GNG2101

Design Project User and Product Manual

MotionWorks BTD – 1 User Manual

Submitted by:

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December 10th, 2023

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Table 1. Glossary

Term	Acronym	Definition
Backpack Transfer Device	BTD	Our design, or any comparable design with the purpose of creating accessible storage on a wheelchair.
Retract	RET	Lowering the storage box by means of retraction of the linear actuator.
Extend	EXT	Raising the storage box by means of extending the linear actuator.
Backpack Transfer Device	BTD-1	Referring to the specific design of group 1.5 as the final prototype of the backpack transfer device.

1 Introduction

The problem to be solved is to design an automated “back-pack transferring device” for wheelchair bounded individuals to store and retrieve personal items efficiently and securely. This user and product manual provides the information necessary for the users to effectively use the BTD1 and for prototype documentation. Furthermore, the initiation, planning, troubleshooting, and documentation procedures involved in the design and manufacturing of this product will be explained in detail. Lastly, a step-by-step walkthrough of the proper functionality of the device will be discussed.

2 Overview

The wheelchair backpack system is an external accessory system developed for electric wheelchairs to incorporate additional, easily accessible storage. This product was developed for users with limited upper body strength/mobility to allow them to access their belongings independently.

Our original client wished to make use of this device for everyday use at school, allowing him to access his school supplies, books, and lunch without the need of assistance.

In some cases, this product is key for enabling independence and confidence of mobility users to complete their everyday tasks independently.

Users of our product require an easy-to-operate, reliable, and functional design that will not create any barriers to the use of their wheelchair. The design does not increase the footprint of the chair, nor restricts the user's movement or ability to enter and exit the chair. Other requirements are that the design must be strong enough to allow storage of a reasonable quantity and weight of items and that it can meet the duty requirements of the user throughout the day.

The biggest factor that sets our design apart from the rest of the market is its geometry and positioning. Originally, the mandate was for a backpack holder that would bring the users pack from the rear, around to the front for easy access. Previous designs used complicated linkages and rotating mechanisms to achieve this, but ultimately are overcomplicated and bulky and would not meet our functional requirements.

On top of being relatively small and out of the way, our design is easily removable by simply detaching the frame and actuator from the two mounting brackets. The design does not modify the wheelchair in any irreversible way, allowing the user complete peace of mind and full warranty abidance.

Finally, the design also allows relatively unobstructed entrance and exiting from the wheelchair for users that will be doing so frequently.

The basic functionality of the design is as follows:

The frame is a steel L-shaped bracket that hinges at the side of the wheelchair, just below the seat. At one end is a storage box that holds the user's belongings securely in place, and at the other is the linear actuator. The linear actuator is mounted to a second bracket on the wheelchair that allows the whole system to hinge, and the rod extends.

The linear actuator is controlled by the RET/EXT switch mounted by the control cluster on the armrest. It is currently powered by a 12V DC power supply but can be power by a battery as well for mobile use.

When fully extended, the box sits horizontally just above the user's lap, allowing easy access to their items, and serving as a working station for typing, eating, resting, etc. When lowered, the box and frame will rotate to sit vertically in front of the user’s knees.

The construction is very simple as it does not require microcontrollers on any connectivity, simple power distribution. The store box is made from MDF and painted waterproof as it is a strong and lightweight solution. The rest of the components are made from mild steel as they are strong and precise. All the user input is done via a single RET/EXT switch with no additional settings or configurations needed.

2.1 Conventions

ACTION REQUIRED – A task or operation is required be completed by the user.

CAUTION – An advisory remark that is to be read and understood by the user.

TIP – A remark this is not required or essential but improves quality-of-life for the user.

2.2 Cautions & Warnings

2.2.1 - Powering

Currently, the device is not equipped with a power source component, this must be configured by the user. The recommendation of the team is to source a 12V Lead-Acid battery with a minim of 5Ah and with a peak current output of 8A.

2.2.2 - Theft

CAUTION. The design is built with high quality materials and professional grade production and assembly techniques; however, we do not claim it to the theft-proof. Your valuables are certainly more secure than being in an out-of-view backpack, but we do not take any responsibility for the loss, theft, or damaging of items through use of the BTD1.

2.2.3 - Weight Capacity

CAUTION. The design is built to carry a maximum of 10kg in the storage box. Exceeding this limit will lead to excessive stresses on the components and reduced battery life and RET/EXT time.

2.2.4 - Bracket Protrusions

CAUTION. Even when the device is removed from the chair, the two mounting brackets can remain fixed to the side. Proceed with caution around these as the steel rods could be a hazard to those walking around the chair of any loose clothing of the user.

3 Getting started

The backpack transferring device is consisted of 3 major components: the storage compartment, the robotic arm component, and the electrical controlling component. Before installing the device, please make sure that all components are in good condition by making sure that the package is sealed properly.

3.1 Configuration Considerations

Please make sure that the device is installed in the upright position, and the device is fastened on a stable surface so that the BTD does not hinder the mobility of the wheelchair. You will need a few nuts and bolts, a 12V battery with appropriate power rating, and some basic hand tools to complete the installation. All electrical cables should be secured by zip ties to the chassis of the wheelchair and away from all moving components.

Figure 3.1 Correct orientation of box.

Figure 3.2 Incorrect orientation of box.

Once the pivoting joints are bolted to the side of the wheelchair, the robotic arm could be mounted onto it by securing the quick release pins. In a similar fashion, the storage compartment could be attached to the support bracket of the robotic arm by bolts and nuts. It is recommended to use a 12V battery that has at least 5Ah capacity with a nominal output of at least 100W. The positive terminal of the battery should be connected to pin 1 of the DPDT switch, and the negative terminal of the battery should be connected to pin 2 of the switch, as illustrated below.

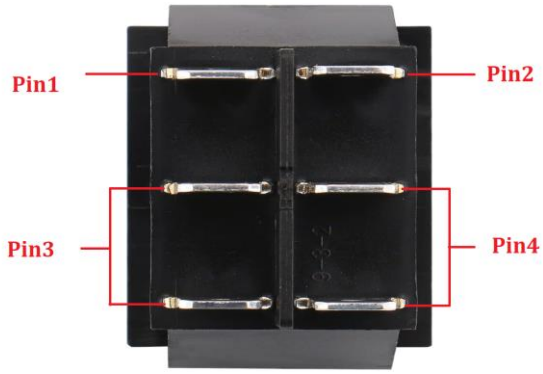

Figure 3.3 Switch pinout.

3.2 User Access Considerations

This device is intended for facilitating wheelchair-bounded individuals to retrieve and put way personal belongings. However, due to the device's tray table accessory functionality, this device might also be fit onto office chairs or car seats. Either way, this device was designed for ease of use and effectiveness. For safety reasons, please do not use this device before you fully read this user manual. Furthermore, please follow the safety guidelines for the battery you choose.

3.3 Accessing/setting up the System

3.3.1 Mount installation

1. The BTD – 1 wheelchair mount requires 4 screws and nuts for the linear actuator mount and 2 screws for the arm mount. Note that the front of the mounts has a pin sticking out from the mount, this is for the linear actuator and arm as seen in figure 3.4.
2. To install, start by inserting the 4 screws into the mounting holes of the linear actuator mount.
3. Loosely screw the square bolts onto the back of the 4 screws
4. Align the bolts to allow them to be slid into the track on the side of the wheelchair.

5. Slide the bolts into the track, ensure to slide the mount as far back as possible on the rail.
6. Tighten the 4 screws for the linear actuator mount and the 2 screws for the rotating assembly mount.
7. Repeat steps 2 through 6 with screws on the arm mount, the final mount is pictured in figure 3.5.

Figure 3.4 Mounting hardware.

Figure 3.5 Completed mount installation.

3.3.2 Linear actuator installation

1. Push the linear actuator into the rear mount point as seen in figure 3.6.

Figure 3.6 Completed linear actuator mount.

3.3.3 Arm installation

1. Slide the arm onto the front mount point as seen in figure 3.7.

Figure 3.7 Rotated assembly mounting.

2. Line up the holes in the linear actuator and the arm. This will be easier by plugging the electrical system in and adjusting the length of the linear actuator. It will also be beneficial to have a second person hold the arm steady.
3. Insert the provided pin to connect the arm and linear actuator as in figure 3.8.

Figure 3.8 Linear actuator and rotating assembly linkage.

3.3.4 Switch installation

1. Insert the screws and nuts to the mounting holes like the actuator and arm mount as seen in figure 3.9.

Figure 3.9 Switch assembly

2. Align the square nuts and slide the switch assembly into the rail under the armrest.

Figure 3.10 Switch mount

3. Tighten the screws.

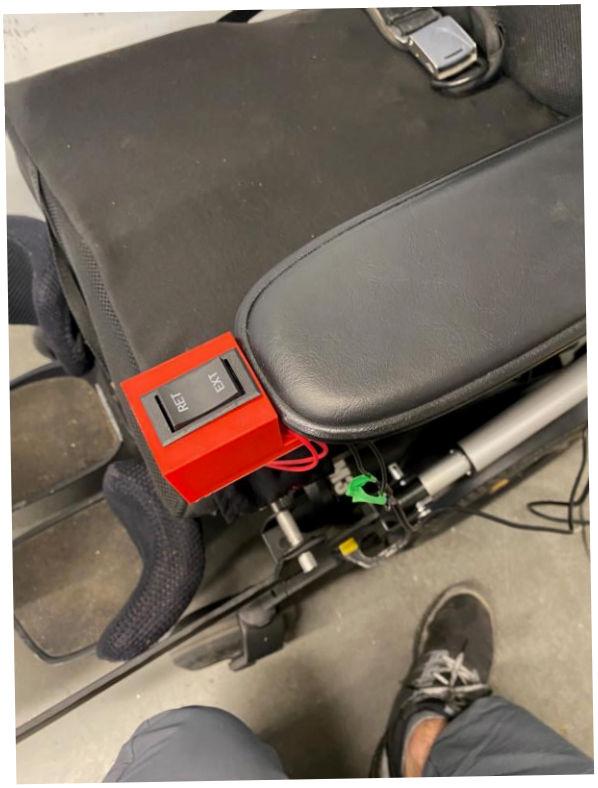

Figure 3.11 Completed switch mount.

3.4 System Organization & Navigation

There is only one switch that controls the device. When the EXT end of the switch is pushed-in, the linear actuator would extend, and the storage box would swing up. When the RET end of the switch is pushed-in, the linear actuator would retract, and the storage box would swing down. The design of the switch does not allow the two ends of the switch to be pushed at the same time. Furthermore, if the linear actuator fully extended, the control module inside of the linear actuator would turn off the motor. The same is true when the linear actuator is fully retracted. When the user adjusting for the robotic arm length, it is the user's responsibility to ensure that the device would not encounter obstacles from the linear actuator being fully retracted to fully extended.

3.5 Exiting the System

Ensure the device is securely stored in a safe location when not in use, particularly due to the presence of a battery in the wheelchair that may pose safety hazards. Exercise caution to avoid leaving the wheelchair in areas prone to dampness, as the storage box for our packages is constructed from MDF and susceptible to mold growth. Safeguarding your wheelchair in a dry environment will contribute to its longevity and minimize potential safety risks associated with the battery. Additionally, remember to check the condition of the storage area regularly to prevent any environmental factors that may compromise the wheelchair's functionality or pose a threat to its safety features.

1. While supporting the arm and storage box, remove the pin holding the arm to the linear actuator.

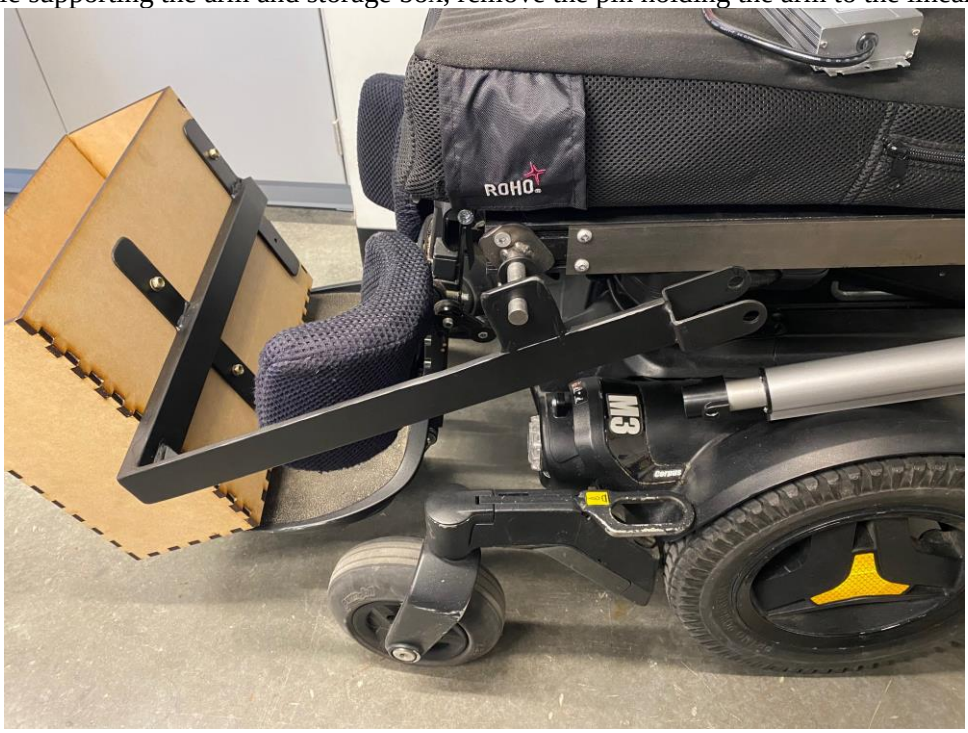

Figure 3.12 Removing rotating assembly and linear actuator linkage.

2. Slide the arm off it the mount.
3. Slide the linear actuator off the mount.

Figure 3.13 Removing mounting hardware.

4. If desired, remove the mounts by loosening the screws and sliding the mounts off the track towards the front of the chair.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the MotionWorks BTD – 1.

4.1 Raise Storage Box / Lower Storage Box

Operation of the storage box is controlled by a single switch, mounted to the armrest of the wheelchair. Before operating the switch, ensure that no items are resting on the box, and that all items inside the box are secured. Ensure that nothing is in the way, such as your legs, clothes, or other belongings.

Using the switch, hold down on the RET side to lower the storage box, and hold on the EXT to raise the box. Keep holding either side until the box is in the storage position or the upright position. The box can be safely stopped at any point in the process, resting safely at any angle.

Complete extension should take around 50 seconds, varying depending on the battery level, weight, and temperature.

Figure 4.1 Control switch

5 Troubleshooting & Support

5.1 Error Messages or Behaviors

This section explains unusual behaviors that can be seen from the device's operation, which can help narrow down or identify the cause of a problem and proceed with corrective action. If corrective action cannot be taken by the user, contact support.

- Slow operation - **ACTION REQUIRED**
    - If the linear actuator is extending or retracting slowly or looks like it is having difficulties or “fighting” to extend or retract. Check extending rod for marks such as gashes or cuts, a solution is to apply grease to the rod and to perform extend and retract operation to coat extending rod.

- Intermittent on and off operation while switch is being used - **ACTION REQUIRED**
    - If the device turns on and off during operation with the switch pressed in either RET or EXT position, check all wires for loose electrical connection and check battery level.

- Linear actuator causing excessive noise/abnormal vibration – **ACTION REQUIRED**
    - Check all electrical connections, if noise is coming from the motor, contact support as soon as possible.
- The devices extend and retract buttons are swapped – **ACTION REQUIRED**

- Ensure the wires are connected to the correct terminals on the switch (see wiring diagram)

5.2 Special Considerations

- CAUTION - The device should not be extended or retracted manually. Only operate the device with the linear actuator!
- CAUTION – Do not overextend or over retract the linear actuator. The device is designed with a 90° range of motion with its limits being perpendicular to the ground while retracted and parallel to the user's lap when extended.
- TIP - If troubleshooting requires extensive operation of the linear actuator, depending on the situation, it is recommended the linear actuator be disconnected from the rotating assembly and have the battery charging to avoid negative effects to battery life and health.

5.3 Maintenance

Parts such as the linear actuator, Unitrack mounts, and electrical connections should be checked periodically to avoid any issues that may arise from neglect of maintenance.

Unitrack mounts are greased to maintain smooth operation as the rotating assembly and linear actuator rotate about the dowels on the Unitrack mounts. All electrical connections are to be checked for loose connections at the battery, linear actuator, and switch to prevent burning wires and electrical arc. If you see any burnt wires, replace them as soon as possible and contact support.

5.4 Support

Have any questions or concerns about the operation of your product? Please contact any of our team members, and we will get back to you as soon as possible. The report case describes the best and most knowledgeable member to contact about a certain system.

Table 2. Contact information of MotionWorks Team

Name	Email	Report case
Dominic Roy	droy008@uottawa.ca	Mechanical
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Chris King	cking028@uottawa.ca	Electrical
Ez Aziz	Eaziz056@uottawa.ca	Mechanical

6 Product Documentation

6.1 Electrical system

6.1.1 BOM (Bill of Materials)

Table 3. Electrical BOM

Material	unit	How to get it	Unit Cost	Link
12” linear actuator	1	buy	64.95$	Homend DC 12V 12 Inch Stroke Linear Actuator with Mounting Bracket 300MM 6000N/1320LB Maximum Load for Recliner TV Table Lift Massage Bed Electric Sofa Linear Actuator : Amazon.ca: Industrial & Scientific
Electrical Switch	1	buy	9.00$	https://www.amazon.ca/weideer-Momentary-Reverse-Polarity-KCD2-7-223-4P-X/dp/B08T77K2YY/ref=sr_1_8?crid=2RHJXNAAAJE78&keywords=Motor+Polarity+Reversing&qid=1698865942&sprefix=motor+polarity+reversing+%2Caps%2C219&sr=8-8
Electrical control panel (3D printed abs)	1	custom	free	Makerspace
Total cost with 13% tax:			**83.56$**	
Total cost with 13% tax and 10% redundancy:			**91.91$**	

Note: the 10% redundancy is for mitigating the risk of inflations, sales, and fees.

6.1.2 Equipment list

6.1.3 Instructions

- Follow the wiring diagram below. This can be assembled by means of soldering, crimping with spade connectors etc.

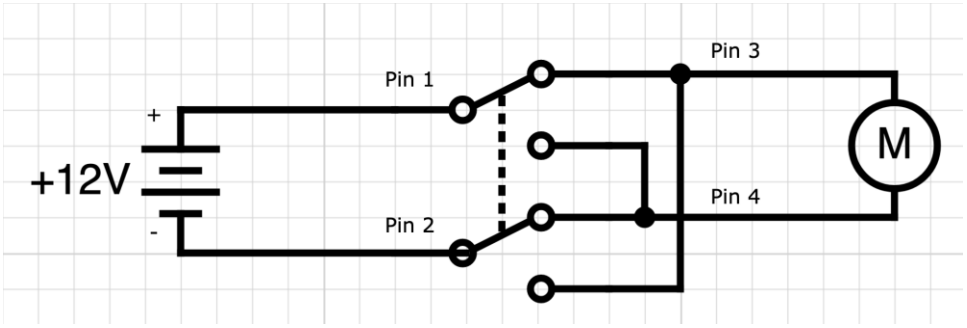

Figure 6.1 Electrical system wiring diagram.

Note that the switch has jumper bars installed to reverse the polarity when the retract button is pressed. This is visualized by the 4 connections to the motor instead of 2. Pinout of the switch can be seen in figure 3.3.

6.2 Mechanical system

6.2.1 BOM (Bill of Materials)

Table 4. Mechanical BOM

Material	unit	How to get it	Unit Cost	Link
Linear actuator mount (1/4" steel)	1	custom	17.75$	STEM Brunsfield Centre
Bell crank (1" box steel)	1	custom		STEM Brunsfield Centre
Bell crank (¼" steel sheet)	1	custom		STEM Brunsfield Centre
Reinforcement plate	1	custom		STEM Brunsfield Centre
Unitrack mounting bracket	2	custom	5$	
Storage box (laser cut MDF)	1	custom	9$	MakerStore
AN4 bolt	4	bought	0.33$	https://www.aircraftspruce.ca/catalog/hapages/an4.php
AN4 washers	8	bought	0.03$	https://www.aircraftspruce.ca/catalog/hapages/flatwashers.php
AN4 lock nuts	4	bought	0.33$	https://sbsimpson.com/product/nylon-insert-lock-nut-1-4-unf-ss-fasteners-hardware-16-02600/?gad_source=1&gclid=Cj0KCQiA4NWrBhD-ARIsAFCKwWtvojQA9DYv4IRmtQr6aBAok14yn0ArriFXZTZhsCA0UwUwyuXovAkaAinnEALw_wcB
Total cost with 13% tax:			**39.13$**	
Total cost with 13% tax and 10% redundancy:			**43.04$**	

Note: the 10% redundancy is for mitigating the risk of inflations.

6.2.2 Equipment list

- MIG welder
- Bandsaw

- Laser cutter
- 3D printer
- Drill press

6.2.3 Instructions

- Start with all the steel you will need for this project by welding the ¼' flat stock cut to 420mm (about 1.38 ft) with a linear actuator mount on the rear side,
- Weld a small piece of ¼' flat stock on the top side of the piece 3.5 inches from rear edge to center of piece and drill a ½” inch hole centered and 1” from the top.
- Cut out an 18” section of rectangular tube steel and weld it to the flat side of the long flat stock piece flush with the front edge.
- Weld a small triangular support in the inside edge of the flat stock and rectangular tube.
- Grab 4 steel tickets with a ¼" inch hole drilled in the center and weld flush to front facing edge of rectangular tube, evenly spaced.

Figure 6.2 Storage box and arm assembly

- Make two pivot mounts for the linear actuator and rotating assembly using a steel ticket and ½" dowels welded vertically in the center. Drill two 6mm (about 0.24 in) holes on each side of the dowel.
- Cut a 20-inch section of 1/8” flat stock and drill four 6mm holes, two at the front in the upper and lower corner. And two more 12 inches from the last two holes (ctr-ctr) at the top and bottom. Weld one pivot mount to the far end of the flat stock.

Figure 6.3 Mounting hardware.

Figure 6.4 Completed mounting hardware.

- Depending on the mounting hole of the linear actuator, you may need to drill it out to ½”.

Figure 6.5 Mounting hardware with linear actuator.

- 3D prints the switch mount using the dimensions below.

Figure 6.6 Switch assembly

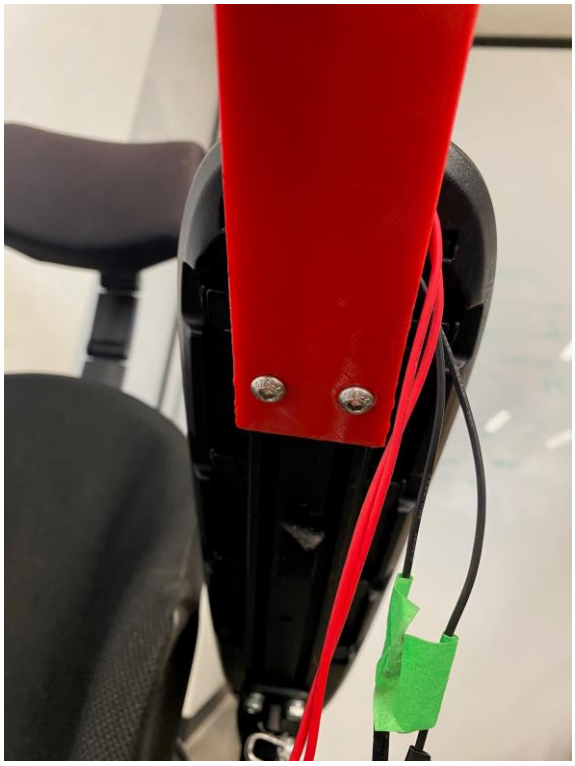

Figure 6.7 Switch mount

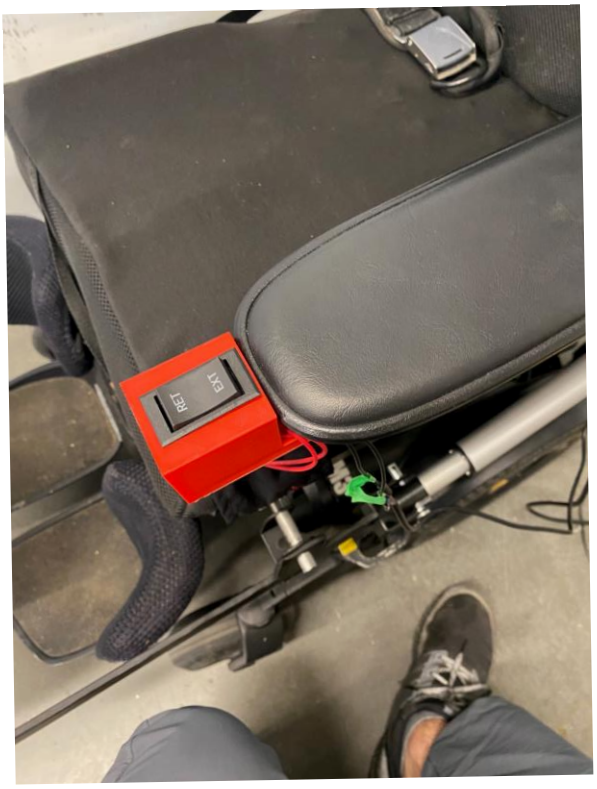

Figure 6.8 Completed switch mount.

6.3 Testing & Validation

A variety of tests were performed on the device as seen in table 5.

Table 5. Testing and Validation criteria

Description	Desired spec	Obtained spec	Action taken
Knee room when lowered	>5cm knee room	~10cm knee room	No changes needed
Lap Height when raised	~20cm above lap	~30cm.	Will lower tabletop when designing storage box or create an adjustable mechanism
Weight of Prototype	The prototype weighs 2kg without storage box and using wood.	Must be under 10kg when complete	Still within spec for final design.
Feasibility of single-arm design	Minimal wobble when extended	Significant strengthening needed	Will design metal pivot to support structure and create support triangle from metal.
Time to extend/retract	10-20s	~30 s	Increase voltage to linear actuator
Weight	20-40 lbs	20lbs	No changes needed

Gross carry weight	10kg	>10kg	No changes needed

From the figure below, an improvement on the storage box mounting bar provided much needed strength and rigidity over the original design. The previous design was an aluminum rod, which would've proved advantageous in weight savings, however, the mounting solution of using U-bolts and mounting a rectangular box onto a round bar would've been very inconsistent. Also, this was not used in the final design due to the rotating assembly arm being made of steel, this would increase the complexity of the arm since welding would've not been possible.

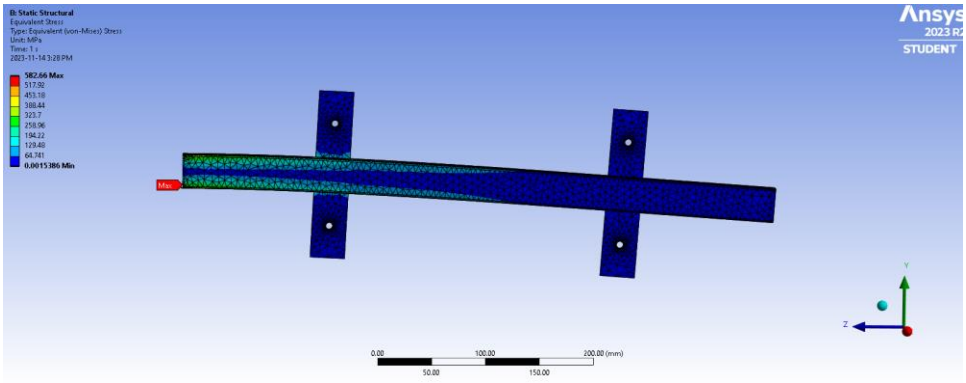

Figure 6.9 Ansys simulation

7 Conclusions and Recommendations for Future Work

Throughout the development of the BTD – 1, there were many features proposed that MotionWorks did not have the resources to implement. Some of these features, while basic, will provide significant quality of life improvements for the user.

7.1 Electrical Improvements

The current electrical system of the BTD – 1 is basic and limited in functionality. Ideally, the system would contain a microcontroller and display capable of providing information about the systems electrical state to the user. This could include a battery indicator, power information, and even help diagnose faults and troubleshooting.

7.2 Mechanical Improvements

There are a variety of minor mechanical improvement that could improve the user experience of the BTD – 1. The storage box could be lined with a felt like material to protect the user's belongings. Furthermore, the storage box could contain separate compartments to organize items and ensure they do not collide while the system is in motion. The storage box could also be fitted with a lid that would prevent items from being stolen from the box. The lid could either be spring loaded or controlled with a motor to allow easy opening and closing of the box.

Lastly, the design and construction of the arm could be altered for improved strength. The original designed included a triangle for improved rigidity.

APPENDICES

8 APPENDIX I: Design Files

Table 6. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
MotionWorks-BTD-1-Solidworks-Files.zip	Solidworks CAD Files	Dec 1st 2023