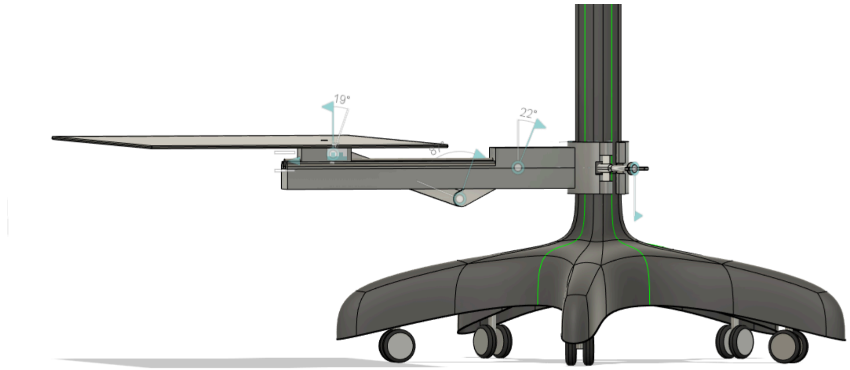

ARROW Footrest

Adjustable and Removable Room/Office/Work Footrest

ME170 Design Team

AB6-5

Team Members

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Aysha Patel

Nathan Chung

Patrick Cabrera

Date: 12/08/2023

1. Product Description and Ideation Process

One of the primary focuses in the development of the ARROW Footrest came through our lengthy interview and ideation process, with an emphasis on human-centered design. The interview process involved speaking with several undergraduate students on campus to identify potential issues that could be addressed by creating a product that directly tackled the problem or by offering a better alternative to existing products on the market.

In our first round of interviews, we learned that comfort is very limited on campus. After moving into their dorms, some students found it difficult to find comfort while working at their desks, and they also encountered challenges in finding study space at the university library or Grainger Library. During our second round of interviews, we received concerns from campus commuters who used bikes. A common concern involved bike security, as bikes would frequently be stolen or lost as a result of poor bike security. As one interviewee states, "It's hard to secure your bike, [...] a majority of good options [...] are super expensive and heavy." In our final round of interviews, students expressed annoyance with the task of cleaning their rooms. First-year students often found it to be "time-consuming [...] cleaning almost every day."

Following our interviews, sketches for prototypes that could potentially solve the problems present in each interview were produced. One sketch aimed to solve the problem regarding bike security, another aimed to solve the issue students had with convenience in a dining hall setting, and another resembled a footrest. Ultimately it was decided that a footrest that prioritized both comfort and convenience would be developed. Not only could a footrest solve the issue of comfort and convenience, but it had the potential to be versatile in multiple applications. Immediately, several sketches were produced for the production of a prototype footrest that students could conveniently use in different environments. One sketch utilized a scissor mechanism, another used a pedal-like design, and another used a slider. After evaluating the pros and cons of every design, the slider prototype was chosen for its favorable construction material and unique design.

The footrest would consist of a slider, clamp, and platform, each designed as separate parts that would be pieced together as one complete product. The slider mechanism would consist of a steel base, a plastic connecting rod, and a plastic slider that is attached to a pan. The pan would then have a thread that secured a simple, flat plastic footrest on top of it via a quarter-inch flathead screwdriver. The clamp would resemble that of a pipe clamp, opening with a hinge-like mechanism that would be tightened and adjusted using an eye bolt fastened by a wingnut. Designing the footrest this way allowed for complete modularity, and ease of replacement. If any part of the footrest were damaged or broken, the plastic components would be easy to manufacture and replace. Additionally, the footrest's design allowed for the platform to be swapped out with potentially different types of platforms for the user to place their feet. Of course, there were other considerations, like the material. Originally, a full metal footrest was considered for its pure durability, however, it proved to be too costly and far too heavy for any practical use. A full plastic design was also considered, but the durability of the mechanism became questionable. And a balance between the two was found.

Besides the convenience and comfort that the footrest provides, the modular design of our product brings something that other products in the market don't have. Because parts are easily replaceable, our product has the potential to last consumers years. Additionally, future designs that are developed by our company could be easily bought separately and attached to the footrest. And if the consumer wishes to make a custom attachment, they have 100% freedom to choose so, as our product gives them the freedom to do so.

2. Concept Sketches

The sketches below from Figure 2.1 through Figure 2.4 illustrate initial sketches for product concepts during the post-interview ideation phase. The sketches in Figure 2.5 through Figure 2.8 represent the finalized sketches used in the concept selection pugh matrix as part of the next phase of the design process.

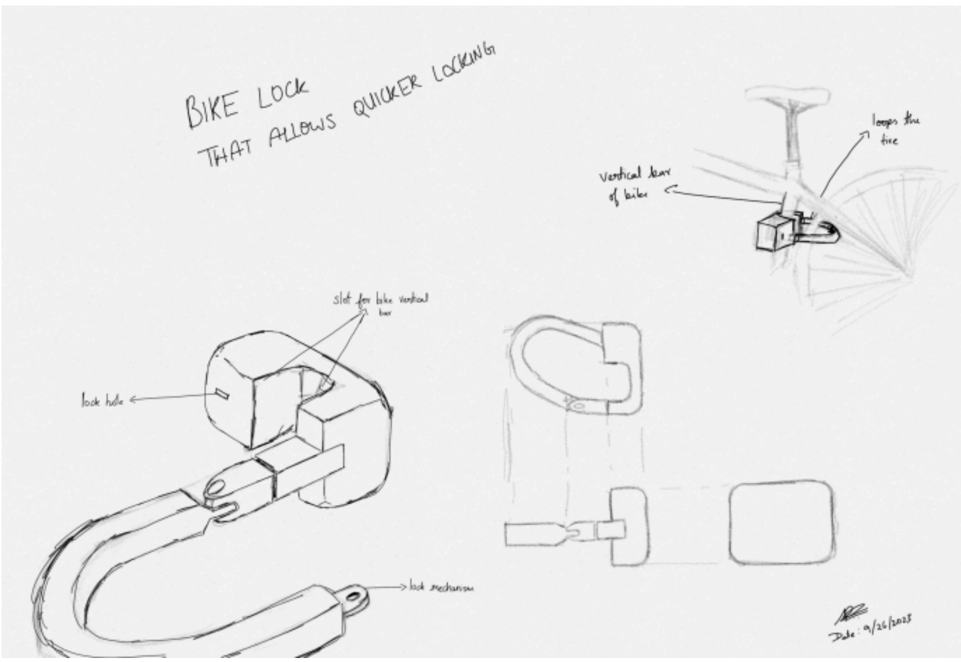


Figure 2.1: Bike Lock with Quick Lock Mechanism Ideation Sketch

The bicycle lock concept shown above involves an easier locking mechanism as opposed to traditional bicycle locks in order to effectively lock the rear wheel in a timely manner. The goal of this design was to increase the efficiency of being able to lock a bicycle effectively, but also quickly.

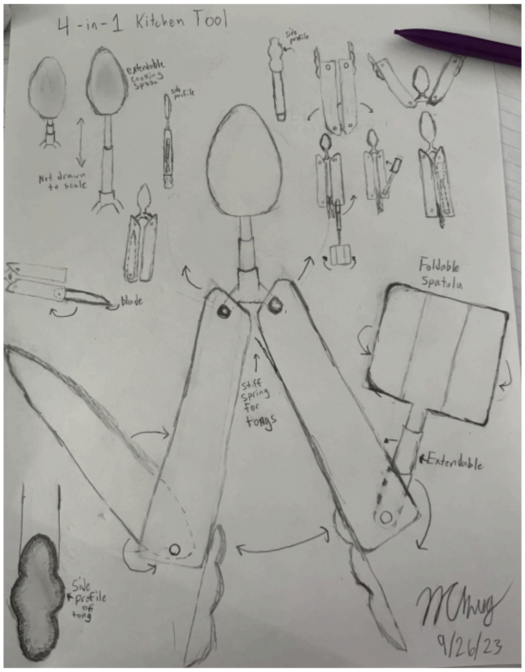


Figure 2.2: Kitchen Multi-Tool Ideation Sketch

The Kitchen Multi-Tool was created to increase the efficiency of a college student in the kitchen. With this tool, they would have access to 4 different tools all in one design, so that it is effective in cooking as well as storing.

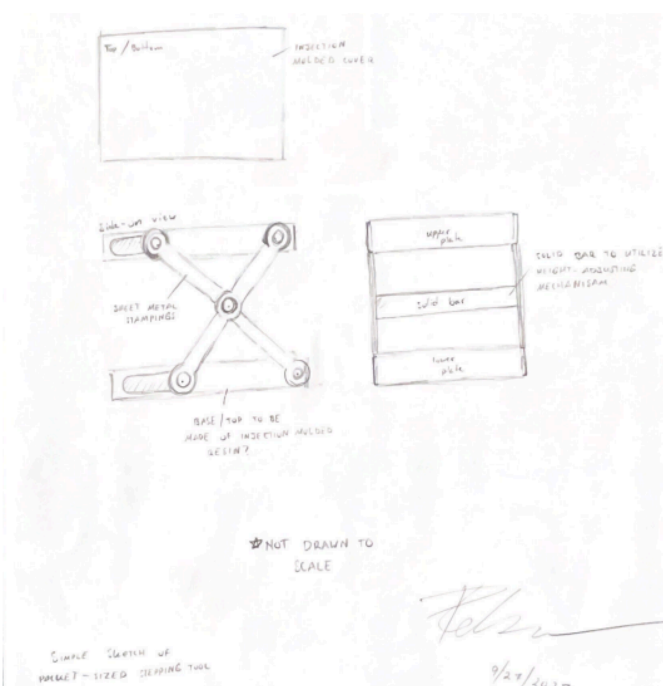


Figure 2.3: Pocket-Sized Collapsible Stepping Stool Ideation Sketch

The Pocket-Sized Collapsible Stepping Stool was designed to be easy to carry around and easy to use. The goal of the product is to provide extra height to reach hard-to-reach places at a moment's notice.

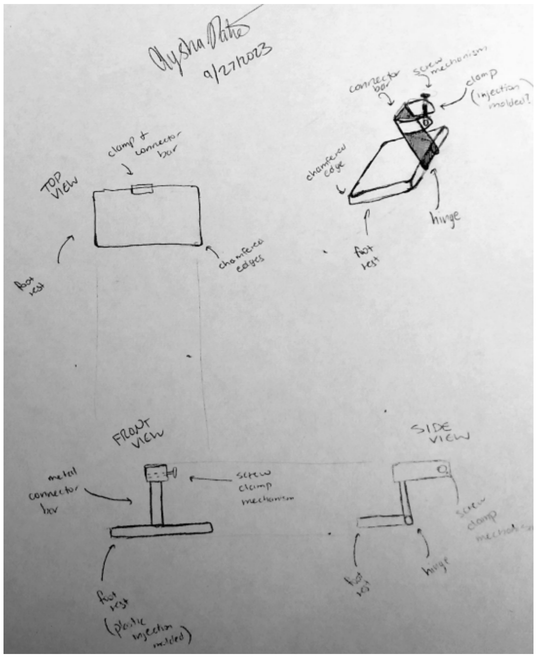


Figure 2.4: Detachable and Adjustable Footrest for Office Chairs Ideation Sketch

The footrest design is meant to be a portable footrest that can be clamped to an office chair and adjusted to the needed height. It would be beneficial as it would not take up any floor space for use or storage.

Ultimately, the team decided to continue with the concept of the adjustable footrest for office chairs as depicted in Figure 2.4 This decision was made with consideration for the necessary material processes of injection molding and sheet metal stamping illustrated in the project brief. Further, the design seemed to have a unique place in the market for office/work comfort-enhancing devices.

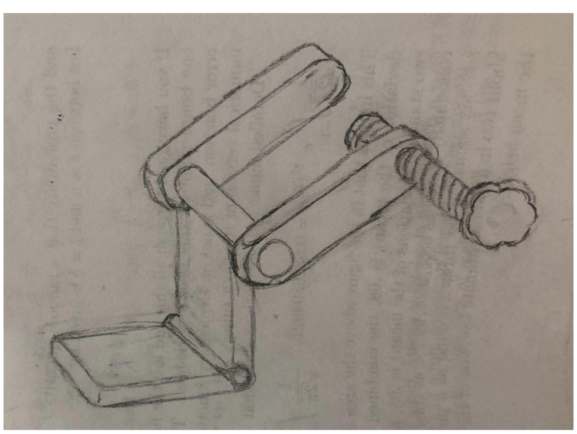


Figure 2.5: Pugh Matrix Concept 1 Finalized Sketch

Design concept 1 utilizes a screw clamp to attach to the central portion of an office chair. The footrest is a hinge that can rotate from a contracted storage position to an expanded use position.

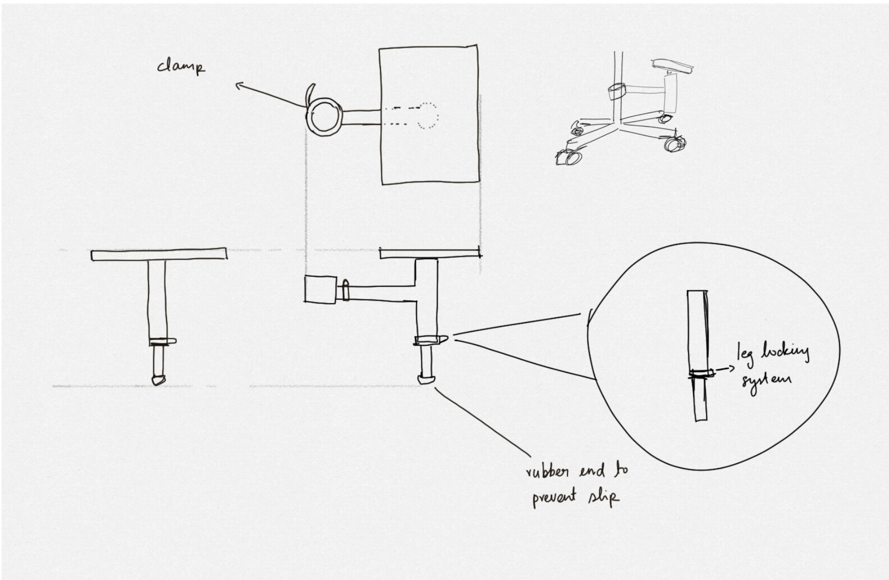


Figure 2.6: Pugh Matrix Concept 2 Finalized Sketch

Concept 2 is a single clamp design that attaches to the base of the office chair. It also has a rubber stopper that can extend to the ground for support and to prevent forward tipping.

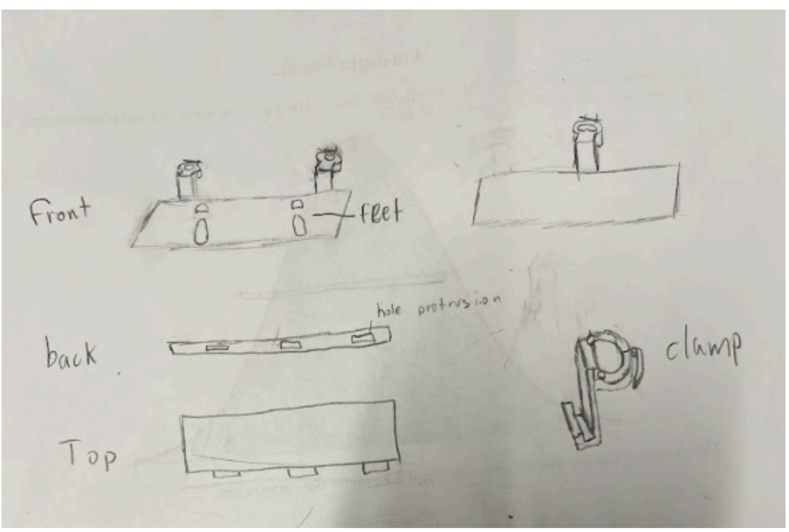


Figure 2.7: Pugh Matrix Concept 3 Finalized Sketch

Concept 3 involves a 2 clamp design to function on traditional 4 leg chairs. By using adjustable clamps, the design will attach and hinge to be stored away in a compact position.

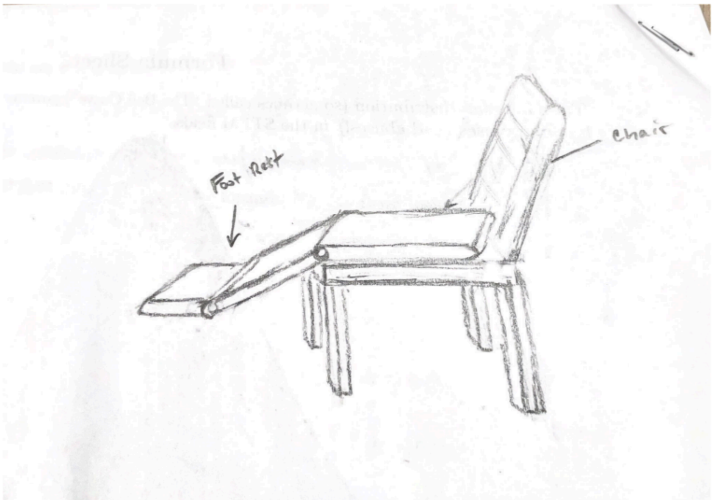
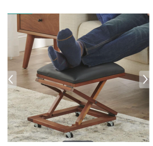
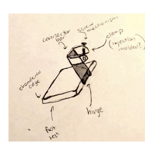
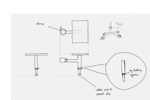
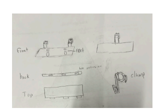
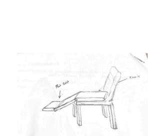


Figure 2.8: Pugh Matrix Concept 4 Finalized Sketch

Concept 4 involves a folding mechanism to make a compact design. Using body weight to stay on the chair, the design would lay on the chair and hinge as necessary to adjust to the user's desired height.

The final decision regarding the design concept was made through a pugh matrix involving a datum and Figure 2.5 through Figure 2.8 as is depicted in the next section.

3. Concept Selection process (Pugh Matrix)

Pugh Concept Selection Matrix					
Criteria	Concepts				
					
	Datum	1	2	3	4
Expected/ known service life		S	+	S	-
Resistance to staining and corrosion		+	+	+	+
Ease of portability	D	S	-	+	-
Aesthetics and Finish	A	-	-	-	-

Range of height adjustability and accommodation	T	S	+	-	+
Maximum load capabilities	U	-	-	-	+
Product Cost	M	+	+	+	-
Attachable to/ usable on multiple common chair designs		S	-	+	-
Manufacturing complexity		+	+	+	+
Comfort/ ergonomics		-	-	-	+
Feasibility		-	+	+	-
	+0 **-0**	**+3** **-4**	**+5** **-5**	**+6** **-4**	**+5** **-6**

To finalize, Design Concept 3 is the design for the product, with minor reiterations based on feasibility and manufacturing capabilities within the scope of this project. Design 3 was selected as it has the most positives of all of the concepts in comparison to the datum. Furthermore, the most important criteria including feasibility, manufacturing complexity, and product cost were all positive in comparison to the datum, and not all other concepts were successful in these criteria. With all this in mind, there will still be alterations and improvements to Design 3 as the selection process revealed that a more in-depth analysis of the clamp mechanism and load capabilities will be required as the project progresses.

Ultimately, this design underwent significant modifications throughout the rest of the design process. After gaining further insight from the target market, the design concept that was selected was modified into a single clamp footrest to suit office chairs as requested by interviewees. The hinge mechanism was also altered to better suit the design criteria outlined in the initial design brief at the start of the project.

4. Product Design Specification (PDS)

- Performance
    - The performance of this product is to optimize comfort. Accommodating for users of different heights and seating preferences.
    - The footrest shall deflect no more than 1.5 inches under 40 lbs of vertical force.
    - The clamp portion of the design shall move no more than 0.5 inches under 40 lbs of vertical force.
    - The footrest shall compensate for 40 lbs of vertical force continuously for 2 hours without excessive deflection as defined above.

- Environment
    - The design will withstand contact with fluid, specifically water and other food liquids, without corrosion.
    - The clamp portion will not corrode from up to 60% relative humidity within 5 years.
- Service Life
    - Consumers shall be able to reasonably expect the product to last for 50,000 hours (approximately 5 years) of use under 40 lbs of vertical load without damage that would prevent the safe and effective use of the product.
- Maintenance
    - Regular maintenance of the product will not be required in order to meet accepted reasonable standards of use for the service life.
    - Clamp mechanisms will be made with commercially available parts for ease of repair by consumers.
- Target Costs
    - The simplistic design of the product implies that the cost should be fairly inexpensive. Consumers can expect the price to range from $25 to $35.
- Competition
    - There are different designs of foot rests that consist of separate parts that do not connect to the chair.
    - Our product offers a storage solution that other products lack.
    - Similar products range from $10 to $50, varying based on features, materials, and aesthetics.
- Shipping
    - The product will be shipped through mail systems individually by order to the house of the consumer.
- Product Volume
    - There is a shipping product volume of 1.
    - Each product consists of the leg rest and the attaching clamp.
- Packing
    - The product comes encased in a plastic mold to avoid damage during shipping.

    - The product will be fully constructed when packaged.
    - All packing materials will be fully recyclable.
- Manufacturing Facility
    - The product is manufactured at the University of Illinois at Urbana-Champaign in the Siebel Center for Design.
- Size
    - The product in its storage (contracted) position will not exceed 20in x 20in x 8in.
- Weight
    - The finished product shall not exceed 6.5 lbs of weight for ease of portability.
    - The finished product and packaging weight will not exceed 10 lbs for ease of shipping and reduction of transportation costs.
- Aesthetics and Finish
    - The product will have a sleek and minimalist finish/design.
    - The product will be available in a black and silver metal color scheme.
- Materials
    - The materials used in the design will consist of injection molded ABS plastic and stamped steel.
- Product Life Span
    - Due to competition in the market and new discoveries in engineering, our product can expect a life span of around 3-4 years.
- Standards, Specifications, and Legal Aspects
    - The product will be safe for use, meeting all safety requirements in order to avoid product liability issues.
    - The design will be tested for stability under different conditions and follow relevant safety standards, such as ANSI/BIFMA X5.1 for office furniture safety.
- Ergonomics
    - The footrest shall deflect no more than 1.5 inches under 40 lbs of vertical force.
    - The clamp portion of the design shall move no more than 0.5 inches under 40 lbs of vertical force.

    - The footrest shall compensate for 40 lbs of vertical force continuously for 2 hours without excessive deflection as defined above.
    - The adjustable height of the product allows for additional user comfort.
    - Additional padding can be placed on top of the platform for additional comfort as the user needs.
- Customer
    - The product satisfies the need of the customer for a device that solves the issue of comfort in their everyday environment (i.e. at work, in school, in dorms, etc.)
    - The target customer is an office worker or student under 5’3”.
- Quality and Reliability
    - The quality of the product must be sturdy and strong enough to withstand given weight conditions.
    - The ability of the product to hold weight will have a high standard to ensure that users will be able to use the product without thought.
- Shelf Life
    - The product does not expire.
    - The product shall withstand exposure to relative humidity of up to 60% for 3 months without corrosion for storage purposes.
- Processes
    - Injection molding and steel stamping are the primary processes of producing the product.
- Timescales
    - Manufacturing lead times shall not exceed 1 week.
    - Product Development Cycle Time shall not exceed 1 year to maximize the ability to capitalize on workplace, and thereby consumer, trends and achieve sales targets.
- Testing
    - Controlled weight limit testing will be conducted until the maximum weight limit is reached after full-scale prototyping.
    - Incremental testing shall be done after the development of the footrest part to ensure material quality meets the predetermined standards for deflection.
- Safety

    - Test for stability under different conditions and follow relevant safety standards, such as ANSI/BIFMA X5.1 for office furniture safety.
- Company Constraints
    - The company's manufacturing processes contain limitations on injection molding production capabilities, as expanding production may require significant capital investment.
- Market Constraints
    - The fluctuations in the cost of materials, such as plastics, or metals, can affect product profitability
    - Market demand is subject to constant change, and can impact production schedules and inventory management. The overproduction or underproduction of our product can strain resources.
- Patents, Literature, and Product Data
    - Compared to other patents, our product is cheaper and much simpler to manufacture, as it utilizes a single leaf member for the foot to rest on, and thereby is easier to transport.
- Political and Social Implications
    - In regions with limited female office employees, demand for the product will likely decrease drastically as the number of potential consumers is reduced.
    - In regions with limited office employment, specifically, in which the vast majority of the population works in trades or manual labor positions, the number of potential consumers is reduced drastically.
- Disposal
    - Due to environmental purposes, the product shall be recyclable without requiring excessive dismantling by the consumer.

5. CAD Models

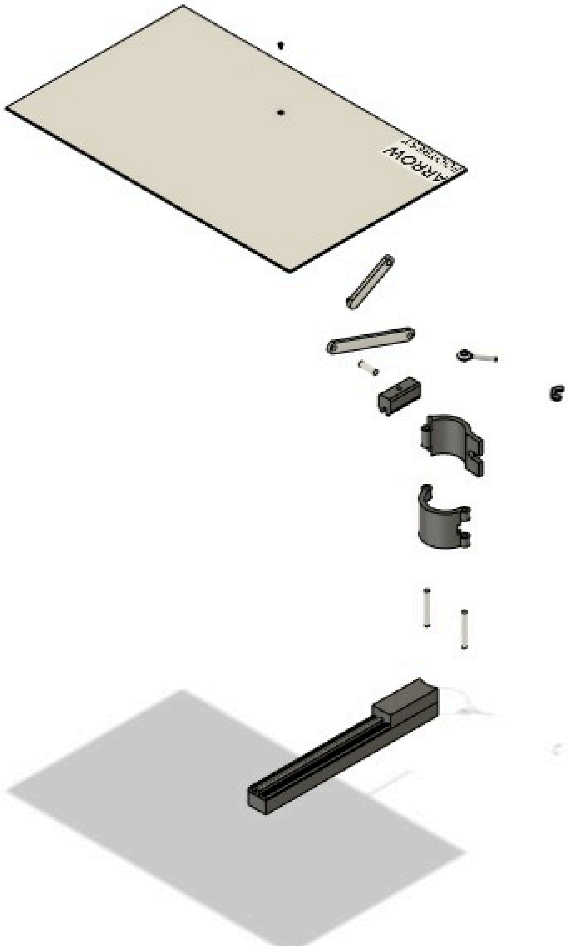


Figure 5.1: Shaded Exploded Assembly View

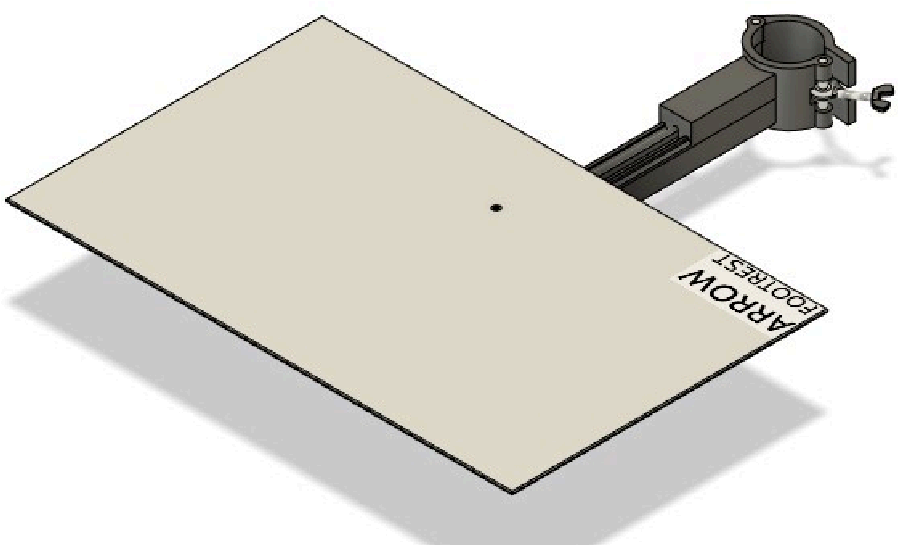
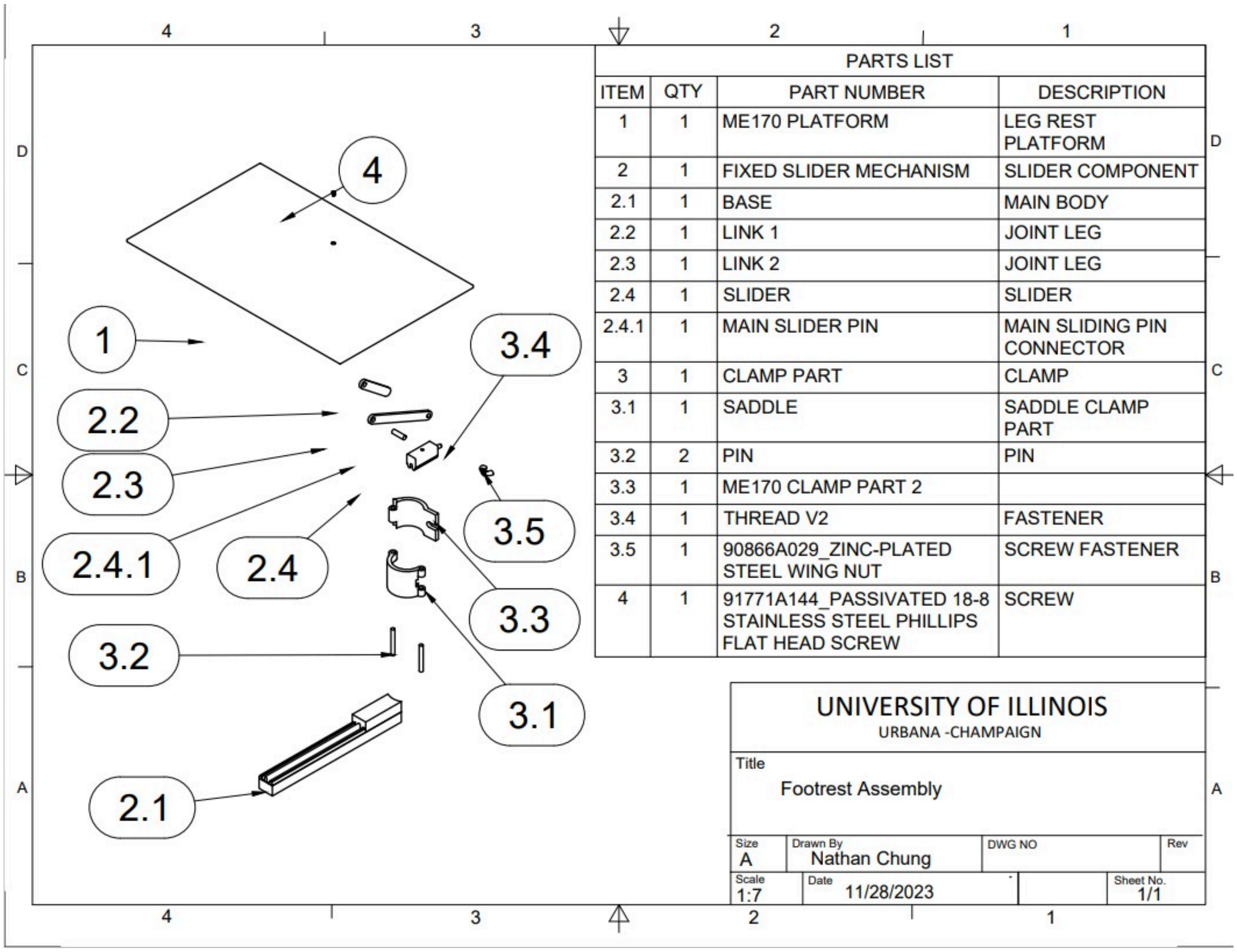


Figure 5.2: Shaded Unexploded Assembly View

6. Exploded Assembly Drawing and Bill of Materials (BOM)



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	ME170 PLATFORM	LEG REST PLATFORM
2	1	FIXED SLIDER MECHANISM	SLIDER COMPONENT
2.1	1	BASE	MAIN BODY
2.2	1	LINK 1	JOINT LEG
2.3	1	LINK 2	JOINT LEG
2.4	1	SLIDER	SLIDER
2.4.1	1	MAIN SLIDER PIN	MAIN SLIDING PIN CONNECTOR
3	1	CLAMP PART	CLAMP
3.1	1	SADDLE	SADDLE CLAMP PART
3.2	2	PIN	PIN
3.3	1	ME170 CLAMP PART 2	
3.4	1	THREAD V2	FASTENER
3.5	1	90866A029_ZINC-PLATED STEEL WING NUT	SCREW FASTENER
4	1	91771A144_PASSIVATED 18-8 STAINLESS STEEL PHILLIPS FLAT HEAD SCREW	SCREW

Figure 6.1: UofI Assembly Template Exploded Part Drawing

Items 3.4, 3.5, and 4 are off-the-shelf items.

7. Assembly drawing w/ Cross Sections

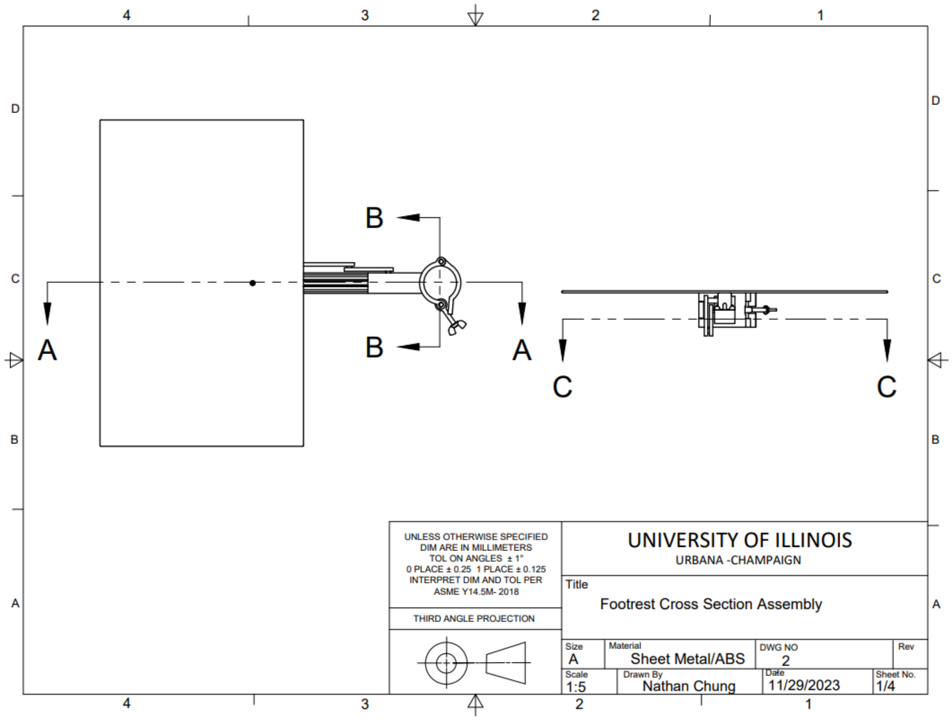


Figure 7.1: Footrest Cross Section Assembly Cutting Planes View Drawing

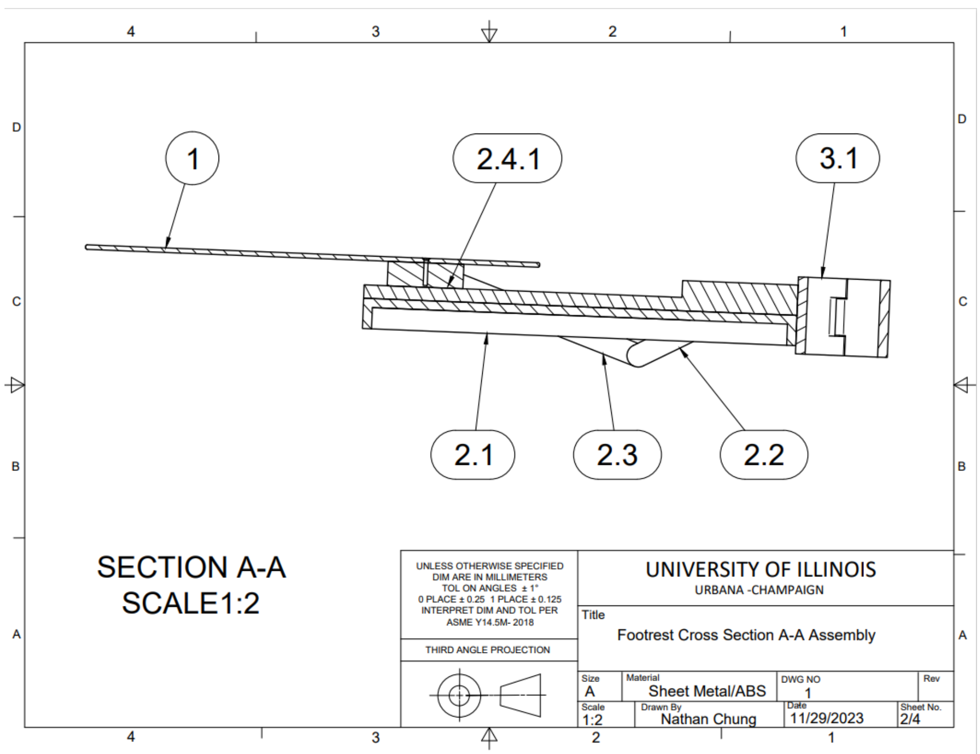


Figure 7.2: Footrest Cross Section Assembly Section A-A View Drawing

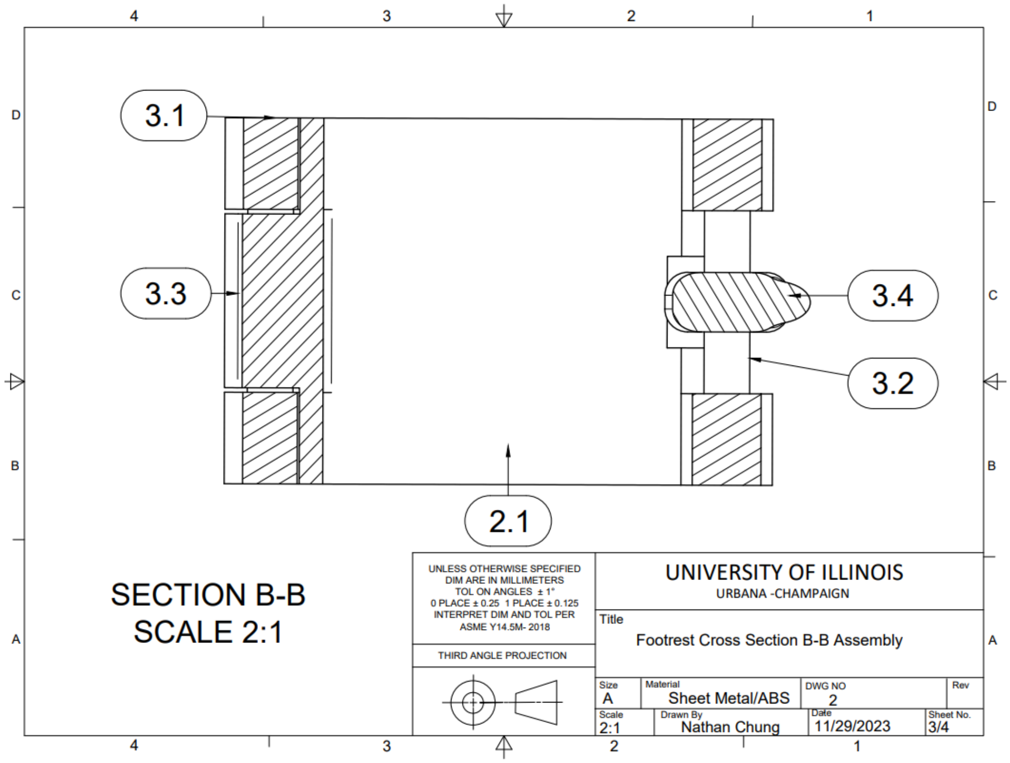


Figure 7.3: Footrest Cross Section Assembly Section B-B View Drawing

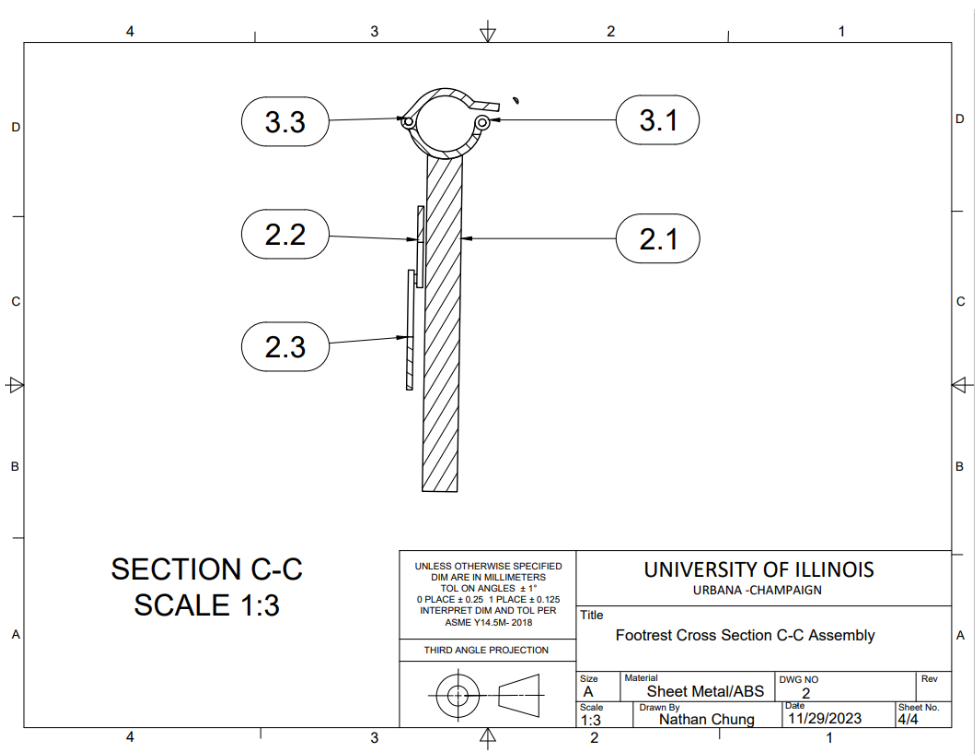


Figure 7.4: Footrest Cross Section Assembly Section C-C View Drawing

8. Detailed Engineering Part Drawings

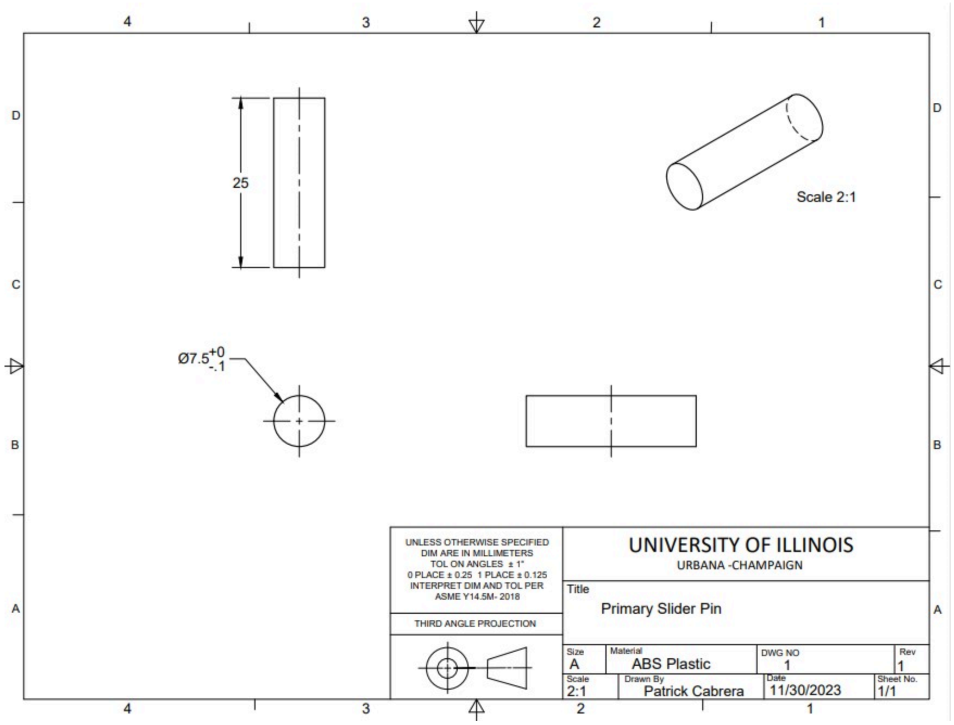


Figure 8.1: Primary Slider Pin Part Dimensioned Drawing

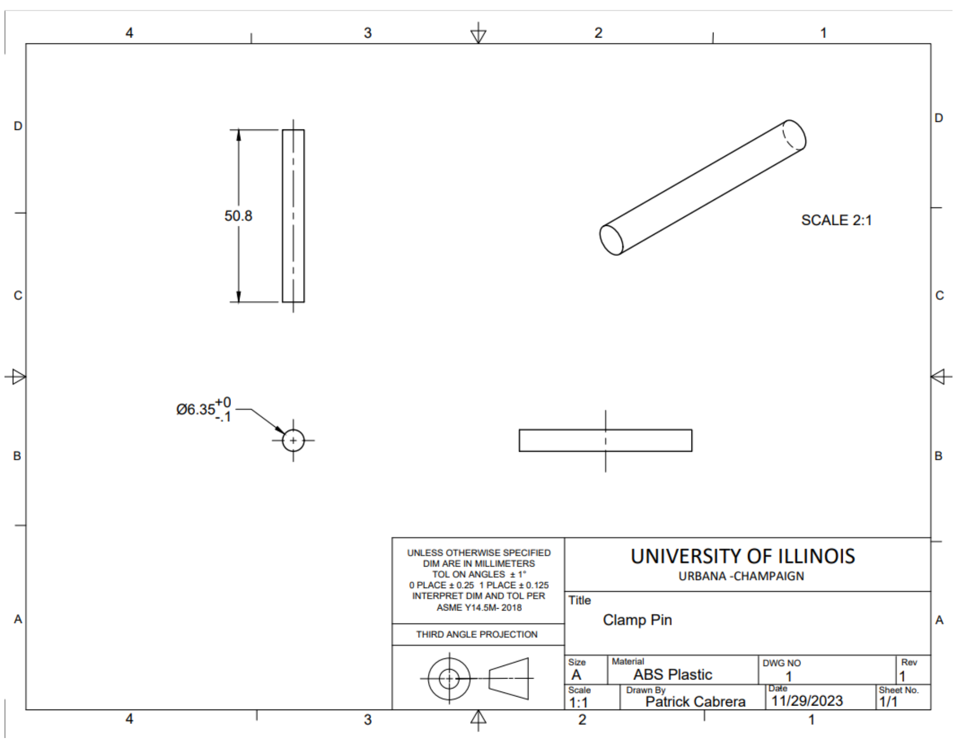


Figure 8.2: Clamp Pin Dimensioned Drawing

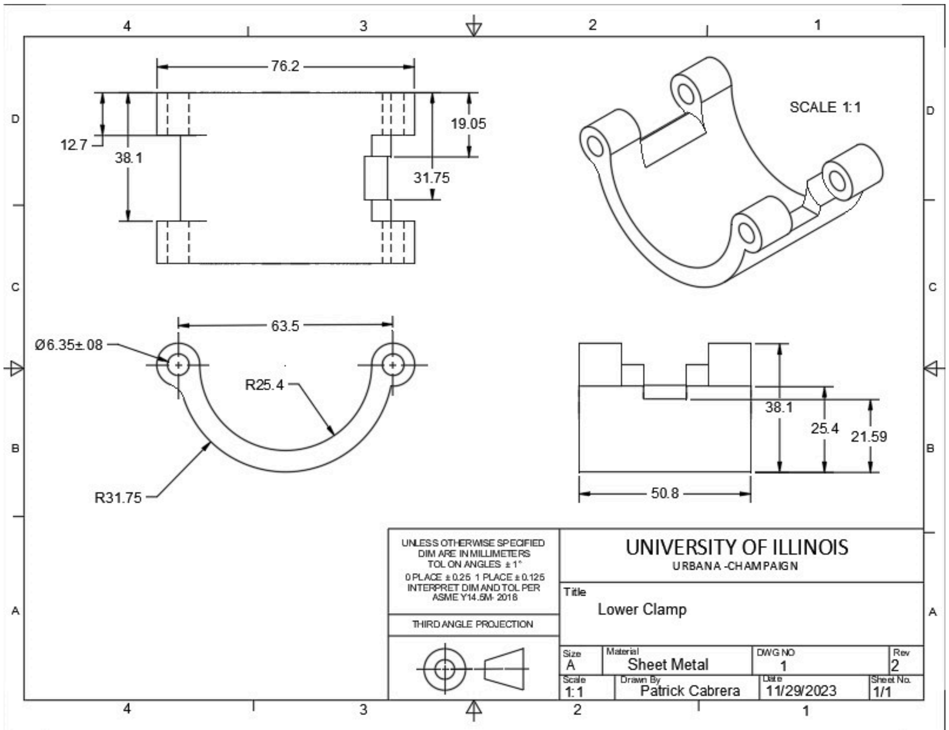


Figure 8.3: Lower Clamp Dimensioned Drawing

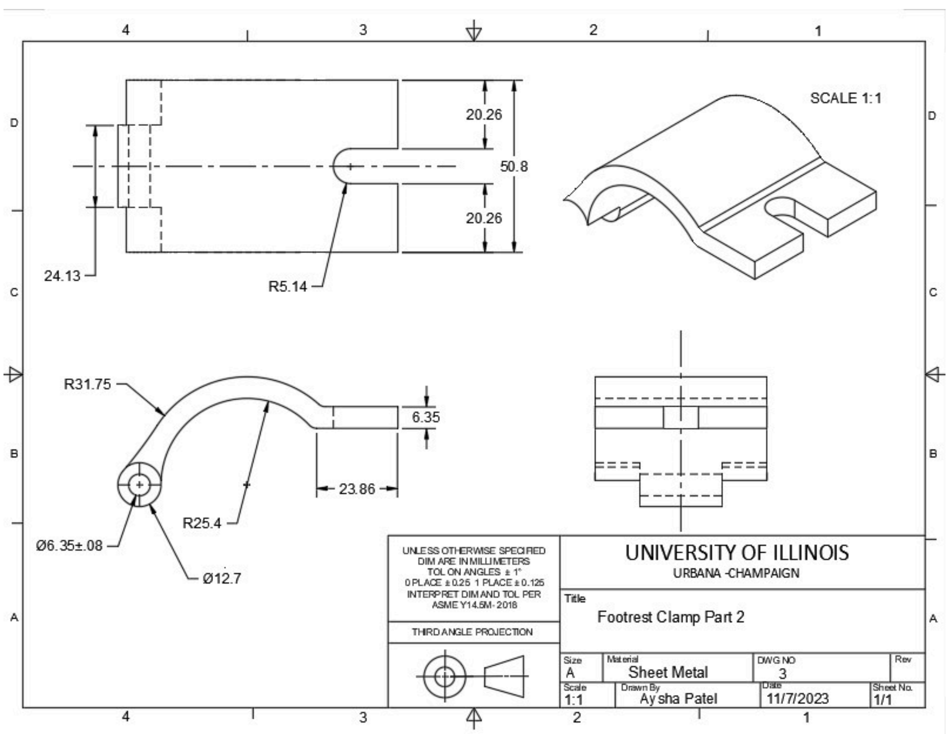


Figure 8.4: Upper Clamp Dimensioned Drawing

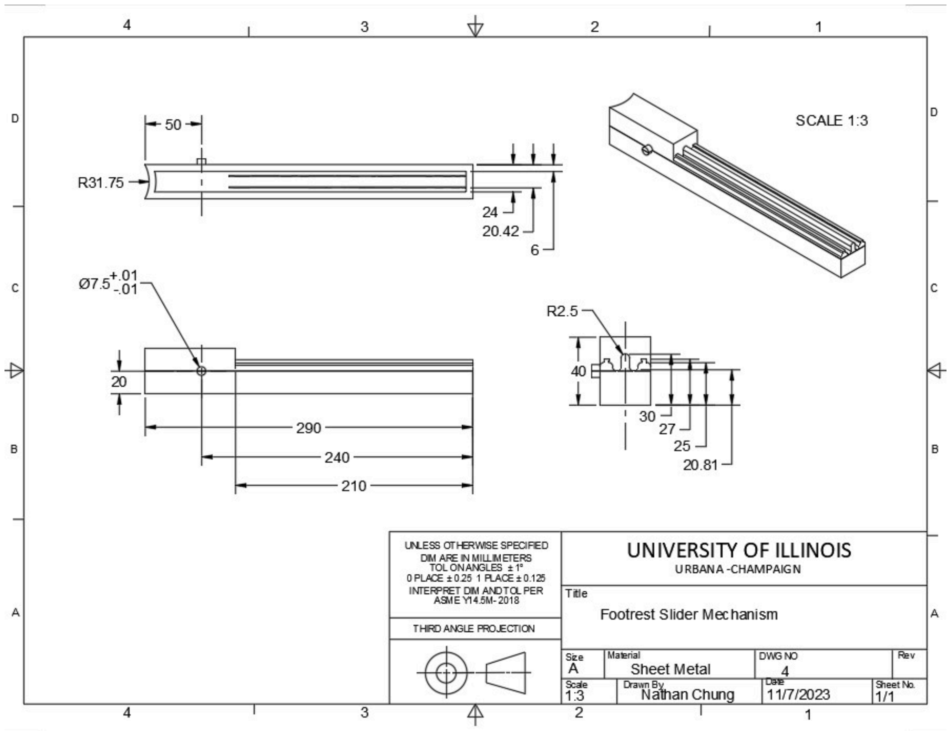


Figure 8.5: Slider Rail Mechanism Dimensioned Drawing

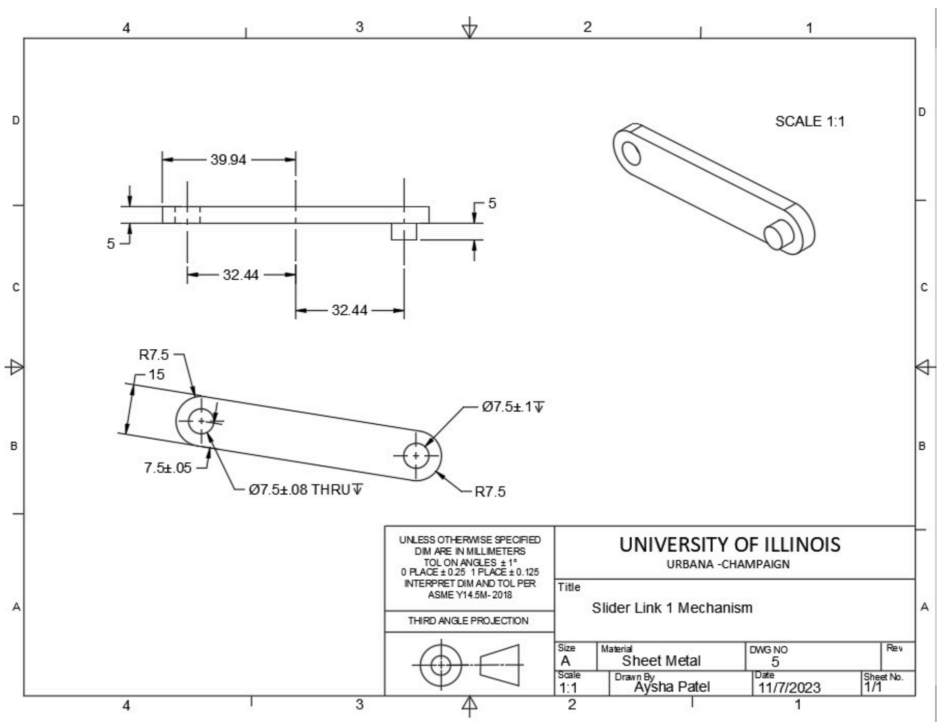


Figure 8.6: Link 1 Mechanism Dimensioned Drawing

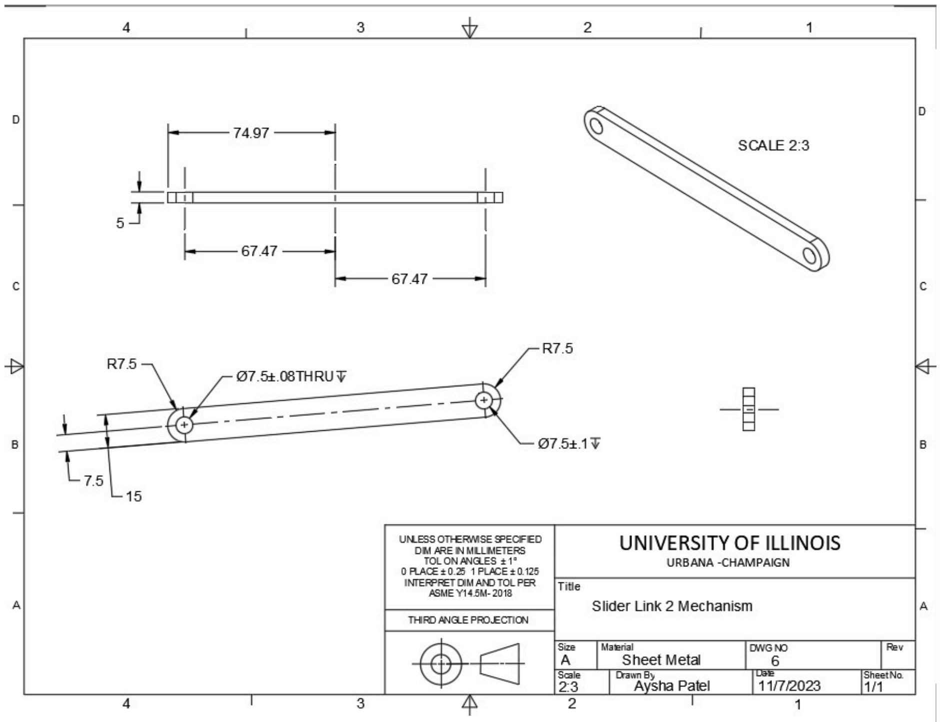


Figure 8.7: Link 2 Mechanism Dimensioned Drawing

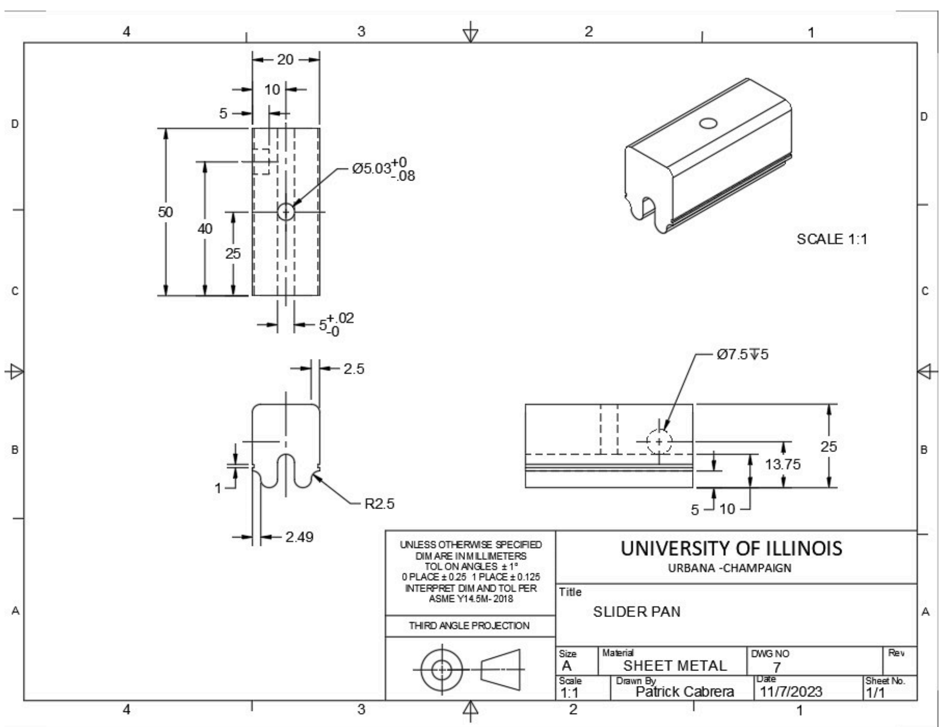


Figure 8.8: Slider Pan Dimensioned Drawing

9. Tolerance Analysis

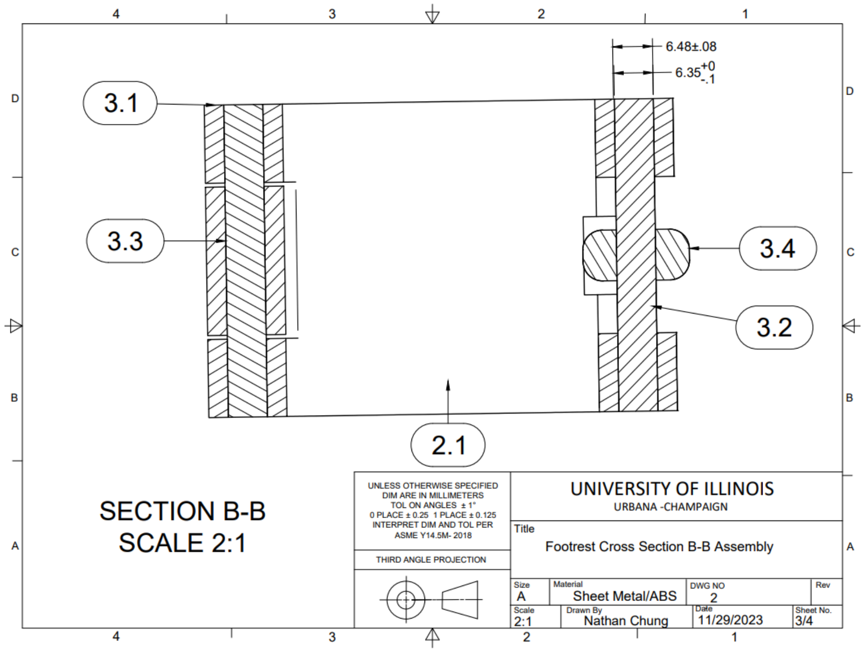


Figure 9.1: Cross-Section Clamp View with Pin and Hole Dimensions

The radial fit outlined in the dimensioned pin and hole drawing above is meant to be an H7/g6 sliding fit, allowing for a bit of interference in the worst case but the pin is still accurately fit into the hinge shaft hole with limited range of movement. This decision is also in line with machine tooling commercial tolerancing capabilities and industry standards. The radial worst-case clearance is 0.29mm and the worst-case allowance is 0.05mm.

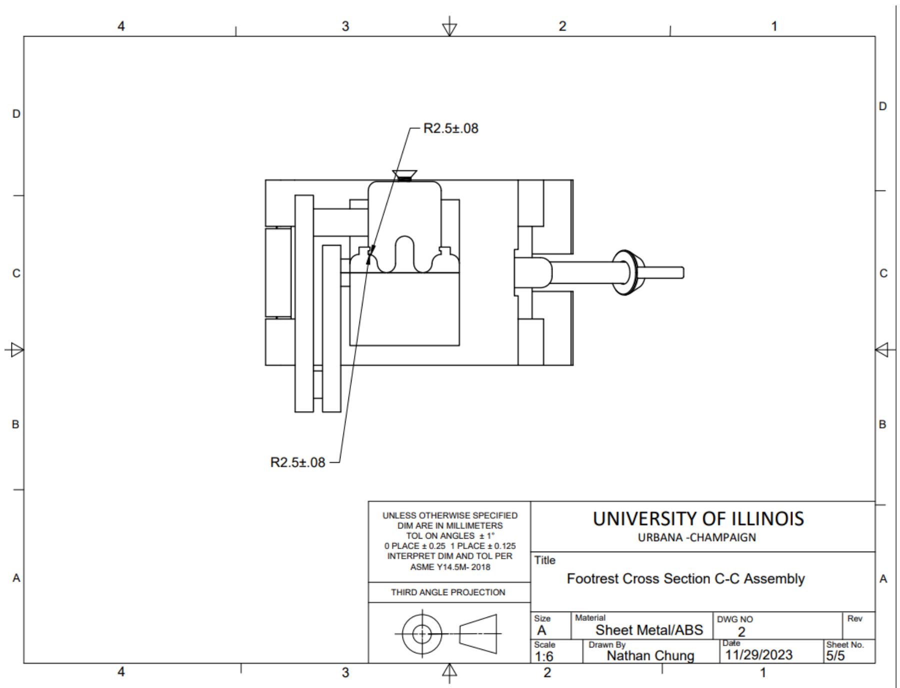


Figure 9.2: Cross Section View Slider Pan and Rail Drawing and Dimensions

The axial fit between the slider pan and rail is meant to be a locational transition H7/k6 fit with greater interference to maintain contact between the pan and rail at all times and ensure there is no catastrophic failure of the design. The worst-case clearance is 0.26mm, and the worst-case allowance is -0.26mm.

10. Materials, Manufacturability, and Cost Analysis

Part #	Description	Material and Manufacturing Method (or order details if an off-the-shelf item)	Part Cost (fully burdened and catalog)	Quantity	Total Part Costs	Investment Costs (tooling, fixtures etc)
1	**Leg Rest Platform**	Molded Plastic - ABS : Injection molding	$6.80	1	$6.80	$16,234
2	**Slider Component**				$0.00	
2.1	Main Body	Steel. Cold Worked - Prog Die : Sheet Metal	$4.93	1	$4.93	$14,762
2.2	Joint Leg	Molded Plastic - ABS : Injection Molding	$0.22	1	$0.22	$5,118.37
2.3	Joint Leg	Molded Plastic - ABS : Injection Molding	$0.14	1	$0.14	$5,716.85
2.4	Slider	Steel, Cold Worked - CTL/Bend : Sheet Metal	$4.02	1	$4.02	$89.09
2.4.1	Main Slider Pin	Molded Plastic - ABS : Injection Molding	$0.01	1	$0.01	$4,383.09
3	**Clamp**					
3.1	Saddle Clamp Part	Steel, Cold Worked - CTL/Bend : Sheet Metal	$0.28	1	$0.28	$68.29
3.2	Pin	Molded Plastic - ABS : Injection Molding	$0.16	2	$0.32	$4,738.18
3.3	Main Clamp Part	Steel, Cold Worked - CTL/Bend : Sheet Metal	$0.17	1	$0.17	$68.22
3.4	Fastener	Steel, Cold Worked - CTL/Bend : Sheet Metal	$0.70	1	$0.70	$74.23
3.5	Screw Fastener	McMaster Carr - catalog ID : 90866A029 (Vol. Disc. Applied)	$0.18	1	$0.18	$0
4	**Screw**	McMaster Carr - catalog ID : 91771A144 (Vol. Disc. Applied)	$0.08	1	$0.08	$0
				TOTALS	**$17.85**	**$51,252.24**

Figure 10.1: Manufacturing Bill of Materials (BOM)

Product manufacturing methods were determined firstly based on project brief constraints/ In terms of materials, the slider and other parts taking large amounts of load were made out of sheet metal to ensure minimal deflection and allow for a larger width that was needed in the design. The platform and pins that are not ultimately taking the majority of the load were made from injection molding ABS plastic because of the safety concerns with daily use of sheet metal items as well as the need for a lightweight product.

For selling price, the specifications outlined previously set the selling price of the product in a range of $25 to $35. To gain a minimum of a 10% profit on each item sold, the manufacturing and shipping cost needed to be under approximately $20. With this in mind, it was vital for the product to be made predominantly from ABS plastic wherever possible.

11. Conclusion

Ultimately, the product is not ready to go to market at this time. Further testing is needed to ensure it meets all necessary ANSI/BIFMA X5.1 standards for office safety and can successfully handle the specified load for the expected lifespan of 4 years. This would be a medium-risk product as there is limited infrastructure investment needed, with approximately $20,000 needed in tooling. However, it is difficult to forecast the sales volume of the product over 5 years and the rate at which investors would see a significant return. Specifically, with current working conditions shifting once again towards in-office desk work, the product has the potential to reach the sales goal outlined in the design brief. The target retail price is realistic as it is approximately $30 minimum, and after taking into account distribution, manufacturing, and additional costs there will be a 10% profit margin minimum. Therefore, with some further testing and design adjustments, the product has the potential to be market-ready in 1-2 years.