Crutch Buddy: Final Report

User Manual **2**

- Design for Manufacturing 3
  - Manufacturing the Male/Female Clamp Components 3
  - Manufacturing the Handles 4
  - Manufacturing the Rods 4
- Design for Servicing 5
  - Servicing Instructions 6
  - CAD Modification for Servicing 7
- Design for Sustainability 7

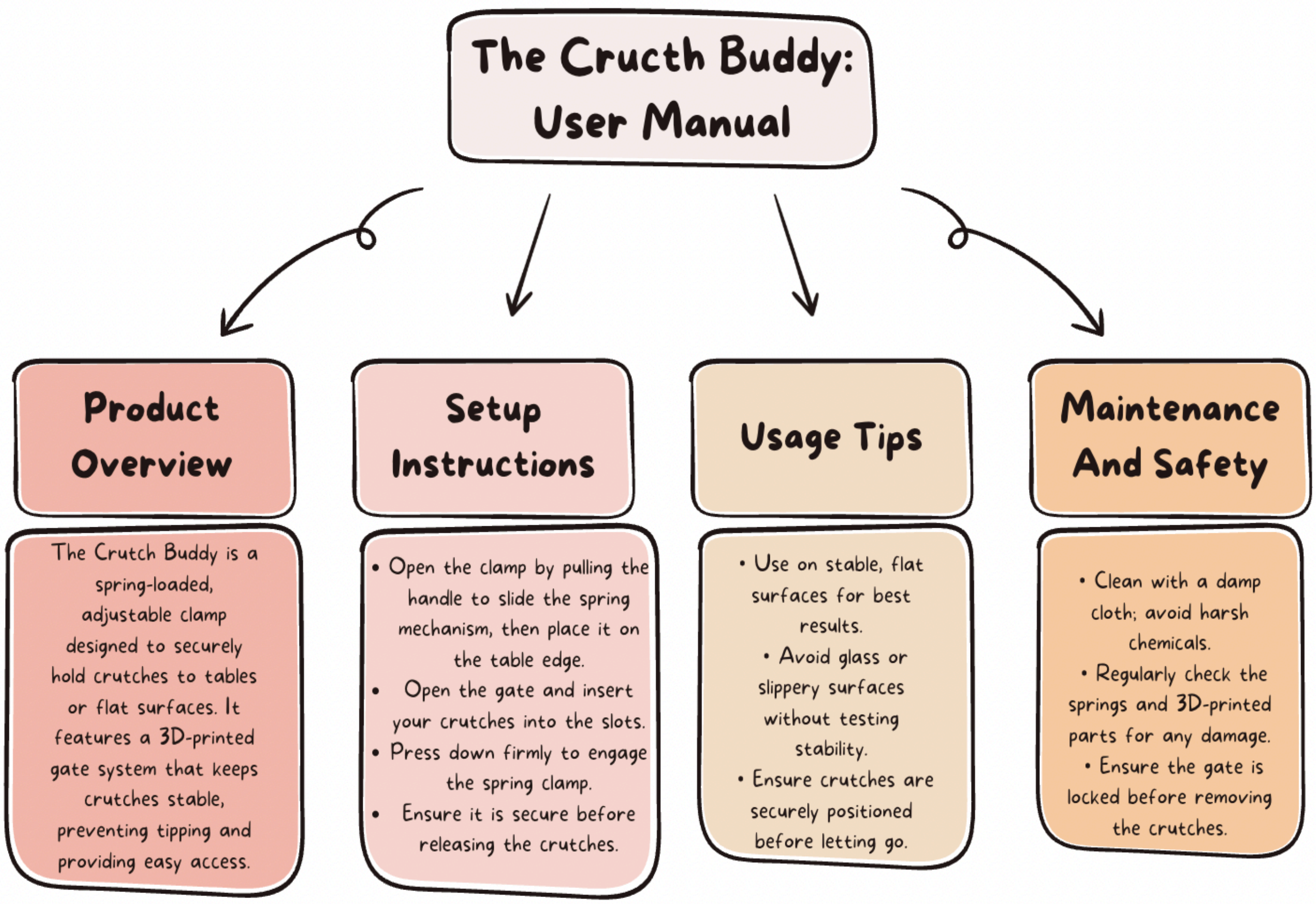
Bill of Materials **9**

Additional Instructions **10**

Final Product CAD Model **11**

Reflection **11**

User Manual



The Crutch Buddy enhances accessibility by securely holding crutches to flat surfaces, preventing tipping and minimizing tripping hazards. Its lightweight, portable design makes it easy to use at home, in medical facilities, or on the go, ensuring stability and convenience wherever it is needed.

It is designed for easy one-handed operation, making it easy to use for users with limited strength. The spring mechanism requires minimal force to secure so that this simple design makes setup quick and damage-free.

For best stability, position the Crutch Buddy near the edge of the table. It’s also perfect for travel; compact enough to fit in a bag and easy to attach to surfaces wherever you go. Besides crutches, it can also hold canes and walking sticks for added versatility.

To maintain smooth operation, occasionally lubricate the spring mechanism. Tighten any loose screws if you notice instability. Avoid long exposure to sunlight to prevent material wear. Regular care will keep your Crutch Buddy reliable and safe.

Design Decision Making

Design for Manufacturing

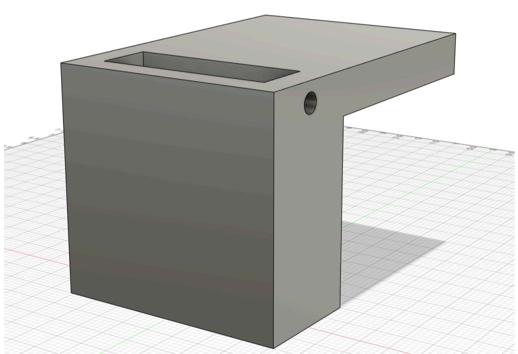
Crutch Buddy is composed of six unique parts. The main body consists of a male and female clamp components. Four identical rods are inserted into the main body, a rubber sheet is superglued to the top (male) clamp side, and two identical springs are located on each side to control the clamp's motion. The rotating handles are inserted onto the rods and are identical on each side.

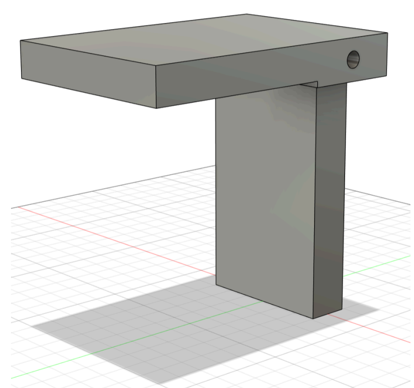
Two of the Crutch Buddy components are sourced from an industrial supply distributor (McMaster-Carr): the rubber and the springs. The parts remaining to be manufactured in house are then only the male and female clamp components, the rods, and the handles.

Manufacturing the Male/Female Clamp Components

These two components are the largest part of the assembly. Despite this, they have simple, flat geometry. To manufacture these components on a large scale, we would redesign them to leverage laser cutting. Due to the larger wall thicknesses required for these two components (to withstand the spring force during clamping and the internal moment due to the difference in the line of action of the spring force and normal force from the table) and non-uniform geometry, other plastic manufacturing techniques like injection molding are not possible. To conform with the lightweight structure and portable form factor requirement established in the design criteria, metal is also ruled out as an option. Laser cut acrylic provides an easily and cheaply scaled alternative that meets the design criteria.

Each flat face of the male and female clamp components will be an individually laser cut piece. These pieces will be screwed together using internal brackets to achieve the same final geometry as the 3D printed prototype. M2 fasteners and corresponding nuts will be used for ease of assembly and replaceability. Please note: this manufacturing technique was not reflected in the final CAD submission as only two were required via the rubric – the two changes modeled in CAD are discussed below.

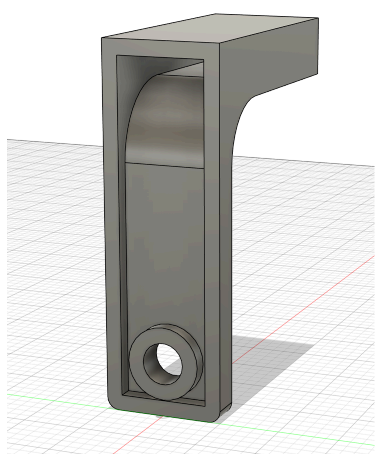




Manufacturing the Handles

Injection molding was chosen as the optimal method to manufacture the handles. Other plastic manufacturing techniques like thermoforming are not possible due to its thicker 3D geometry. After modifying the CAD model to reflect the manufacturing technique, injection molding will accurately produce handles that can be produced on a large scale. There are some drawbacks of injection molding the handles, though. Preparing tooling and molds takes time and iteration, as well as a fair amount of capital investment. Testing and inspecting the results for tolerances and proper fit are necessary, meaning the setup process is also more involved. Once completed however, the handles can be manufactured easily and without post-processing or other assembly.

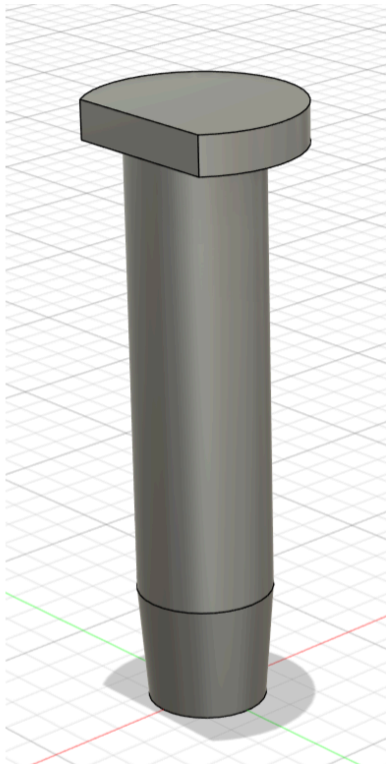
To prepare for injection molding, the handles must be redesigned to support the material choice and be otherwise conducive to the injection molding process. The first design consideration is material choice. The worst case loading scenario for the handles occurs in the upright position during application of the Crutch Buddy to a thick table. In this position the handles experience and force equal to that of the restoring spring force in both the tensile and shearing directions. To avoid failure in these loading cases, a stronger material that supports a thicker wall is preferred. With this in mind, PC/ABS thermoplastic alloy was chosen. The handle was redesigned to incorporate a wall thickness of 0.130” (see picture below), which falls on the higher end of the recommended range for PC/ABS of 0.035” - 0.140” to accommodate the loads of use. PC/ABS was chosen because it tends to handle thicker walls better than regular ABS and is cheaper than regular PC. To further support the walls and add extra strength, internal ribs were added to the handles. They were designed to be within the recommended 40-60% thickness of the adjacent walls. Due to the simple geometry, we do not expect ejection from the molds to be a challenge, but if it becomes apparent during manufacturing, we would add a draft to the handles to eject from the molds easier.



Manufacturing the Rods

The rods cylindrical and 3D geometry again specify injection molding as the optimal manufacturing technique. The rods are load-bearing structures facing the same forces experienced by the handles–but entirely in the shearing direction. For this reason, the same material choice was made:

PC/ABS with the same wall thickness of 0.130” (again on the higher end of the recommended range for added strength). With the rods, we can expect the long cylindrical geometry may cause ejection issues. To prevent this, a slight draft (see picture below) was added at the bottom of the rod redesign to ensure ease of injection after the molding process is complete.



Design for Servicing

Customer Service Manual

Component	Why It Needs Servicing	Recommended Action	Who Will Service This
Springs	May lose stiffness, or deform after a few years making the clamp lose its grip	Order Replacement from McMaster-Carr (Part 5108N517) or another industrial supply company	User
Rubber grip	May wear down, break, or come off over time	Super glue a replacement rubber sheet	User

Connection Rods	If connection rod snaps in half, breaks or wears down	Buy new part from our company	User
Handles	Breaks or doesn't rotate	Buy a new part from our company	User
Male/Female Clamp Components	Breaks	Buy a new crutch buddy	N/A

Servicing Instructions:

Springs: If the springs break follow these steps to replace them:

Purchase Replacement:

- Go to McMaster-Carr and search for part number 5108N517 to buy a replacement spring

Replacement Procedure:

1. Remove broken springs by spinning the rods 180 degrees so that flat side is up and lifting them over the end caps of the rods
2. Install the new springs by lifting them over the same end caps, and spinning the rods 180 degrees back to the initial position, preventing the spring from sliding off during use

Note: the servicing design change is reflected with the redesigned rods in the final CAD files

Rubber Grip: If the rubber part detaches or wears down:

Purchase Replacement:

- If intact keep old part
- If not, buy a ⅛'' rubber sheet from Lowes, McMaster-Carr, or a convenience store nearby.

Replacement Procedure:

1. Disassemble the assembly using the instructions at the bottom
2. Cut the rubber sheet, if you need a new one, to match the area that contacts the table
3. Apply superglue to one side of the rubber
4. Press the rubber into place
5. Let dry under a weight for 24 hrs
6. Reassemble the Crutch Buddy

Rods: If the rod breaks or wears out

Purchase Replacement:

- Contact our company to order a replacement, as this is a custom part

Replacement Procedure:

1. Remove the connection rod dowels using the disassembly instructions below
2. Replace with new connection rods using the reassembly instructions below

Handles:

Purchase Replacement:

- Contact our company to order a replacement, as this is a custom part

Replacement Procedure:

1. Remove the handles using the disassembly instructions below
2. Replace with new handles using the reassembly instructions below

Instructions for Disassembly and Reassembly:

Disassembly:

1. Take off the connection rods
2. Take off the springs and handles
3. The two parts of the body will slide off

Reassembly:

1. Put together the two body parts by ensure the top piece is aligned in the same direction as the bottom piece
2. Place the handles on the top part aligned with the hole
3. Place the dowel through this
4. Then attach the spring
5. Repeat on both sides

CAD Modification for Servicing:

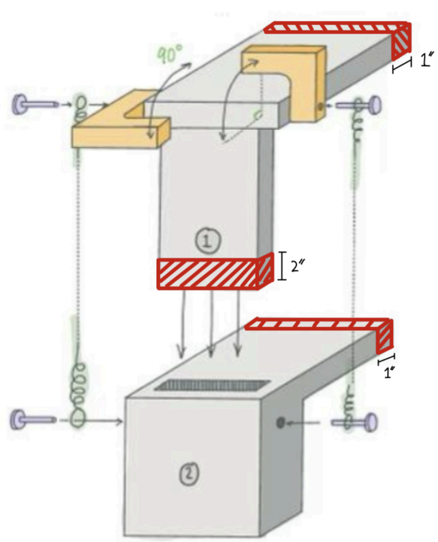
For easier spring replacement we changed the design of the end cap of the connection dowel to have a cutout designed to easily lift the spring out of the design while still holding it in place for usage. With this there is no need to disassemble the whole design for a spring replacement (see this change in the Design for Manufacturing part of this document).

Design for Sustainability

Overall, we are pleased with the design choices we made when it comes to sustainability. The bulk of our product can be recycled as the 3D printed filament is made of polylactic acid (PLA) and the springs of metal, both of which have processes for breaking them down and reusing. We anticipate that most consumers who care about the environment will take the time to recycle it, as the product can be manually disassembled and does not have that many parts. Both metal and PLA can be recycled and even if the product does end up in a landfill, the PLA will eventually decompose. Best of all, our product does not have any components that are dangerous to the environment, such as e-waste or toxic metals.

By obtaining the masses of the parts and using 2030's carbon footprint calculator, producing it outputs 2.25 kilograms of carbon dioxide, of which 1.48 comes from material acquisition (the majority), 0.4 from material processing, and 0.37 from assembly. Since we cannot control McMaster's production and transport processes, the best way to bring this number down would be to modify our own 3D printed parts.

Based on the 2030 calculator, design changes we can make are switching materials, reducing lengths where we can on the 3D printed parts, and taking an environmentally friendly approach when it comes to packaging for our product once we bring it to market. Although PLA is biodegradable, it does take more time to do so compared to other plastic-type materials. One alternative we found is polyhydroxyalkanoate (PHA) filament, which is produced naturally by fungi and bacteria, and it is not only more biodegradable, but more durable than PLA. Another idea would be to "shave off" areas of the 3D printed material that can be smaller without loss in functionality (see picture below and final CAD file). Through testing, we established that reducing the clamps by 1 inch can still fit on all tables, and most tables are not thick enough to warrant the length of the male clamp. This would have many added benefits, such as reducing manufacturing time, the energy it takes to 3D print, and the associated costs for both. Finally, we can modify the packaging of the product once it hits the market by avoiding plastic, which is notorious for being unable to decompose. For instance, we can eliminate using opt for plant-based fibers when it comes to the box for the clamp and trays smaller components like the rods and springs, like how Apple switched over to. Since the rods are prone to breaking due to their low cross-sectional area, we need some material to cushion them during transport. In lieu of plastic-based packing peanuts, we can use corrugated cardboard, which is biodegradable and can be sourced from shredding recycled old boxes instead of having to make them from scratch.



Weight of Parts: (for 2030 Calculator)
Weight of springs: 3.6 g. each (2) → 7.2 g total
Weight of gate: 17.2 g. each (2) → 34.4 g. total
Rods: 1.5 g. each (4) → 6.0 g. total
Female component: 204.5 g.
Male component: 271.2 g.
Weight of rubber based on density, neoprene (⅛" by 5.25" by 4"): 1.75 g.
Total: 525.05 g.

<u>Bill of Materials</u>

Assembly: Crutch Buddy								
Date created: 5/12/2025 Created by: The Microchips Last updated: 05/12/2025 Updated by: The Microchips								
Part No.	Name	Supplier	Manufacturer	Supplier Part No. / CAD File Name	Unit Cost	Quantity	Total Cost	Design Phase
001	Pinion Gear	McMaster	N.A	2662N343	$11.84	1	$11.84	ODP 3 (Not Included)
002	Rack	McMaster	N.A	2662N54	$3.89	2	$7.78	ODP 3 (Not Included)
003	Shaft	McMaster	N.A	8669K634	$6.39	1	$6.39	ODP 3 (Not Included)
004	Crank	McMaster	N.A	6547N15	$23.49	1	$23.49	ODP 3 (Not Included)
005	Extension Spring (k = 1.7 lbs/in)	McMaster	N.A	9654K306	$10.58	1	$10.58	ODP 3
006	3D Printed Pegs	RPL	RPL	Spring_Connection_Rod	$1.26	4	$5.04	ODP 3
007	Extension Spring (k = 1.3 lbs/in)	McMaster	N.A	5108N517	$18.85	1	$18.85	ODP 5
008	3D Printed rods	RPL	RPL	Final_Spring_Connection_Rod	$2.41	7	$16.87	ODP 5

Assembly: Crutch Buddy								
009	3D printed handle	RPL	RPL	Handle_Gate	$22.26	3	$66.78	ODP 5
010	Rubber Sheet	McMaster	N.A	1374N25	$30.16	1	$30.16	ODP 3 + 5
011	3D Printed “Female” Clamp Component	RPL	RPL	Main_Body_Female	$170.98	1	$170.98	ODP 3 + 5
012	3D Printed “Male” Clamp Component	RPL	RPL	Main_Body_Male	$193.53	1	$193.53	ODP 3 + 5
Total Spending: $562.29								

Additional Instructions:

Components: 1 “Male” Clamp Component, 1 “Female” Clamp Component, 2 Handles, 4 Rods, 2 Springs

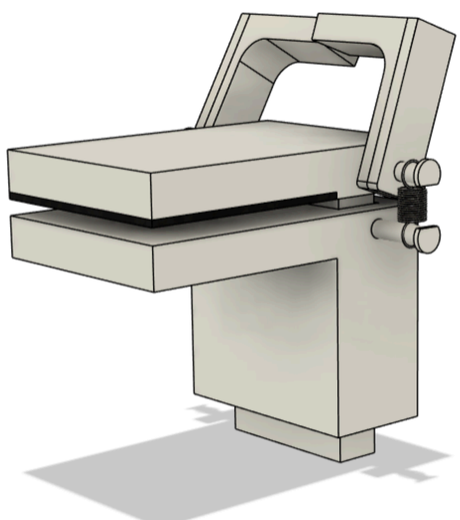
Usage:

1. With one hand holding the handle upright, and the other holding the base of the Crutch Buddy, open the clamp
2. With the clamp open, place it on the desired table or surface and close
3. Lower one handle/gate and slide your crutch through the slot
4. Slide your second crutch into the same slot
5. Lower the second handle/gate
6. Evenly space the two crutches in the allotted space

Assembly:

1. Insert the male component into the female component
2. Insert two rods through either loops of one spring
3. Insert one of these rods through the hole in a handle component
4. Insert the rod with the handle into the upper hole on one side of the male/female components assembly
5. Insert the second rod into the lower hole on the same side of the assembly
6. Repeat steps 2-5 using the remaining spring, two rods, and handle component on the other side of the assembly

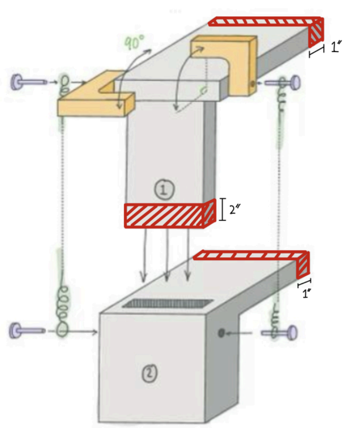
Final Product CAD Model

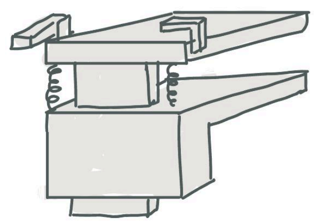


Final Recommendations

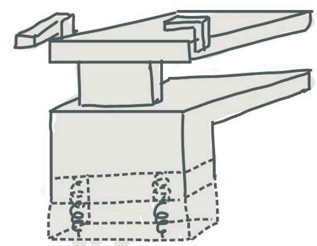
After developing our final prototype of Crutch Buddy for ODP 5, we've identified the need to refine and improve. At this stage, our focus is on redesigning certain elements to eliminate excess material and enhance the product's overall usability, efficiency, and ergonomics.

If we were to further improve our prototype, the Crutch Buddy, we identified any excess material that isn't essential to its function. As described in the Design for Sustainability section above, we would shave off excess on the tips of our product. A goal if we were to further improve our prototype we would streamline the design to make it lighter, more comfortable, and more efficient for users. In addition to reducing the overall length of some pieces that are unnecessary, we would also try to find a way to make the spring more sleek with the overall design. For our ODP 5 prototype, the springs are attached to pegs which are attached to the main body. The pegs stick out slightly awkwardly, and if dropped could make the pegs susceptible to breaking. By shaving off unnecessary components and making the spring system more sleek to the body, we can reduce overall weight and bulk, making the Crutch Buddy easier to handle and more practical for everyday use. This refinement process would make the Crutch Buddy more polished and user-friendly.





Possible spring sleekness iteration #1



Possible spring sleekness iteration #2

Reflection

Our team worked through the design process for the Crutch Buddy with strong teamwork and adaptability. One aspect that went particularly well was how quickly we were able to move from initial ideas to physical prototypes. Using 3D printing, we could rapidly test our designs, identify problems, and make adjustments without major delays. This helped us improve the clamp mechanism and the 3D-printed gate system so that it held crutches securely and was easy to use. The flexibility of 3D printing allowed us to experiment with different geometries and materials, which made our iterations much more efficient. Communication within the team was also a major strength. We held regular meetings to discuss our progress, address any issues, and make sure everyone was on the same page. This open communication helped us solve problems quickly and kept the project moving forward smoothly.

One of the main challenges we faced was ensuring the durability and functionality of the 3D-printed parts, especially the handle and spring mechanisms. During testing, we noticed that the original strap-based design did not provide enough support, so we decided to replace it with a 3D-printed gate system. This change greatly improved the stability of the crutches during use. We also realized that the original spring constant was too high, making it difficult to clamp onto tables. To fix this, we replaced the springs with ones that had a lower stiffness, which made the Crutch Buddy easier to open and adjust while still holding firmly. Another challenge was addressing minor deflection in the handles during use. We considered design adjustments and material changes, but ultimately reinforced key areas to improve strength.

Through this project, we learned how important clear planning and communication are during a design process. We found that understanding each person's strengths and weaknesses allowed us to divide tasks more effectively and avoid delays. It also showed us how important it is to be flexible when designs don't go as planned. Our ability to quickly adapt and make improvements was a big part of our success. We also gained a better appreciation for project management—keeping track of deadlines, organizing team meetings, and making sure we stayed on task. Overall, working on the Crutch Buddy taught us a lot about teamwork, problem-solving, and the value of quick iteration.