response to the lack of regular, cost effective gun disposal options [2]. This semester, Dr. Humphreys has sought the help of ME-450 students to design an engineering solution to the lack of accessible gun disposal options for the public.

There are currently few options available for disposing of unwanted firearms. In 2018, the Huffington Post did an investigation into this and interviewed several unwanted firearms owners [4]. Shane Hooper, a 31 year old unwanted gun owner, says “it’s actually harder to get rid of a gun than it is to get one” and he is wary of the few options out there because he doesn’t trust police departments to destroy them. Gregory Bloom, a 50 year old unwanted gun owner, says he contacted at least three police departments to get rid of a pistol he inherited, but was turned back by each because the pistol had its serial number altered. The few options that are available have social and technical gaps.

An example of a social gap in current options is shown in gun buyback events. Gun buyback events purchase firearms from the community by offering cash or a gift card in exchange for firearms, but these programs are expensive for taxpayers, require identification from the person turning in the firearm, and require participants to be the registered owner of the firearms [5]. There are justified reasons, such as immigration status, why someone would not want to be identified, but still do their civic duty and safely dispose of a firearm. There are also justified reasons, such as finding a firearm on the street, why someone would not be the registered owner of a firearm.

Another example of a social gap in current options is shown with Gun Busters. Gun busters is a third party company that receives firearms from law enforcement agencies. They primarily deal with firearms acquired at gun buyback events and firearms turned into the police directly. Gun Busters states on their website that they remove usable components for resale before destroying firearms [6]. However, since Gun Busters does not work with unwanted firearms owners directly, users can be misled. In 2023, a gun buyback program in Flint, Michigan advertised that firearms turned in would be incinerated, but in reality were sent to Gun Busters and resold.

An example of a technical gap in current options is shown with the National Center for Unwanted Firearms. They offer a service where unwanted firearms owners can request a package in the mail to ship their unwanted firearms for disposal [7]. However, this service requires a lengthy form to fill out, waiting for your request to be approved, and waiting for your package to come in the mail. This is not a good user experience for someone if they urgently need to get rid of their unwanted firearm.

Another example of a technical gap in current options is shown in destroying the firearm yourself. The ATF provides guidelines to properly destroy a firearm that cover options like crushing, smelting, slicing, and shredding [8]. If an unwanted firearms owner has access to the tools necessary for any of these options, then this is viable, but not many people have access to industrial equipment like this.

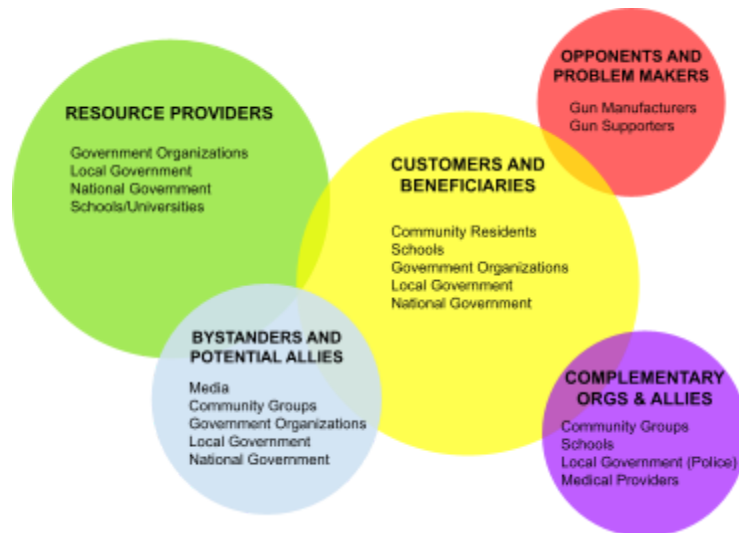
Based on these gaps, we have established this project needs to destroy firearms, or at least store them, if the community lacks the funding necessary. The product should accept any firearm, regardless of type, shape, or registration status. The product should be anonymous and able to be operated by any community member, without the help of an attendant. Before and after disposing of the collected firearms, the solution should store destroyed and intact firearms in a way that is secure from theft and protects the user from accidental discharge.

The goal of this project is to provide communities with a safe, anonymous way to dispose of their unwanted firearms. This project would be considered successful if any community members use our solution to dispose of

their unwanted firearms. Every unwanted firearm that is permanently taken out of communities helps to prevent possible firearm related injury and death, which will create safer communities.

### Stakeholder 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 below in Figure 5.



**Figure 5:** The above figure shows our project’s stakeholder mapping.

An example of important customers and beneficiaries are any citizens with unwanted firearms. They are the target audience for this project. Their desires are important because we need them to trust this project to destroy their firearms if we want them to use our product. Shane Hooper, a 31 year old unwanted gun owner, is an example; he stated he is wary of gun buyback programs specifically because he doesn’t trust police departments to destroy firearms [4]. Community residents and local business owners are also important beneficiaries because they will benefit from less risk of gun violence in their communities. Their desires are important because they may advocate their local government either for or against this project if their needs are met or not met, respectively.

An example of important resource providers is the local government that may be providing some of the funding necessary to get this product in their communities. There are many potential resource providers whose needs are important to get the funding, including the sponsor, advertisers, corporate sponsors, and philanthropists, but local governments have historically funded gun buyback programs, so their needs are important as well.

An example of important opponents and problem makers are gun law repeal activists. They will be against a product that removes guns from circulation. Their needs are important because we will 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 example of important bystanders and potential allies are media outlets. They are bystanders and 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 in their article “It’s Way Too Hard To Dispose Of Unwanted Guns In The U.S.” [2]. They are very influential, having 51.4 million visits to their site in February 2024 [13], and articles such as this that call out the lack of gun disposal options have the potential to inform the public

about our product. An example of an opposing media outlet is the CATO institute, a controversial right wing think tank, in their article “Have U.S. Gun Buyback Programs Misfired?” [14]. They are very influential, having been responsible for large misinformation campaigns, and articles such as this that negatively report gun buyback programs have the potential to dissuade the public from turning in their unwanted firearms.

An example of important complementary organizations and allies are gun control advocates. They believe in reducing the number of guns in communities and will agree with our cause. Their needs are important because their support will be 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 [15]. 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.

### Design Process

As novice designers, we looked into several design process models to follow, shown in Figure 1-4.

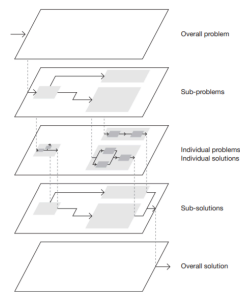


Figure 1: Decomposition / Recombination Model

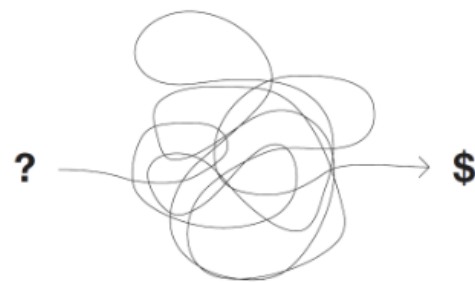


Figure 2: Tim Brennan Model

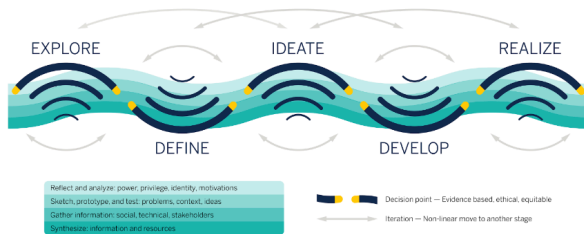


Figure 3: C-SED Socially Engaged Model

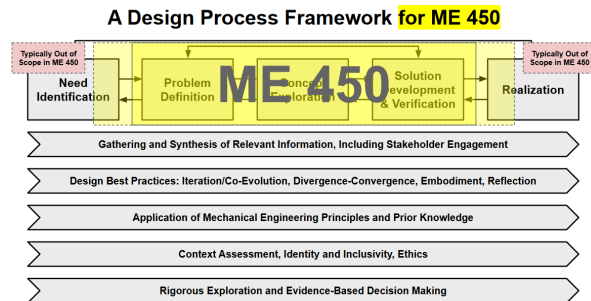


Figure 4: Standard ME450 Model

As we learned more about what makes a good design model in ME450, we could eliminate some and look more into others. We eliminated the Tim Brennan model, because this is a descriptive model. Designers use prescriptive models with prompts to guide work and descriptive models to highlight characteristics of design that align with their goals. The Tim Brennan model highlights non-linearity and profit as useful priorities, but is not a model that can be followed like a prescriptive model.

We also considered the C-SED Socially Engaged model, since it is a very structured model and the undercurrents help guide us to reflect, sketch, gather information, and synthesize often. However, we chose not to implement this model because it is a little too structured for us and we'd spend more time trying to adhere to the model than being productive. We are still novice designers and we have a tight timeline for this project; trying to halt progress to focus on a model that's out of our league would be counterproductive. As more experienced designers in the future and with a longer timeline, however, this can be a useful tool.

We have also considered following the ME450 design process introduced in this class. This model seems the most useful to us in the context of our project because it is basic enough for novice designers, while also being precise. This process is different from the process we have been using because our process focuses on how many sublevels of a problem there have been, whereas the ME450 design process doesn't keep count of how many levels of iteration have been made. The ME450 design process, however, adds activities that our model does not have to weave during each phase of the design process. These are good checks to reflect on the state of the project that our current design process does not consider.

### Intellectual Property

Investigating intellectual property rights was a medium priority for this project. There are several patents protecting firearm disposal methods that we needed to be mindful of to not infringe on anyone's intellectual property. Gun Busters has a US patent for their "Firearms Pulverizer System and Method" [12] which utilizes cameras within the machine to document the firearms that are being destroyed. The destruction method Gun Busters utilizes is shredding. There is another US 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 [16]. We have also found a World patent that utilizes the crushing method for destroying a firearm, "Weapon demilitarization system and process" [17]. We were not required to sign an NDA or an intellectual property agreement with our sponsor, but we did not consider any patent protections. This would be something we would consider after we present our recommendations, if we want to protect the work we have accomplished.

### Information Sources

Key examples of information sources include the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) [8] which provided us with information regarding the proper ways to destroy guns and firearms safety and regulatory compliance. Additionally, Michigan gun disposal records [9] provided us with information on the procedure the Michigan State Police follows for the disposal of firearms, such as legal requirements, internal policies and methods of disposal. It also provided a list of weapons to be destroyed as a legal notice and an email and a phone number where people can claim a weapon upon providing the necessary documentation showing they are the legal owner of said gun. Everytown Research's Gun Law Navigator [10] is a tool that provides information on gun laws and policies across the states in the United States. It also provides a n interactive map that allows users to compare and explore gun laws across different states. In some areas, the website provides access to studies and reports related to gun violence, laws, and public safety. We also used a Philadelphia DA's Office memo on the legality of gun disposal units written at the request of Dr. Humphreys.

Table 1 below shows the current options for firearm disposal. Our team found a couple of different ways people have been using to dispose of their unwanted firearms and we have organized them in the following table to compare with the ideal scenario in the aspects of accessibility, trustworthiness, documentation, and whether or not the destruction happens on the spot.

**Table 1:** Options for firearm disposal

Attribute	Ideal	Gun Busters [6]	DIY [8]
-----------	-------	-----------------	---------



<b>Accessibility</b>	Anyone can access	Only law enforcement	Anyone with access to proper tools
<b>Trustworthy?</b>	Yes	No	Yes
<b>Documentation?</b>	No	Yes	No
<b>On the spot destruction?</b>	Yes	No	Yes

Gun Busters [6] 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 Gun Busters and are taken to their facilities for destruction, they are not destroyed on the spot. Once at the Gun Busters 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 [4]. The remaining components are then destroyed using their patented firearms pulverizer system [12]. 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.

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 methods of shredding, crushing, or cutting with blow torches [8]. This method of disposal is trustworthy because the user will be the person executing the method, on the spot. There will be no documentation for this method unless the user themselves records down the details.

### **REQUIREMENTS AND ENGINEERING SPECIFICATIONS**

To determine our project's engineering targets, we first created a list of the stakeholder's requirements. We then categorized each condition as either an engineering requirement or a project constraint. Below in Table 2, we have listed the stakeholder's requirements with their assigned category and justification.

**Table 2:** Stakeholder requirements with categories and justifications

<b>Requirement</b>	<b>Category</b>	<b>Justification</b>
<b>Anonymous</b>	Project Constraint	Will not restrict anyone from turning in an unwanted firearm, identification is not required. Firearms will not be investigated for possible involvement in crimes.
<b>Accessible</b>	Project Constraint	Ideally, the project will be placed within the community to collect firearms, so it must be usable by all community residents.
<b>Accepts all firearms</b>	Engineering Requirement	Firearms come in many different sizes, we must be able to accept all firearms, no matter the size.

<b>Safe to the community</b>	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.
<b>Store or destroy firearms</b>	Engineering Requirement	Firearms will not be going back into circulation.

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 [5]. 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 [4].

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 [6]. 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 of the firearm without fear of legal consequences.

The most important requirement of our project is being safe to the 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 [18] and other engineering standards for the different levels of bulletproofing.

Currently, our team’s engineering specifications are reasonable. We were able to find standards from online sources showing different levels of bulletproofing and we utilized the specifications listed on our desired level and incorporated them into our 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.

**Table 3:** Project requirements and specifications

<b>Requirement</b>	<b>Specifications</b>
<b>Must fit inside footprint of shipping container</b>	The product must have the following dimensions: Width $\leq 8'$ Length $\leq 40'$ Overall height $\leq 13' 6''$
<b>Must be light enough to be put on and moved by a semi truck</b>	The product must weigh $< 45,000$ lbs
<b>Must be able to accept firearms of any size</b>	Length of unit intake must be $> 45''$ , Width of firearm deposit opening must be $> 16''$ , Height of firearm deposit opening must be $> 4''$

<b>Must be safe to the users and community</b>	Level IV bulletproof material (NIJ Standard 0101.06, 0108.01) User should be > 60” away from the shredder at all time
<b>Must destroy firearms (via shredding)</b>	Adhere to ATF destruction guidelines A shredder must apply shear force of > 800 MPa

**Must fit inside footprint of 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 done research and found out that the standard size of a shipping container is 8’ x 40’. We have also found out that in the state of Michigan, the maximum height of a vehicle must not exceed over 13’6”. Therefore, the specification of this requirement is that the product itself cannot go over the dimensions of 8’ x 40’ x 13’6”.

**Must be light enough to be put on and moved by a semi truck:**

Our team has done research and found that the largest weight a semi-truck can legally haul is 80,000 lbs [19]. 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 wastes within the product. Our team requires further research to have an estimation of the weight of firearm waste that can be contained within our design. Since the weight of an unloaded 18-wheeler semi-truck is approximately 35,000 lbs [20], we temporarily specified the product should not exceed the weight of 45,000 lbs. This requirement may need to be updated in the future.

**Must be able to accept firearms of any size:**

Our team has researched firearm thickness, lengths, and other dimensions, and determined that the product has to at least be able to take in firearms of the largest dimensions we found through research. 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. 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.

**Must be safe to the users and community:**

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[18]. This is the highest level of bulletproofing to include any type of ammunition or firearm type the user might dispose of. 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 opening of our design, which is the location where the user inserts their firearm, must be more than 60” away from the stored firearms. This is to prevent people from reaching inside the product and removing any stored firearms. To come up with the value of 60”, our team researched average human arm lengths [21]. We also performed empirical testing by measuring our own arm reach through a 4” x 16” cardboard cutout, which we created to simulate the opening of the product. This is demonstrated below in Figure 6. In the end, we came up with an average distance of arm reach of 30”, used a safety factor of double to ensure no one can reach the stored firearms, which gives us the safety distance of 60”.



**Figure 6:** Empirical testing of measuring our own arm through the cardboard cutout

**Must destroy firearms (via shredding):**

ATF guidelines list several methods of destruction to properly destroy a firearm, including crushing, smelting, cutting, and shredding [8]. We chose shredding because out of these options, it has the highest reliability to render the firearm destroyed while also being more efficient than something like smelting. This was decided after concept generation, however, so we do have some concepts that use methods other than shredding. This is not a flaw in our design process, however. Were we to use a different destruction method, we would have defined a specification for it. We just chose to only define a specification for the destruction method that we ended up using.

We specified that the product must be able to shred the firearms with a shear force that is greater than 800 MPa. We researched common metals used in firearm manufacturing and listed their respective shear strength in Table 4. We found that 4150 chromoly steel requires the highest shear force of over 800 MPa to shear. For this reason, we require a shear force greater than 800 MPa to be able to shred any firearm metal.

**Table 4:** Common metals used in firearms manufacturing and their shear strength

	4140 Steel <a href="#">[22]</a>	4150 Steel <a href="#">[23]</a>	1020 Steel <a href="#">[24]</a>	Stainless Steel <a href="#">[25]</a>	Titanium <a href="#">[26]</a>
<b>Shear Strength [MPa]</b>	476	410 - 800	280	400 - 690	550

## CONCEPT GENERATION

To generate concepts to work with, we used the Theory of Inventive Problem Solving (TRIZ) method and traditional brainstorming. The TRIZ method transforms a problem into a generalized version and encourages brainstorming within that realm. At this stage of the design process, we had not yet defined shredding as a requirement, so we generalized our problem as simply how to destroy solids. We then used Oxford University’s Effects Database to generate methods for how to destroy solids, as shown in Figure 7 [27].

### FUNCTION QUERY

Select an Action and an Object on which the Action is to be performed.  
Then click on the Submit Query button.

ACTION	OBJECT	RESULTS TYPE
<input type="radio"/> Absorb <input type="radio"/> Accumulate <input type="radio"/> Bend <input type="radio"/> Break Down <input type="radio"/> Change Phase <input type="radio"/> Clean <input type="radio"/> Compress <input type="radio"/> Concentrate <input type="radio"/> Condense <input type="radio"/> Constrain <input type="radio"/> Cool <input type="radio"/> Deposit <input checked="" type="radio"/> Destroy <input type="radio"/> Detect <input type="radio"/> Dilute <input type="radio"/> Dry <input type="radio"/> Evaporate <input type="radio"/> Expand <input type="radio"/> Extract <input type="radio"/> Freeze <input type="radio"/> Heat <input type="radio"/> Hold <input type="radio"/> Join <input type="radio"/> Melt <input type="radio"/> Mix <input type="radio"/> Move <input type="radio"/> Orient <input type="radio"/> Produce <input type="radio"/> Protect <input type="radio"/> Purify <input type="radio"/> Remove <input type="radio"/> Resist <input type="radio"/> Rotate <input type="radio"/> Separate <input type="radio"/> Vibrate	<input type="radio"/> Divided Solid <input type="radio"/> Field <input type="radio"/> Gas <input type="radio"/> Liquid <input checked="" type="radio"/> Solid	<input type="radio"/> Effect <input type="radio"/> Application <input checked="" type="radio"/> Both
Submit Query		

**Figure 7:** Effects Database from Oxford Creativity

We received 109 suggestions for ways to destroy solids. Examples include combustion, detonation, smelting, deformation, and more. We then used these suggestions to perform traditional brainstorming. Each team member generated 20 concepts, so our team had a total of 80 concepts to work with. At this stage of the design process, we encouraged many kinds of ideas and entertained any creative solutions because we wanted many options to work with. We then used design heuristics to refine those concepts and add more substance to them. Figure 8 shows the 77 design heuristics our team used to refine our concepts.

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

**Figure 8:** Design Heuristics

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 1. Though the concepts were not really distinct from one another when inspected by category –for example, in the deformation category, the methods are similar to each other – the executions and methods of dealing with the waste produced after destruction are unique. Some concepts went toward recycling the scrap metal from the firearm, and some concepts have the user keep the non-functioning firearm as a memento.

### Examples of Generated Concepts

The first example of our generated concepts is the shredder in “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 9.

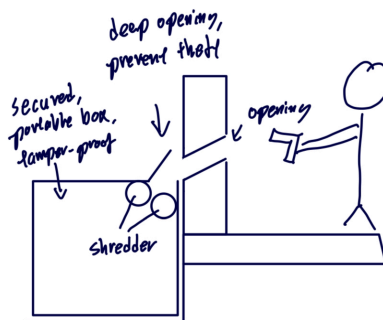


Figure 9: Shredder in “ATM” like machine

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 10.

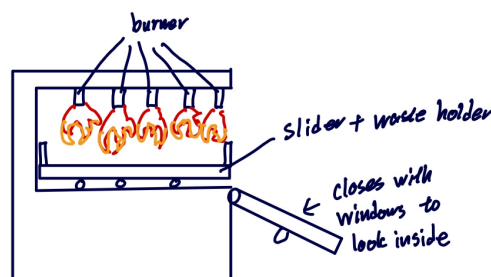
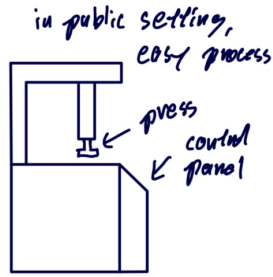


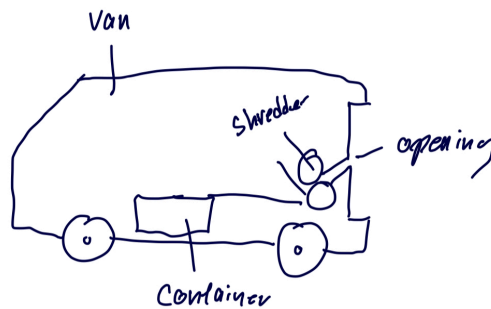
Figure 10: Cremation for firearms

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 11.



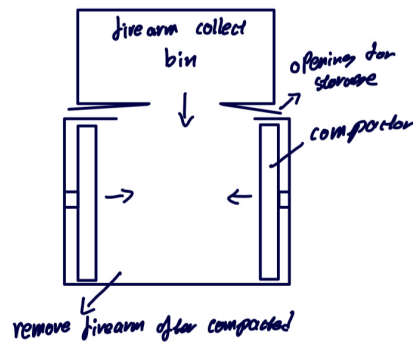
**Figure 11:** Easy press unit

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 12.



**Figure 12:** 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 13.



**Figure 13:** Firearm compactor

## CONCEPT SELECTION PROCESS

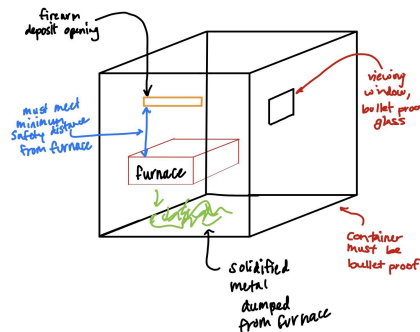
As a reminder, we had not decided on shredding as our method of destruction at this point. After compiling all of the team's generated concepts into a table, the team categorized and sorted each concept by its method of destruction – cutting, deforming, melting, upcycling / preservation, entertainment, and unrealistic. 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.

The first concept 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. [17]. 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.

### **First Concept**

Our first concept, shown below in Figure 15, 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 15:** A top concept featuring the destruction method of melting. This concept is not ideal due to the increased energy and time required to melt 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.

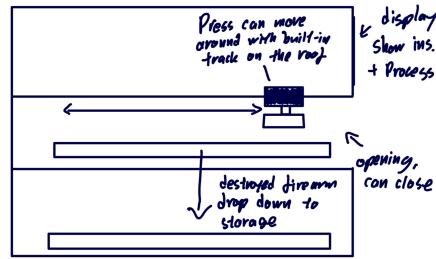
The material of the concept unit can also affect its ability to meet the safety requirements of the storage subfunction. If the proper material is selected, the concept unit could meet the level IV bulletproof requirements per the NIJ Standard 0101.06 and 0108.01[18]. The deposit opening is greater than 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 does not align with half of our requirements for the destruction subfunction. This concept was developed prior to our team deciding to go with the shredding method for destruction. 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 16. 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 16:** 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.

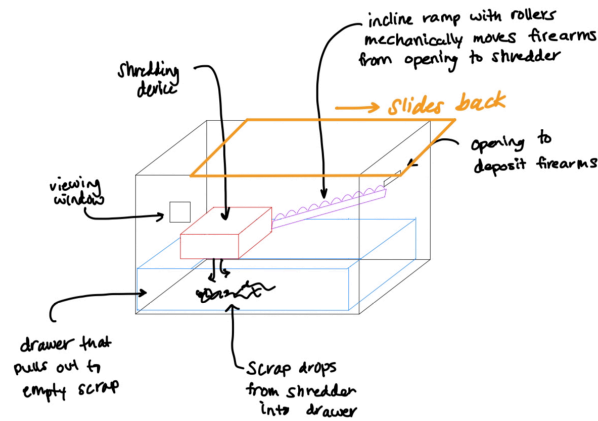
This concept can meet some of the shell subfunction requirements. It has a solid design that is hard to implement with many modular and replaceable parts. However, it should be able to fit inside the footprint of a shipping container easily because the biggest component in the concept unit would be the 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 [18]. 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. The design was generated before our team made the decision to fully focus on the method of shredding. 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.

### Third Concept

Our third concept, shown below in Figure 17, 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 17:** 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.

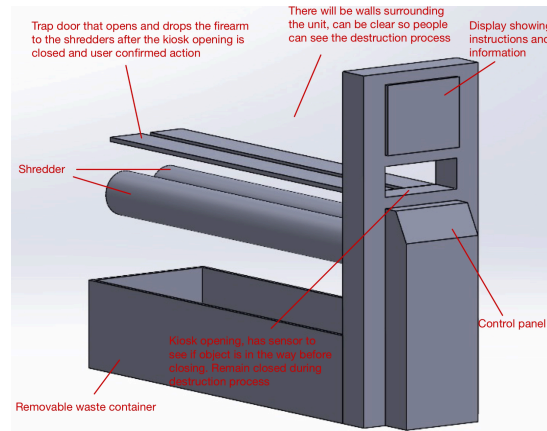
The material of the concept unit will also affect its ability to meet the requirements of the storage subfunction. If the proper material is selected, the concept unit could meet the level IV bulletproof requirements. The concept unit should be able to accept firearms of any size, and the ramp with rollers 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 18. 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 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 18:** 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 [18] and the opening of the kiosk can be easily designed to be more than 60” away from the stored firearm wastes.

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.

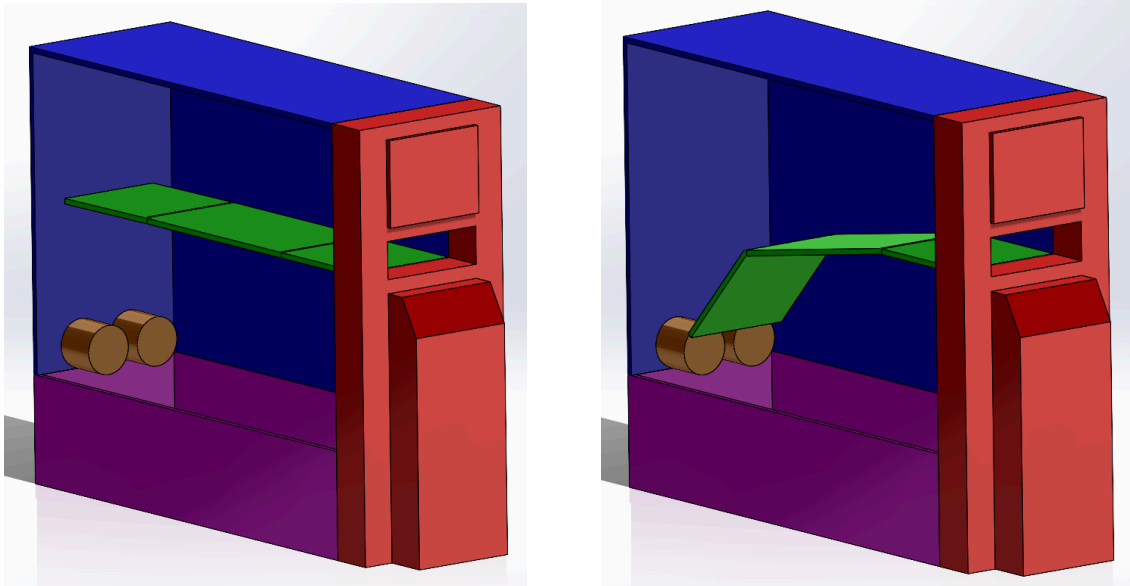
Overall, this design is consistent with our engineering requirements and customer specifications, and this design’s advantage of utilizing a shredder and having different safety functions for the user make it a competent choice for our team.

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.

### **CONCEPT DESCRIPTION**

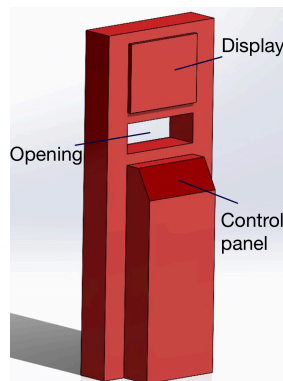
After the concept selection process, our team decided to use the fourth concept as a starting point and also refine the design based on suggestions from our sponsor, David Humphreys. A low fidelity prototype is shown below in Figure 19 and 20. We have updated the design of the trapdoor (green) to allow 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.

The design can be separated into three subfunctions. Kiosk (red) and shell (blue) are grouped together to form the shell subfunction. The waste container (magenta) is in a subfunction by itself – storage. The shredder (orange) and trapdoor (green) are grouped together to form the destruction subfunction.



**Figure 19 & 20.** Shown above is the low fidelity prototype of our selected concept. Figure 19 on the left shows the starting position of the design and Figure 20 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.

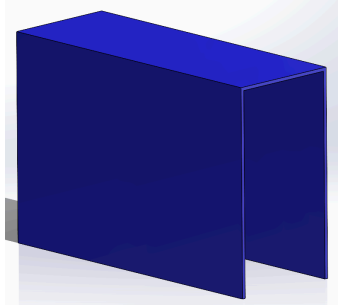
Figure 21 on the next page shows the kiosk of the unit, which is the part of our concept unit that the users will interact with. The kiosk has a display on the top to provide users with instructions and other information. The opening of the kiosk stays closed until the user is instructed by the kiosk 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 21:** Shown above is the low fidelity prototype of kiosk

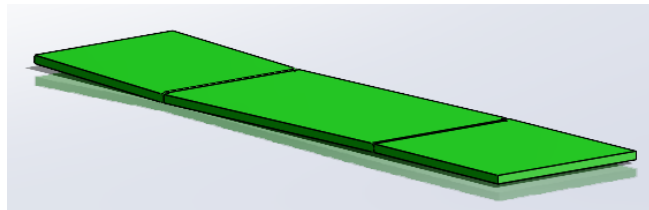
Figure 22 below shows the outer shell of the product, which will completely cover the entire product. The shell may have small windows that users may look in to observe the destruction process. The shell should be bulletproof

according to the NIJ Standard 0106.01 and 0108.01 [18] to protect the community against accidental discharge during the destruction process.



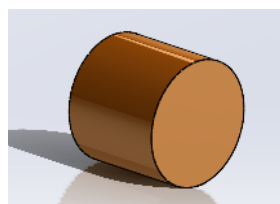
**Figure 22:** Shown above is the low fidelity prototype of the outer shell. The model shown here is the full model that will completely cover the components inside the design, unlike the part shown previously in figure 19 and 20.

Figure 23 below 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.



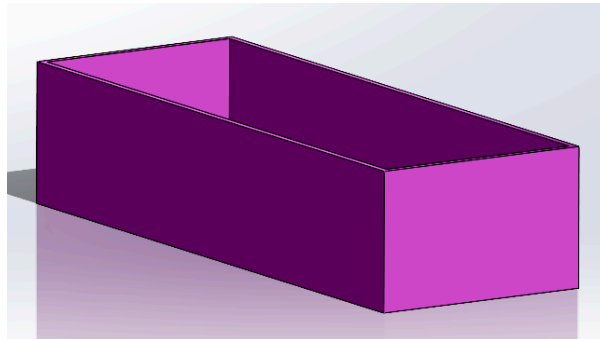
**Figure 23:** Shown above is the low fidelity prototype of the articulating trapdoor. Divided into three segments, with a shorter panel on the side and the longer panel in the middle. The trapdoor tilts down one segment at a time to position the firearm in a vertical orientation when it is sliding into the shredder.

Figure 24 below 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 24:** Shown above is the low fidelity prototype of shredder.

Figure 25 below 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 25:** Shown above is the 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.

## **ENGINEERING ANALYSIS**

It is at this stage that our team split and that I worked on the remainder of the project. The final design I have worked on is based off of the concept our team selected in DR2. The goal of this design was to finalize the shape and dimensions of the product, so the engineering decisions I made mostly pertained to specifications like “user should be > 60” away from the destruction part at all time” and “length of unit intake must be > 45””.

Because most of these decisions pertain to dimensional requirements, my calculations were done within the final design model in SOLIDWORKS. SOLIDWORKS has a high level of detail and I used accurate dimensions based on real life building materials to make my model, so I can be confident in my analysis of these dimensions. I will not be making a physical model of this design, so there is no relationship to what might be physically produced. I can, however, be confident in my analysis of the dimensions.

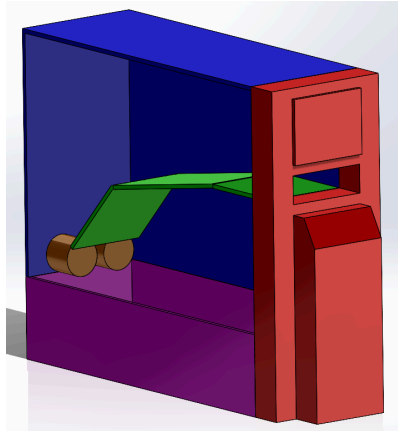
An important decision I made was allowing versatility in the thickness of the shell. At the time, I had not picked a bulletproof material yet, so I designed the unit around a frame that can have any thickness of shell I need. I researched what kind of material the frame should be made out of and found that 2” x 4” steel tubing is a popular choice for machine frames [\[28\]](#).

Another important decision I made was which bulletproof material to use. I researched many different manufacturers for materials that were Level IV bulletproof and found Bulldog Direct’s SAP12 material. It comes in 48”x96” sheets, is 1/2” thick, and is 20.4lbs/ft<sup>2</sup>. The thickness works well with the frame design I’ve chosen and the sheets can be cut to the required dimensions for the unit. Luckily, Bulldog Direct provides ballistic data on their product page and advertises that SAP12 passes Level IV tests, so I did not need to do any more calculations than they’ve already done [\[33\]](#).

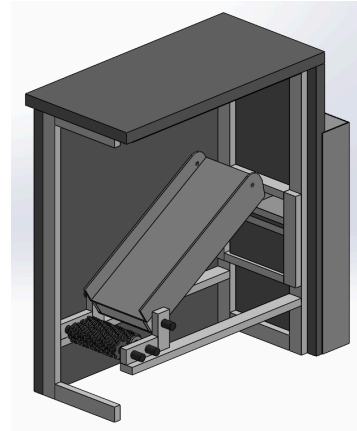
Another important decision I made was which shredder model to use. I calculated the horsepower required to apply 800MPa of shear force, as per the specification for “must destroy firearms via shredding”, to be 10-14HP. I then researched shredder manufacturers that made models capable of 10-14HP and would also fit within the unit. I found Taskmaster’s TM1600 to be a good fit; it is capable of 10-20HP and is 20”x63.75”x10”, so it fits within the frame of the unit [\[32\]](#).

Another important decision I made related to the “articulating trapdoor” in our selected concept. Instead of three segments articulating from the front of the unit, I designed it as one articulating ramp articulated from the rear. The idea of the articulating trapdoor was to position the firearm vertically into the shredder, but the same idea can be accomplished if the ramp articulates from the shredder and goes completely vertical. Figure 26 compares the low fidelity concept with the final design to demonstrate this. This reduces the number of actuation points required and improves structural rigidity, since it is just one solid piece. The only other decision I had to make to accommodate this was to ensure the height of the shell accounted for the arc of the ramp as it swings vertically. I ensured this by using SOLIDWORKS construction lines and verifying clearance in the assembly.





**Figure 26.1:** Three-segment trapdoor in selected concept



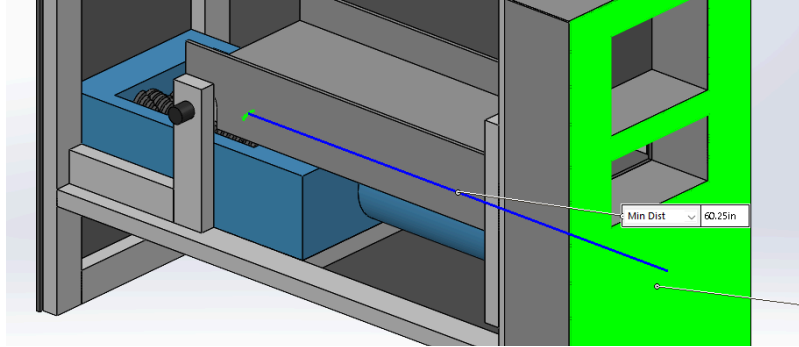
**Figure 26.2:** Articulating ramp in final design

Another important decision I made related to the height of the kiosk display. I researched the height of standard kiosk displays and found that there is an ADA specification requiring a maximum height of 48” [29]. I also found that KIOSK Information Systems uses 48” as a standard height [30], so I chose this as well to ensure the display feels familiar to users.

Another important decision I made was based on the “must be able to accept firearms of any size” requirement. The specification requires dimensions of the firearm deposit opening be greater than 16” x 4”. I designed the deposit opening to be 16” x 8”, using a safety factor of 2 on the height because users might be inserting the firearms at an angle or be inserting multiple firearms at a time. To ensure the deposit opening is at a comfortable height, I placed it as high as possible while still being below the kiosk display.

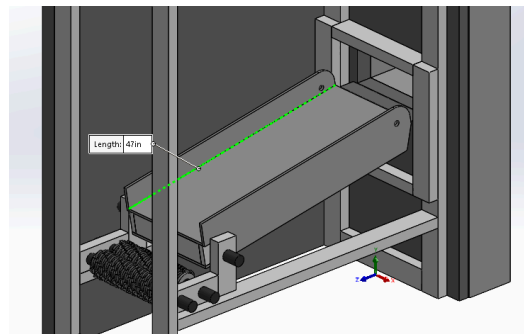
Another important decision I made related to the disposal of shredded waste. I will need to do more research to determine how much volume and weight shredded firearms might take up, but for now I assumed a container height of 12”. I made this decision based on our “must be able to accept firearms of any size” requirement. We specified a minimum deposit opening height of 4” based on sizes of common firearms, so I used 12” as a rough height assuming the container can store three firearms vertically. This is not a final decision, since it does not take into account how shredding can optimize volume, how the rest of the container can fit more firearms, and how the weight of the firearms might have an effect. I will need to do more research.

Another important decision I made was based on the “must be safe to user” requirement. The specification requires the user to be greater than 60” away from the shredder at all times, so I designed the frame to be long enough to accommodate this and placed the shredders at the back of the unit. I used SOLIDWORKS to calculate the distance from the shredder to the closest point outside the kiosk and changed the length of the frame until this distance was greater than 60”, as demonstrated in Figure 27.



**Figure 27:** Verifying the user is greater than 60” from the shredder

Another important decision I made was based on the “must be able to accept firearms of any size” requirement. The specification requires the length of the unit intake to be greater than 45”. In this design, the unit intake is the articulating ramp, so the length of the ramp must be greater than 45”. The shredder and deposit opening are already in fixed positions, based on my previous engineering decisions, so I designed the ramp to connect these two areas. I then used SOLIDWORKS to calculate the length of the ramp and ensure the length was greater than 45”, as shown in Figure 28.



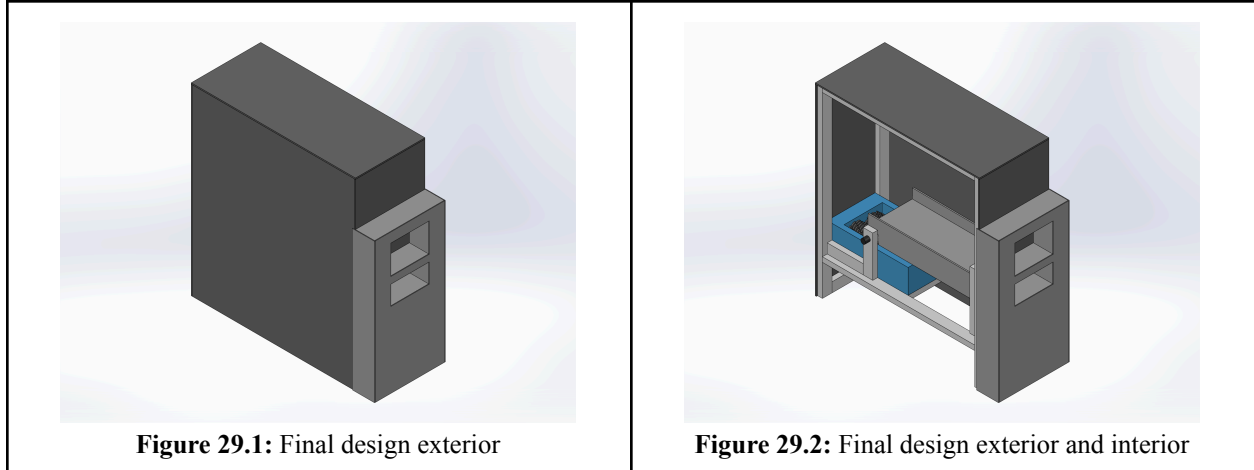
**Figure 28:** Verifying the length of the unit intake is greater than 45”

Another important decision I made was based on the “must be safe to user” requirement. The specification requires the shell be made of a Level IV bulletproof material, but the deposit opening is an area that does not have this protection. To remedy this, I designed a door made of the same material as the shell that opens and closes on the inside of the deposit opening. The kiosk will also require that this door be closed for the machine to function, to further protect the user.

## **FINAL DESIGN DESCRIPTION**

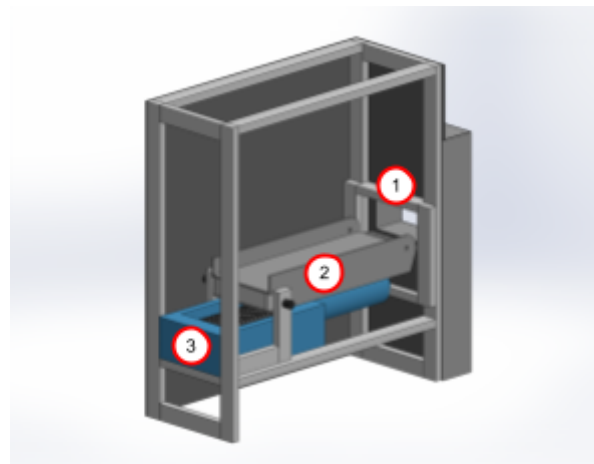
### **Design Overview**

Figure 29 shows the current state of the final design. The unit consists of a kiosk for user interaction, a firearms deposit opening, a bulletproof shell, a frame for mounting components, a shredder, an actuating ramp, and a bulletproof door over the deposit opening. The user interacts with the kiosk display and deposits their firearms while a computer in the kiosk automates the door, actuating ramp, and shredder. The left side of the unit can be removed by a technician for maintenance and shredded waste removal.



### **Operation Overview**

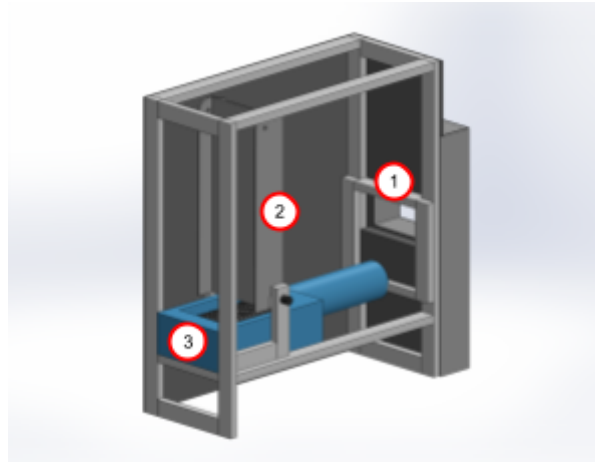
The unit is operated by a touchscreen display in the kiosk. The door to the firearm deposit opening will start closed, the actuating ramp will start horizontal, and the shredder will start turned off, as shown in Figure 30. When a user wants to deposit their firearms, they will begin the process on the touchscreen and the deposit door will open. The user will then be able to load their firearms into the opening. The unit will timeout if the user walks away without canceling and the user does not answer a prompt on the screen in a certain amount of time, to ensure the unit is not left open unattended.



**Figure 30:** Starting configuration of the unit

The user then confirms they have deposited their firearms on the kiosk display. After this, the deposit door closes. If the door successfully closes, as detected by limit switches, the unit is safe to begin the shredding process. The shredder turns on and a motor in the top rear of the unit pulls the ramp vertical by two cables, as shown in Figure 31. The firearms slide down the ramp, fall into the shredder, and are shredded. The unit can detect when the firearms are

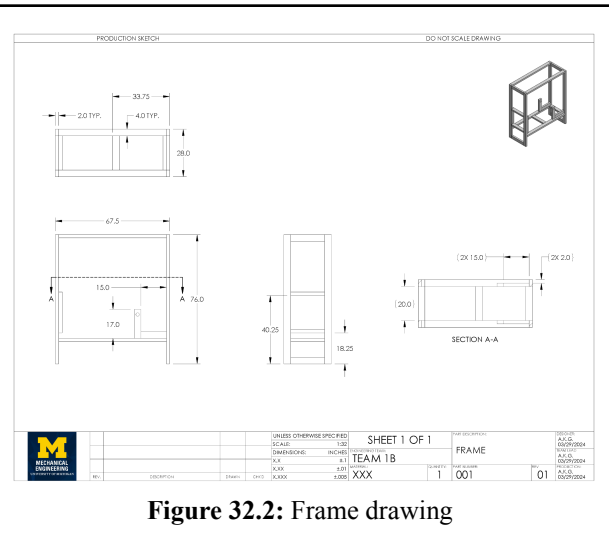
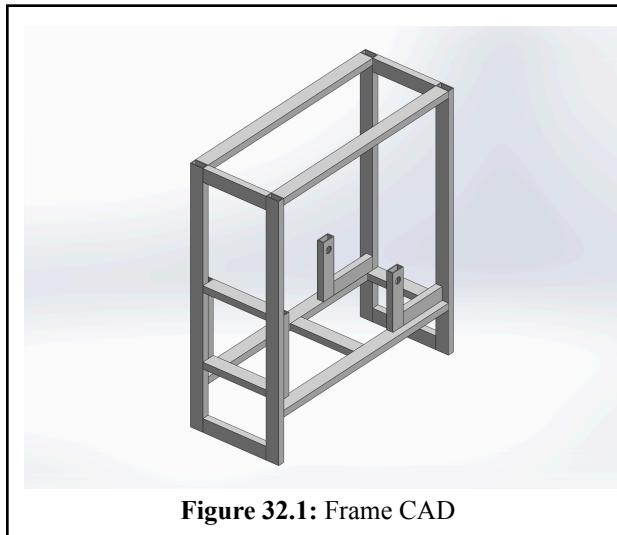
finished shredding by measuring the load on the shredder motors. When there is no more load, the shredding is complete and the unit can return to the starting configuration. The waste metal is deposited below for later removal by a technician.



**Figure 31:** In-use configuration of the unit

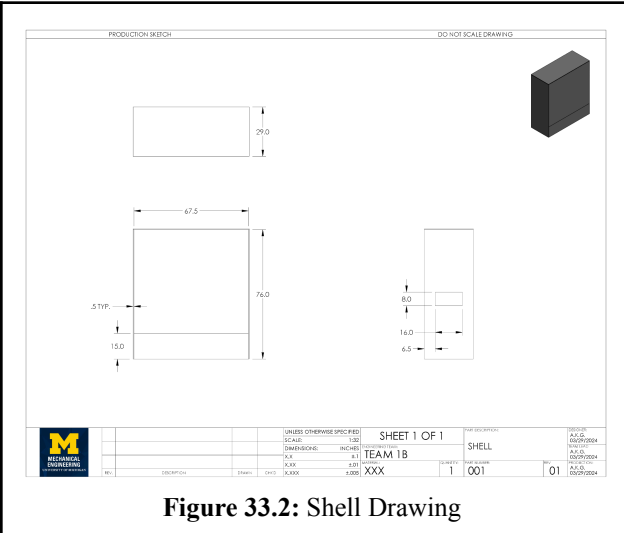
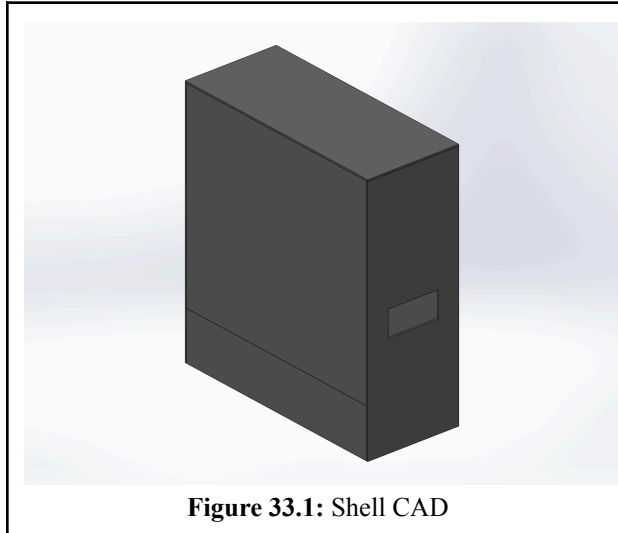
### Steel Frame

Figure 32 and Appendix 2 show the steel frame of the unit. The frame is what the interior components mount to and is made of 2" x 4" steel tubing. The frame is welded together, but has holes drilled for the ramp to actuate on.



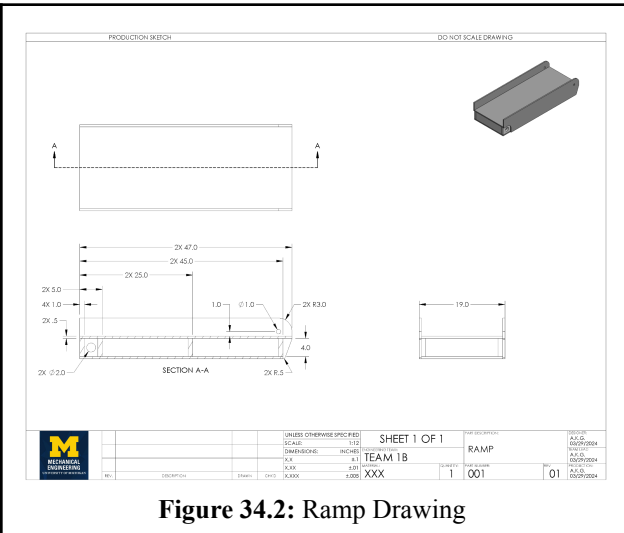
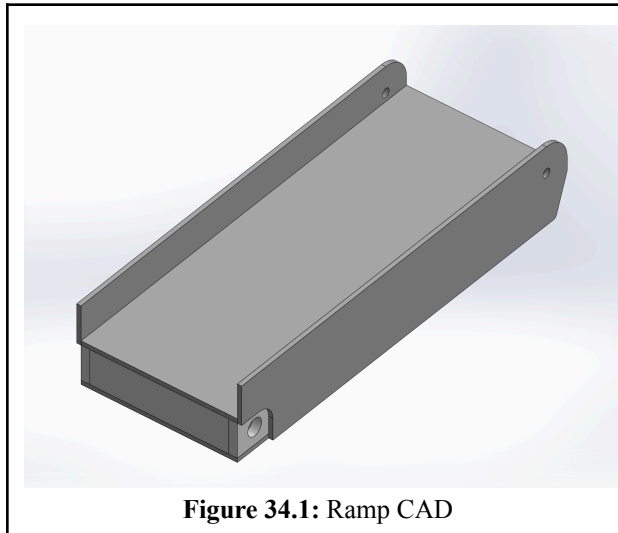
### Bulletproof Shell

Figure 33 and Appendix 3 show the bulletproof shell of the unit. The shell is made of Bulldog Direct’s SAP12 1/2” thick bulletproof material. The shell is welded together and welded to the steel frame for extra rigidity. However, the left face of the shell is split into two sections that are instead bolted to the frame. They are bolted so that the bottom section can be removed for waste disposal and the top section can be removed for maintenance. There is also a hole in the front face of the shell for firearms to be deposited into the unit.



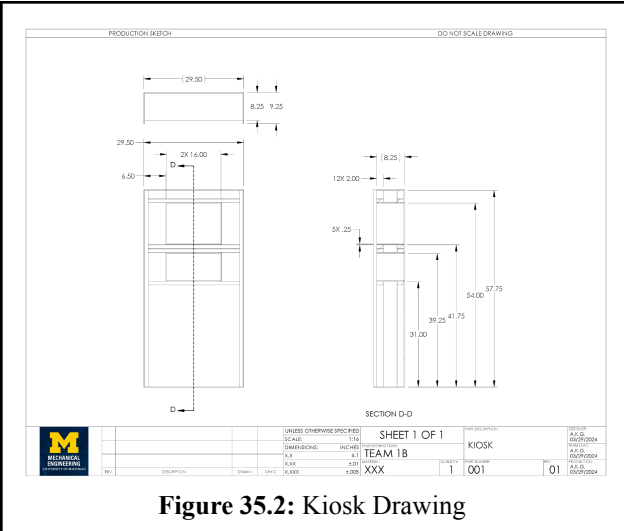
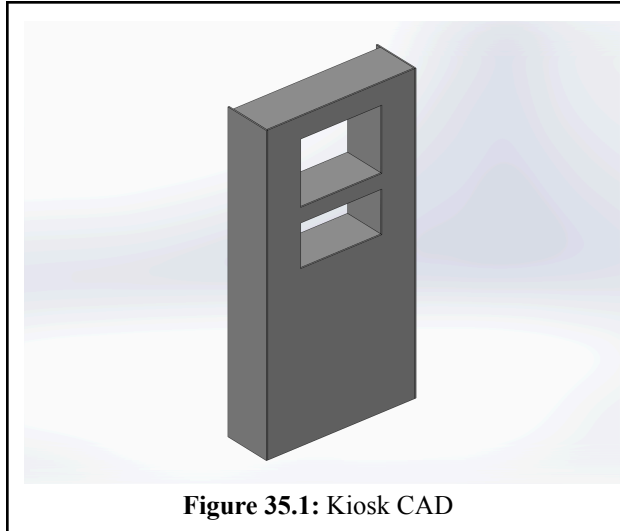
### Articulated Ramp

Figure 34 and Appendix 4 show the articulated ramp inside the unit. The frame is made of 1” x 4” steel tubing and the panels are 0.5” thick aluminum plates. The frame and plates are welded together and the ramp itself rotates around a point built into the frame at the rear. The ramp has two mounting points for cables. A motor at the top rear of the unit will pull the ramp vertical by cables when the door is shut and the user confirms on the kiosk display. Firearms slide down the ramp when vertical and go into the shredder.



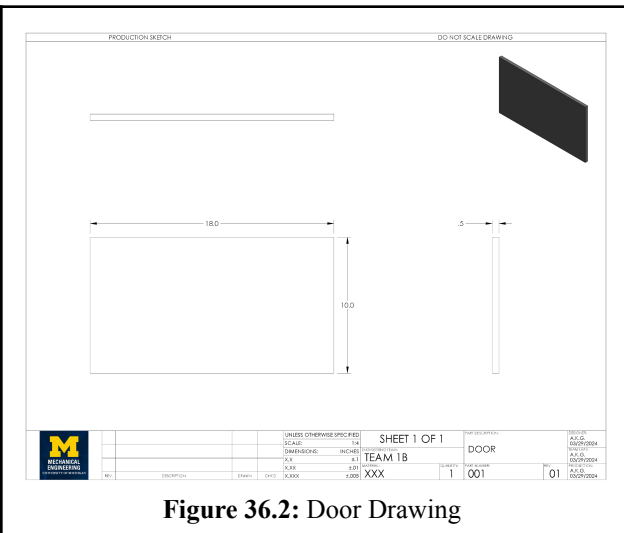
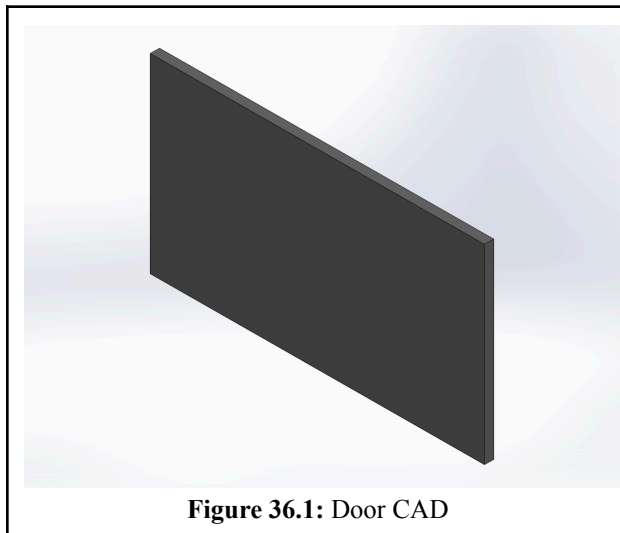
## Kiosk

Figure 35 and Appendix 5 show the kiosk. The lower opening is the firearm deposit opening and the upper opening is for a touchscreen display for the user to interact with. The frame is of 2" x 1" aluminum and the panels are 0.25" aluminum plates. The frame and plates are welded together, and the whole kiosk is welded to the shell of the unit.



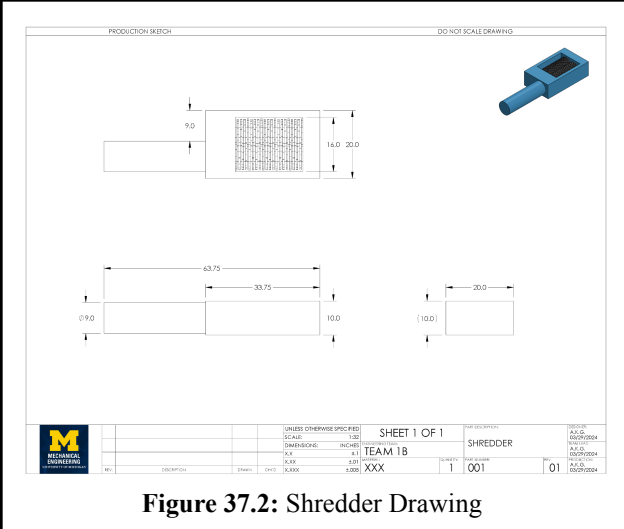
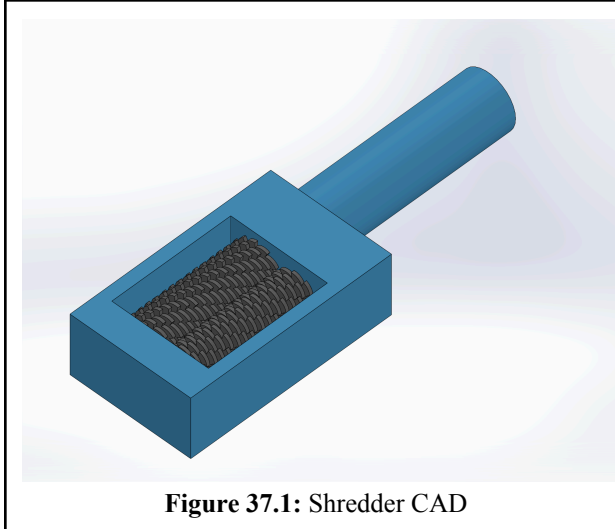
## Bulletproof Door

Figure 36 and Appendix 6 show the bulletproof door. This seals the firearm deposit opening and closes the bulletproof shell to prevent injury to the user. The door is raised and lowered by a motor, but the user controls when to close it when they confirm they've deposited their firearms. The door will also not open while the firearms are being shredded, for added safety to the user.



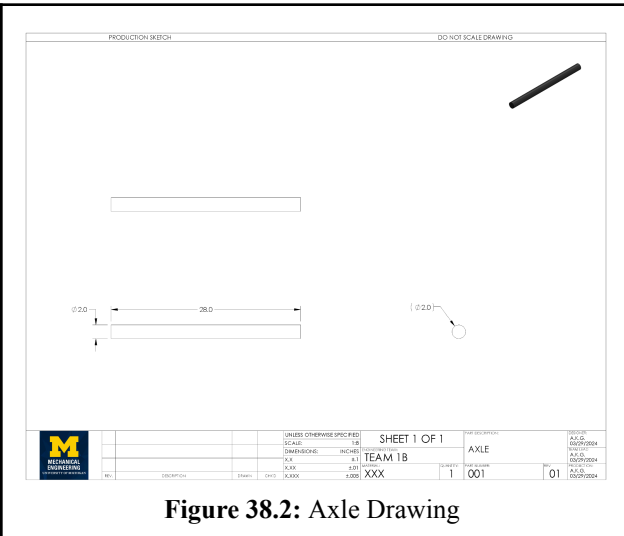
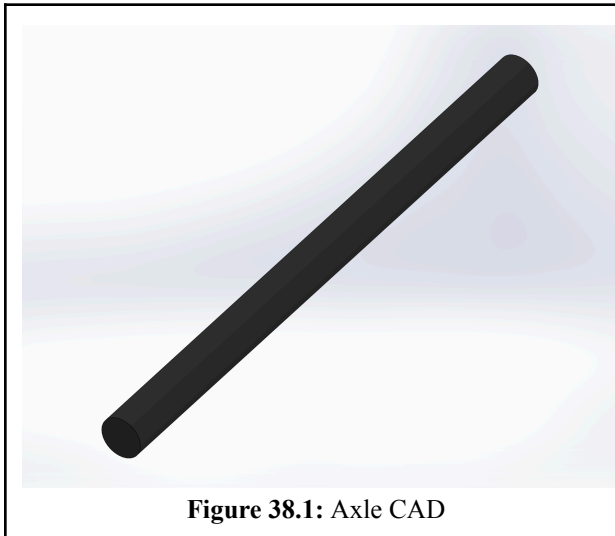
## Shredder

Figure 37 and Appendix 7 show the shredder. I used the dimensions of the Taskmaster TM1600 from their website to construct a simple model. This simple model allowed me to adjust the size of the frame to accommodate the shredder. The shredder operates after the user confirms they are finished depositing and the door is closed.



## Axle

Figure 38 and Appendix 8 show the axle. This axle is what the articulating ramp rotates around and is made of plain carbon steel.



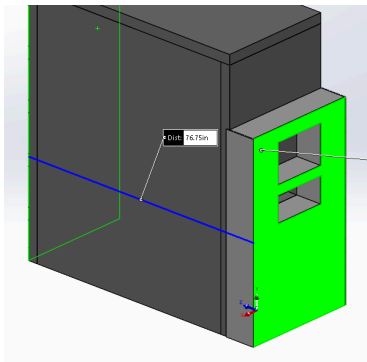
**VERIFICATION AND VALIDATION APPROACH**

Because I will not be constructing a model of this design, I will be relying on SOLIDWORKS to verify dimensional requirements and research on existing empirical data to verify any other requirements. I can be confident in my results of SOLIDWORKS because of my diligence to design the model using accurate building materials. The dimensions and weights should be very similar to the actual product, assuming manufacturing tolerances are reasonable. If the model only barely passes any specifications, I may want to take note of it for anybody manufacturing this product to account for tolerances, but I can still be confident the design passes the verification tests. I can also be confident in my research using existing data, so long as I use data from reputable sources and ensure the data is applicable to my model. The following are my verification tests for the requirements and specifications of this project:

**Verification Test #1:**

Requirement	Specifications
<b>Must fit inside footprint of shipping container</b>	The product must have the following dimensions: Width ≤ 8' Length ≤ 40' Overall height ≤ 13' 6"

To verify this, I used SOLIDWORKS to measure the width, length, and height of the unit. Figure 39 shows an example of this method and Table 5 shows the results of the test:



**Figure 39:** Final Design Measurement Method

Dimension:	Result	Passes
<b>Width:</b>	29.00"	Yes
<b>Length:</b>	76.75"	Yes
<b>Height:</b>	76.50"	Yes

**Table 5:** Final Design Measurement Results

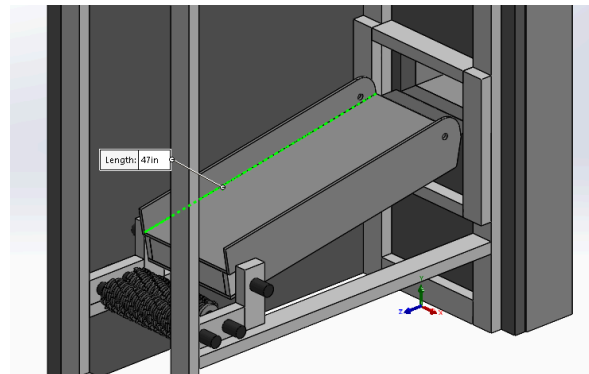
All dimensions adhere to the specification, so this verification test passes.



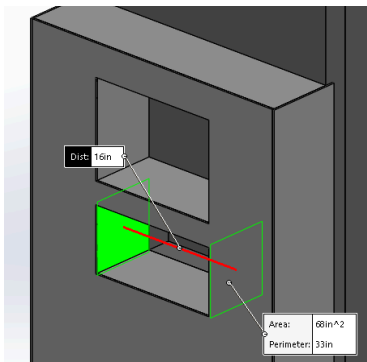
**Verification Test #2:**

Requirement	Specifications
<p><b>Must be able to accept firearms of any size</b></p>	<p>Length of unit intake must be &gt; 45",                      Width of firearm deposit opening must be &gt; 16",                      Height of firearm deposit opening must be &gt; 4"</p>

To verify this, I used SOLIDWORKS to measure the length of the actuating ramp, the width of the deposit opening, and the height of the deposit opening. Figure 40 shows how I measured the actuating ramp, Figure 41 shows how I measured the deposit opening, and Table 6 shows the results of the test:



**Figure 40:** Length of unit intake measurement method



**Figure 41:** Deposit opening measurement method

Dimension:	Result	Passes
Ramp Length:	47"	Yes
Opening Width:	16"	Yes
Opening Height:	8"	Yes

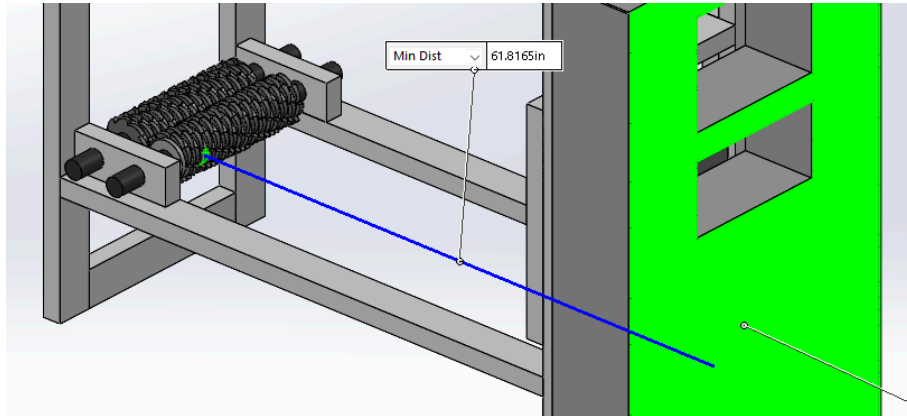
**Table 6:** Final design deposit opening measurement results

All dimensions adhere to the specification, so this verification test passes.

**Verification Test #3:**

Requirement	Specifications
<b>Must be safe to the users and community</b>	User must be > 60" from the stored firearms User must be > 60" from the shredder at all times

To verify this, I used SOLIDWORKS to measure the distance from the shredder to the closest point on the outside of the kiosk. Figure 42 shows how I measured this and Table 7 shows the results from the test:



**Figure 42:** Shredder distance to kiosk exterior measurement method

Dimension:	Result	Passes
<b>Shredder Distance:</b>	62"	Yes

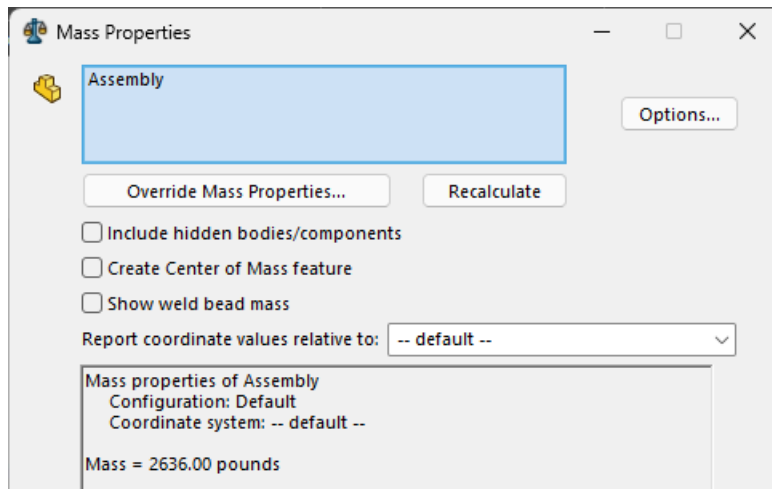
**Table 7:** Shredder distance to kiosk exterior measurement results

This dimension adheres to the specification, so this verification test passes.

**Verification Test #4:**

Requirement	Specifications
<b>Must be light enough to be put on and moved by a semi truck</b>	The product must weigh < 45,000 lbs

To verify this, I used SOLIDWORKS to calculate the mass of the unit using the densities of the materials used. I got the densities of plain carbon steel and aluminum from the SOLIDWORKS default library and I got the density of the bulletproof material from Bulldog Direct’s website [33]. I then excluded the shredder weight from the calculation because my model is crude and instead used the weight from Taskmaster’s product page [32]. Shown in Figure 43 is the mass SOLIDWORKS calculated.



**Figure 43:** Final design weight measurement method

Adding 2500 lbs for the shredder, the total weight is 5136 lbs, so this verification test passes.

**Verification Test #5:**

Requirement	Specifications
<b>Must be safe to the users and community</b>	Level IV bullet-proof material (NIJ Standard 0101.06, 0108.01)

It would be dangerous, expensive, and time intensive to experimentally test different bulletproof materials, but bulletproof material manufacturers have already done these tests, so I used their data. Bulldog Direct advertises that their SAP12 material is a Level IV bulletproof material and has data from their tests, as shown below in Table 8, so this verification test passes [33].

**Table 8:** Bulldog Direct SAP12 ballistic test results

Threat Level	Ammunition	Weight Grain	Weight (grams)	Velocity (m/s)	Number of shots
Level IV	.30-06 armor piercing	166	10.8	868 ± 15	1

**Verification Test #6:**

Requirement	Specifications
<b>Must destroy firearms</b>	The shredder must apply shear force of > 800 MPa

It would be expensive to buy different shredders to experimentally test their applied shear force, but shredder manufacturers publish their technical specifications on their websites. I calculated the horsepower required to apply a shear force of 800 MPa to the firearms using different kinds of cutting blades and any shredders that can't generate the horsepower necessary fail the verification test. I chose two popular cutting blade sizes and calculated the horsepower necessary to apply 800 MPa of shear force using the area of the cutting blade and the blade radius:

**Table 9:** Horsepower required for different blade sizes to apply 800 MPa of shear force

Blade Thickness (mm)	Blade Length (mm)	Cutting Area (mm <sup>2</sup> )	Blade Radius (mm)	Force Required (kN)	Torque Required (kN-m)	Horsepower Required (HP)
12.70	50.8	645.16	88.9	516.13	45.88	10.2
19.05	50.8	967.74	88.9	774.19	68.83	14.5

The Taskmaster TM1600 is advertised as being capable of 10-20HP, so this verification test passes [32].

## **DISCUSSION**

### **Problem Definition**

If I had more time and resources for this project, I would like to investigate the number of people who actually have unwanted firearms. This could provide very useful insight to estimate disposal frequencies, pick communities for beta testing, and possibly change the scope of the project, if numbers are much higher or lower than expected. I would investigate this using surveys across many communities, since that could also provide information about trends across America.

I would also like to investigate specific unwanted gun owners and get more testimonials about their experiences. The research we did only provided a few stakeholder testimonies and we only attended two sessions with stakeholders in our community, so this would provide valuable context about our users. I would investigate this using interviews, since interviews would provide more intimate information over a blanket survey.

### **Design Critique**

A strength of this design is that this specific shredder is compact, while also capable of the power required to shred metals. This unit has a small footprint, so it can be deployed in tight spaces in public areas. A weakness of this design, however, is that the unit is very tall to accommodate the arc of the articulating ramp. A redesign that uses another way to feed firearms into the shredder could reduce the height of the unit and save manufacturing costs for the bulletproof shell.

A weakness of this design is that I did not have time to research the costs of the bulletproof material and the shredder. These manufacturers do not have their prices publicly available and require contacting them for a quote, so it is possible that I chose a shredder model or a bulletproof material that is much more expensive than necessary. In the future, more research can be done by contacting manufacturers and requesting quotes that can be compared.

A strength of this design is that the unit is fully automated. The kiosk handles user interactions and automates the shredder, door, and articulating ramp to reduce user input and keep the user safe. Future designs should keep this functionality.

### **Risks**

The biggest challenge in this project was having our team split up. This added a lot of unnecessary pressure and reduced my ability to do as much design critique in the moment as I'd have liked. This shows in that I chose the first shredder model and bulletproof material that passed the verification tests because I didn't have time to evaluate other options. This also had adverse effects because I did not have time to evaluate if shredding was even still the best destruction method. It is possible that another method may have worked well, but it would not have been feasible to look into other alternatives that late into the project and with the situation I was placed in.

## **REFLECTION**

In this project, public health, safety and welfare were of high priority. The goal of this project is to reduce injuries from restored firearms and remove firearms from communities that don't want them, so this was very relevant when making decisions about safety features and the community's interactions with the unit. This design also has the ability to benefit any community, so global context was very relevant to this project.

As the final design stands, the manufacturing of this unit should not have any negative social impacts. The materials used are common materials and the shredder is from a mass shredder manufacturer, so there should be little environmental impact that would negatively affect society. The use of the unit, however, may have significant social impact. This product may be controversial for communities and will also have significant operating costs for the environment. The disposal of this design should have little social impact, however, since the materials used can be recycled and the shredder can be resold.

As the final design stands, the manufacturing of this unit will have significant economic impact. The bulletproof material and the shredder are quite expensive and the construction of the unit will likely require manual labor. The use of the unit will also have negative economic impacts. The shredder will require large amounts of energy to completely shred firearms and the shredded waste will require routine disposal. The disposal of this design, however, should have little economic impact since the materials used can be recycled for cash and the shredder can be resold.

Our approach to this project was mildly influenced by cultural differences between team members. We all grew up with different backgrounds, so our experiences with firearms were very different and this showed early on in the design process. However, as we worked more together and developed the scope of the project, we made sure to keep the approach neutral with respect to debates about firearms.

Our approach to this project was also mildly influenced by privilege differences between team members. For example, when approaching documentation, some members did not understand at first why documentation of users might be a problem, while the others explained how undocumented users with less privilege would be wary of using our product. However, once the scope of the project was developed, privilege did not come up often anyways, so the influence was mild.

Our design process was rarely influenced by cultural differences with our sponsor. Our sponsor had cultural differences with us to the same extent that we had with each other, but he still allowed us to work whatever way was comfortable for us. Our final design was also rarely influenced by cultural differences with our sponsor. Our sponsor had no cultural reservations about our design.

Our design process was rarely influenced by power differences with our sponsor. Our sponsor allowed us to work however we liked and follow any design model we chose. Our final design was also rarely influenced by power differences with our sponsor. We developed the design using our own design process and the sponsor approved of our decisions along the way.

## **Inclusion and Equity**

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. The sponsor has the ability to discontinue the project if they wish and we relied on their expertise in certain areas, so our decisions could have been heavily influenced by them. However, this was not the case; our relationship was very healthy and our sponsor rarely steered our project.

There is also a power dynamic between ourselves and the users. We have the most influence over the design of the product, so we might have ideas that don't align with the end users' needs. However, we avoided this; we conducted

thorough research about our stakeholders and attended sessions with stakeholders to hear their thoughts. It is possible, however, that validation tests focused on user experience could further improve this.

### **Ethics**

Firearms in America is a serious subject, so there are many ethical issues. One dilemma is how to address criminals that may have ill intent to destroy the evidence of a gun used in a crime. We considered this and 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. As a result, while we don't condone their actions, we would rather their gun be disposed of in a safe way than in an unsafe way where somebody could find it and hurt themselves or others, so this dilemma was managed. Another dilemma is how to address stolen firearms. Similarly, if a thief wanted to dispose of a stolen firearm, they'd dispose of it in another way anyways, so we'd rather them dispose of it in a safe way.

Because of the complicated issues around firearms in America, some of our personal ethics differed from the professional ethics we are expected to uphold in this project. We avoided their influence on the project by scoping our project in a way that it is clear this project is not intended to take away people's firearms, only to get rid of people's firearms that are already unwanted.

### **RECOMMENDATIONS**

After working on this project, the first thing I recommend is to reconsider the placement of the unit in public spaces. The shredder in the unit will be very loud and while our legal research found no issues with the destruction of firearms, we did not do research into whether the zoning of the property matters. It is likely not a good idea anyways to be bringing firearms to public spaces, so I recommend this unit be used in industrial areas like landfills or scrap yards. These are still publicly accessible locations, while also being in an environment that is more suitable.

The next thing I recommend is to further investigate bullet proof materials and shredder models. I did calculate that specifically Bulldog Direct's SAP12 material and Taskmaster's TM1600 shredder would pass our verification tests, but there could be other options that work better or similarly. These companies also do not have prices on their websites, so I would recommend contacting multiple companies to get multiple quotes and compare their prices.

### **CONCLUSION**

Working on this project was very informative into the state of firearms in America. There are many Americans with firearms they do not want and potentially storing them in unsafe ways. This project focused on those users and developed a concept for a technical solution to disposing of guns in communities. The solution proposed in this project is a good option to start working with. The final design destroys firearms, does so safely, and can be deployed in a versatile set of communities. It is still recommended that other options be explored, however, given the setbacks that this project faced and the situations we were placed in. More research should be done on bulletproof materials as well as different shredder models, or different destruction methods entirely.

### **ACKNOWLEDGEMENTS**

I'd like to thank our sponsor, David Humphreys, for providing valuable insight for this project and offering the opportunity to investigate this issue. I'd also like to thank Prof. Shanna Daly for providing support and thorough feedback during this project. I'd also like to thank Prof. Alex Shornter and Prof. Randy Schwemmin for providing valuable feedback on my DR4 presentation.

### **BUILD DESIGN BILL OF MATERIALS**

There was not a prototype for this project, so this is not applicable.

### **MANUFACTURING/FABRICATION PLAN**

There was not a prototype for this project, so this is not applicable.



## **REFERENCES**

1. <https://www.cnn.com/2022/06/02/us/gun-ownership-numbers-us-ccc/index.html>
2. [https://www.huffpost.com/entry/gun-disposal-buyback-us\\_n\\_5bb64d69e4b028e1fe3bd152](https://www.huffpost.com/entry/gun-disposal-buyback-us_n_5bb64d69e4b028e1fe3bd152)
3. Sponsor: David Humphreys
4. [https://www.huffpost.com/entry/gun-disposal-destruction\\_n\\_5ba01f1ee4b013b0977debe1?qe](https://www.huffpost.com/entry/gun-disposal-destruction_n_5ba01f1ee4b013b0977debe1?qe)
5. <https://www.theoaklandpress.com/2022/10/09/pilot-gun-buyback-program-launches-this-month/>
6. <https://gunbustersusa.com/>
7. <https://www.unwantedfirearms.org/what-we-do/>
8. <https://www.atf.gov/firearms/how-properly-destroy-firearms>
9. <https://www.michigan.gov/msp/services/ccw/public-notice-of-intent-to-dispose-of-firearms>
10. <https://maps.everytownresearch.org/navigator/country.html>
11. <https://maps.everytownresearch.org>
12. <https://patents.google.com/patent/US9106809B2>
13. <https://www.similarweb.com/website/huffpost.com/#overview>
14. <https://www.cato.org/research-briefs-economic-policy/have-us-gun-buyback-programs-misfired#>
15. <https://momsdemandaction.org/>
16. <https://patents.google.com/patent/US9714803>
17. <https://patents.google.com/patent/WO2021118669A2/>
18. <https://www.ojp.gov/pdffiles1/nij/223054.pdf>
19. <https://www.salinastriallaw.com/san-antonio-truck-accident-lawyer/what-is-the-maximum-weight-limit-of-an-18-wheeler/>
20. <https://www.onsitetruckaz.com/post/how-much-does-a-semi-truck-weigh-ultimate-guide-2022>
21. <https://gitnux.org/average-male-arm-size/>
22. <https://www.onlinemetals.com/en/product-guide/alloy/4140>
23. <https://www.azom.com/article.aspx?ArticleID=6770>
24. <https://www.metalsuppliersonline.com/propertypages/1020.asp>
25. [https://en.wikipedia.org/wiki/Stainless\\_steel](https://en.wikipedia.org/wiki/Stainless_steel)
26. <https://en.wikipedia.org/wiki/Titanium#>
27. <https://wbam2244.dns-systems.net/EDB/>
28. <https://www.industrialtube.com/structural-tubing/>

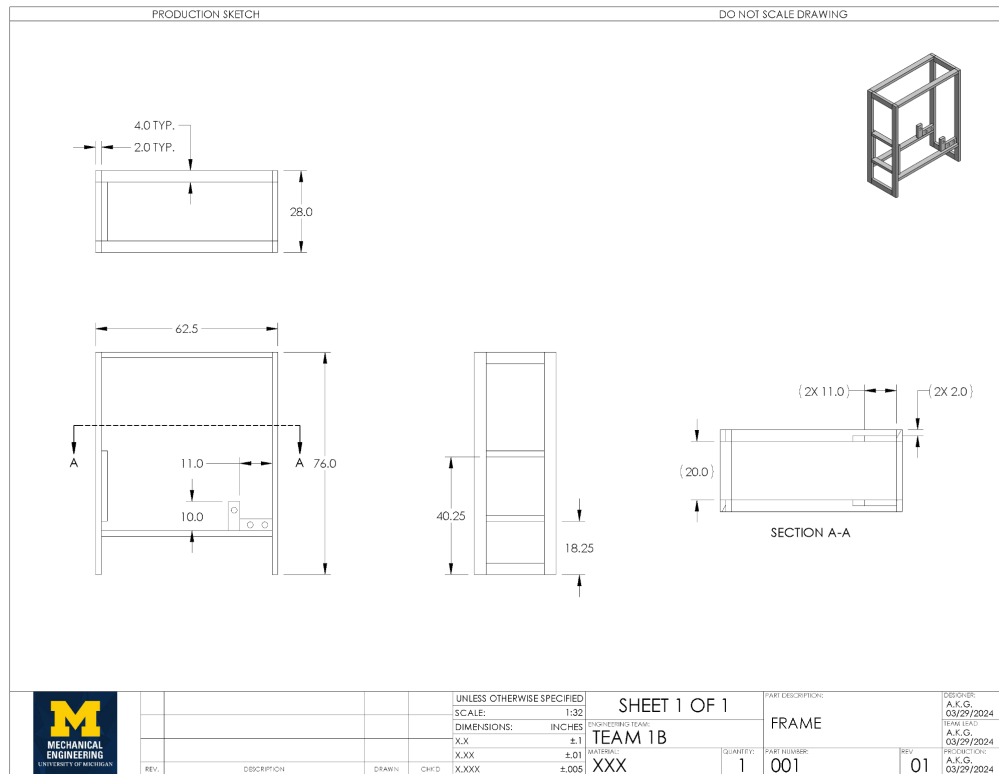
29. [https://www.anixter.com/content/dam/Suppliers/Peerless-AV/ADA%20Kiosks%20Accessibility\\_white%20paper\\_2.pdf](https://www.anixter.com/content/dam/Suppliers/Peerless-AV/ADA%20Kiosks%20Accessibility_white%20paper_2.pdf)
30. <https://kiosk.com/wp-content/uploads/kiosk-ada-design-guidelines.pdf>
31. <https://www.iqsdirectory.com/articles/shredder/metal-shredders.html>
32. <https://www.franklinmiller.com/product/taskmaster-tm1600>
33. <https://www.bulldogdirect.com/steel-armor-plate/>

# APPENDIX

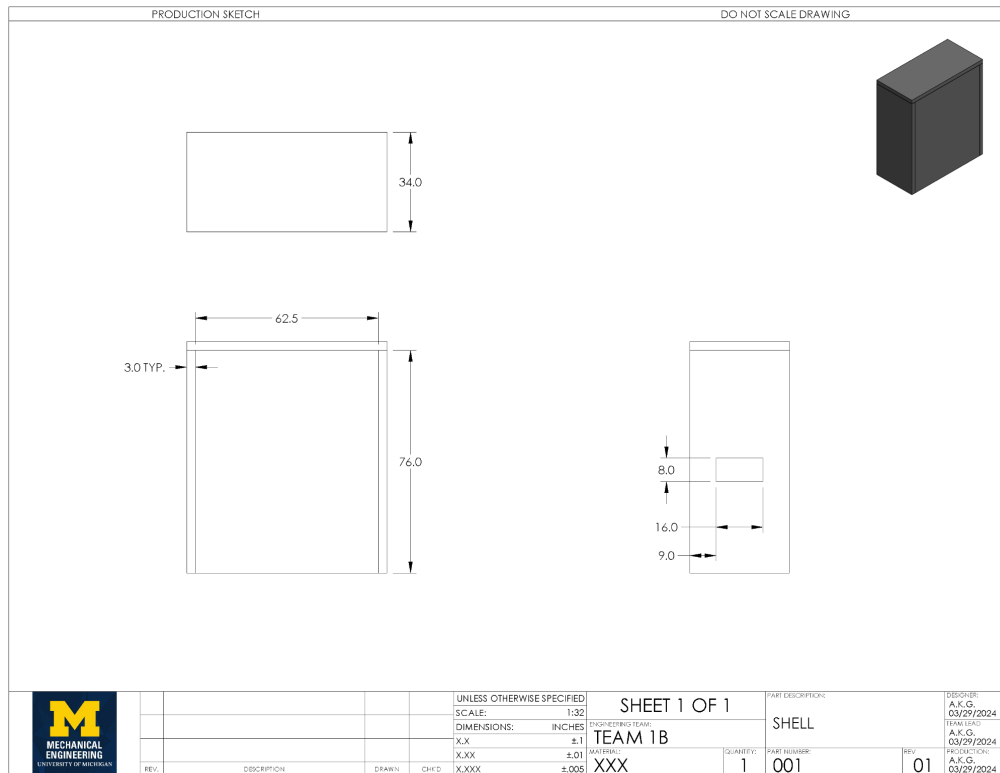
## Appendix 1: Concept Generation Table

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	Attendant 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. Attendant 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							

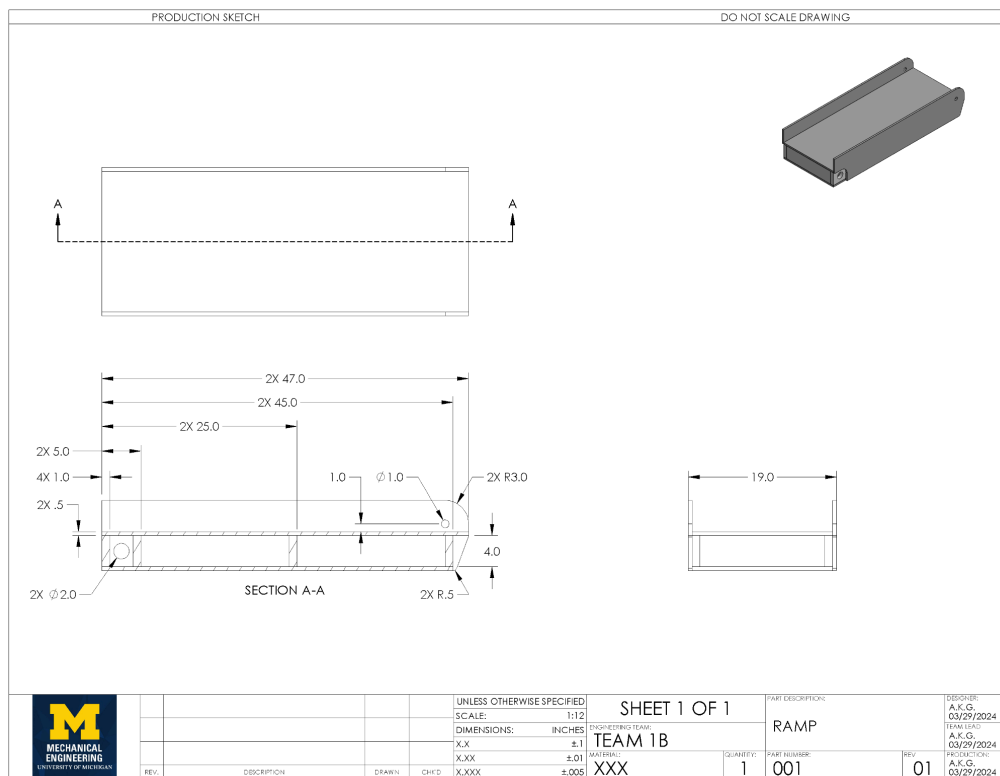
## Appendix 2: Final Design Steel Frame Drawing



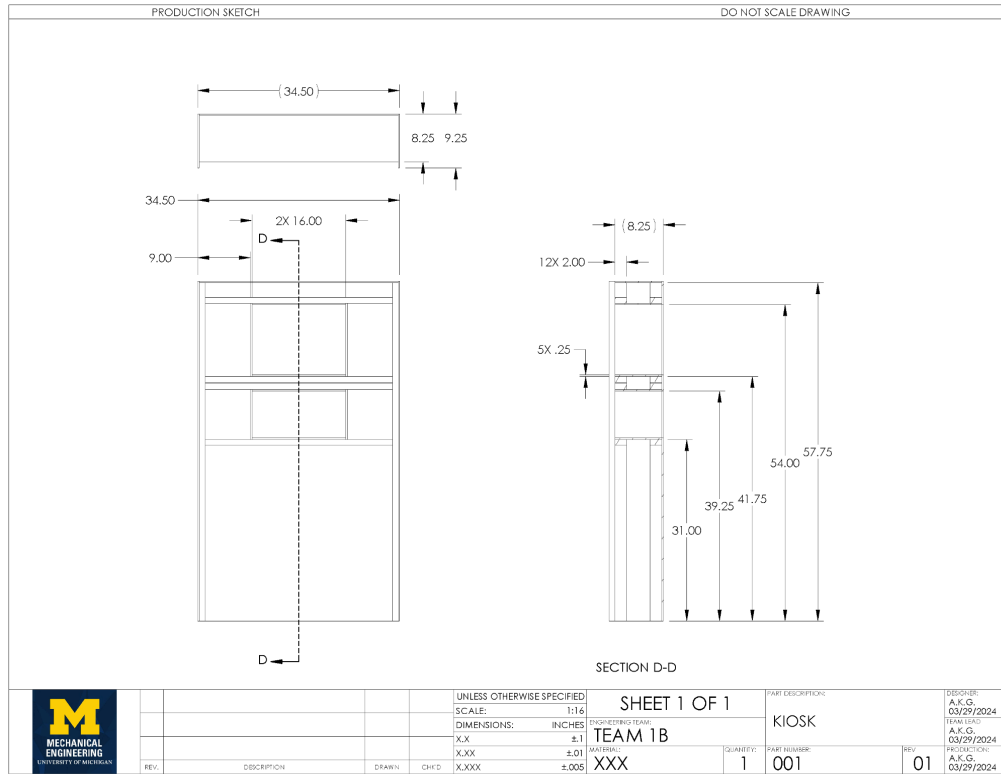
### Appendix 3: Final Design Bulletproof Shell Drawing



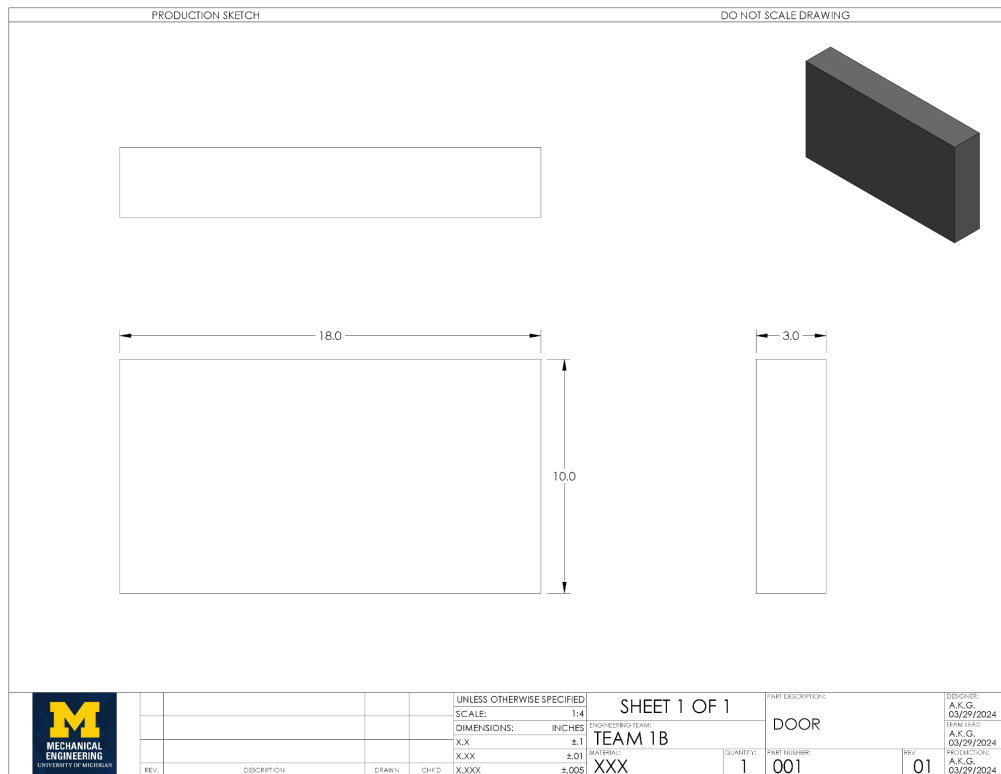
### Appendix 4: Final Design Articulated Ramp Drawing



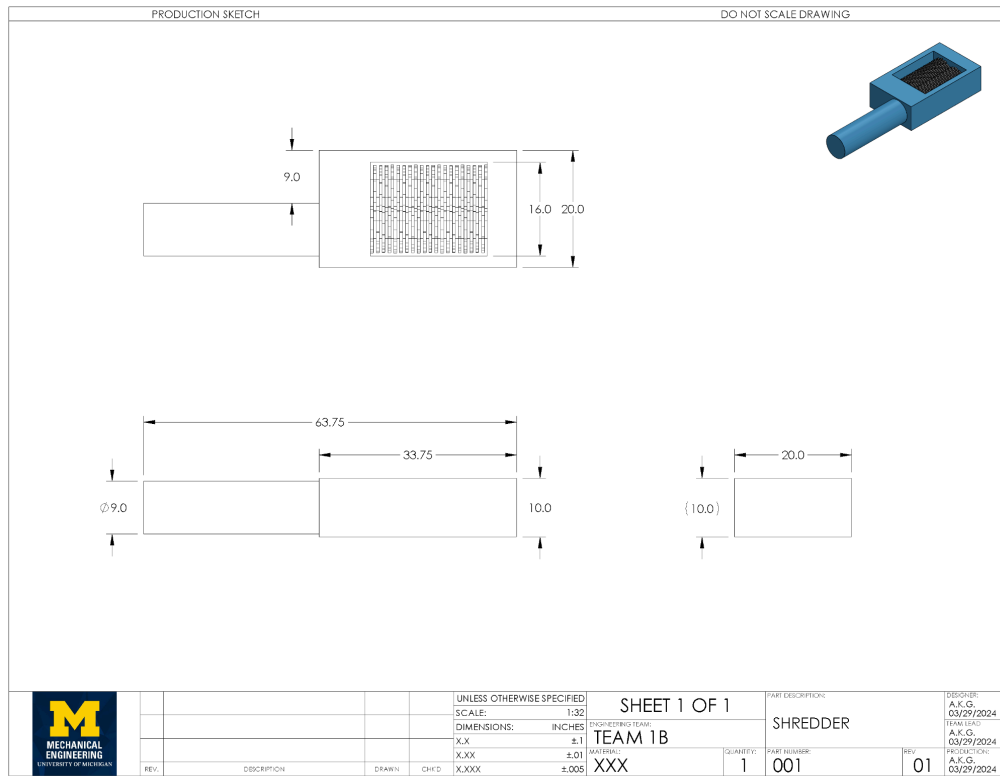
### Appendix 5: Final Design Kiosk Drawing



### Appendix 6: Final Design Bulletproof Door Drawing



### Appendix 7: Final Design Shredder Drawing



### Appendix 8: Final Design Axle Drawing

