

Criterion A | The Design Opportunity

Description of the Problem

Acquiring accurate measurements is an important factor towards completing projects. These include, but are not limited to, scientific experiments, architectural, and construction projects. Overall, there are numerous situations where numerous measurement tools are required. This causes inconvenience to an individual as it provides unnecessary multi-tasking.

While it's important to utilize several types of measurements within a project, using too many individual tools can become time consuming and overwhelming to handle. Acquiring one multi-purpose tool for implementing effective measurements will help facilitate the tracking and using of many different measurements.

Photos Relating to the Problem

With various types of measuring tools, multi-tasking is required to remember and use each measuring tool in effective manners. Multi-tasking is more difficult to utilize within human beings than single tasking. Given “just 2.5% of people are able to multitask effectively” this means 97.5% require single tasking to effectively complete their tasks.

Given these statistics, people want easy-to-follow products that will simplify tasks. In fields that require measuring the same concept follows, where simplistic methods of measuring will lead to quicker, easier, and more convenient ways of obtaining physical data with the right tools.



Levels will be included as one measuring tool



Measuring tape will be incorporated as it is widely used



Multiple types of units will make converting measurements easier

Design Brief

The practicality of a single use tool provides efficiency and the ability to place a singularity into a multi-tasking situation. The product will be expected to incorporate numerous measuring tools into a single tool to help solve this problem. Certain materials that will be integrated into this measuring tool would be tools such as a ruler, a carpenter's level, a meter stick, etc. without the need of handling each of them separately.

In terms of user groups, the user range will be vast since the tool will incorporate tools many people find practical in portions of their lives. For specific groups, individuals such as architects and construction workers will find this tool the most inclusive in their lives as it's directly integrated in their line of work.

From research, it's clear single use practicality is more efficient than multi-tasking. Including such a tool for use will help minimize disorganization.

The product must:

- Be easily accessible for a wide age range
- Be small and portable
- Incorporate an easy-to-follow design
- Have durable material for practical use
- Not have too many uses, causing disorganization
- Withstand long-term use
- Be lightweight

The product will help provide singular and practical use for individuals utilizing numerous measurements.

Design Specifications

Specifications		Justification
Target Audience	1.1 Should appeal towards builders, designers, and construction workers.	1.1 Since measurements are largely incorporated into building and construction, the target audience strives towards builders and designers.
Target Market	2.1 The product should largely appeal towards construction workers aging from 20-40.	2.1 The construction industry is the most involved in measurements. Therefore, the product should appeal to construction workers and their age ranges (20-40 years old according to construction worker demographics; average is 38 years old).
Function	3.1 Adequately provide effective and reliable measurements 3.2 Must be easy to use, and cannot obstruct workflow.	3.1 The product's purpose is to ensure measurements are genuine, meaning these measurements must correlate to industry standard measurements. 3.2 If the product obscures typical workflow, indicated by the ability to complete a work task, then the product's goal will fail. When using the product, one should be able to increase their workflow, or at least maintain their workflow.
Size	4.1 The inside of the product shouldn't exceed 1' x 1.5" x 3".	4.1 The product's inside shouldn't exceed the size of the largest length, width, or height of a single tool. The length shouldn't exceed 1' since the ruler is the largest tool for that dimension. The width shouldn't exceed 1.5", determined by the width of a Stanley PowerLock's 16' measuring tape compartment. The

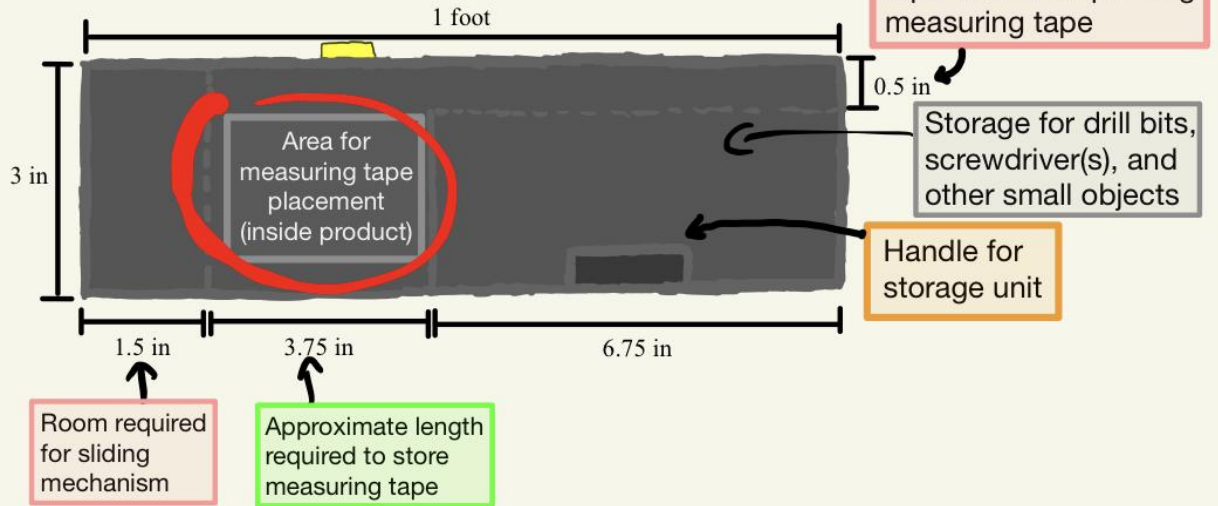
		height shouldn't exceed 3", determined by the height of a Stanley PowerLock's 16' measuring tape compartment. The thickness of the product's material will vary.
Material Selection	<p>5.1 The product must be resistant against rust</p> <p>5.2 The product must not exceed 11 lbs.</p> <p>5.3 The product must be durable</p>	<p>5.1 Rust ruins material strength, and could also make certain aspects of the measuring tool harder to see or interact with. A rust resistant material would be more applicable.</p> <p>5.2 The maximum weight for a 1-handed lift is about 11 lbs. The average adult weight is about 136.7 lbs, meaning the product should be about 8% of a person's body weight. Although the product should be as light as possible, this percentage should not be exceeded.</p> <p>4.3 Since the product will largely be involved in a construction environment, it's crucial the product is able to withstand damage.</p>
Aesthetics	6.1 Product's tools are easily visible	6.1 Each tool from the product is incorporated so they're able to be used and are known to be used as intended. In regards to being "easily visible," this visibility will be determined based on how easily individuals determine the incorporation of each tool from the product.
Cost	7.1 Price should not be significantly greater than market price of all measuring tools incorporated within the product.	7.1 For customers to buy the product, incorporating an expensive product when it's significantly cheaper to buy the separate components isn't beneficial to the consumer practically and financially.
Quantity	8.1 One product per person (1:1 ratio)	8.1 There is little necessity for an individual to have more than one product since the goal is to condense measuring tools into one product. Therefore, a 1:1 product to person ratio is necessary.

Criterion B | Conceptual Design

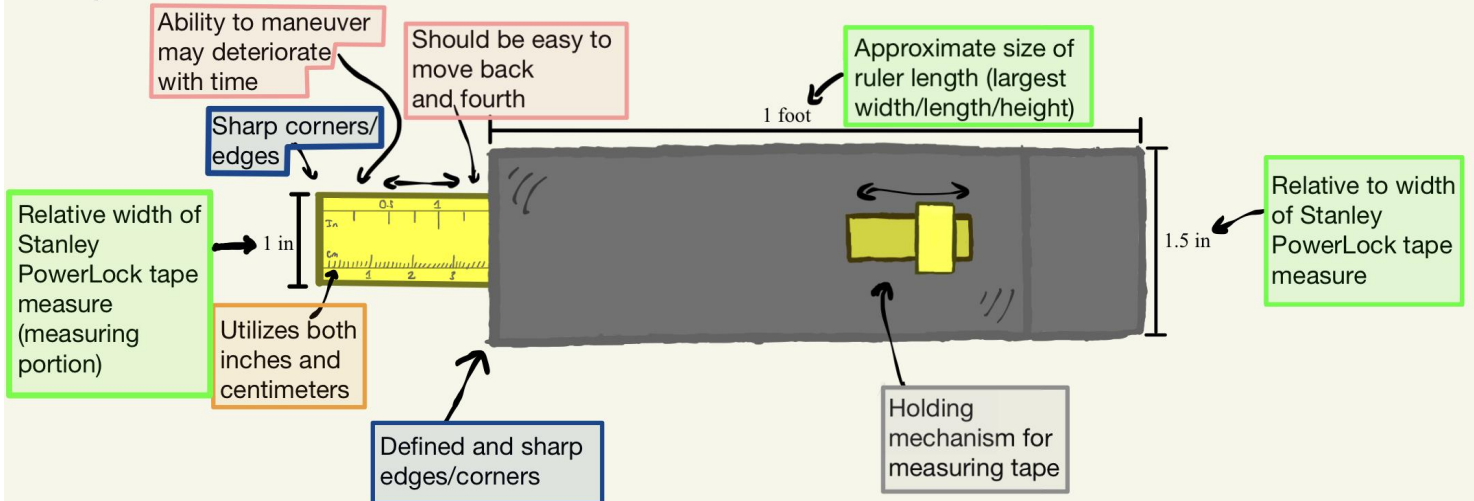
1.) Outside Conceptual Design

Specifications Side view

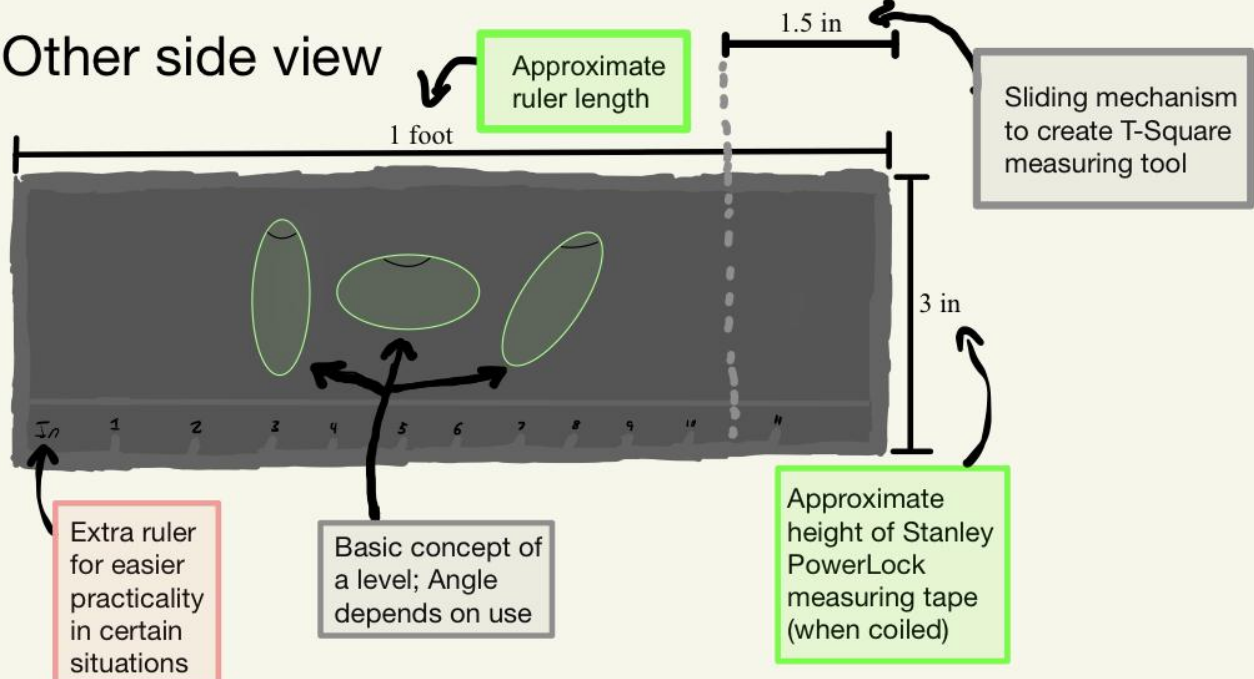
-  = 2.1
-  = 3.1
-  = 3.2
-  = 4.1
-  = 5.3
-  = 6.1
-  = Extra



Top view



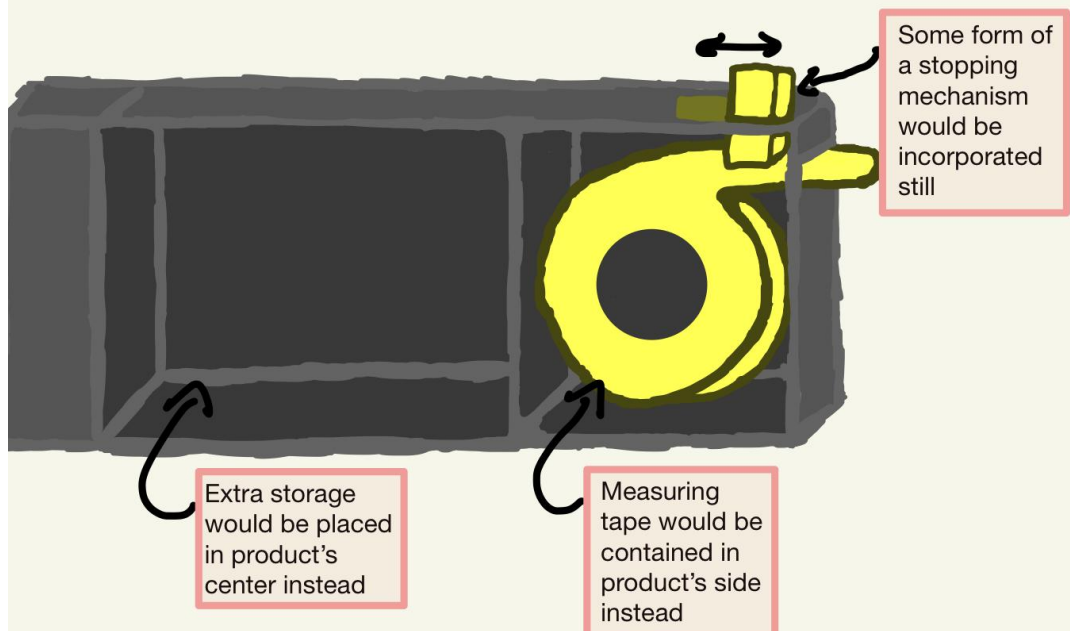
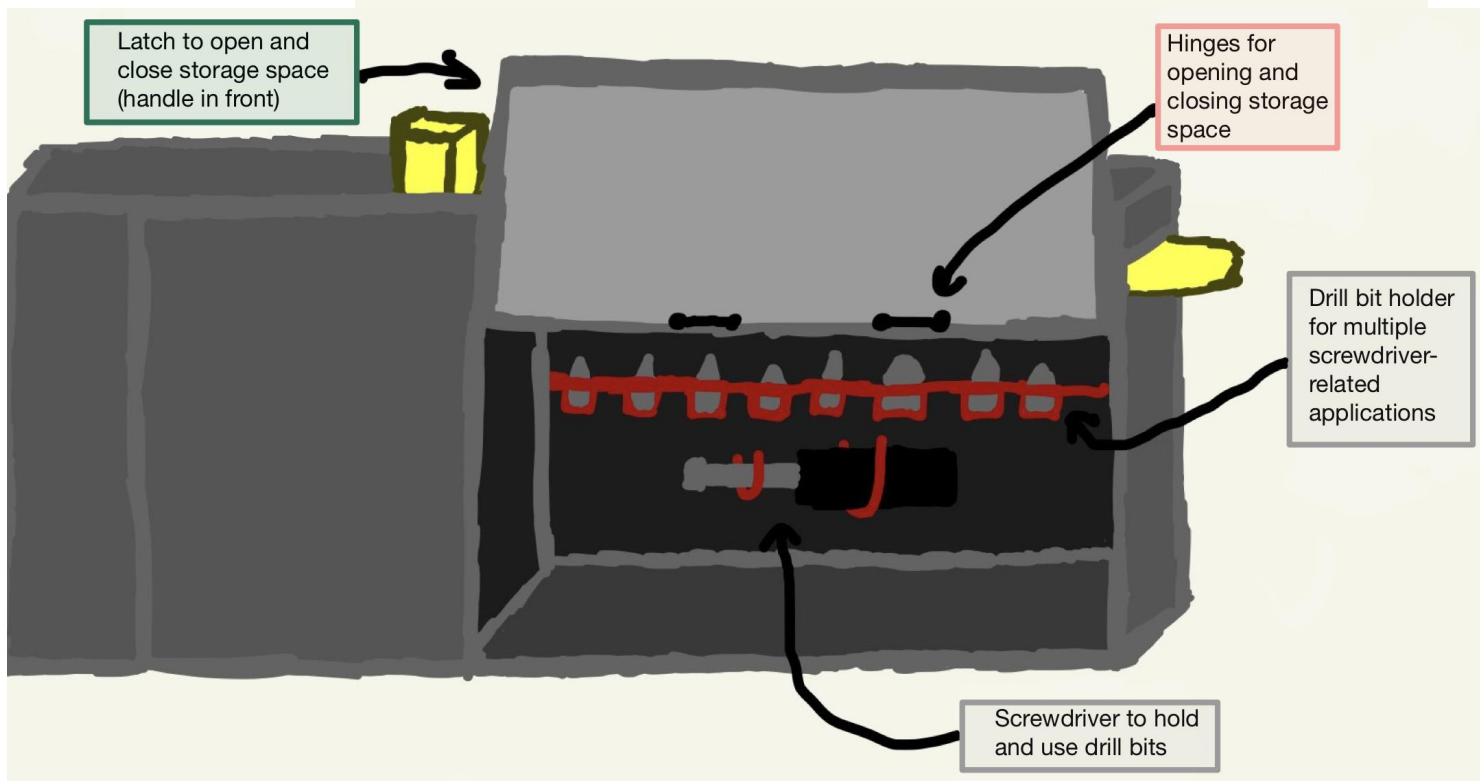
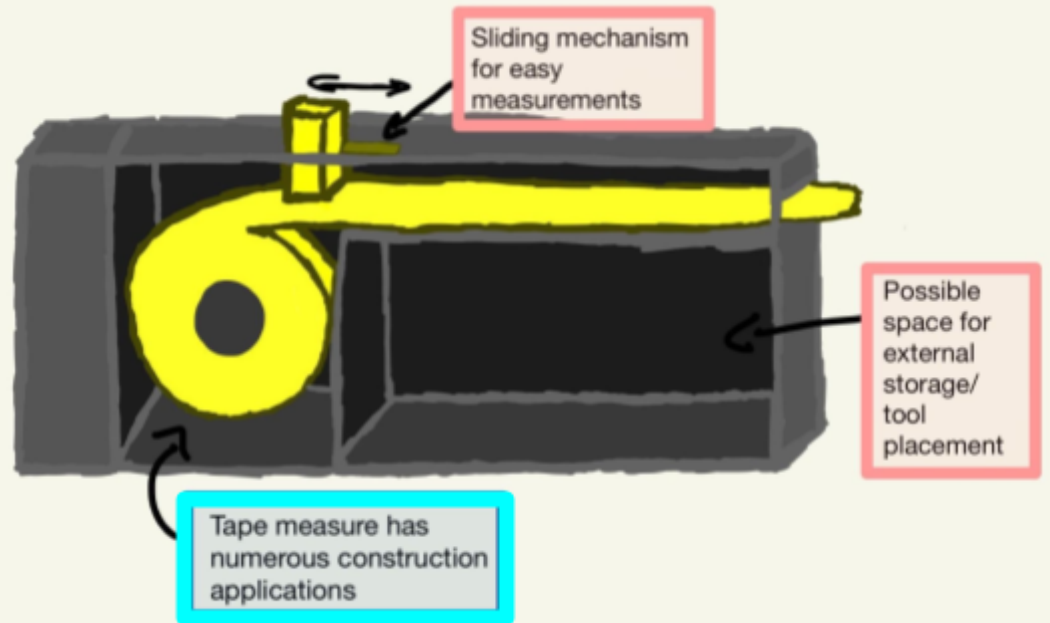
Other side view



2.) Inside Conceptual Design

Specifications

-  = 2.1
-  = 3.1
-  = 3.2
-  = 4.1
-  = 5.3
-  = 6.1
-  = Extra



3.) Slider Conceptual Designs

Specifications

 = 2.1


 = 3.1

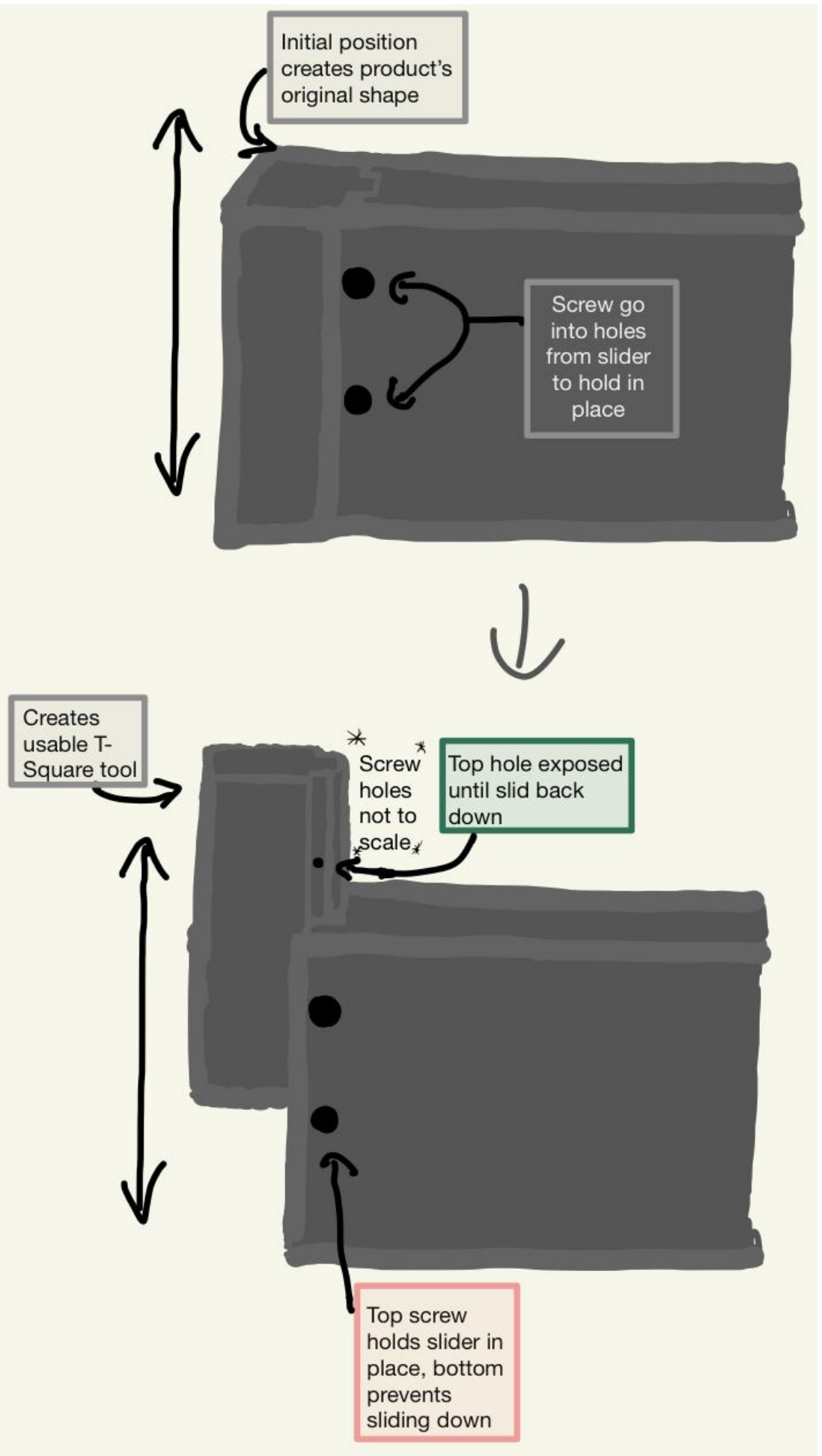
 = 3.2

 = 4.1

 = 5.3

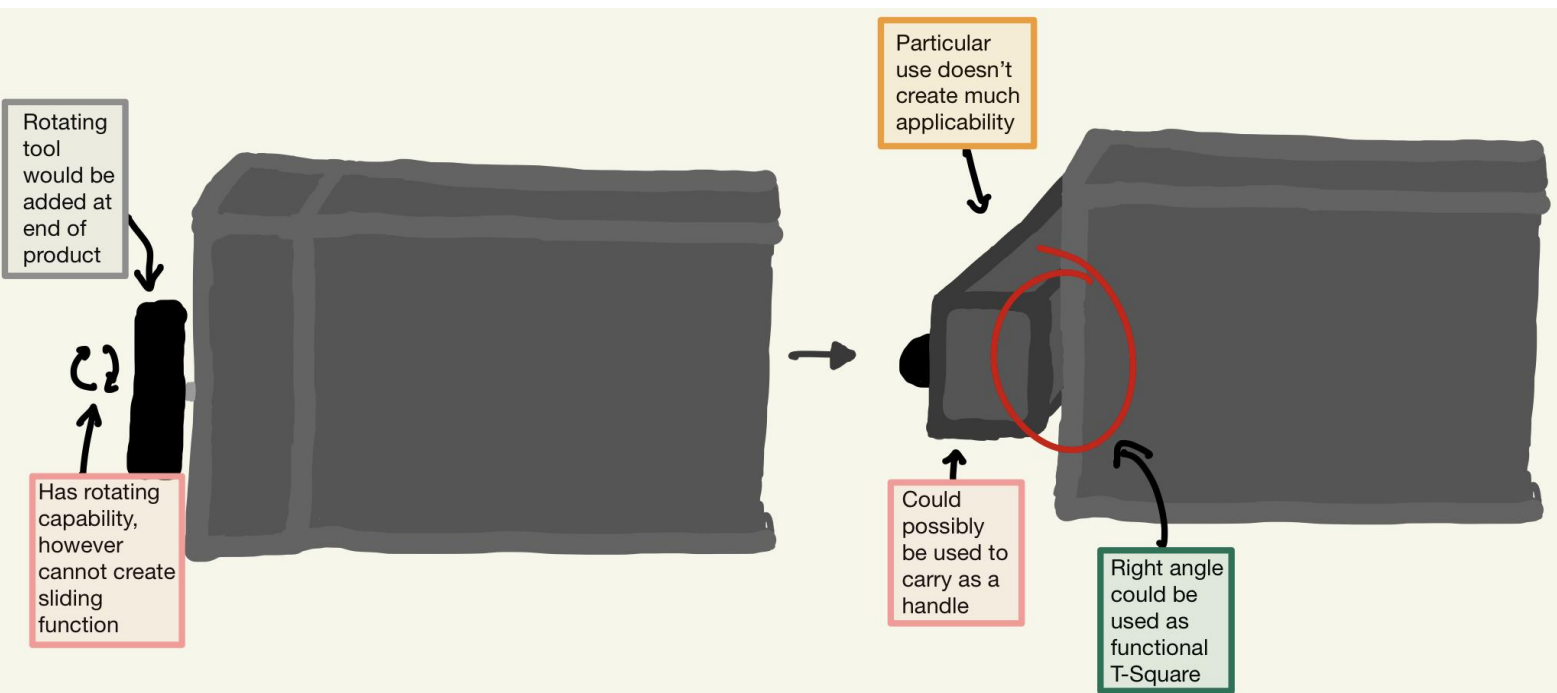
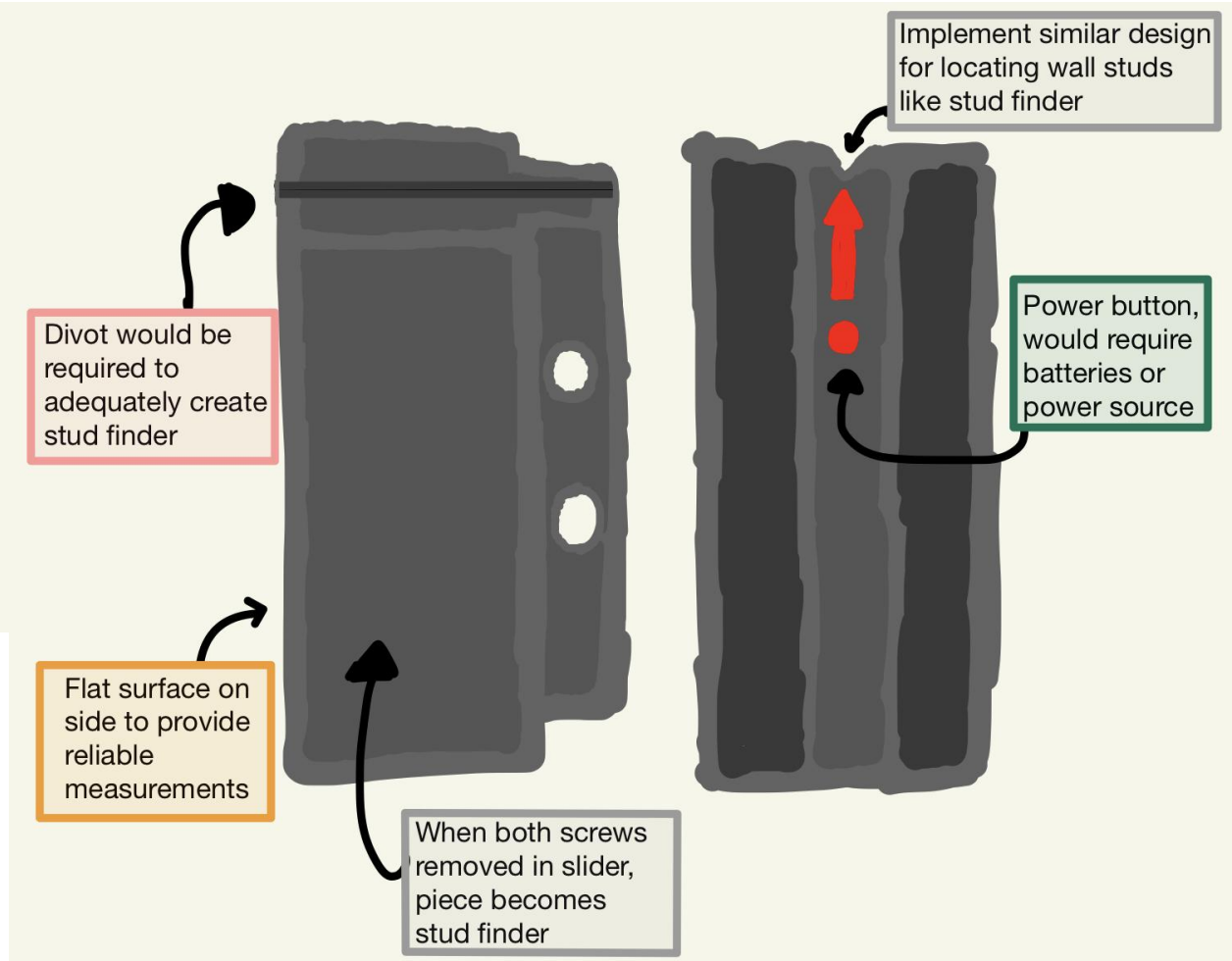
 = 6.1

 = Extra




Specifications

-  = 2.1
-  = 3.1
-  = 3.2
-  = 4.1
-  = 5.3
-  = 6.1
-  = Extra



4.) Extra Conceptual Designs

Specifications

 = 2.1


 = 3.1

 = 3.2

 = 4.1

 = 5.3

 = 6.1

 = Extra

Bumpers will be permanently placed to make T-Square use easier

Bumpers would be permanently on both sides of product

Bumpers create an easier to use right angle for product

Possibility to include all-purpose screwdriver for extended tool use

Drill bits from storage could be implemented

Pushing mechanism to spring screwdriver in and out

Large base could prevent usability of screwdriver tool

Extra protractor tool for more applicability

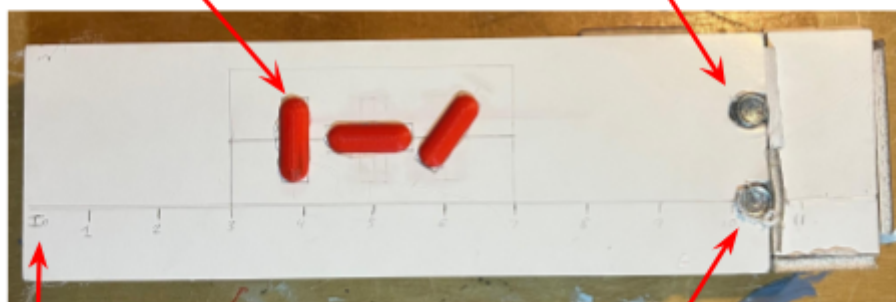
Can open and close when necessary

Must be added on edge to make measuring easier

Development of Conceptual Designs:

Level sticks out, creating non-flat side, promotes difficulty in measuring

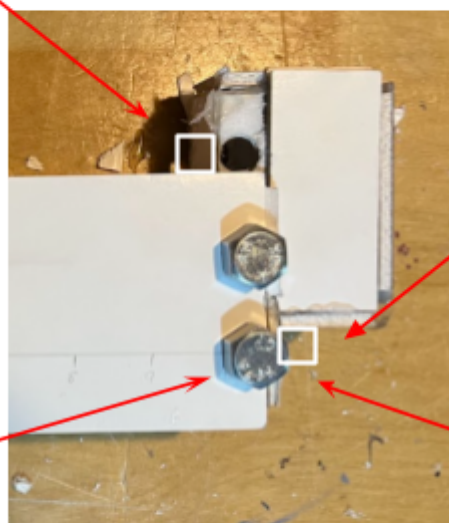
3" Test screws with 3/8" diameter fits perfectly



Ruler only in imperial units and 10.75 inches without slider

Screws don't create non-flat side, aids in effective measuring

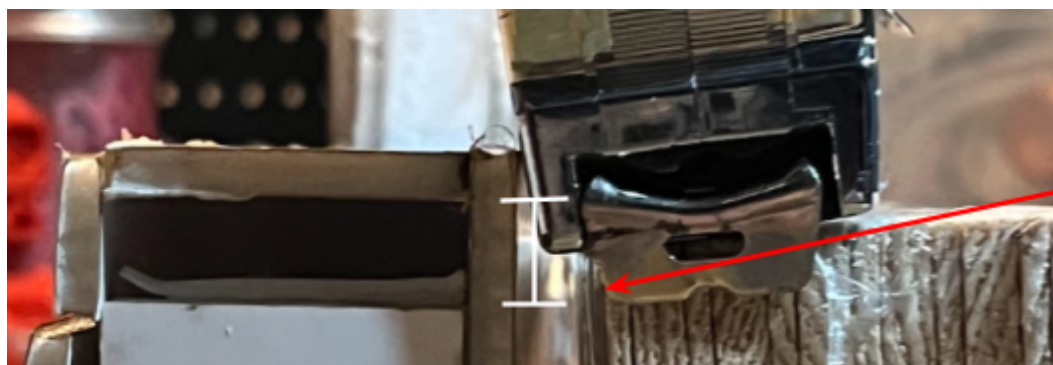
Effective right angle created to indicate T-Square



Previously unknown possibility to create another T-Square location

Screws noticeably block ruler, removing ability to effectively measuring

Bottom screws fit perfectly underneath sliding mechanism

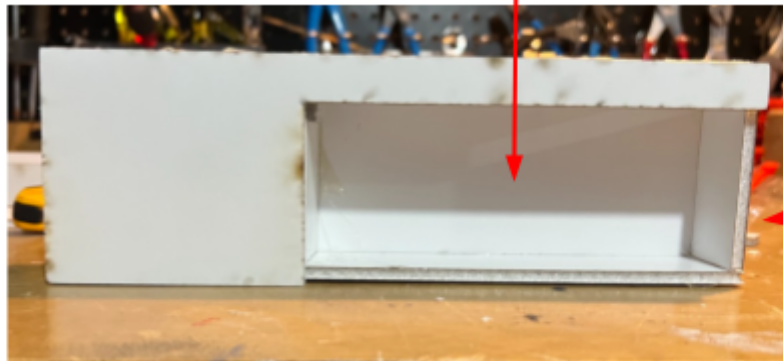


Distance relatively 1/2", indicating possibility that hook may fall inside.

Through personal hand grip circumference, product height satisfies 75th percentile



Relatively sizable space inside of product storage

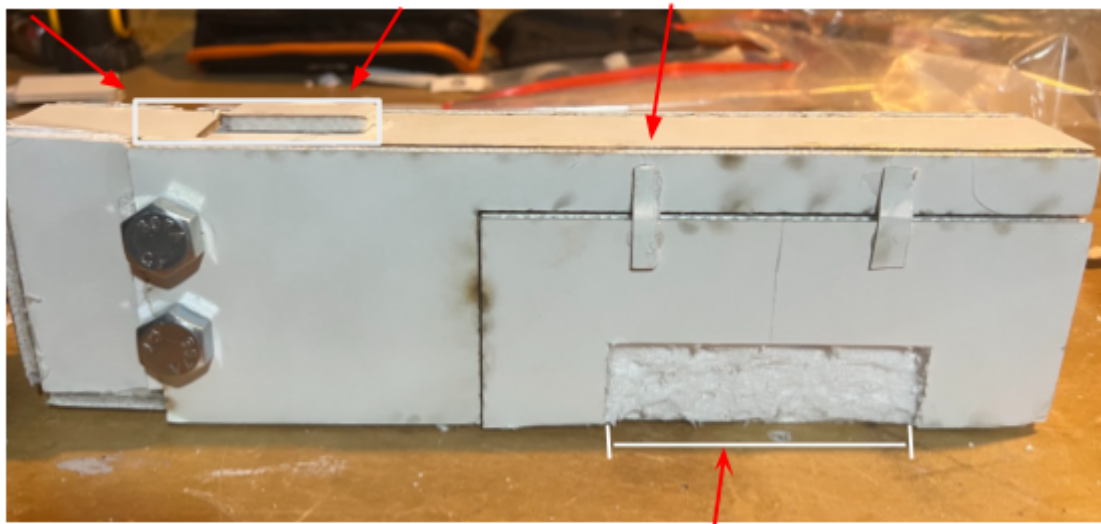


Although dimensions uphold specification, thickness increases product's size

Bumpers would be vital to aid in reliable measurements

Noticeable problem regarding flat surface on top of product

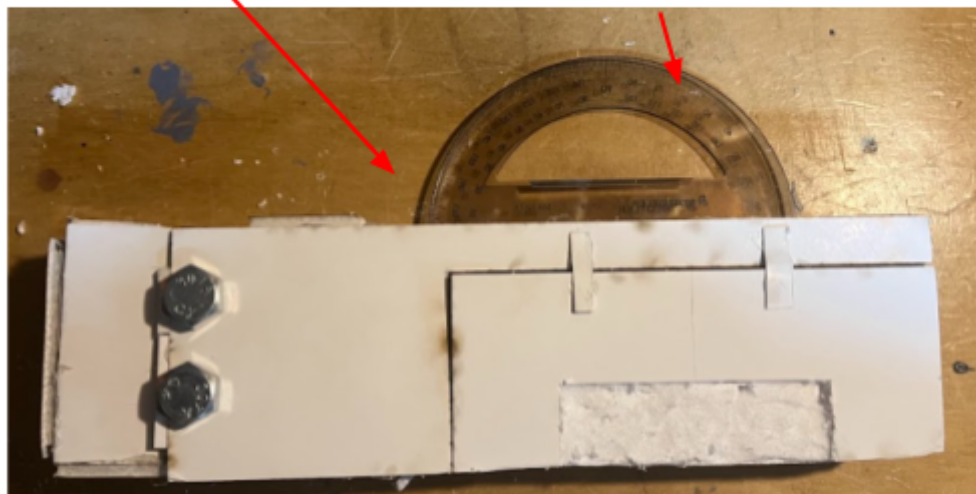
Functionality of hinges work as anticipated



Handle satisfies 90th percentile (3.75 inches)

Indication of where protractor may appear if added

Protractor fails to lie flat due to levels



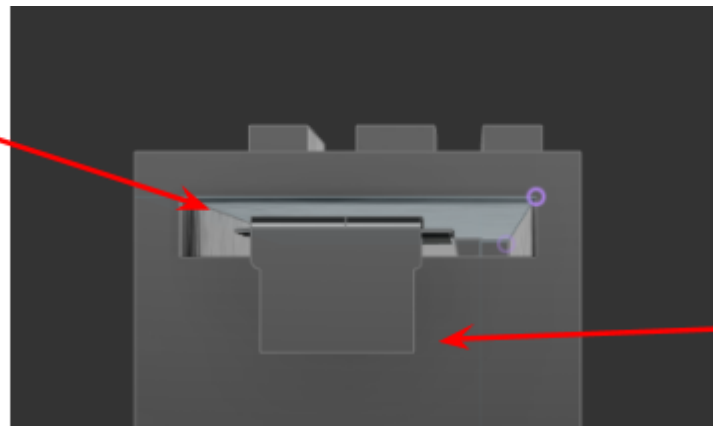
Problem with screw holes interfering with ruler

Sliding mechanism cuts off ruler at 10.75 inches if removed

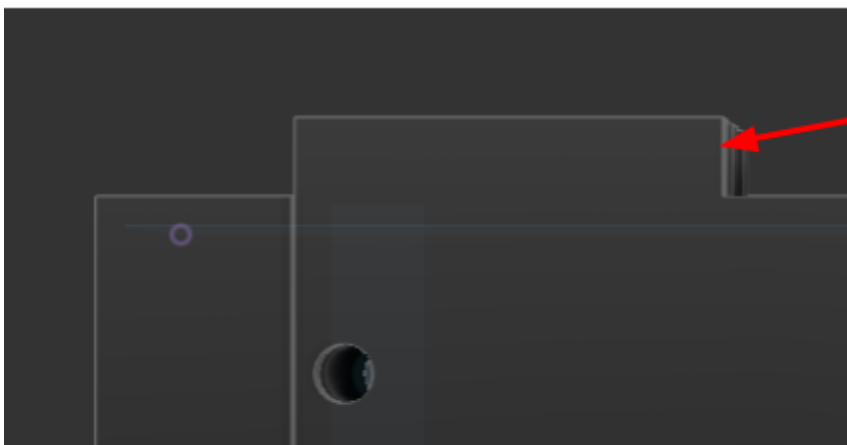


Screw holes would reach through product to create sliding mechanism

Sizable room within measuring tape area

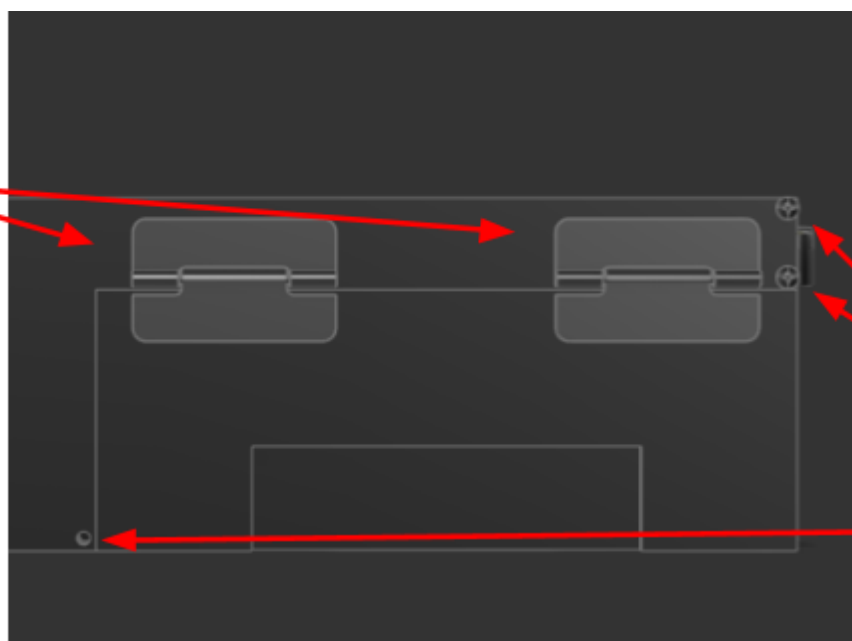


Measuring tape will not fall inside product unless hook breaks



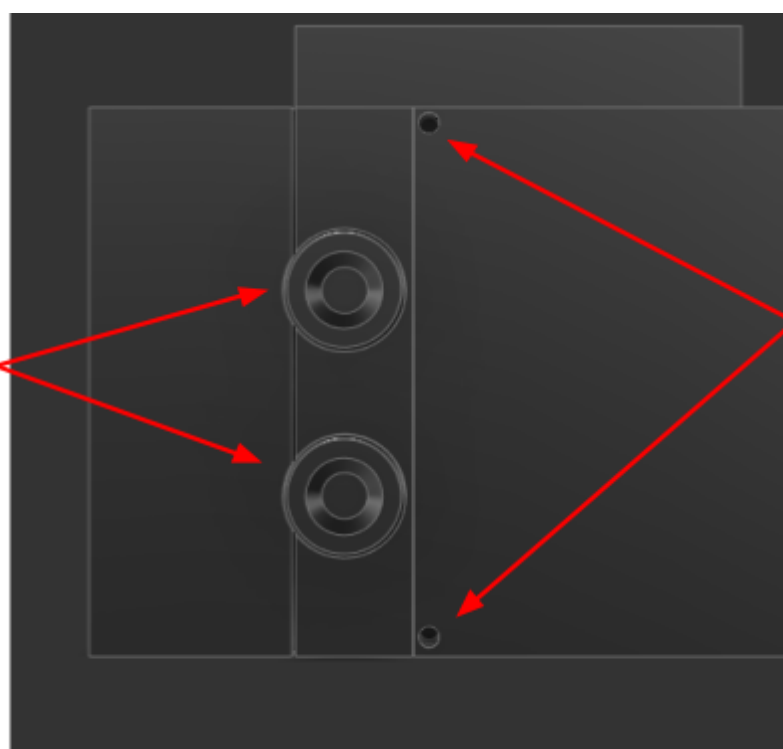
Bumpers extended to cover measuring tape thumb lock; flattens surface.

Hinges allow
for opening and
closing storage



Screws added
to allow access
to measuring
tape, if
necessary

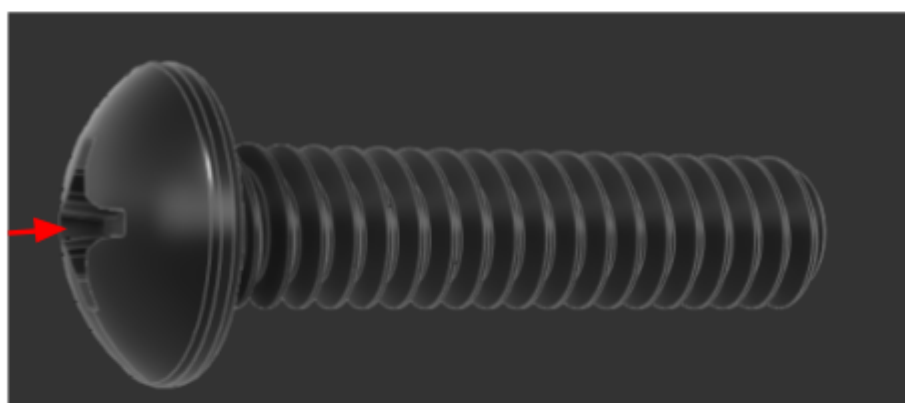
Thumb screws
will be easier
to turn than
other screws



Other screw
holes added for
allowing
measuring tape
access

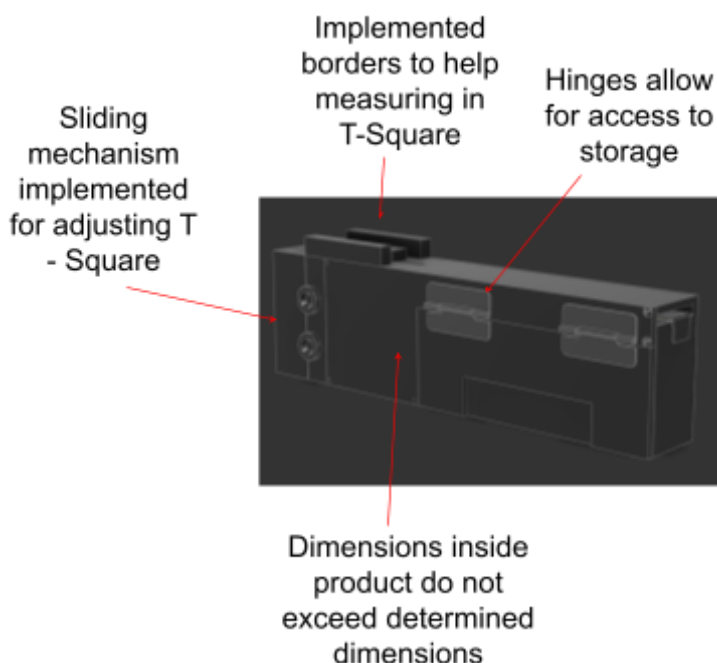
Screw is not to scale

Phillips head
based off of
popular use of
phillips heads



Final Decision and Justification

0/5 = Doesn't meet specifications	3/5 = Meets an acceptable amount of specifications
1/5 = Barely meets any specifications	4/5 = Meets most specifications
2/5 = Meets few specifications	5/5 = Perfectly meets specifications
Specification	Evaluation
1.1 Target Audience	5/5
2.1 Target Market	5/5
3.1 Effectiveness of Measurements	4/5
3.2 Doesn't Obstruct Workflow	5/5
4.1 Size	5/5
6.1 Aesthetics	4/5
8.1 Quantity	5/5
Ex.1 Adjustability	3/5
Ex.2 Number of Measuring tools	3/5



Self Evaluation:

- I decided the concept meets acceptable specifications for the product, including extra specifications like adjustability and the number of measuring tools.

Justification for Specifications:

- The target audience and market are satisfied as the product appeals to construction workers and builders.
- Measurements are reliable and able to work efficiently. However, effectiveness ranked a 4/5 because of difficulty to measure with the measuring tape.
- Workflow isn't obstructed since the product is compact and easy to carry. This correlates to size, where the size does meet specification 4.1.
- Appeal to the product is well maintained, however, the product lacks appeal in certain parts (Example: the top of the measuring tool).
- Quantity is satisfied since only one product is required per person.

Extra Specifications:

- Extra specifications were created during the design process and after creating initial specifications.
- Adjustability is partially accounted for, however there are aspects that could allow adjustability, such as allowing a personal measuring tape.
- Although the number of measuring tools in the product satisfies the product's goal, more measuring tools could be implemented.

Criterion C | Design and Inquiry

Materials

The product's main base will be made out of aluminum 6061. Aluminum has a density of 0.0975 lbs/in³ (5.2), and although this specification is sufficient for the product, other aspects of aluminum provide a greater benefit for incorporating aluminum. For instance, aluminum has a high fracture toughness of 35 MPa.m^{1/2}. This greater durability (5.3) enables the product to withstand sizable damage, such as from accidentally dropping the product. The material's ability to incorporate a smooth surface and sharp corners allow the product to create effective measurements (3.1). Aluminum also exceeds its resistance to rust, since the material doesn't rust (5.1).

Components

Component	Justification	Manufacturing Technique
Measuring Tape	A measuring tape is one measuring tool for the product, meaning this component is necessary. This component must include metric and imperial units.	N/A
Acrylic Levels	Levels are required for the product. Regarding the level's material, polymethyl methacrylate, this material is sufficient due to its acceptable tensile strength (72 MPa) and transparency, which is necessary for use.	N/A
Steel Thumb Screws	Thumb screws are the easiest screws to turn by a human hand, which will be repeatedly screwed in and out, proving its vitality. Steel will be their material since steel is a highly durable material and a required component that holds the sliding mechanism and the rest of the product together.	N/A
Aluminum Hinges	Hinges are required for the storage container door. Aluminum will be used to match the product's main structure.	Welding would be required to join the aluminum hinges with the rest of the product.
Steel Phillips Head Screws	One section of the product's base can be removed to access the measuring tape inside of the product. Therefore, screws will be added to hold this section together and allow removal of this section, if necessary.	N/A

Other Manufacturing Techniques

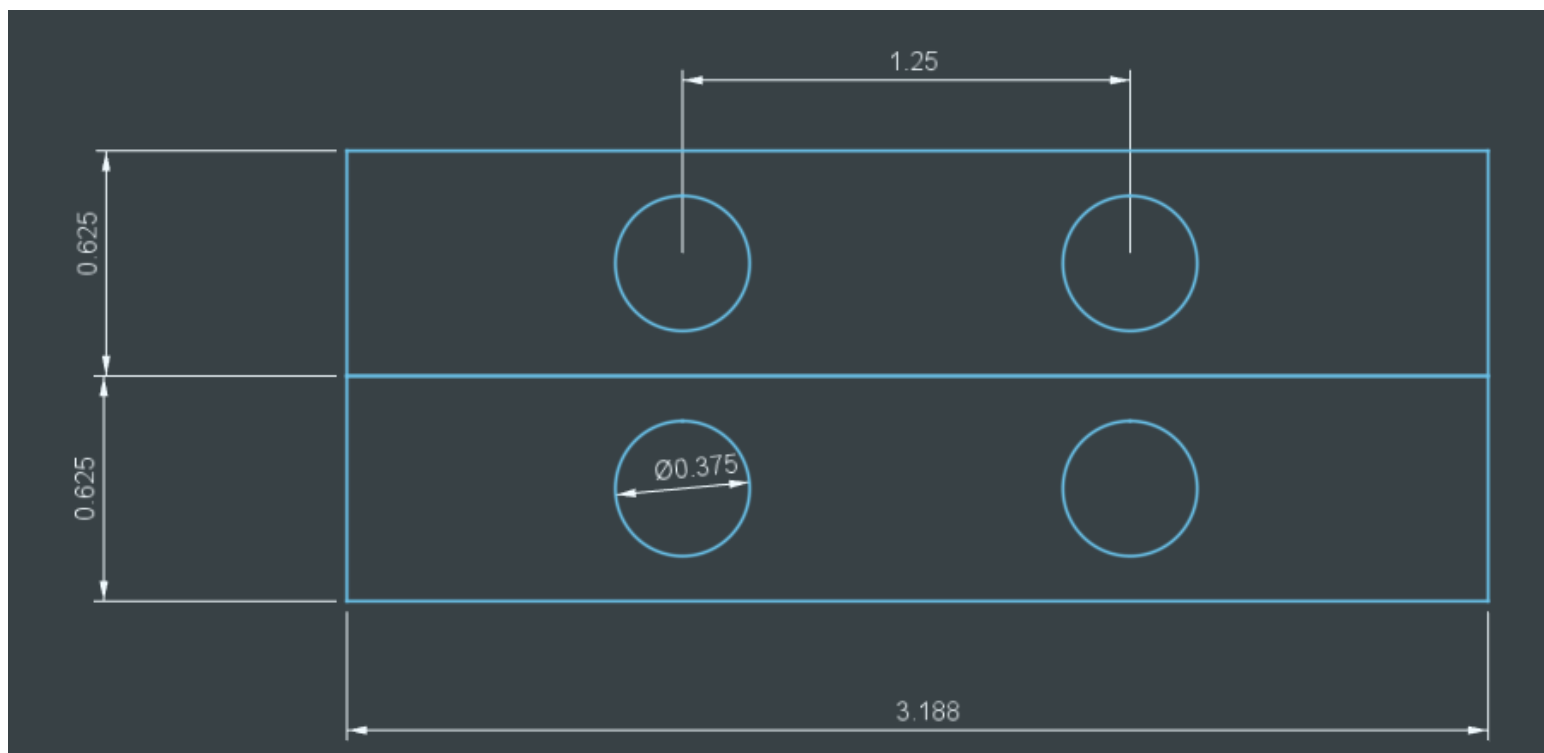
Welding is necessary to fuse aluminum components and base pieces together. Welding allows a durable and strong connection between parts of the product (such as aluminum hinges to the product's base). For excess weld, the aluminum would require grinding for a smooth surface. Since welding isn't available in school, a third party provider would be required.

Aluminum would need to be cut since the product will be a rectangular prism-shape product. To do this, metal shears would aid in cutting aluminum since the material is less than 0.5 mm thick. Certain parts of the product might not need to be cut and could be bent at a 90° angle. This 90° angle would ensure the product will be able to perform effective and reliable measurements.

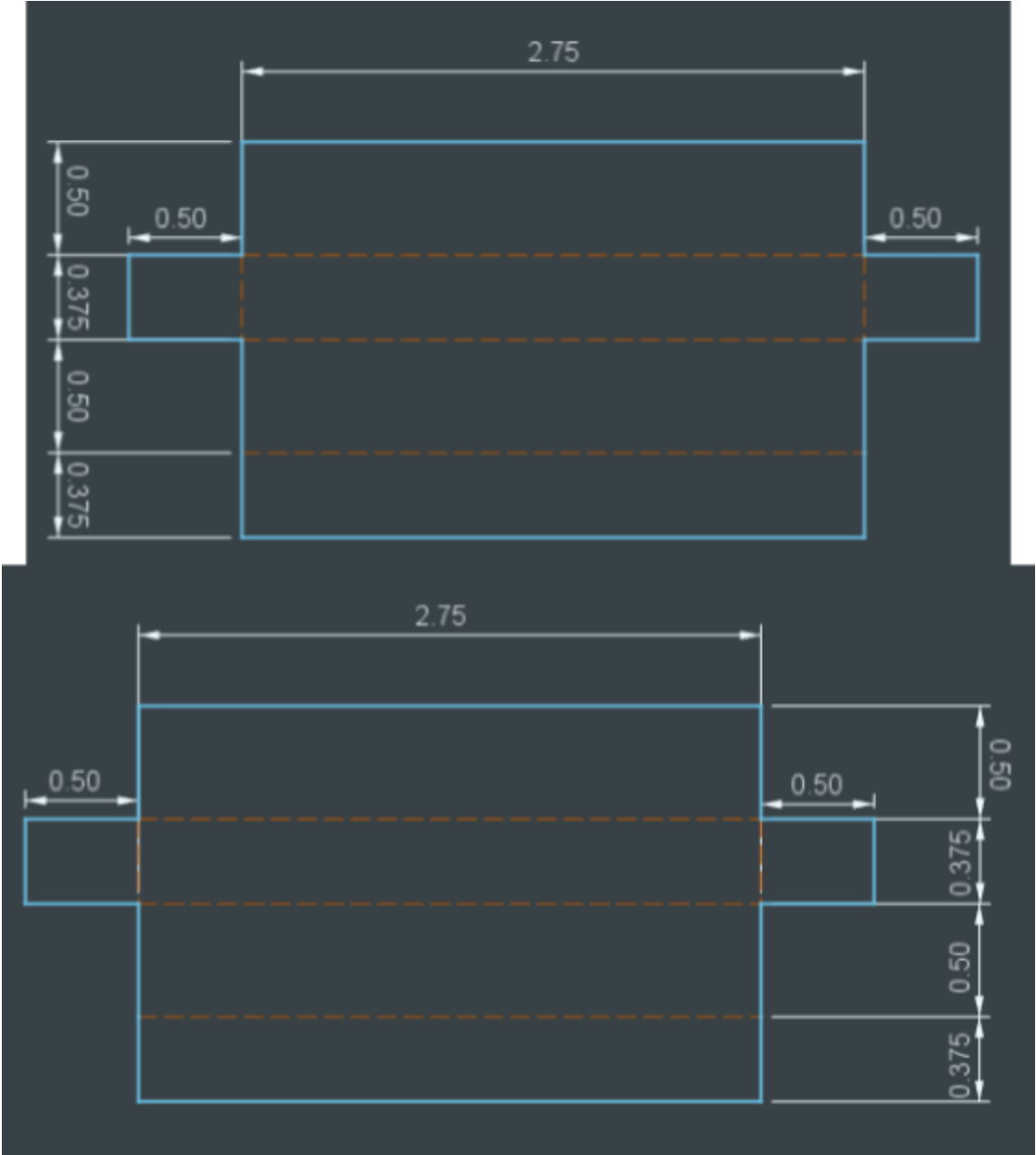
Technical and Assembly Drawings

For all technical drawings, unless stated otherwise, measurements are measured in inches.

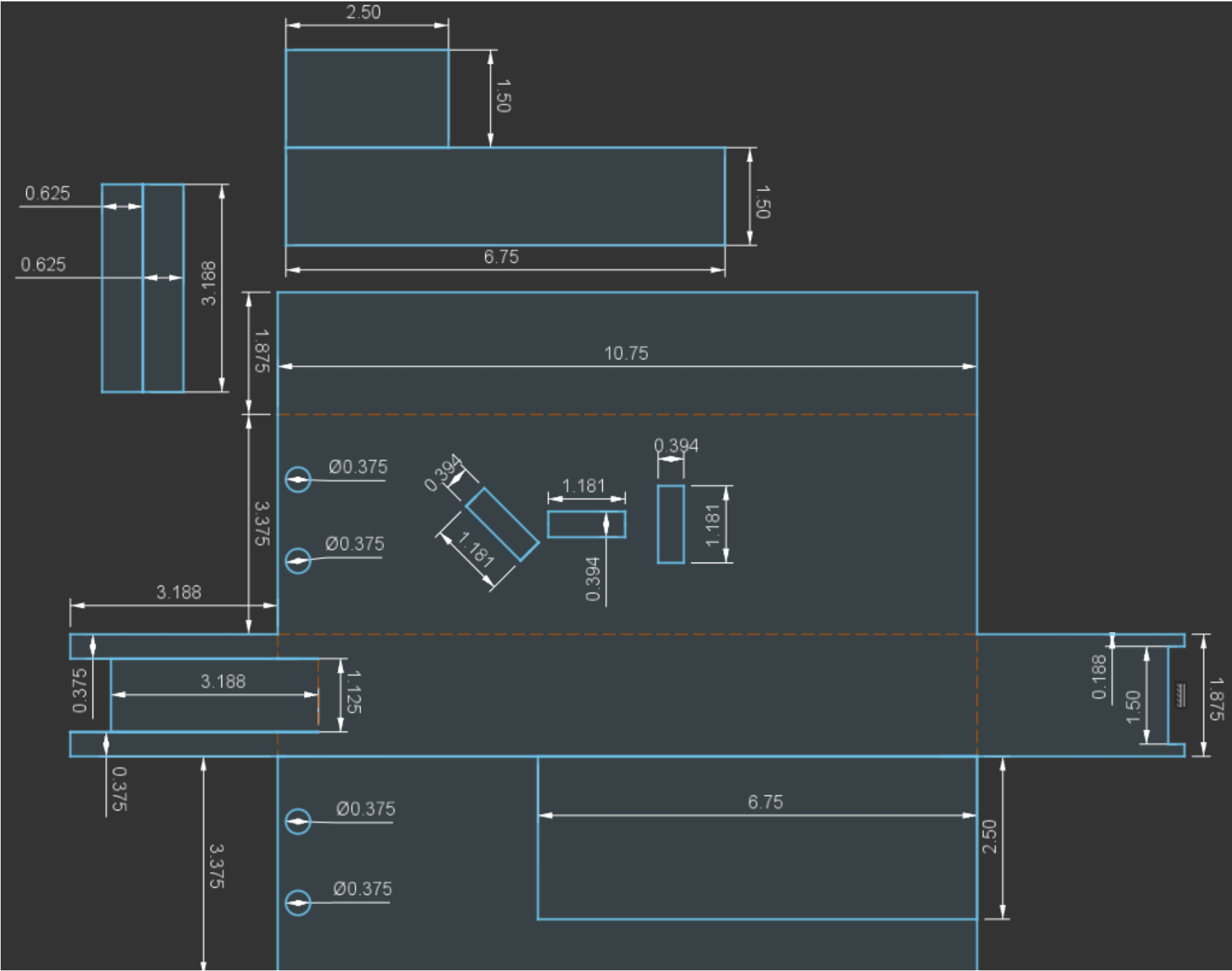
Technical Drawing A:



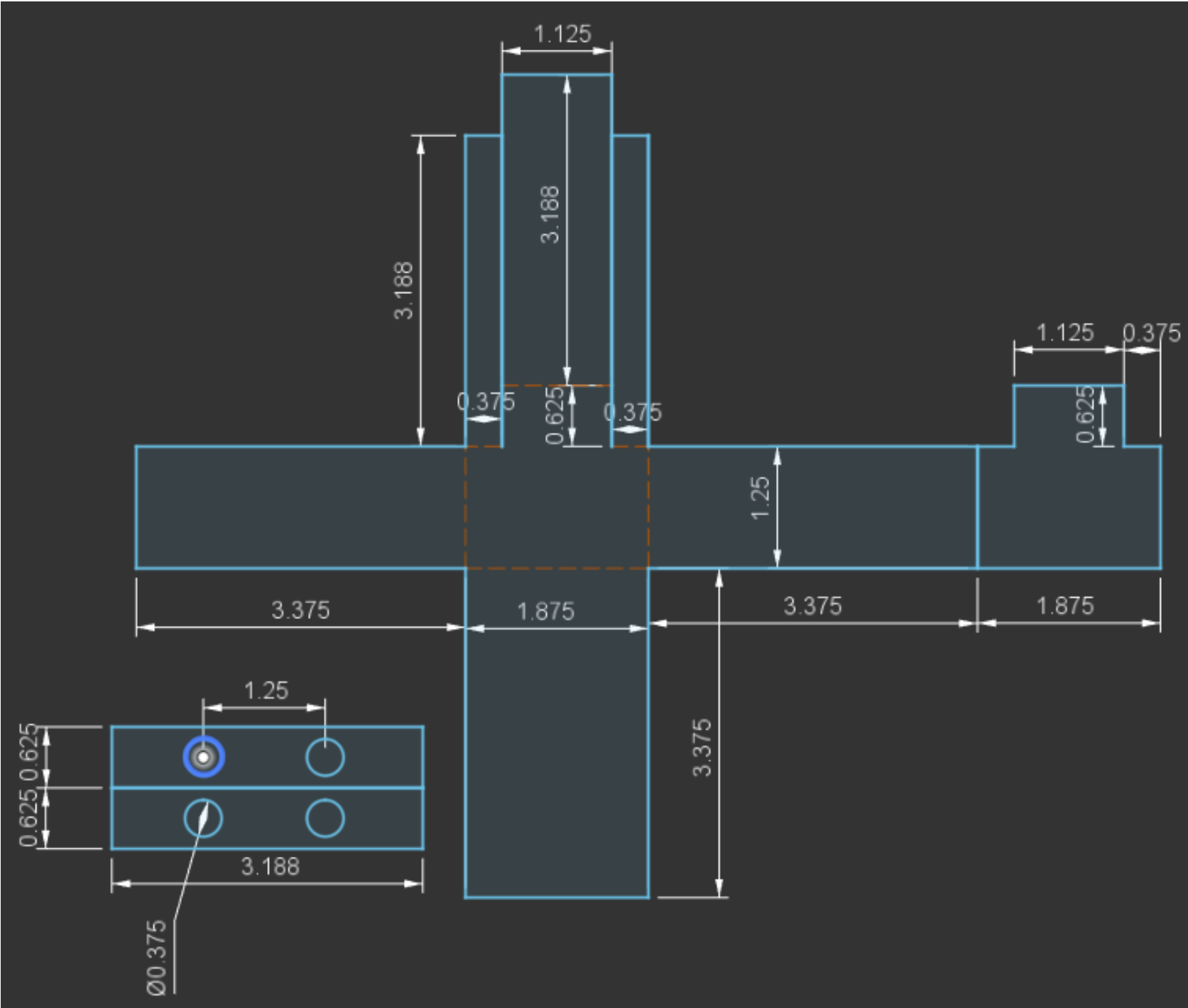
Technical Drawing B:



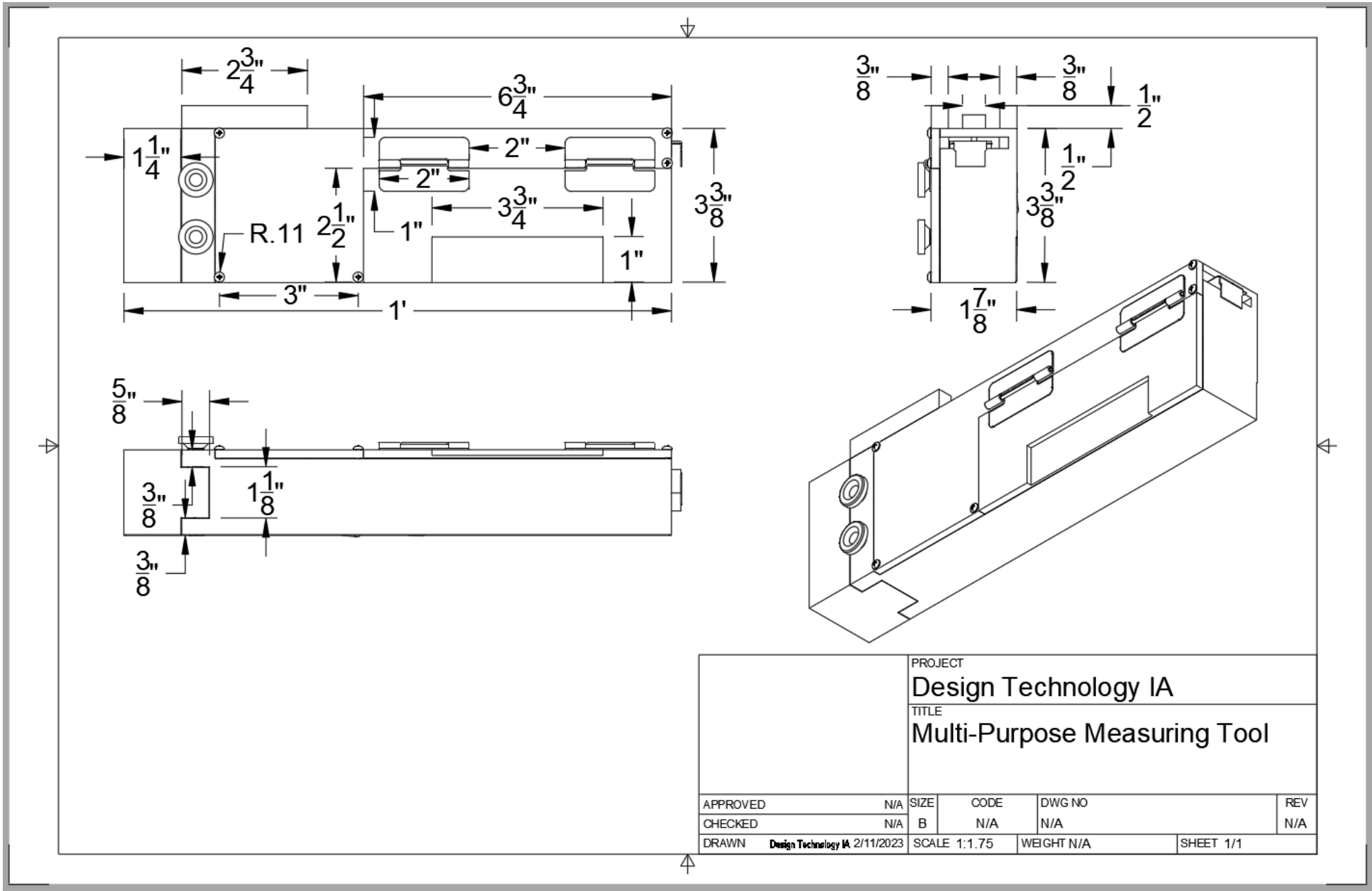
Technical Drawing C:



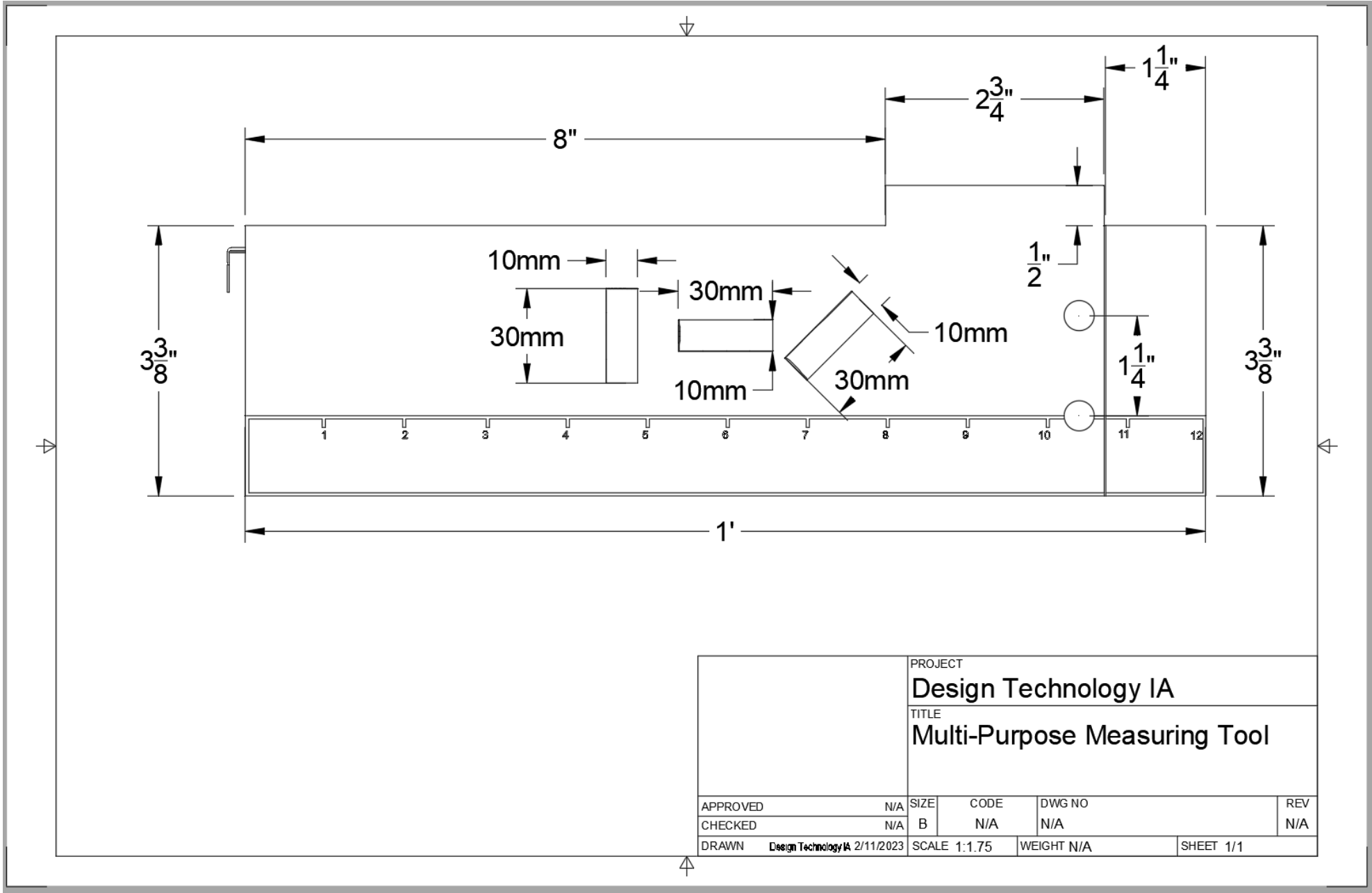
Technical Drawing D:



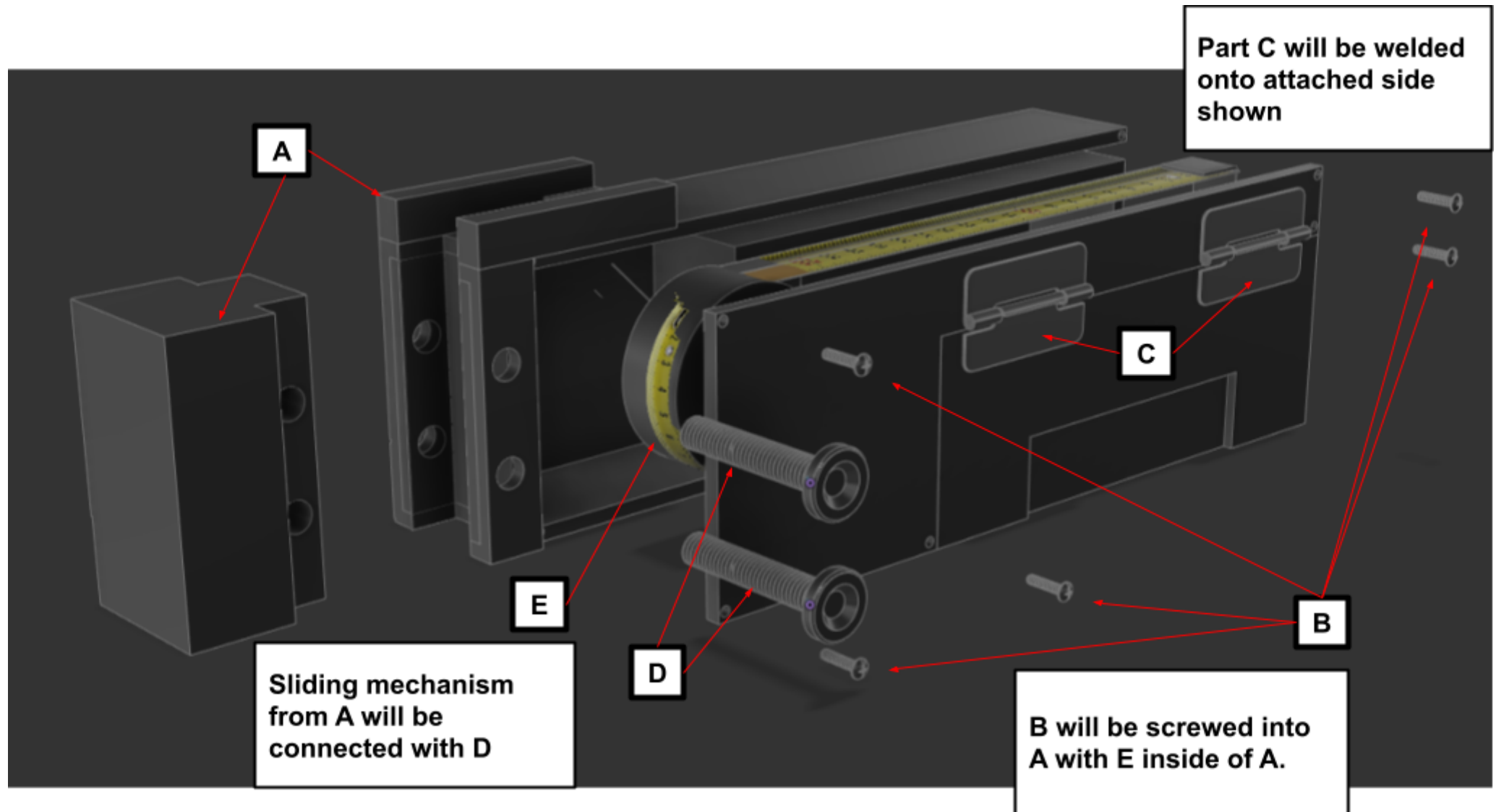
Technical Drawing E:



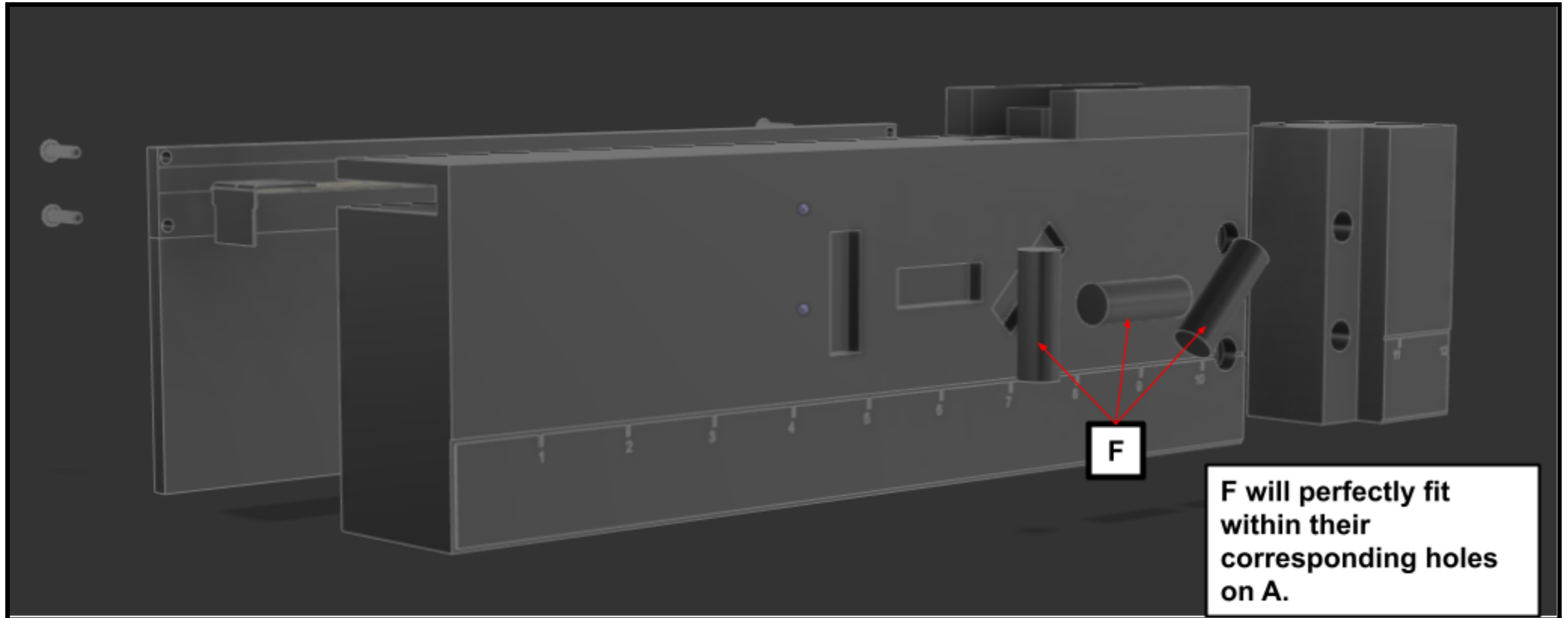
Technical Drawing F:



Assembly Drawing A:



Assembly Drawing B:



Assembly List

ID	Description	Qty.	Material	Length	Width	Height	Finish	Cost
A	Base (Bumpers and Sliding Mechanism Included)	1	Aluminum 6061	13.44 in	13.44 in	0.0179 in	Anodized	\$14.34 total
B	1/2" Screws	5	Stainless Steel	See components list below				\$0.61 each
C	Hinges	2	Aluminum					\$1.42 each
D	3" Screws	2	Stainless Steel					\$2.75 each
E	Measuring Tape	1	Various					\$6.00 total
F	Levels	3	Polymethyl Methacrylate					\$0.66 each
Total Cost: \$33.71								

Components List

Component ID	Component Name	Length	Width	Thickness	Finish
B	1/2" Screws	1/2 in	Ø1/8 in	N/A	Passivated
C	Hinges	1 in	2 in	1 mm	None
D	3" Screws	3 in	Ø3/8 in	N/A	Plain
E	Measuring Tape	3 in	1.5 in	3 in	None
F	Levels	30 mm	Ø10 mm	N/A	None

Processes	Equipment	Scheduling	Quality Control	Risk Assessment	
Cut aluminum with following precise dimensions (See A-D)	Metal shears	1 hour	Ensure precise dimensions and sizes are being cut	Flying metal shards might become a hazard, possibly requiring eye protection	Never feed material from backside of metal shear; potential hazard
	Protective gloves		Clamps may be required for holding aluminum for precise cut	Wear protective gloves when handling aluminum to avoid injury	Ensure to keep fingers away from blade to avoid injury
	Protective eyewear		To ensure precise cuts, draw exact lines to increase quality	A supervisor may be required to properly use metal shears	Do not use metal shears if malfunctioning
			Experienced users improve quality of use and ensure quality control	Check covers and safety features of shears to minimize risk	Turn off metal shears after use to avoid potential injury
Use metal brake to bend aluminum components (See A-D)	Metal brake	30 minutes	Ensure the proper position and distance to bend	Ensure safe position to avoid jamming between stock and slide	Be wary of electric shocks when around switches and wires
	Protective hand wear		Ensure aluminum is of good quality and doesn't possess damage	Wear protective footwear to avoid injury from metal bending brakes	Wear protective hand wear when dealing with sharp metal
	Protective footwear		Ensure the brake is properly locked in position with use	Personal fatigue could be dangerous from lack of self awareness	Brake's noise could cause ear damage; earplugs may be necessary
			Mark positions for where metal will bend (Reference drawings A-D)	Ensure no abnormalities in functioning to reduce risk of injury	Ensure a supervisor and/or experienced user is present

Weld components and base parts (See E-F)	MIG welding machine	30 minutes	Verify weld creates a strong connection and of good quality	Remove items with potential hazard for welding (increased injury risk)	Be wary of sparks or flames which could create fires
	Welding rod		Remove unnecessary items in welding area (ex: dust or dirt)	Wear protective equipment to prevent burns or other injuries	Brightness from MIG welding could impact visibility; wear welding visor
	Metal vice to hold metal		Ensure the argon shield is 20-30 chf for proper weld.	Ensure welding is at 45° angle and check flow speed	Weld flames could penetrate surfaces; could be dangerous to surroundings.
	Welding visor		Experienced user required to well, otherwise quality may be poor	Ensure proper breathing techniques due to high temperatures	Certain gasses released from welding could be hazardous
	Heat protective clothing			Ensure a supervisor or person is present to provide support	Wear protective clothing and footwear (ex: leather) for protection
	Welding gloves				

Criterion D | Design and Inquiry

Priority 1: Survey with target users

Gather qualitative feedback from target audience (1.1) from ages 20-40 (2.1) on the product's ability to provide reliable measurements (3.1). Data will also be gathered on tool visibility (6.1) and ease of use (3.2). Users will view the product and its tools, then will provide feedback, specifically towards the effectiveness of measuring tool placement and the effectiveness of materials used to create the product.

Priority 2: Performance Testing

A drop test experiment will be conducted on the product's durability (5.3) based on anthropometric data of a person's standing functional overhead reach. Tests will gather qualitative data and be conducted on the male 95th percentile (88.1") of standing overhead reach. The male percentiles were chosen since males have a higher 95th percentile than females and this test will determine the product's durability from a fall. Since the final product is not completed, an aluminum rectangular shape of the product will be used instead. This may create limitations, however, the test will still provide significant durability results.

Priority 3: Product Comparison

The prices of different measuring tools will be compared to gather quantitative data and determine the possible cost of the product (7.1). These prices will be determined by adding the smallest market price that could be found for each measuring tool incorporated within the measuring tool and determining if the product will sell well based on this cost.

Priority 4: Tool Prioritization Survey

Quantitative data will be gathered based on the prioritization and appeal towards tools used by builders, designers, and construction workers (1.1). Individuals will be asked to rank (from 1 to 5; 1 being never and 5 being always) each tool from the measuring tool based on how often they use a specific tool. Results from this survey will be analyzed to determine which tools from the product should express greater visibility and use than others (6.1). Also the data will be analyzed to determine what tool(s) could be altered or removed, if necessary in the product's redesign.

Evaluation Against Specification

Target Audience

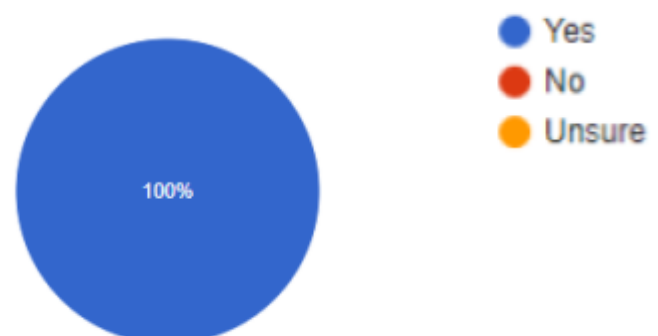
1.1 Should appeal towards builders, designers, and construction workers.

Testing Strategy: Survey with target users, tool prioritization survey

Strengths: All 10 users surveyed said they would be willing to use the product during their typical workday, demonstrating a high appeal towards the target audience. Based on the tool prioritization survey, the T-Square's mean reached an average of 4.2/5, the measuring tape's mean reached an average of 4.7/5, the level reached an average of 4.2/5, and the ruler reached an average of 4.6/5. These averages further indicate a high demand for these specific tools in the workplace of the target audience, indicating the benefit that these tools were added.

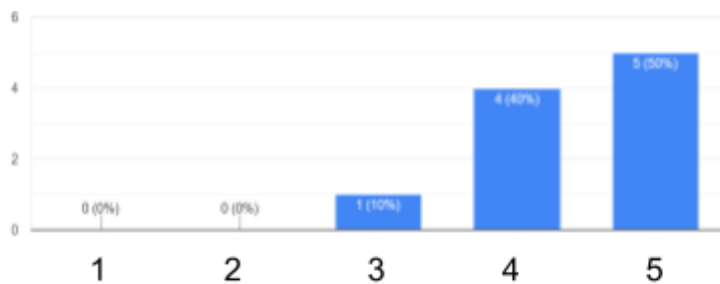
After viewing the product, would you be willing to use this product during your workday?

10 responses

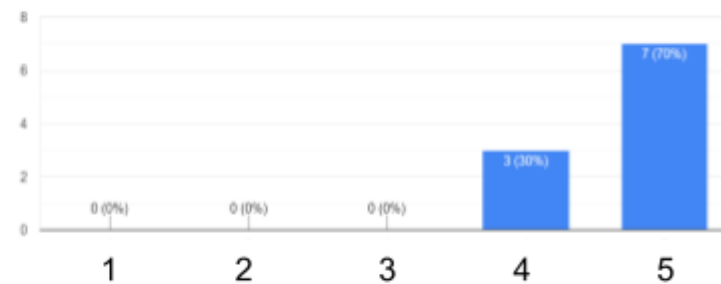


Weaknesses: In the tool prioritization survey, the screwdriver tool reached a mean of 4.0/5, indicating the screwdriver tool should be incorporated into the product, rather than be removed.

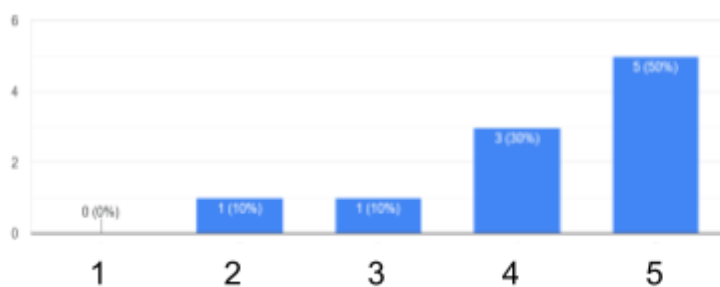
T-Square



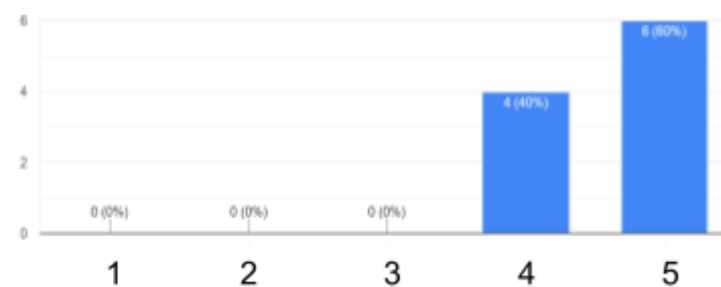
Measuring Tape



Level



Ruler



Target Market

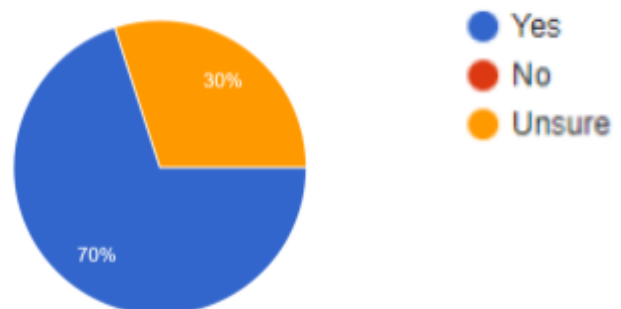
2.1 The product should largely appeal towards construction workers aging from 20-40.

Testing Strategy: Survey with target users

Strengths: 7/10 users surveyed would suggest the product to others, such as coworkers and friends. Since coworkers were mentioned, this would indicate the product would appeal towards the target audience and market.

Weaknesses: Since the question didn't specifically indicate the age range, this question might be limited in satisfying criteria. Furthermore, since 3/10 users were unsure about suggesting the product, this exposes a weakness in target market criterion.

Would you suggest the product to other people, such as coworkers, friends, etc.?
10 responses



Function

3.1 Adequately provide effective and reliable measurements.

3.2 Must be easy to use, and cannot obstruct workflow.

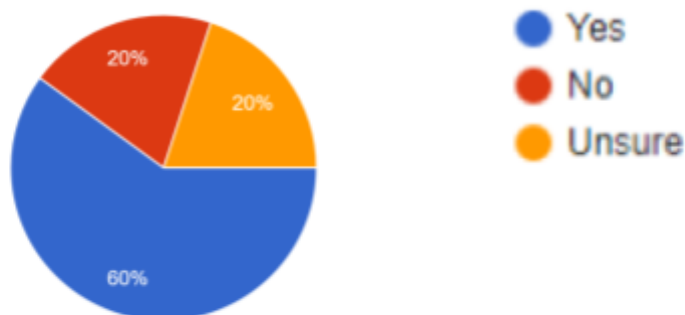
Testing Strategy: Survey with target users

Strength: 6/10 users agreed the product would produce the same measurements similar to the stand-alone tool and the product wouldn't obstruct their workflow after initially using the product. This indicates these specifications are reasonably met, although improvements could be made.

Weakness: 2/10 users believed the product's tools couldn't produce the same measurements as a stand-alone tool and 2/10 being unsure, exposing weakness in how reliable the product would function. Furthermore, since 1/10 users said the product would obstruct workflow, with 3/10 being unsure, this exposes a large weakness in the tools ability to be used in the workplace.

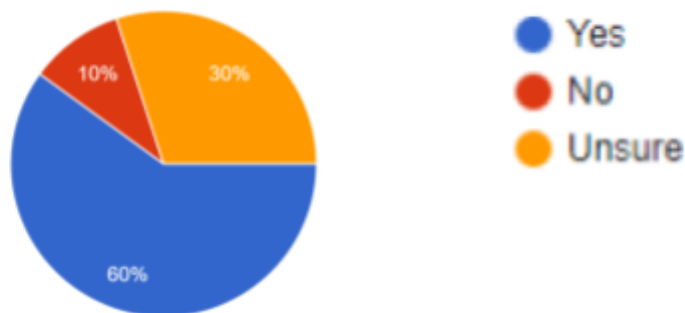
Based on the different measuring tools, do you believe the product's tools can produce the same measurements similar to the stand-alone tool?

10 responses



In your opinion, do you think that the product is easy to use and won't obstruct your workflow?

10 responses



Size

4.1 The inside of the product shouldn't exceed 1' x 1.5" x 3".

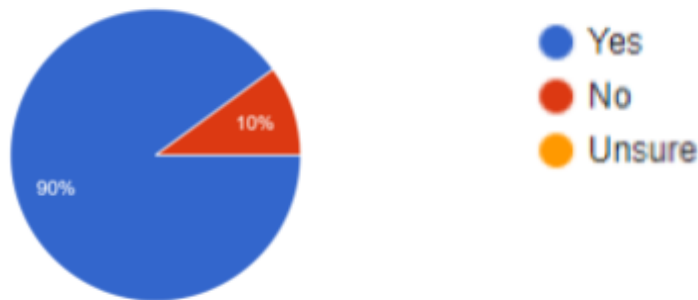
Testing Strategy: Survey with target users

Strength: 9/10 users agreed the product's size was reasonable, indicating the specification is very well met.

Weakness: 1/10 users believed the product's size wasn't reasonable, indicating some speculation as to whether or not the product's size is a reasonable fit.

Would you agree that this product is a reasonable size?

10 responses



Material Selection

5.1 The product must be resistant against rust.

5.2 The product must not exceed 11.1 lbs.

5.3 The product must be durable.

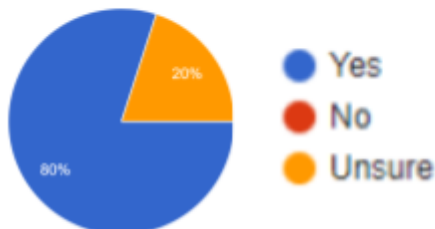
Testing Strategy: Survey with target users, performance testing

Strength: 8/10 users believed the product would be light enough to use normally agreed the product would be durable enough in regular use.

Weakness: 2/10 users were unsure about the product's durability and weight. This highlights a need to reflect on the type of material used.

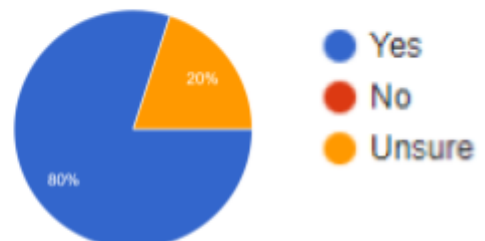
In your opinion, would you say that this product is durable?

10 responses



Do you believe that the product is light enough to use normally?

10 responses



Before Drop Test



After Drop Test



Strength: Very minor scratches after drop test; great durability.

Weakness: Although small scratches, only one drop required to scratch

Aesthetics

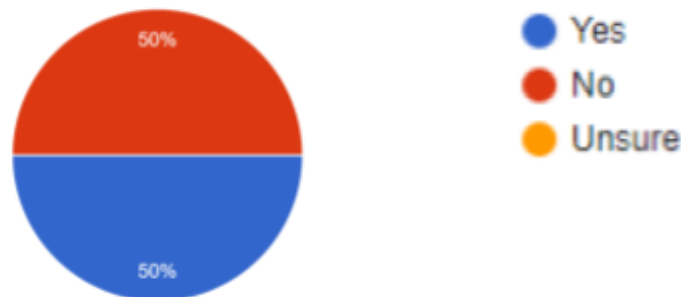
6.1 Easily visible to use.

Testing Strategy: Survey with target users

Strength: 5/10 users believed the product's tools were easy to see, indicating a fair amount of visibility of the product's tools.

Weakness: 5/10 users said the product's tools weren't entirely easy to see. These users also believed the T-Square wasn't clear enough without being told of the sliding mechanism's purpose. This indicates some difficulty in being able to make the T-Square tool easily visible.

After viewing all the product's tools, do you think that the product's tools are easy to see?
10 responses



Cost

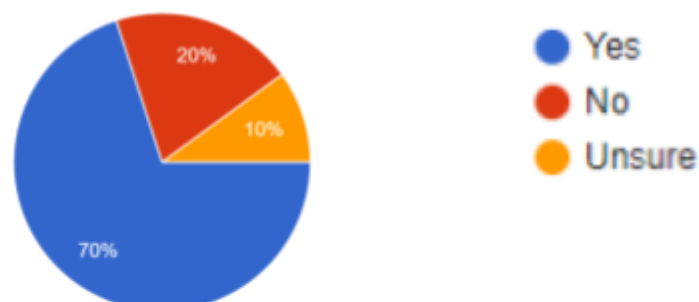
7.1 Price should not be significantly greater than market price of all measuring tools incorporated within the product.

Testing Strategy: Survey with target users, product comparison

Strength: The approximate cost of the product's tools is about \$27.00, suggesting the specification is not entirely met (the product's determined price is about \$33.71). However, since this difference isn't significant, the product's storage could account for this difference. Therefore, the test's results don't indicate a significant strength or weakness. Despite this, 7/10 users agreed they'd buy the product for \$30-40, indicating a noticeable strength.

Weakness: One weakness regarding the product is the lack of satisfying the market price. Also, since 2/10 users interviewed stated they wouldn't buy the product for \$30-40, while 1/10 were unsure, this indicates some weakness regarding product cost.

Would you be willing to pay for this product if it were \$30-\$40?
10 responses



Quantity

8.1 One product per person (1:1 ratio)

Testing Strategy: Survey with target users

Strength: All 10 users agreed they would not buy more than one of the products. The survey clearly indicates the specification is perfectly met.

Weakness: None

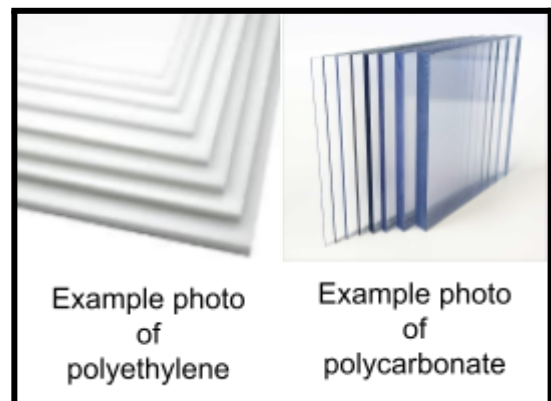
Would you buy more than one of this product?

10 responses

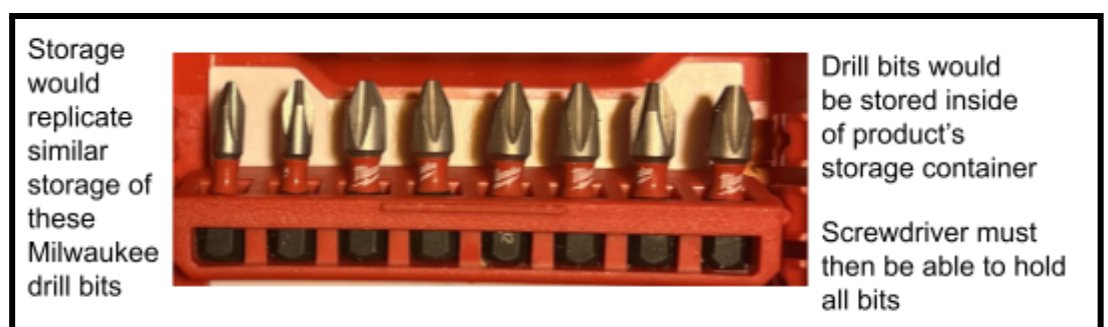


Improvements

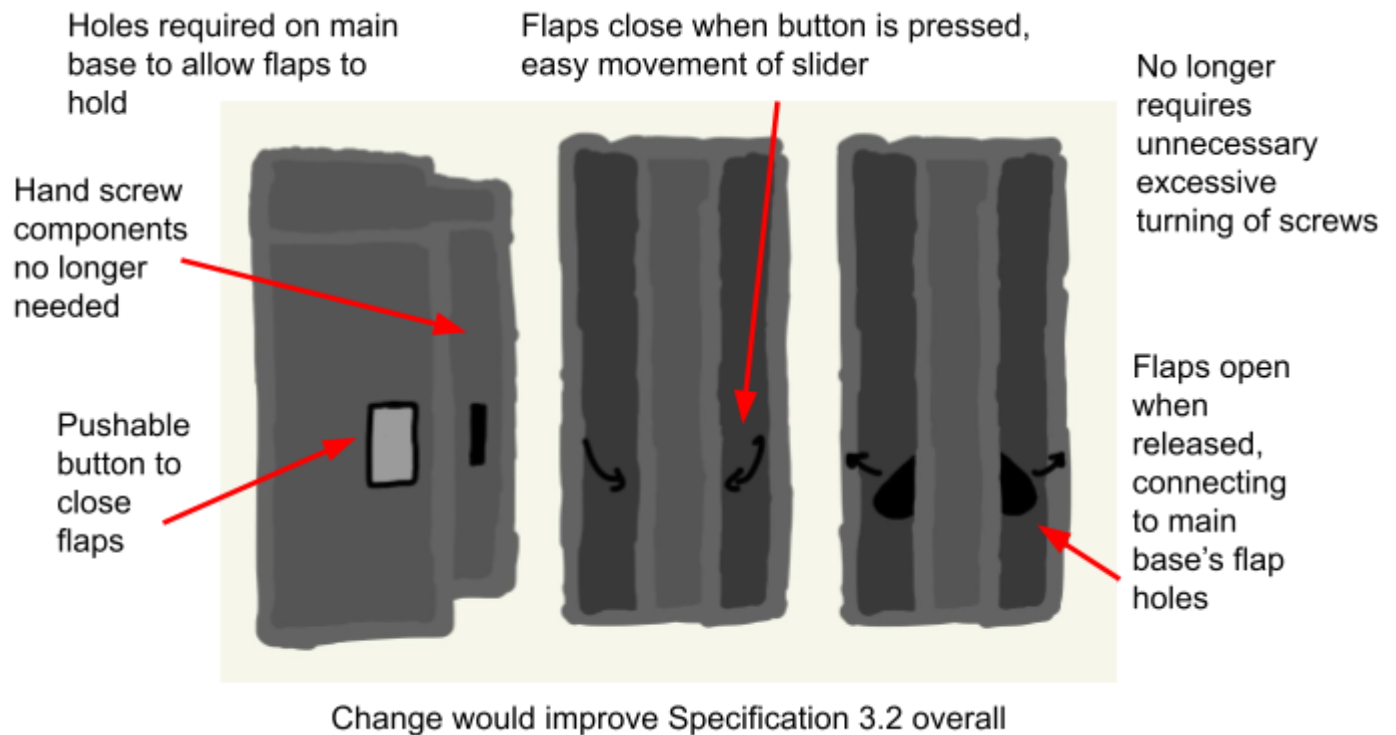
- 1.) **Material Option 1:** Although aluminum is well-applied for the product, polyethylene plastic could be an alternate material. One benefit of using polyethylene plastic is its lower density (0.035 lb/in^3) compared to aluminum (0.0975 lb/in^3), meaning the product will have a lighter weight (5.2).
- 2.) **Material Option 2:** Polycarbonate could be another option for the product, which has a tensile strength of $70\text{-}80 \text{ N/mm}^2$. This is a higher tensile strength than polyethylene ($0.2\text{-}0.4 \text{ N/mm}^2$), improving product durability (5.3).



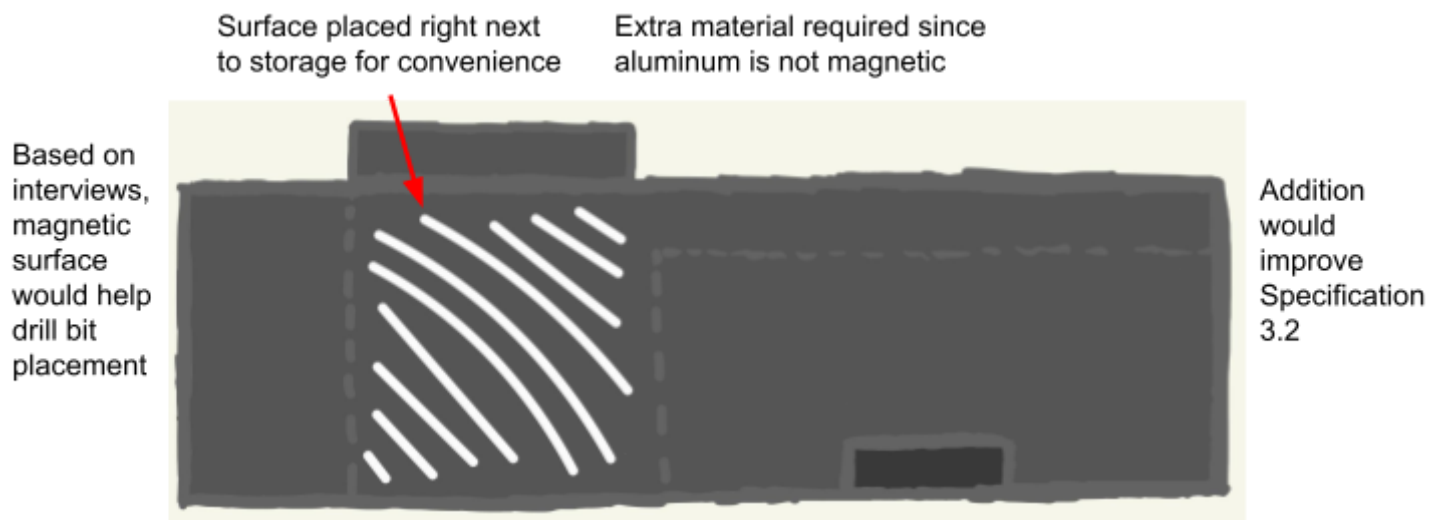
- 3.) **Added Tool Option 1:** Based on surveys, a screwdriver would provide a benefit to builders and construction workers (1.1) because of how often the tool is used. As such, the tool's incorporation would suggest improvement.



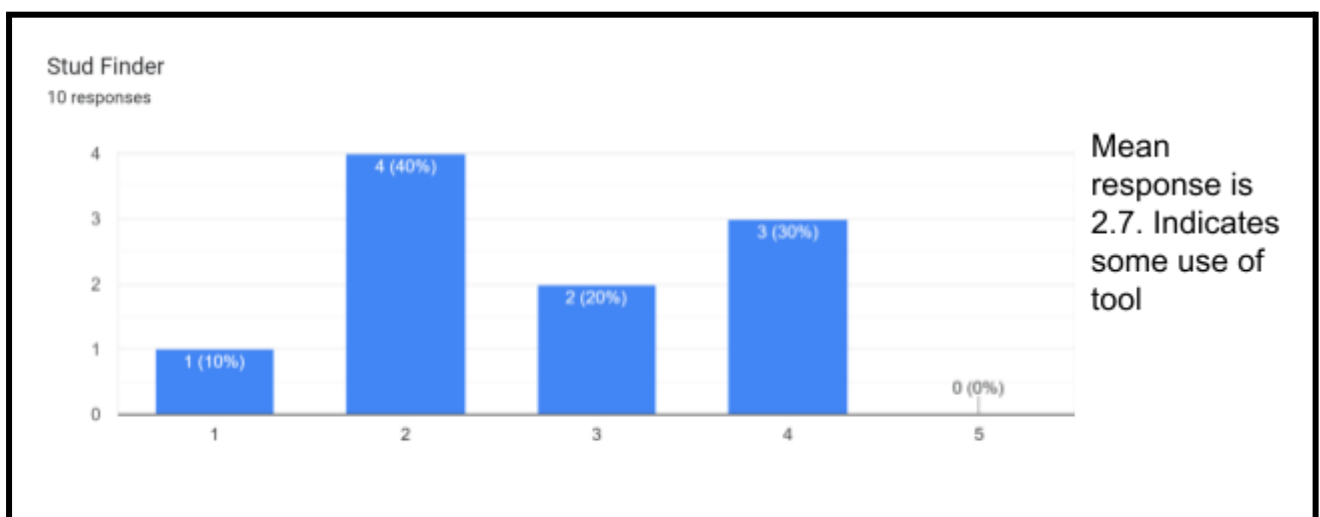
4.) Alternate Sliding Mechanism:



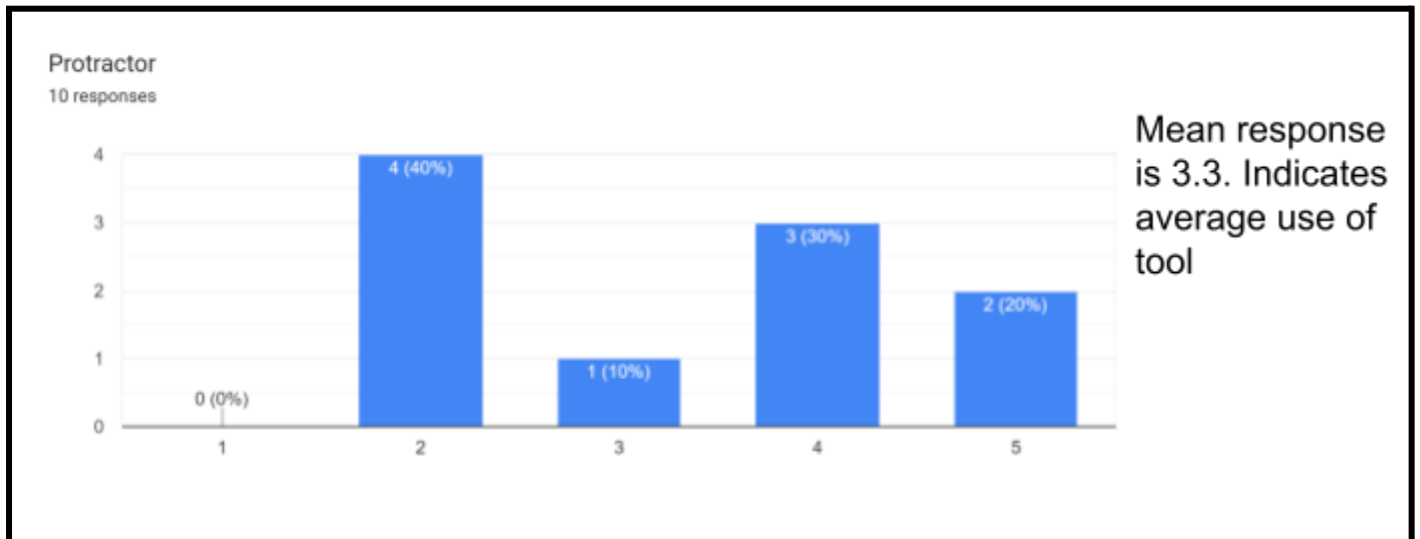
5.) Magnetic Surface:



6.) Added Tool Option 2: Adding a stud finder would be a better option, increasing the number of the product's tools (Ex.2).



7.) Added Tool Option 3: Adding a protractor would be more applicable to add, increasing the number of the product's tools (Ex.2).



(Word Count: 2999)