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EML4551-2

Team 502: Retractable Storage Rack for Inert Atmosphere Glove Box

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1 Project Scope

The objective of this project is to create fully functional retractable racks that will be implemented into an inert atmosphere glove box. The retractable racks will be used to store materials, tools, scales, etc., inside the glove box, creating an organized, uncluttered working area for the user.

1.1 Key Goals

The retractable racks for the inert atmosphere glove box will be fully functional by a single user. The retractable racks will be secured to the top, back, or sides of the glove box. Furthermore, the retractable racks will be accessible with the gloves on and non-restrictive to the work space in the glove box. The retractable racks will also be mobile within the workspace. The long-term goal is to have the retractable racks created and implemented by April 2020.

1.2 Markets

The primary market for this project is the Applied Superconductivity Center (ASC), specifically, the project sponsor Bill Starch. The secondary market for the project is the chemical engineering department at the FAMU-FSU College of Engineering, as well as glove box manufacturers around the world.

1.3 Assumptions

It is assumed that an old glove box will be supplied for prototyping and a new glove box will be provided for the team to understand the functionalities and limitations of the gloves. It is also assumed that the glove boxes have similar interior designs and dimensions. Furthermore, the product will be used within the interior of the glove box; however, the storage solution can be removed from the box.

1.4 Stakeholders

All parties to be affected by the success of this product include the sponsor (Bill Starch), advisor (Dr. Hellstrom), overseeing professor (Dr. McConomy), and any individuals who would utilize the glove box.

2 Customer Needs

Needs Statement:

The objective of this project is to create retractable storage racks for an inert atmosphere glove box, which optimize storage space without restricting the workspace while the retractable storage rack is not in use.

For identifying the customer needs the following questions were asked. Dr. Hellstrom and Bill Starch's response to the questions are shown below in Table 1. From the customer statements, an interpreted need was determined.

Table 1

Interpreted Customer Needs from Advisor and Sponsor Questionnaire

Question	Customer Statement	Interpreted Need
What materials can be used inside the glove box?	"There cannot be materials that contain water or rust easily. Wood cannot be used."	The materials used for the storage racks can be aluminum or steel.
What material is the glove box made of?	"The glove box is either aluminum or stainless steel."	The materials used for the final product can be aluminum or stainless steel.

Question	Customer Statement	Interpreted Need
How much weight should the racks be expected to hold?	"The racks can hold tools or materials needed by the graduate students."	The storage solution can carry tools or materials.
Where can the racks be implemented?	"The bottom and the side where the antechamber is located can't be used."	The racks can be mounted onto the back, top, and side panels.
Can the glove box be penetrated?	"You can drill into the side of the glove box if needed. However, it cannot be drilled from the bottom or front viewing window."	The glove box may be breached to mount the storage solution from the sides or top.
Does the design have to work for a single- or double-sided glove box?	"Focus on creating a design for a single sided glovebox for now."	The racks are going to be implemented on single a sided glove box
Can the box be disassembled for installation?	"We will need to ask the graduate students if they are okay with the box being decommissioned or not. If not, the storage racks will have to be retrofitted."	An installation procedure/process can be created for installation if the box cannot be decommissioned.
Do the items on the racks have to be accessible with the gloves on?	"The items on the storage racks should mainly be accessible with the gloves on, can possibly be reached with a tool."	The user can access the storage racks either with the gloves or using a tool to reach it.
What is the budget for the project?	"The given budget is $2000; however, expect to spend much less than that."	The project will be able to be designed and created for $2000 or less.
How long do material orders take through ASC?	"Materials usually arrive a day to a week after being ordered."	Any project materials that need to be ordered can be expected within the week

3 Functional Decomposition

The functional decomposition represents the key components or functions of the retractable racks that will be implemented into the inert atmosphere glove box. The functions of this project were determined to be accessibility, functionality, and installation. The accessibility retractable rack is determined by how easily the user can reach and utilize it. There must be an open workspace in a single sided glove box while the retractable rack is in its storage position. Functionality is determined by how well the retractable rack serves its purpose of storing lab materials and tools within the apparatus. The retractable rack must be able to support the objects needed in the experiment without interfering with the lab. The installation will be determined by how well the shelf can be implemented in existing glove boxes without risk of damaging the apparatus. It can only be fastened to the sides, top, and back of the box as the front and bottom are too restrictive. The main functions are related since the functionality is dependent on both the success of the installation and whether it achieves the goal of easier accessibility.

As seen in the functional decomposition flow chart in Figure 1, the three main functions of the retractable racks are accessibility, functionality, and installation. Based on the three main functions, several sub functions were determined based off of the customer needs. The arrows connecting each box show the flow between the functions and sub functions. The Functional Relation Matrix is shown in Table 2. Each main function is displayed in the top column, while the sub functions are displayed in each row. The main functions are associated with their sub functions with an X in the appropriate row/column.

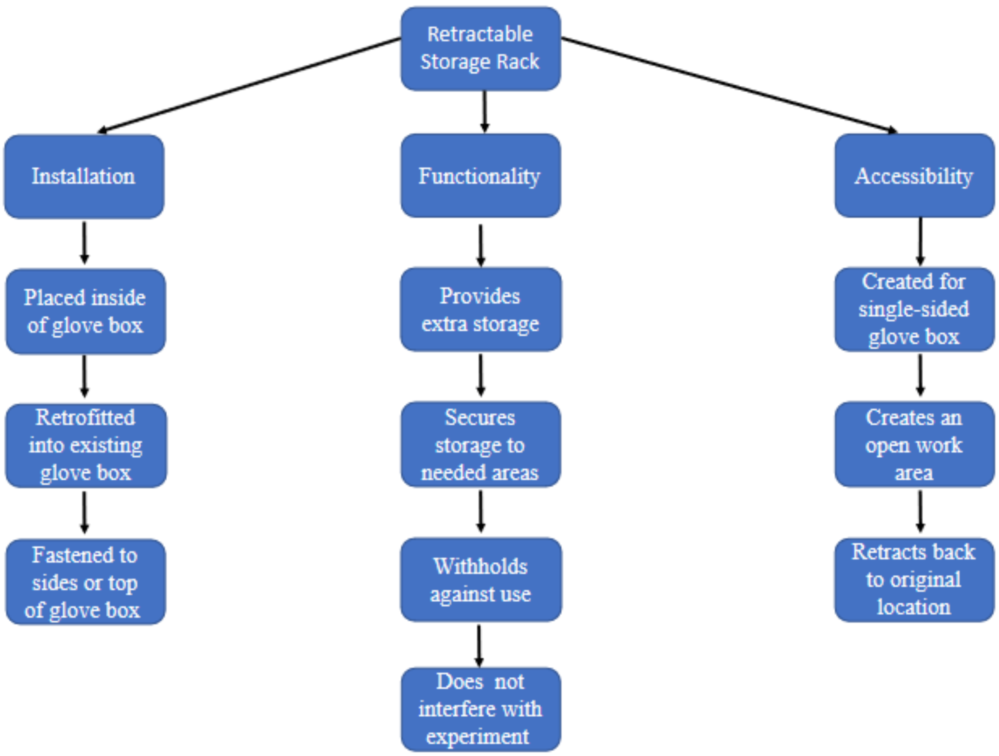

Figure 1: Functional Decomposition Flow Chart

Table 2

Functional Relation Matrix

	Accessibility	Functionality	Installation
Placed inside glove box			X
Created for single-sided glove box	X		
Secures storage to needed areas		X	
Retrofitted into existing glove box			X
Withholds against use		X	
Retracts back to original location	X		
Creates an open work area	X		
Does not interfere with experiment		X	
Provides Extra		X	

	Accessibility	Functionality	Installation
storage			
Fastened to sides or top of glove box			X

4 Targets and Metrics

The information received from the sponsor and the customer needs were used to create a functional decomposition. The three main functions were functionality, accessibility, and installation. From the functional decomposition, the targets and metrics were determined for the three main functions as well as several other aspects of the project. The targets and metrics are shown in Table 2. The three critical targets, shown in bold, are dimensions, functionality, and usability.

Table 3

Critical Targets Summary

Targets	**Metrics**
Dimension	7in x 10in x14in
Functionality	Surface area gained by storage solution (1ft^2)
Usability	Storage solution within the back of the glovebox wall for easy reach (1.5ft)

The overall dimensions of the product were determined using the area inside the antechamber in which it will be built. Because the storage must be small enough to fit inside the box, while still being large enough to hold required experiment materials it was decided that the dimensions should be 7 in x 10 in x 14 in. The functionality of this product was determined by the amount of storage the lab tech will gain inside the box during use. The surface area of storage space gained will be a square foot in order to provide enough workspace without interfering with the experiment. The usability was determined by whether the user could reach the shelf while wearing the gloves. Due to the constraint of the length of the gloves, the shelf must be reachable within 1.5 feet of the front panel.

To test and validate the critical targets, the dimensions of the future design will be measured prior to installation, as well as after installation in order to check for functionality. The functionality of the retractable storage racks will be tested by calculating the surface area of the storage racks to check for a gain in storage space. The usability of the retractable storage racks will be tested by implementing a prototype into the glove box and ensuring the user can access the materials from the racks.

Table 4

Target Catalog

Category	Targets	Metrics
Quantitative	Cost	Budget of $2,000 USD
	Dimension	7in x 10in x14in
	Weight	~10 lbs
	Carrying Capacity	~40 lbs
	Longevity	The life of the glovebox (~40-50 years)
Qualitative	**Functionality**	Surface area gained by storage solution (1ft^2)
	Wall Support	Screw fasteners or magnets
	Usability	Storage solution within the back of the glovebox wall for easy reach (1.5ft)
	Material	Stainless Steel and/or Aluminum

5 Concept Generation

Several design concepts were created for the retractable storage racks for the inert atmosphere glove box. The concept generation tools that were used in determining the designs were brainstorming, crap shoot, anti-problem, and a morphological chart. During brainstorming, team members discussed possible designs for the retractable storage racks and how the user would benefit from each design. Table 5 shows the morphological chart. With four options and three features, there are 64 possible designs created from the morphological chart. The concepts that were created using the concept generation tools can be found in the Appendix. All of the tools provided potential designs, but the higher fidelity concepts came from brainstorming.

Table 5

Morphological Chart

Feature	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Support	Free Standing	Hanging	Screwed	Tracks
Movement	Spin	Pull	Swing	Stationary
Location	Wall	Ceiling	Back	Floor

After analyzing the designs that were created, three high fidelity concepts and five medium fidelity concepts were selected as the designs that fit the customer needs and are most likely to be successful design ideas.

5.1 High Fidelity Concepts

<u>Concept 1:</u>

The rotating shelves will be attached to the box using rails and will be able to swing out of its position in the corner and forward to the user, where it can be rotated 360 degrees. The advantages of this design are that it provides much more storage area using multiple levels of rotating plate to only have needed materials within reach. The cons of this design are that it may take up a significant amount of space. A two-person glove box may be the more ideal target for the rotating shelves but they still provide the most extra storage. Shown below in Figure 2 are drawings of the rotating shelves.

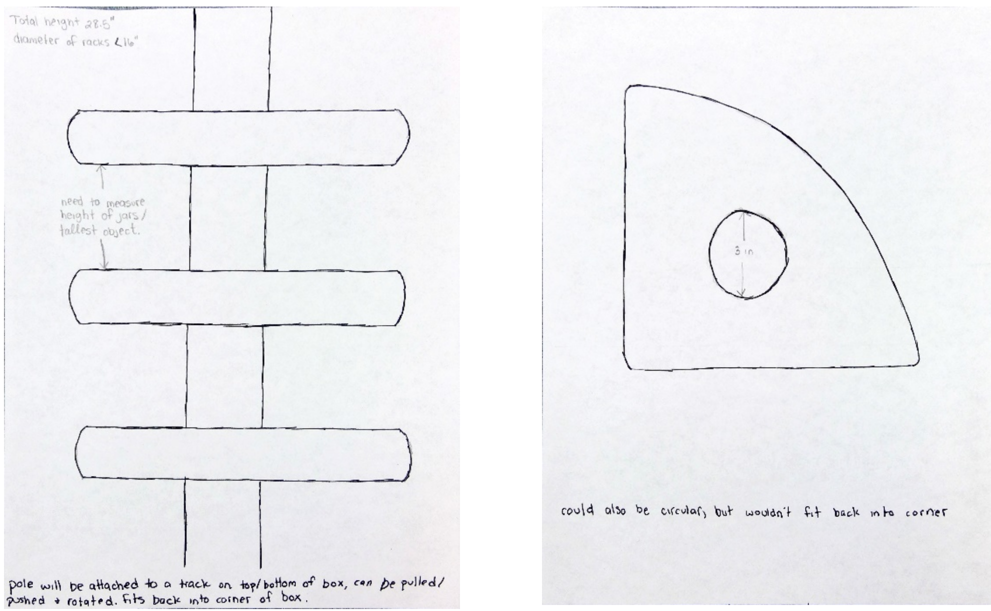

Figure 2: The Rotating Shelves

Concept 2:

The Accordion style rack will sit against the back of the box and can be pulled forward towards the user on an extending wall support. A box or platform will be used to store the experiment materials and this area can be pushed back out of the way after use. The pros of this design are that it can easily be adjusted to better suit the specific user's needs. The cons of this design are that a long extension would be prone to bending failure with heavier loads and could risk dropping materials down onto the experiment area if failure occurred. Shown in Figure 3 is drawing of the accordion style design.

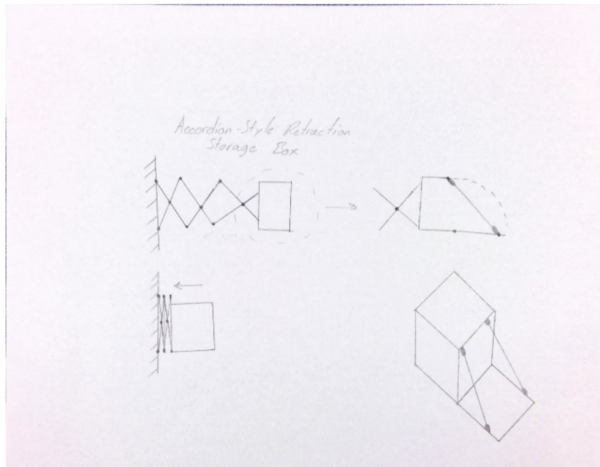

Figure 3: The Accordion Style

Concept 3:

A four-bar linkage could be used to create a swinging platform that pulls outwards and towards the user from the corners which are out of reach. When the rack is fully extended it will lock into a forward storage area that holds it securely to the wall. This design can accommodate for the loss of space that the gloves cannot reach and provides storage that is available whether it is pulled forward or backward. Cons of this design include a need for very smooth transition in order to keep materials from spilling over while it is being pulled out. Shown in Figure 4 is the design of the four-bar linkage.

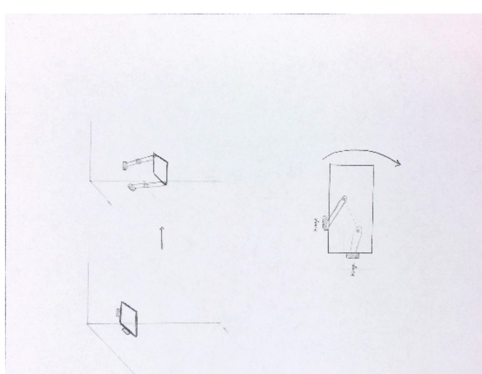

Figure 4: The Four-Bar Linkage

5.2 Medium Fidelity Concepts

Concept 4:

The fold out wall design consists of a plate pressed up against the wall that can be folded out and provide and extra platform for lab materials. The pros of this design are that is uses very little space and can securely provide extra storage area in the needed locations. The cons of this design are that the storage area disappears when the rack is folded up and all materials must be removed. The preferred option would be a solution that can constantly hold materials and still be out of the way.

Concept 5:

The telescope style extending rack uses increasingly small cylinders to pull the shelf out towards the user where materials can be stored and then pushed back against the wall. One flaw with this design is that the rack cannot sit flush against the wall because it can only sit as close as the first cylinder is long. Another issue is that the fine powders used in the boxes could get in the spaces between the cylinders and create an unsmooth motion. Strengths of this design are that it provides secure storage that can be as mobile as the user requires.

Concept 6:

The pegboard shelf concept takes a typical pegboard found in many workshops around the world to hold tools and materials, and adapts it to create a pegboard to can be utilized in the inert atmosphere glovebox. The adaptions made would most likely be the material the pegboard would be needed to be made out of as wood would not be able to be used inside of a glovebox. Another adaptation that can be included could be the use of shelves that and built onto the pegboard to hold things that the peg tool holders would most likely not be able to hold. Things like canisters and materials or even larger tools that normally would be able to be held on a typical pegboard could utilize the built-in shelf to allow the user to use the pegboard for whatever they desire.

Concept 7:

A hide-able rack that is able to be opened by pressing a button is a concept that was created for users with high ceiling spaces inside their gloveboxes. This space could be utilized by making a rack that is able to hide inside the ceiling when not in use. This space could be used for materials or tools that are not utilized as often as the retracting process would likely take a little bit for it to come safely down. This design would be able to utilize the tall ceiling space that glovebox users cannot access due to their limited length of gloves. The hide-able rack would function by using some hydraulic pistons that would allow it to come down from the ceiling and then stop when the hydraulics are fully extended.

Concept 8:

A window shutter design could be implemented using several elevated shelves that can be slid out of the wall and into a lab platform position from a shutter mechanism. A pull area will be available for the user to open up all the shelving area at once. The advantages are multiple levels of storage allow for a greater use of space and the mechanism that would operate the design is relatively simple and reliable. The disadvantages include the rack possibly interfering with the work area and providing no storage space when in the shut position. The shelves would also have a height limit for materials that can be stored.

6 Concept Selection

After constructing several different concepts for the retractable racks, various concept selection tools were implemented in selecting the best design. For the retractable racks, the customer requirements are glove box lifetime, retractable, more usable storage space, active installation, non-obtrusive, usable with gloves on, and compatibility with multiple glove box designs. The binary comparison was used to determine the importance weight factor of each customer requirement. The importance weight factor is determined by comparing each customer requirement to every other customer requirement and through group discussion, determining which customer requirement is more important to the customer needs. Each requirement is ranked with a 0 or a 1 based on if it is better than the other. The total row number is the importance weight factor that will be used later in the house of quality. Shown below in Table 6 is the binary piecewise comparison of the customer requirements.

Table 6

Binary Piecewise Comparison of Customer Requirements

	1	**2**	**3**	**4**	**5**	**6**	**7**	Total Rows
1	-	0	0	1	0	0	0	1
2	1	-	0	1	1	1	0	4
3	1	1	-	1	0	0	0	3
4	0	0	0	-	0	0	0	0
5	1	0	1	1	-	0	0	3
6	1	0	1	1	1	-	1	5
7	1	1	1	1	1	0	-	5
Total Columns	5	2	3	6	3	1	1	6

After completing the binary piecewise comparison of the customer requirements, the house of quality was created. The house of quality determines the importance of the engineering characteristics by comparing them to the customer requirements based on the importance weight factors that were determined in the binary piecewise comparison. An exponential scale was used to rank the engineering characteristics to allow the results to be more clear. The process of finding the importance of the engineering characteristics is done by multiplying the importance weight factor to the given rank of the engineering characteristics and summing them to create a raw score. Each raw score is divided by the total raw score to determine the percent of importance and show the rank order of each engineering characteristic. The house of quality is shown below in Table 7. *Table 7*

House of Quality

		Engineering Characteristics								
Improvement Direction		↑	↑	↑	↑	↑	↑	↑	↓	↓
Units		lb.	psi.	n/a	n/a	in^3.	in^2.	n/a	min.	lb./lb-ft.
Customer Requirements	Importance Weight Factor	Weight Held	Material Rigidity	Corrosion Resistant	Mechanism Simplicity	Storage Volume Increase	Surface Area Increase	Ease of Use	Time to Install	Force or Torque Required to Use
Glovebox Lifetime	1	1	9	9	3					1
Retractable	4	3			9					1
More usuable storage space	3					9	9	3		
Glovebox active installation	4		3		1				9	
Non-Obtrusive	3					3	3	3	6	3
Usable with gloves on	5							9	6	9
Compatability with multiple glovebox designs	5	1	1	1	3	3	3		1	1
	Raw Score (434)	18	26	14	58	51	51	63	89	64
	Relative Weight %	4.14746544	5.99078	3.22581	13.3641	11.7512	11.7512	14.5161	20.5069	14.7465
	Rank Order	9	7	8	4	5	5	3	1	2

Table 7 shows the rankings of each engineering characteristic for the retractable rack. Time to install was determined to be the most important engineering characteristic as it correlated with the most of the customer requirements. This is important as it reflects how simple the mechanism is which helps for several other categories. The second most important design characteristic was force or torque required to operate the device. The amount of force needed has to be enough to operate the mechanism, but not disturb the materials in the glove box. The next most important design characteristic was ease of use. Whether the shelf is easy to use determines how often and easily the user can utilize the mechanism. The mechanism simplicity was the fourth most important characteristic and effects the use, installation, and lifetime of the product. Surface area and volume of storage space gained were tied for the fifth/sixth most important characteristic. Both of these standards measure how much extra space is gained but do not take into account the mobility requirements which make up a good portion of the focus. The next most important characteristic was material rigidity. Materials that are able to bend easily would cause stability and performance consistency issues. Corrosion resistance is the eighth most important characteristic as it can greatly affect the life of the product. The final design characteristic was weight held, as the storage unit must be able to support a varying amount of weight throughout different experiments and uses.

From the house of quality, a Pugh chart was created. The Pugh chart was created to assist in the concept selection by comparing the medium and high-fidelity design ideas. The eight concepts that were discussed in concept generation are shown in Table 8. Each concept was compared to a datum that has storage shelves similar to glove boxes that already exist. The storage solution in the datum are shelves that are mounted to the back of the glove box. In the Pugh chart, each concept is either given a positive, negative or satisfactory for their engineering characteristics compared to the datum.

Table 8

Pugh Chart with Existing Storage Solution as Datum

		Concepts							
Engineering Characteristics	Storage Solution in PureLab HE2GB	1	2	3	4	5	6	7	8
Weight Held	DATUM	+	S	-	+	-	+	-	S
Material Rigidity		S	S	S	S	S	S	S	S
Corrosion Resistant		S	S	S	S	S	S	S	S
Mechanism Simplicity		-	-	-	-	-	+	-	-
Storage Volume Increase		+	+	-	-	+	-	+	-
Surface Area Increase		+	+	-	+	+	-	-	+
Ease of Use		-	-	-	S	-	S	-	-
Time to Install		-	-	-	-	-	S	-	-
Force or Torque Required to Use		-	-	-	-	-	+	-	-
Positive		3	2	0	2	2	3	1	1
Negative		4	4	7	4	5	2	6	5
Satisfactory		2	3	2	3	2	4	2	3

As seen above in Table 8, Concept 1, 2,4, 5, and 6 had the most positive aspects compared to the datum. Since Concept 1, had the most positive aspects, it was selected as the new datum and concept 2, 4, 5, and 6 were selected to be compared to the new datum. Shown below in Table 9, a new Pugh chart was created comparing concepts 2, 4, 5, and 6 to concept 1. The same process from the previous Pugh chart was done in selecting the best designs compared to the datum.

Table 9

Pugh Chart with Concept 1 as the Datum

		Concepts			
Engineering Characteristics	Concept 1: Lazy Susan	2	4	5	6
Weight Held	DATUM	-	-	-	+
Material Rigidity		S	S	S	S
Corrosion Resistant		S	S	S	S
Mechanism Simplicity		-	+	-	+
Storage Volume Increase		+	-	+	-
Surface Area Increase		-	-	-	-
Ease of Use		-	S	-	+
Time to Install		S	+	S	+
Force or Torque Required to Use		S	-	S	S
Positive		1	2	1	4
Negative		4	4	4	2
Satisfactory		4	3	4	3

After analyzing the results from Table 9 it is evident that concept 4 and concept 6 are the best designs. Although these concepts are ranked the best, they do not satisfy the customer needs on their own. Due to this, concept 4 and concept 6 will be implemented into the final design. Referring back to Table 8, the best design for the retractable storage solution is the Lazy Susan (rotating shelves) design because it had the most positive aspects compared to the storage shelves that are currently in an inert atmosphere glove box.

From the Pugh matrices above, the overall best design is concept 1. Concept 1 provides the most surface area and surface volume for storing materials, as well as holds more weight compared to the existing storage racks. To confirm that concept selection was not based on personal bias an Analytical Hierarchy Process (AHP) was performed on the engineering characteristics to determine which characteristics were to be prioritized during concept selection.

Criteria comparison was done by looking at each design consideration against all the other considerations. Table 10 determines weight by rating whether one aspect is more important than the other. If the property being focused on was more important than its comparison a rating of 1-9 was given. If it was less important than its comparison, a rating of 1/9 to 1 was given. Those with the greatest relevance had a weight that was higher than less important aspects and these weights determine the most important aspects of the project. The properties measured were chosen as the most important specifications for the given circumstances.

Table 10

Criteria Comparison Matrix

Selection Criteria	Time to Install	Force or Torque Required to Use	Ease of Use	Mechanism Simplicity	Storage Volume Increase	Surface Area Increase	Material Rigidity	Corrosion Resistance	Weight Held
Time to Install	1	7	7	3	7	7	3	5	7
Force or Torque Required to Use	0.14	1	3	0.33	5	5	1	1	7
Ease of Use	0.14	0.33	1	0.2	1	1	0.33	0.33	5
Mechanism Simplicity	0.33	3	5	1	5	5	3	1	7
Storage Volume Increase	0.14	0.2	1	0.2	1	1	0.2	0.2	3
Surface Area Increase	0.14	0.2	1	0.2	1	1	0.2	0.2	5
Material Rigidity	0.33	1	3	0.33	5	5	1	1	5
Corrosion Resistance	0.2	1	3	1	5	5	1	1	5
Weight Held	0.14	0.14	0.2	0.14	0.33	0.2	0.2	0.2	1
Sum	2.56	13.87	24.2	6.4	30.33	30.2	9.93	9.93	45

As the results show in Table 10 the characteristics were rigorously compared and used to weigh the importance of the criteria. The most important quality was determined to be the weight that the rack can support when in the box. Clearly the weight limit of the rack must be well above the average weight of experiment materials, otherwise failure could endanger the experiment. The second most important condition was storage volume increase, as a main goal is to increase storage space. Volume is used as a storage box would provide a great increase in space as well as protecting from items falling off edges. Also providing accessible storage that is too small would severely hurt the design. The third most important criteria was surface area gained. This would be applicable for a shelf situation that only has 2 dimensional units as its storage area. Shelves do possess certain design advantages, such as flat storage, that would require properly sized surface areas. Ease of use was determined to be the next most important criteria, as a major goal is to simplify the process for glove-box users and give them a way to effectively and easily store lab materials. This can be determined by the force needed to operate or the reach of the product. Table 11 shows the characteristics when normalized in order to prove the importance of these criteria.

Table 11

Normalized Criteria Comparison Matrix

Selection Criteria	Time to Install	Force or Torque Required to Use	Ease of Use	Mechanism Simplicity	Storage Volume Increase	Surface Area Increase	Material Rigidity	Corrosion Resistance	Weight Held	Criteria Weights
Time to Install	0.39063	0.50468637	0.28926	0.46875	0.23079	0.23179	0.30211	0.50352	0.15556	0.3419
Force or Torque Required to Use	0.05469	0.07209805	0.12397	0.05156	0.16485	0.16556	0.1007	0.1007	0.15556	0.10997
Ease of Use	0.05469	0.02379236	0.04132	0.03125	0.03297	0.03311	0.03323	0.03323	0.11111	0.04386
Mechanism Simplicity	0.12891	0.21629416	0.20661	0.15625	0.16485	0.16556	0.30211	0.1007	0.15556	0.17743
Storage Volume Increase	0.05469	0.01441961	0.04132	0.03125	0.03297	0.03311	0.02014	0.02014	0.06667	0.03497
Surface Area Increase	0.05469	0.01441961	0.04132	0.03125	0.03297	0.03311	0.02014	0.02014	0.11111	0.03991
Material Rigidity	0.12891	0.07209805	0.12397	0.05156	0.16485	0.16556	0.1007	0.1007	0.11111	0.11327
Corrosion Resistance	0.07813	0.07209805	0.12397	0.15625	0.16485	0.16556	0.1007	0.1007	0.11111	0.11926
Weight Held	0.05469	0.01009373	0.00826	0.02188	0.01088	0.00662	0.02014	0.02014	0.02222	0.01944
Sum	1	1	1	1	1	1	1	1	1	1

The consistency check table takes the criteria weights from the previous Normalized Comparison Matrix table, and performs matrix multiplication between the row of each engineering specification and the criteria weights column. When done for each distinctive engineering specification, the Weighted Sum Vector is formed. From there, the weighted vector sum is then divided by the criteria weights and is then put into the column on the left of the table named Cons. This refers to the consistency values that when averaged, come out to the lambda value in table 13.

Table 13 then shows the final steps in the AHP process. Table 13 takes the lambda value from Table 12 and then uses it along with the Random Index (RI) value in several computations to find the consistency index (CI) and consistency ratio (CR) values. The CR value refers to the ratio between the consistency index and the Random index values.

Table 12

Consistency Check

Weighted Sum Vector{Ws} = [C]{W}	Criteria Weights {W}	{Cons} = {Ws}./{W}
3.547259	0.341899	10.375166
1.0909151	0.109966	9.920476
0.41228911	0.043857	9.40076
1.80894867	0.177428	10.195396
0.32889146	0.034968	9.405498
0.36776346	0.039906	9.215743
1.11700391	0.113275	9.860992
1.1914338	0.119264	9.989886
0.18233686	0.019436	9.381398

Table 13

Consistency Index and Consistency Ratio Summary

Random Index Value	1.45
λ	9.74948
Number of Engineering Criteria	9
Consistency Index	0.093684954
Consistency Ratio	0.064610313

There are several takeaways from the AHP process. First, the Consistency Check did show that the values were accurate as the Consistency Ratio Value (CR) was below the threshold of 0.10. The number the calculations presented was 0.06461. Also, the AHP was able to show that the highest weighted specifications in the design were weight held, storage volume increase, and surface area increase. This is a logical conclusion as a storage solution should increase storage capacity by increasing volume and surface area. With this, the AHP process determined that the Pugh Matrix was able to accurately display what concepts were the most important to the project and was able to put weights of which engineering specifications had the highest appeal to the design and the customers alike.

Appendix A

Code of Conduct

Mission Statement

Team 502 is dedicated to creating a fully functional storage solution using high levels of professionalism, integrity, respect, and trust. Team 502's goal is to create a product that impacts the customer and their work in the most positive and productive way possible.

Roles

Each team member has been delegated a specific task at the beginning of the project and will strive to perform the selected requirements for their role.

Team Members:

Lead Mechanical Engineer: Jacqueline Matthews

Responsible for organizing meetings with the advisor and sponsor, creating a constant and efficient line of communication over the duration of the year. Leads both the team and the project as a whole by implementing the timeline for the project targets. Delegates tasks for the team and responsible for finalizing all documents and presentations. The project lead is responsible for promoting a positive and productive work environment among the team.

Manufacturing Engineer/Financial Advisor: Micheal Rodino

Responsible for both the manufacturing and financial aspects of the project. These include but are not limited to: manufacturing prototypes of designs created by the design engineer. Creating or obtaining the tools required for manufacturing and installation of storage solution. Fixing or revising previously made designs. Managing budget of project materials and resources in a transparent manner. Records all payment history and spending on the project. Any information required by the other team members for budget will be dealt with in a punctual and professional manner. All budget requests to the sponsor and stakeholders will also be dealt with by the financial advisor.

Design Engineer/Research Coordinator: Evan Ryan

Responsible for creating design drawings and researching design methods and specifications. This includes dispersing relative documents and information to group members and maintaining organization with all project materials. Also includes the responsibility of taking photos and videos of relevant benchmarks in the design process. Creates physical designs from theoretical options and implements accurate evaluation of viability.

Communication

The main form of communication between group members will be through text messaging on their personal cellphones. Email will be a secondary alternative for group members if text messaging is either not available or not possible. Email will also be used to exchange files between group members. If files are too large to send through email, a physical option will be used such as a thumb drive or an SD card.

Communication for advisor and sponsor meetings will take place through email. Date and location will be established and agreed upon by both parties. Advisor and sponsor meetings will be set to repeat every three weeks unless notified otherwise.

The determination of how long a reply should take is within 24 hours for inter group dialogue. For advisor or sponsor communication the allotted time is three business days. For any sort of absences of group members, they will be required to notify their fellow group members about the nature of their absence and an estimate for the duration of their absence. If possible, group members should inform each other of absences at the earliest convenience.

Team Dynamics

Student cooperation is vital to the group mentality. All group members will maintain open communication about project ideas, assignments, and progress. The group members will work in a team while allowing freedom of constructive feedback on work done. If a task is too difficult for a group member, they are expected to find help from either other members of their group or from outside sources such as their sponsor.

Ethics

Team members are required to be familiar with the NSPE Engineering Code of Ethics as they are responsible for their obligations to the public, the customer, the team, and the profession as a whole. This Code is to be strictly adhered to in any and all actions any member of the team performs, with the understanding that there will be zero tolerance for any indiscretion.

Dress Code

Team meetings will be held in casual attire. Sponsor and advisor meetings will be in business casual attire. For all presentations and design days, the dress code is business professional.

Decision Making

To create a fair and streamlined decision making policy, all group members will be heard but the decision will be based off of consensus. All members will be involved in the decision-making process whether or not their role is directly assigned to the task.

Conflict Resolution

In the event of a disagreement between members of team 502, the following actions will be implemented:

- A group meeting will be scheduled by the lead mechanical engineer to administer a group vote, favoring the majority.
- If a member of the group is still dissatisfied, an instructor will facilitate a resolution.

Statement of Understanding

By signing this document, the members of Team 502 will hereby be required to obey and follow the code of conduct as written above.

Name	Signature	Date
Jacqueline Matthews	[signature]	9/17/19
Micheal Rodino	[signature]	9/17/19
Evan Ryan	[signature]	9/17/19

Appendix B

Concept Generation: 100 Concepts

Brainstorming

1)Stainless Steel Box that sits on floor of glovebox

2)Stainless Steel Box that slides towards the user on tracks

3) Pyramid with fold out sides to open UP storage area

4)Pyramid with fold out sides to open up storage area connected to roof

5)Four bar extension that pulls storage box out from wall

6)Movable Shelf that uses founder linkage

7)Movable Shelf that uses slider tracks

8)Movable Shelf that uses a motor and motion activation

9) Fold out shelf that hides inside wall

10)Fold out from bottom shelf with locking hinges

11)Locker shelf (high school locker)

12)Pegboard Shelf/ Storage Boxes

13)Roll out Shelf with self-locking hinges

14)Pulley System Storage Solution using a pulley to rai, cloner solution

15)User inside glovebox actively holding supplies

16)Tailgate Track Rack. using steel candle {dampener

17)Accordion style Storage Solution

18)More dividers in current space to help organize

19)More glove channels to have another user hold items while in use

20) hinge shelf

21) Pyramid Balance Weight shelves

22)Snap Ruler/ Chameleon Tongue Roll-up Storage Solution

23)Bookshelf on back wall

24)Mounted Cuddy on wall

25) Lazy Susan shelf

26)Spiral Lazy Susan that folds into itself and expands out

27)L-rachet mounted shelves

28)Drawer Cabinet mounted to back wall or sides

29) Ceiling D raver that folds down (Attic Ladder)

30)Slide Out Gun Rack (spy Movies)

31)Spinning Spice Rack Mounted to Roof it's

32)Wheeled Cart that rolls towards user (with drakes)

33)Modular Storage System that builds towards user

34)Flying Drone Storage Solution inside Glovebox

35)Wine /Beer Glass Holder Rack hanging from top

36)Magnetic Wall to stick tools to

37)Suction Cup movable storage solution (Dent Puller)

38)Fabric Pull Down Shelf (Dorm Shoe Holder)

39)Dorm Shoe Holder on wall of glovebox

40)File Cabinet Extendable Slider Rack

41) Ball Joint Shelf (Drum set Tom Holder)

42)Elevator Style Shelf (Hydraulic Piston)

43)Plantation Shutter style rack

44)Plastic lightsaber extender rods that move shelf

45)Rack that pops down from roof when a button is pressed (Hide-able TV's)

46)Toolbox rack that pushes out from wall when FOP is opened

47)Robot that grabs stuff user cannot reach

48)Hydraulic Lift can raise/lower storage solution

49)Rotating Shelf system that rotates in a vertical pattern

Crap Shoot for current designs --> Lazy Susan/Accordion/Pyramid/Four bar/Ball Joint/Fold out Shelf

50)Lazy Susan combined with Accordion

51)Lazy Susan combined with Pyramid

52)Lazy Susan combined with Four- bar

53)Lazy Susan combined with Ball Joint

54)Lazy Susan combined with Fold Out Shelf

55)Accordion combined with Pyramid

56)Accordion combined with four- bar

57)Accordion combined with ball joint

58)Accordion combined with fold out shelf

59)Pyramid combined with four -bar

60)Pyramid combined with ball joint

61)Pyramid combined fold out shelf

62)Four bar combined ball joint

63)four bar combined with fold out shelf

64)Ball joint combined with Fold out Shelf

Anti-problem

65)Box that does not open to access tools

66)Storage Rack that is placed Vertically

67)Storage Rack put on the bottom of the glovebox

68)Storage Solution mounted on the outside of the glovebox

69)Storage Box that requires a fingerprint reading to open

70)Storage Solution that requires 3 hands to open the box

71)Storage Solution that cannot retract after it is extended

72)Storage Solution that cannot extend after it is retracted

Morphological Chart

73)Free standing spinning storage solution mounted to the wall

74)Hanging storage solution that pulls down from the ceiling

75)Screwed into the back of the glovebox storage solution the swings forward

76)Tracked storage solution that is stationary and is mounted to the floor

77)Free standing storage solution that pulls out from the back wall

78)Hanging storage solution that swings out from the floor

79)Screwed into the wall storage solution that pulls out

80)Tracked storage solution that swings down from the ceiling

81)Free standing storage solution that swings out from the floor

82)Hanging storage solution that is stationary on the wall

83)Screwed into the floor storage solution that spins

84)Tracked storage solution that pulls out from the wall

85)Free standing storage solution that spins located on the ceiling

86)Hanging storage solution that pulls out from the back

87)Screwed into the floor storage solution that swings out

88)Tracked storage solution that is stationary on the wall

89)Tracked storage solution that is stationary on the back

90)Screwed into the ceiling storage solution that swings out

91)Hanging storage solution that pulls out from the wall

92)Free standing storage solution that spins on the floor

93)Free standing storage solution that pulls out from the wall

94)Hanging storage solution that swings down from the ceiling

95)Screwed into the back-storage solution that is stationary

96)Tracked storage solution that spins on the floor

97)Screwed into the back- storage solution that pulls out

98)Hanging storage solution that spins on the ceiling

99)Free standing storage solution that is stationary on the wall

100)Tracked storage solution that swings out from the floor