GNG1103

Design Project User and Product Manual

SELF CENTERING FLUSHBOLT INSTALLATION JIG

Submitted by:

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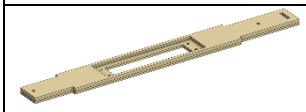
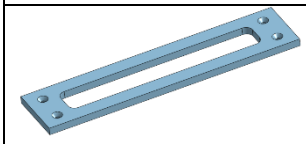
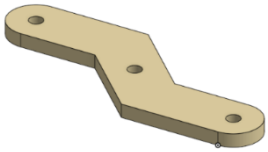
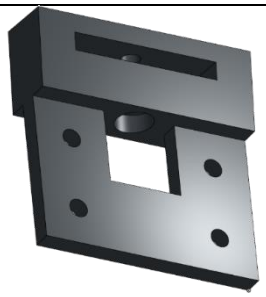
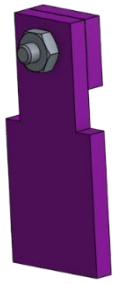
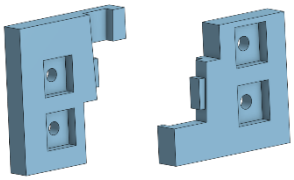
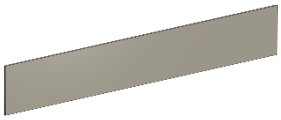
Glossary

Table 1. Glossary

Term	Acronym	Definition
Door style	-	The vertical pieces of the door. This hardware mounted to the right and left of the door.
Door rail	-	The horizontal pieces of the door. This hardware mounted to the top of bottom of the door.
Flush bolt	-	A discreet and functional hardware component designed to secure the inactive door leaf.
Jig	-	A device that holds a piece of work and guides the tools operating on it.

Table 2. Parts List

Render	Name	Material
	Side Plate	50% 1/4" MDF and 50% 1/8" MDF
	Jig Holder	33% ¼” MDF and 66% 1/8” MDF
	Jig	6061 Aluminum
	Parallel Bar	¼" MDF

	Side Pivot	3D printed PLA specifically with 0.8mm nozzle
	End stop	¼" MDF
	Clamp holder	3D printed PLA specifically with 0.6mm nozzle
	Pump-clamps	Steel bar. Plastic handles
	Protection	1/8” rubber

1 Introduction

This User and Product Manual (UPM) is dedicated to a flush bolt adjustable door jig. This jig is adjustable to all AMBICO door thicknesses. The positioning for the cutout that this jig will provide is always 12” from the top or bottom of the door and is also assumed to always be centered horizontally. The team also assumed that an MDF and aluminium construction would be durable enough to resist machining conditions such as a loud and dusty environment. The jig also provides protection to the door material as well as a very strong clamping mechanism when it is used correctly.

The following document contains an overview of the product followed by set-up instructions. Next, there is a guide on the product use and solutions in case of troubleshooting. The last part of the document will contain the documentation of the process that the product has went through to reach all the standards when it comes to the main subsystems such as stability, adjustability, and protection.

Therefore, this manual will be useful for the technicians that will be using the product to ensure the correct use of the jig while conserving its product life. This jig should not be used on non-beveled doors as it can damage the jig and the door. Also, it will provide the users with all the directions to install and proceed with the jig functions with safe manners as this product contains several pinch points.

2 Overview

Flush bolts are a type of door hardware commonly used in commercial settings where improved security and accessibility are desired. While one might initially imagine a simple double door would be sufficient to allow oversized items to move in and out of most buildings, the question is how the doors should lock without requiring a central column which would obstruct the entryway. The most common solution is a setup called a 1-active door where one of the doors is semi permanently attached to the floor and ceiling using flush bolts and the other can freely open and close. When something large needs to pass through, the flush bolts can be retracted to allow the passive door to open as well.

Figure 1: An example flush bolt [1]

Because a flush bolt (obviously) sits flush with the edge of the door, a router is commonly used to remove material to make space for the hardware. Fortunately, flush bolt sizing is standardized at 6-3/4” long by 1” wide. Therefore, at a high level AMBICO needs a simple jig for use with a standard router to create the correct sized cutout for flush bolt installation. Complexity arises because AMBICO works with a variety of door thicknesses ranging from 1-3/4” to 2-3/4” thick and the cutout must always be placed centrally on the door. Additionally, to reduce the amount of friction between the passive and active doors, AMBICO uses a 4-degree chamfer on the edge of the door. This means that the jig will similarly need to account for this angle when it clamps on to the door.

The problem presented by AMBICO can be summarized as follows:

> "AMBICO door assembly laborers need to promptly, precisely, and safely create standard flush bolt cutouts on a variety of door geometries and orientations without resorting to manual measurements."

When comparing against the competition, the JigX jig has several key advantages related to the user needs. Firstly, it is substantially faster to install when compared to similar jigs which rely on threaded clamps which need to be turned many times to tighten on the door. As will be outlined later, the team measured an average installation time of less than 20 seconds thanks mostly to its pump-style clamps. Secondly, the jig is extremely easy to use thanks in part to its automatic centering functionality with no measuring or thinking required to handle all different door thicknesses. Finally, when compared to the competition, the jig is much more durable and easier to repair as it makes extensive use of fasteners allowing broken parts to be easily replaced when damaged.

Figure 2: Final jig prototype

At a high level the jig offers several unique features

- It can automatically center the cutout within the thickness of doors between 1-3/4” and 2-3/4”.
- It places the cutout 12” on center from the top or bottom of the door without measurement.
- It is compatible with a 4-degree bevel on the edge of the door.
- It features a user replaceable aluminium jig in case of damage from accidental contact with the router or to allow different sized cutouts.

Throughout the rest of this document the jig will be decomposed into three subsystems given below.

1. The stabilization subsystem is responsible for generating sufficient frictional force with the door to keep the jig stationary while routing. It consists of two pump-style f-clamps and holders to keep them attached for convenience.
2. The protection subsystem is responsible for ensuring the door is not scratched, dented, or marked up in any way during use. It consists of two large rubber pads to distribute the force over a large area.
3. The adjustability subsystem is responsible for automatically centering the jig cutout within the thickness of the door. It consists of two parallel bars hinged on four pivots. This subsystem will be explored in detail later on.

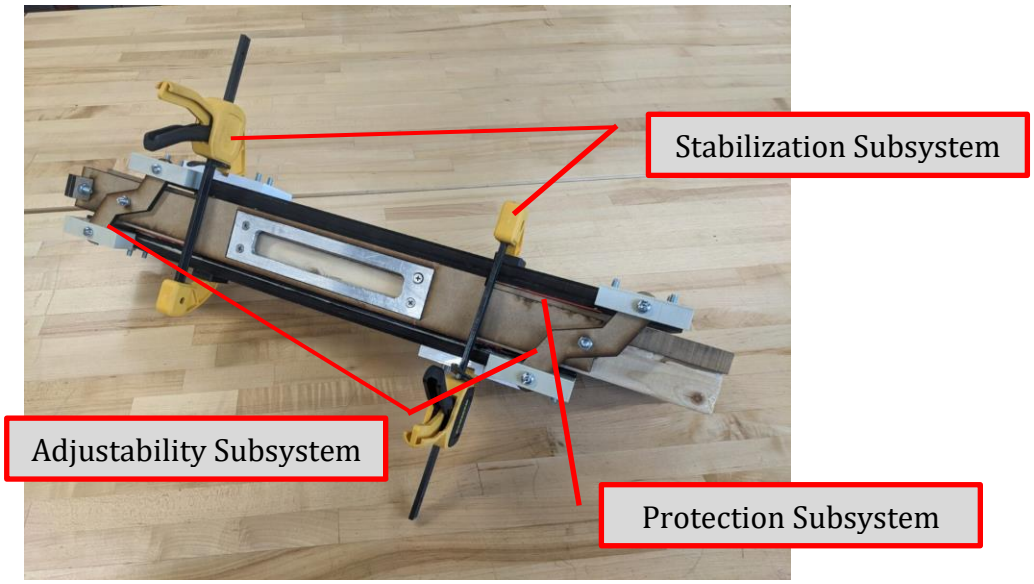


Figure 3: Jig subsystems

3 Using the System

The functionality of the self-centering jig can be broken down into 3 subsystems that help implement the desired qualities. Overall, the actions required to successfully attach the jig on the door can be described in the following steps.

1. Ensure that the clamps are fully open (unclamped). This can be done by pressing the small black trigger that will reset the clamps position.
2. Keep the jig unadjusted, meaning both side plates are at the same location and level.
3. Hook the jig onto the top of the door using the end stop of the jig. Ensure that the end stop is flush to the door surface (see figure 4)
4. Push or pull the side plates to adjust the jig to the desired thickness.
5. Push the yellow trigger of both clamps to secure the jig on the door. Test it by trying to move the jig. If it does not budge, then the jig is attached securely. If it does, make sure to pump the clamps further.

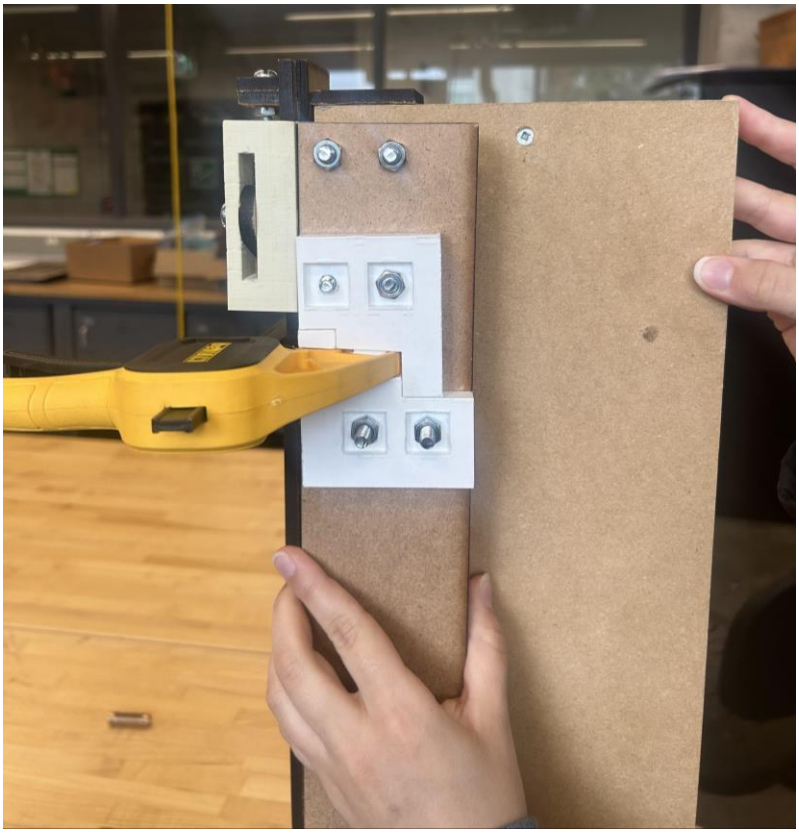


Figure 4 - End stop placed flush on the door surface

3.1 Adjustability Feature

The jig is designed to accommodate for the various door thicknesses using an adjusting mechanism. The x-mechanism enabled the sliding motion of the two slide plates to adjust to the thickness of the door at hand. In order to access this feature, all that needs to be done is to push along the two side plates. With little force, the side plates will slide in opposite directions and move into the desired thickness to be placed flush on the door.

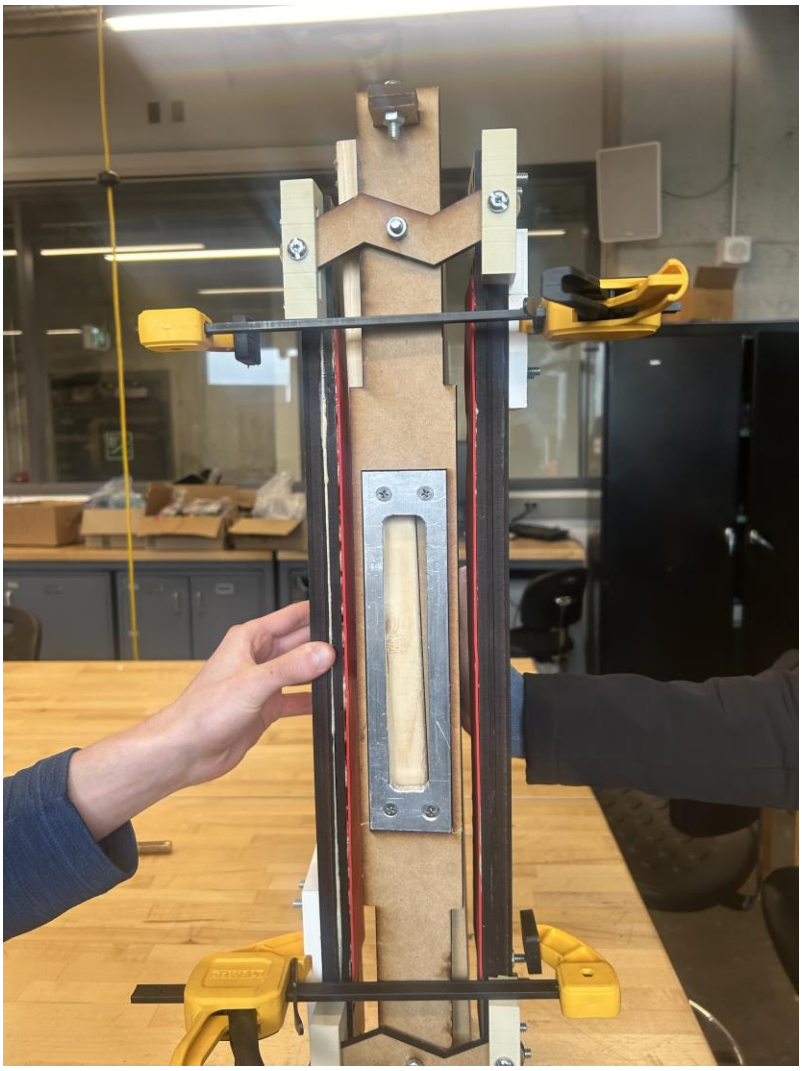


Figure 5: Jig placed on the door without any adjustments

Figure 6: Jig's side plates adjusted to door thickness

3.2 Stability Feature

There is a stability feature in place to ensure that the jig remains secured on the door at all times, especially during the routing process. To implement the stability system, there are two trigger clamps integrated into the jig to keep it firmly in place. To activate this feature, once the the jig is adjusted to the appropriate thickness, begin pressing the trigger for both clamps until the jig cannot move when shaken or pulled.

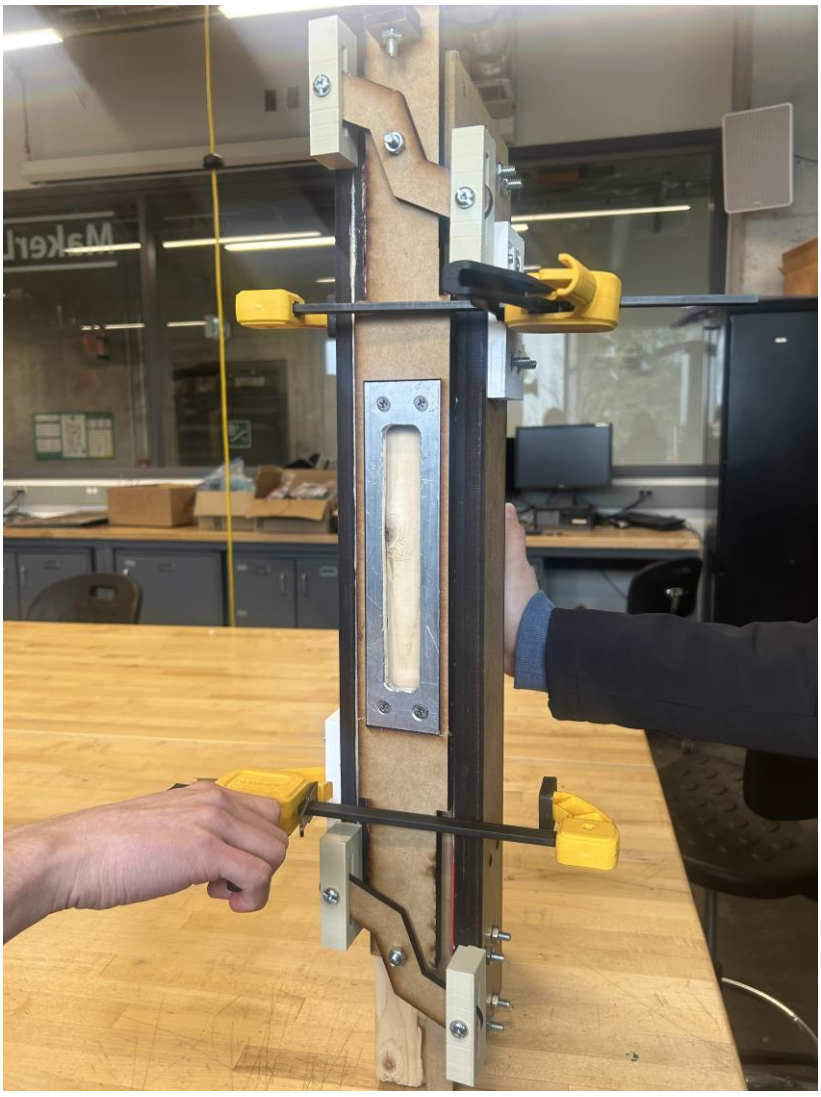


Figure 7: Clamps pumped to secure jig

3.3 Protection Feature

In order to ensure that the jig does not scratch or damage the surface of the door, a protection system is implemented in the design. Rubber sheets are added to the inside surface of both side plates. This ensures that the door surface in contact with the jig is protected at all time. The protection feature is already embedded within the jig's design so there is no action needed to activate it.

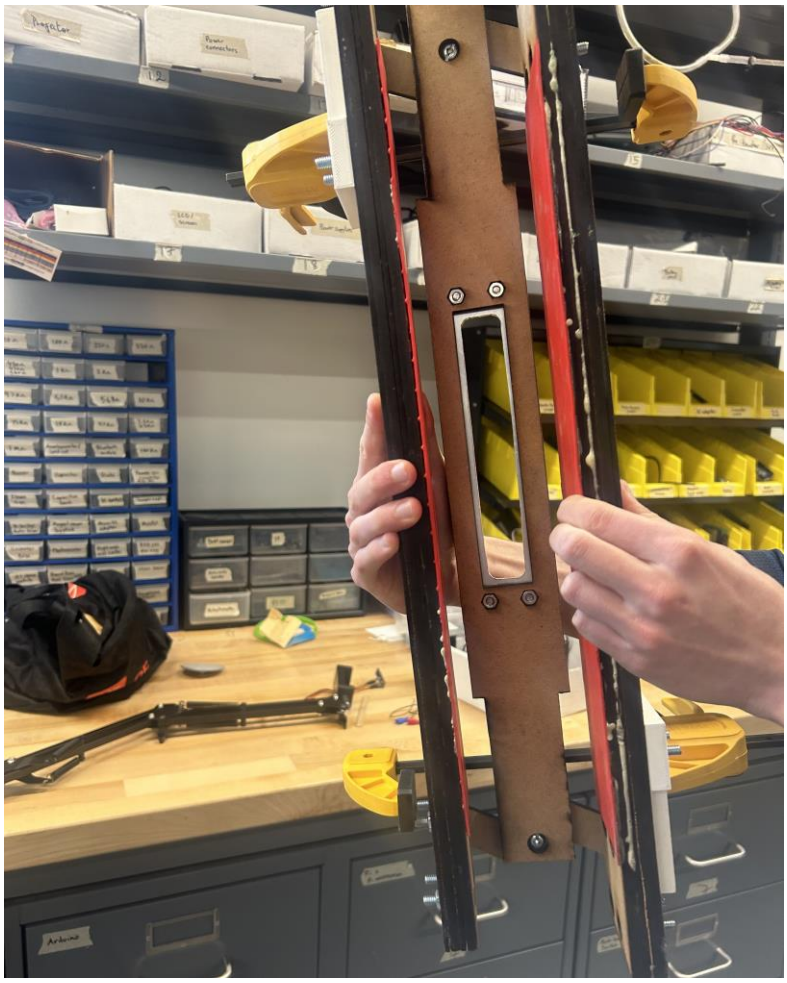


Figure 8: Rubber integrated to the side plates

4 Troubleshooting & Support

In this section, we cover error correction procedures that might be needed in the event of common malfunctions. It also includes a set of maintenance instructions to ensure the jig functions adequately and reliably for a long time.

4.1 Common Malfunctions

Malfunction/Problem	**Part(s) needing action**	**Corrective Action(s)**
Side plates getting jammed before completing full range of motion.	Bolts fastening jig holder to parallel bars.	Fasten bolts until the jig holder is completely even with each of the parallel bars. WARNING: Do NOT overtighten bolts as it might impede motion.
Trigger clamp(s) failure.	Trigger clamp(s) and clamp holder(s).	Change trigger clamp(s) for new one(s). Disassemble clamp holder(s) by unfastening bolts on side plates. Remove trigger clamp(s) and reassemble clamp holder(s) using new trigger clamp(s).
Damaged/broken part(s)* *Applicable to all parts that can be disassembled.	Part(s) needing replacement	Disassemble part(s) needing replacement and swap faulty part(s) with new part(s), then reassemble using new part(s).

4.2 Maintenance

Part needing maintenance	Action required
Bolts fastening jig holder to parallel bars.	Regular fastening is required to guarantee that jig holders remain flush with parallel bars. Fastening specified bolts every 4 to 5 utilizations is recommended for optimal performance. WARNING: Do NOT overtighten bolts as it might impede motion.

4.3 Support

In case of emergency assistance or needing to replace specific parts, contact Eduardo C. Delgado at ecaba024@uottawa.ca.

5 Product Documentation

5.1 Clamping subsystem

This subsystem's function is to provide the horizontal compression force necessary to secure the jig on the door. There were 5 main criteria that were optimized for: weight (minimized), compression force (>minimal force necessary to keep jig secure), manufacturing complexity (minimized), installation complexity (minimized) and cost (minimized). The first option was to use steel F-clamps, the second was to use reinforced nylon trigger or "pump" clamps. The trigger clamps were lighter and made installation easier and faster. The clamp holders were made of PLA because their geometry was too complex to manufacture without using a 3D printer.

5.1.1 BOM (Bill of Materials)

Part(s)	Material(s)	Source(s)	Qty	Unit Cost	Part Cost
Trigger clamps	Reinforced nylon, Steel, Rubber	DEWALT Trigger Clamps [4.5-inch 35 lb.]	1	$19.99	$19.99
Clamp Holder	PLA	MakerSpace	-	$-	$-
Bolts[0.25x1in]	Steel	Home Depot	4	$0.21	$0.84
Nuts[HEX0.25-20in]	Steel	Home Depot	4	$0.16	$0.64
Total					$21.47

5.1.2 Equipment list

- Ultimaker 2+ 3D Printer

5.1.3 Instructions

<table>
<tr>
<td>Parts involved in clamping subsystem

Side Plate (x2)

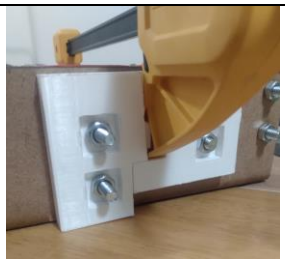
Clamps (x2)

Clamp holder parts (x2)

Bolts and Nuts (x4)</td>
<td> 
Figure 9: Clamping: Parts.</td>
</tr>
<tr>
<td>Step 1

Place the moveable jaw (unprotected) inside the clamp holder by making the rectangular surface of the jaw flush with the rectangular shape of the clamp holder (See Back View). Make sure the teeth of the clamp holder sits inside the space on the side of the jaw (See Front View).</td>
<td> 
Figure 10: Clamping: Step 1, Back view.

 
Figure 11: Clamping: Step 1, Front view</td>
</tr>
</table>

Step 2 Fasten the clamp holder (while it still holds the clamp) to the side plate using nuts and bolts.	 **Figure 12: Clamping: Step 2, Front View**
Step 3 Place the other part of the clamp holder so it is flush with the clamp holder part already attached to the side plate to close the clamp holder (See First view). Make sure the teeth of this second part sits inside the side of the jaw like in Step 2 (See second view). Fasten the bolts on the second clamp holder part to secure everything in place.	 **Figure 13: Clamping: Step 3, First view.**  **Figure 14: Clamping: Step 3, Second view.**

5.2 Adjustability subsystem

This subsystem's function is to allow the jig to adapt its geometry to any door thickness between 1¾" and 2¾" with a 4-degree bevel and 12" apart from the top of the door. MDF was chosen for most parts due to its low cost and ease of use (laser cuttable) compared to other materials such as steel. Another advantage of using MDF plates is it makes the jig fully disassemblable, which is convenient for transportation and for replacing parts in case some of them break with time. The side pivots were made in PLA using a 3D printer because of the complexity of their geometry.

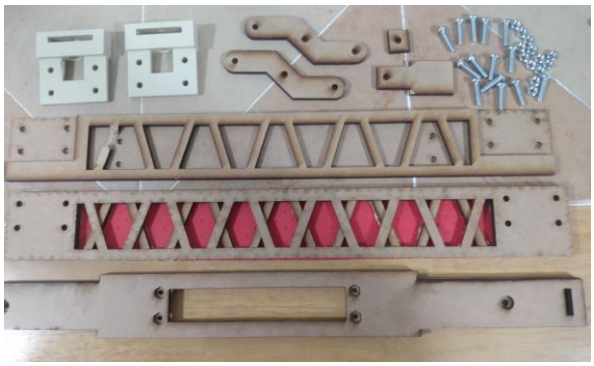
5.2.1 BOM (Bill of Materials)

Part(s)	Material(s)	Source(s)	Qty	Unit Cost	Part Cost
Side Pivots	PLA	MakerSpace	-	$-	$-
Parallel Bars	MDF	MakerStore	2	$0.58	$1.16
Side Plates	MDF	MakerStore	8	$0.87	$6.96
Jig Holder	MDF	MakerStore	3	$0.58	$1.74
End Stop	MDF	MakerStore	1	$0.58	$0.58
Bolts[0.25x1in]	Steel	Home Depot	23	$0.21	$4.83
Nuts[HEX0.25-20in]	Steel	Home Depot	23	$0.16	$3.68
Wood Glue	GORILLA	Home Depot	1	$1.82	$1.82
CAD	Onshape	Online	-	$-	$-
Total					$20.77

5.2.2 Equipment list

- Epilog Helix 24 Laser Cutter
- Ultimaker 2+ 3D printer

5.2.3 Instructions

Parts involved in adjustability subsystem	**Figure 15: Adjustability: Parts**
Side Plates (4x) Parallel bars (x2) Side Pivots (x4) End Stop Nuts and Bolts (x23) Jig Holder	

Step 1 Place side pivot in the indentation of one of the side plates while making sure the side pivot is inclined inward (See side view). Repeat step 1 for second side plate, but place side pivot such that it is inclined outward.	 **Figure 16: Adjustability: Step 1, Front view.**  **Figure 17: Adjustability: Step 1, Side view.**
Step 2 Fasten the parallel bars on the jig holder using bolts through the specified holes (see top view). Make sure the jig holder is facing upwards (see top view).	 **Figure 18: Adjustability: Step 2, Top view.**
Step 3 Slide the end stop largest piece through the rectangular hole of the jig holder still facing upwards (see Step 3.1). Place the smallest piece of the end stop flush with the largest piece (smallest piece facing outward), and fasten them using a bolt (see Step 3.2).	 **Figure 19: Adjustability: Step 3.1.**

	 **Figure 20: Adjustability: Step 3.2.**
Step 4 Slide one end of one of the parallel bars into one of the side pivots such that the holes in both pieces align and the jig holder is parallel to the side plate (see Step 4.1). Repeat for all other side pivots, and then fasten parallel bars to side pivots using bolts (see Step 4.2).	 **Figure 21: Adjustability: Step 4.1.**  **Figure 22: Adjustability: Step 4.2.**

5.3 Protection subsystem

This subsystem is meant to guarantee both the door's and the jig's physical integrity and preservation. To protect the door, it was decided the side plates would be coated with some soft and malleable material, like rubber. Conversely, a very resilient had to be used to keep the router from encountering the wooden parts of the jig. This material also had to be strong enough to withstand contact with the router itself, while also being light, so aluminum was prioritized over steel due to its inferior weight. For convenience, rubber bands were simply glued to the side plates, while the aluminum jig piece was fastened using countersunk bolts to guarantee the jig plate remained flush with the door.

5.3.1 BOM (Bill of Materials)

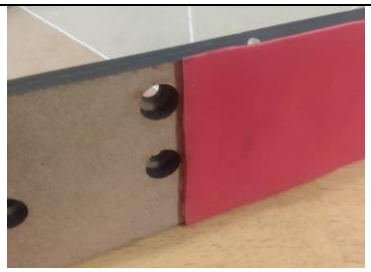
Part(s)	Material(s)	Source(s)	Qty	Unit Cost	Part Cost
Rubber Bands	Rubber	Dollarama	2	$1.00	$2.00
Jig Piece	Aluminum	MetalSupermarkets	1	$7.00	$7
Bolts[0.25x1in]	Steel	Home Depot	4	$0.21	$0.84
Nuts[HEX0.25-20in]	Steel	Home Depot	4	$0.16	$0.64
Wood Glue	GORILLA	Home Depot	1	$1.82	$1.82
CAD	Onshape	Online	-	$-	$-
Total					$12.3

5.3.2 Equipment list

- Jigsaw

5.3.3 Instructions

Parts involved in adjustability subsystem	
Side Plates (x2) Rubber Bands (x2) Jig Holder Metal Jig	**Figure 23: Protection: Parts.**

Step 1 Place the metal jig inside the jig holder, facing up (see Top view).	 **Figure 24: Protection, Step 1, Top view.**
Step 2 Place the nuts (x4) inside the hexagonal holes on the bottom face of the jig holder. Fasten the metal jig to the jig holder using countersunk bolts (x4).	 **Figure 25: Protection, Step 2, Bottom view.**  **Figure 26: Protection, Step 2, Top view.**
Step 3 Glue the rubber band to the inner most side plate (see Side view). This is the side plate with the largest holes. Make sure the rubber band isn't covering the holes (see Side view).	 **Figure 27: Protection, Step 3, Side view.**

5.4 Testing & Validation

5.4.1 Stability

We analyzed the efficiency of our clamping mechanism (F-clamps). The goal was to determine the stability of the jig on the door when it is fully clamped knowing that the side face plates will be moving horizontally to adjust to the door thickness when the door is positioned on its side surface. To do so, we performed the test on a piece of wood shaped like a door. We fully clamped the jig and tried to shake the F-clamps. Because the clamps remained firmly in place, the jig passed the first test. Next, we tried to move the jig with our own hands by applying shear stress. We also shook the piece of wood with the jig placed on it. Following these two steps, the jig was still firmly held in place, so we concluded that it has passed all the tests when it comes to the stability subsystem.

The following picture shows the team verifying the stability of the jig:

Figure 28 - Verifying the stability of the jig

5.4.2 Adjustability

To test if the jig automatically centers for each door thickness, we installed the jig on a door with one of the four possible door thicknesses. The cutout's distance from each side of the jig was measured to determine if it was centered. The results demonstrated that indeed the parallel bar mechanism was accurately centering the cutout in the middle of the door.

To test if a technician could position the cutout in the desired location on the door (12" from the end), while maintaining a centered jig, the jig was once again installed on the door. Another team member then measured the desired distance from the top edge and found it to be almost exactly 12".

The following picture shows a correctly placed cutout created by the jig:

Figure 29 - Testing the adjustability of the jig

5.4.3 Protection

It is very important that the jig designed does not damage the surface material of the door. The jig includes rubber padding on the inner surface of the side plates for exactly this purpose. To test the efficiency of this subsystem, we clamped the jig very tightly to a piece of wood covered in cardboard. Then, after unclamping, we examined the cardboard for marks on the material. Given we did not observe any marking on the soft cardboard we are confident the jig will also not damage any door.

The following picture shows test harness for this test:

Figure 30 - Jig door protection subsystem test harness

6 Conclusions and Recommendations for Future Work

While working on the flush bolt installation jig project the JigX team learned many lessons in engineering design and manufacturing.

Starting on the manufacturing side, the team learned early on that the strength of a 3D printed part is determined by far more factors than one would expect. Intuitively, one would think that to increase part strength, one should simply increase the infill density of the part. While effective, this has two important drawbacks. For one, increasing the density obviously has a large effect of the weight of the part and potentially more problematic, it has a large impact on the print time. Given the vary tight constraints on print time imposed by the makerspace, the team was forced to research other techniques from which two were applied with great success. Firstly, it turns out that wall thickness has an outsized effect on strength without much increase in print time. Increased wall thickness also has the added benefit of making it easier to thread fasteners directly into the 3D print for easy assembly. Secondly, the thickness of the nozzle plays a huge role. A larger nozzle (like 0.8mm) produces fewer layers which need to harden together and allows material to be extruded much faster allowing for higher density prints at the same time. Combining these techniques together allowed the Side Pivot parts (see Appendix) to be substantially stronger with minimal redesign.

Moving over to the jig itself, one especially important discovery we made while testing was that screw clamps have a strong tendency to create lateral forces on the materials they are supposed to be squeezing together. This is likely due to the rotating motion of the screw pushing on the clamp face during tightening. This horizontal force tended to adjust the placement of the jig, reducing accuracy so the team decided to go with pump-style clamps instead which apply only a squeezing force.

Finally, during assembly the team learned an important lesson concerning the selection of glue. To secure the rubber protective layers to the side plates we initially tried a general-purpose multi-material glue. Unfortunately, because the surfaces being glued were uneven and made of different materials (MDF and rubber) the glue did not stick well. To improve adhesion, the team roughed up the rubber surface with a knife and switched to Gorilla Glue. The key advantage of Gorilla Glue is that when it dries it expands to 3-4x its original volume. This allows it to fill in any gaps much more effectively between surfaces leading to a very strong bond. One challenge is that high clamping force over an extended period of time is critical to avoid unexpected expansion in the wrong direction, but this can easily be worked around with planning.

Even with all the above improvements and learnings, with more time there are clearly areas for improvement. Here are the top three.

Firstly, in client meeting 1 we learned from AMBICO that although most doors require the flush bolt cutout to be placed 12” from the top or bottom of the door, some oversized doors require non-standard placements of 18” or 24”. To control scope the team decided not to address this secondary use-case and focus primarily on the centering problem instead. However, nothing prevents the current design from being extended to support a sliding endstop instead of the fixed position one currently implemented for this purpose. With more time the team would have loved to allow the end stop position to be adjusted to cover the edge case of oversized doors.

Secondly, despite the improvements made to 3D printing strategy, the Side Pivot parts were still a weak spot in the design of the jig. The ideal choice of material for these parts would be aluminium but the team quickly realized that no one had the machining experience required to deal with the 4-degree tilt between the stem and the head of the part required to deal with the bevel on the edge of the door. More time would have allowed one or more team members to invest the time required to learn how to machine complicated geometry into aluminium, likely using a CNC which would have led to a much more durable solution overall.

Finally, each of the prototyped produced as part of this project contained many separate parts. One advantage of many smaller, simpler parts is that it facilitates prototyping because it allows for rapid iteration on small pieces of the overall solution and facilitates even work distribution as all team members have a part assigned to them. However, the downsides include increased cost due to increased use of fasteners, increased assembly complexity and decreased overall strength. This was an intentional trade-off made by the team as we felt rapid prototyping outweighed commercialisation viability. With prototype 3 being declared a smashing success by both our own testing and by the judges, it is now the right time to reduce part count and simplify the design as much as possible to control cost and improve manufacturability.

7 Bibliography

[1] Lorient, "LAS9010 FLUSH BOLT + DROP SEAL," [Online]. Available: https://www.lorientuk.com/products/las9010. [Accessed 8 April 2024].

8 APPENDIX I: Design Files

All design files are uploaded to makerepo at https://makerepo.com/Jaredpoole/1970.jigx. Because the jig is exclusively a mechanical device, the following documents are all mechanical. To aid future reproduction efforts they are provided here as editable ".sldprt" SolidWorks files and universal ".stl" files.

Table 2. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Clamp holder CAD	makerepo.com/clamp-holder-partl-solidworks makerepo.com/clamp-holder-part1-stl makerepo.com/clamp-holder-part2-solidworks makerepo.com/clamp-holder-part2-stl	07/04/2024
End stop CAD	makerepo.com/end-stop-part1-solidworks makerepo.com/end-stop-part1-stl makerepo.com/end-stop-part2-solidworks makerepo.com/end-stop-part2-stl	07/04/2024
Jig CAD	makerepo.com/jig-solidworks makerepo.com/jig-stl makerepo.com/jig-design	07/04/2024
Jig Holder CAD	makerepo.com/jig-holder-part1-solidworks makerepo.com/jig-holder-part1-stl makerepo.com/jig-holder-part2-solidworks makerepo.com/jig-holder-part2-stl	07/04/2024

	makerepo.com/jig-holder-part3-solidworks makerepo.com/jig-holder-part3-stl	
Parallel Bar CAD	makerepo.com/parallel-bar-solidworks makerepo.com/parallel-bar-stl	07/04/2024
Side Pivot CAD	makerepo.com/side-plate-part1-solidworks makerepo.com/side-plate-part1-stl makerepo.com/side-plate-part2-solidworks makerepo.com/side-plate-part2-stl makerepo.com/side-plate-part3-solidworks makerepo.com/side-plate-part3-stl makerepo.com/side-plate-part4-solidworks makerepo.com/side-plate-part4-stl	07/04/2024