TEAM 205 – ROBOTIC ARM TO ASSIST MOTORIZED CHAIR USERS

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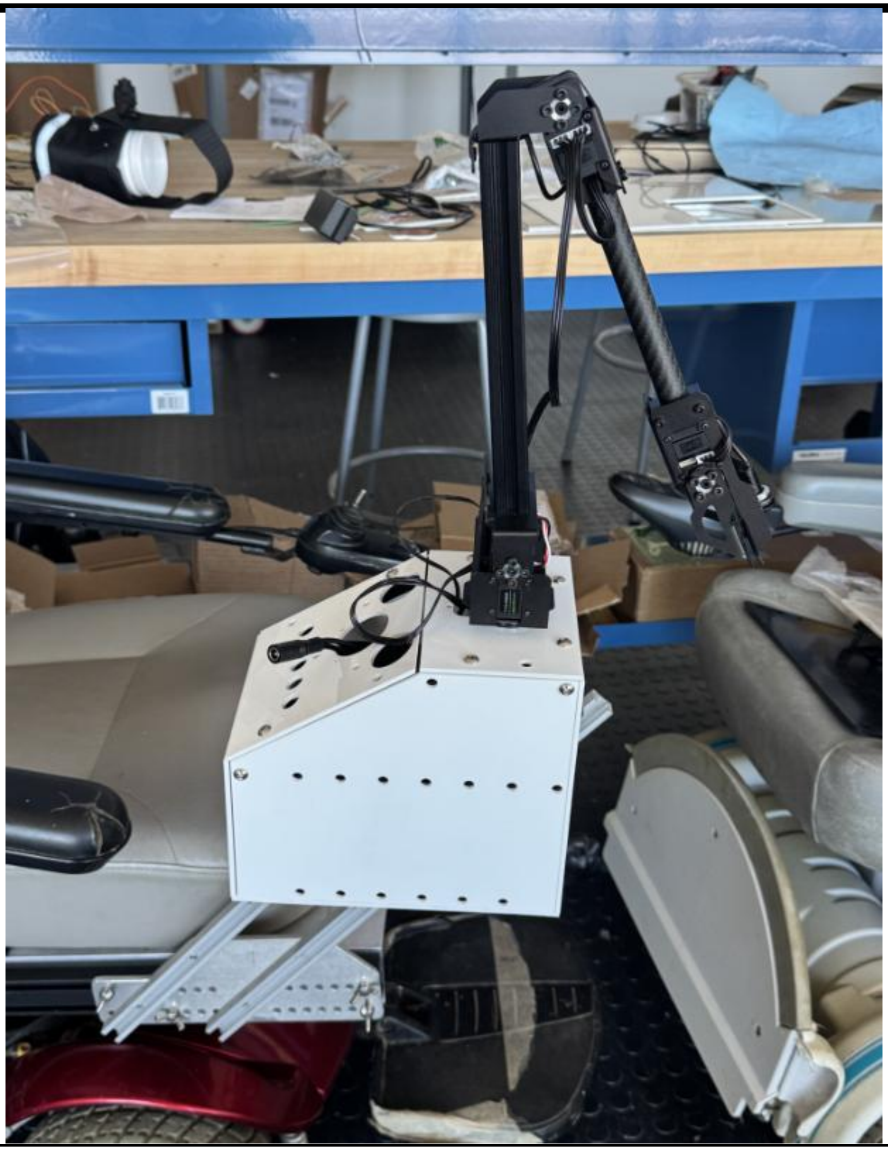


Agenda

Background & Recap	• Objective and Solution Overview
Solution Summary	• High Fidelity CAD • Key/ Important Features • Design Changes
Build Progress	• Mounting Schematic • Electronic Casing • Software Functions
Test Readiness	• Key Requirements • Test Methods
Project Management	• Timeline and Budget

Duchenne Muscular Dystrophy (DMD)

DMD is a progressive disorder that deteriorates muscles over time

- 1 in 5000 boys affected **yearly**

Users with DMD often require the use of motorized wheelchairs (Permobil M3) and aid from caretakers or assistive devices

Figure 1: Kinova JACO mounted on Permobil wheelchair

Figure 2: Kinova JACO robotic arm

Current assistive devices such as the Kinova JACO are:

- Expensive (>$60,000)
- Difficult to control
- Large/Bulky
- Difficult to remove from wheelchair

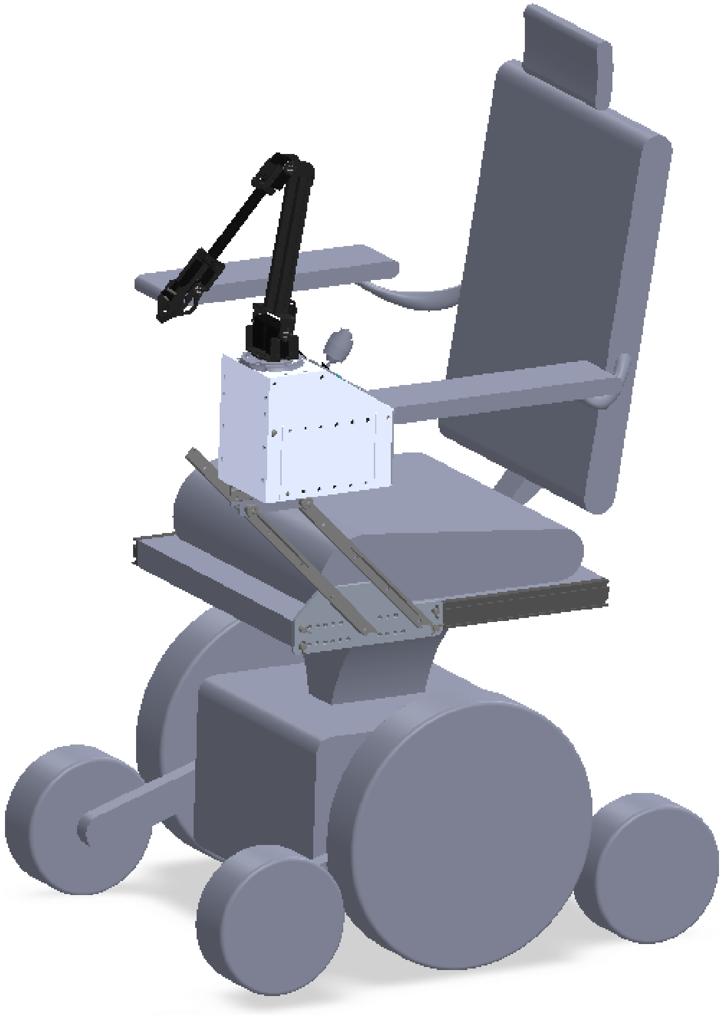
Background | Solution Summary | Build Progress | Test Readiness | Project Management

Key Objectives

Modify a low-cost robotic arm and design mounting structure to attach to common motorized wheelchairs (utilizing Permobil Unitrack)

Complete Two High Value Functions

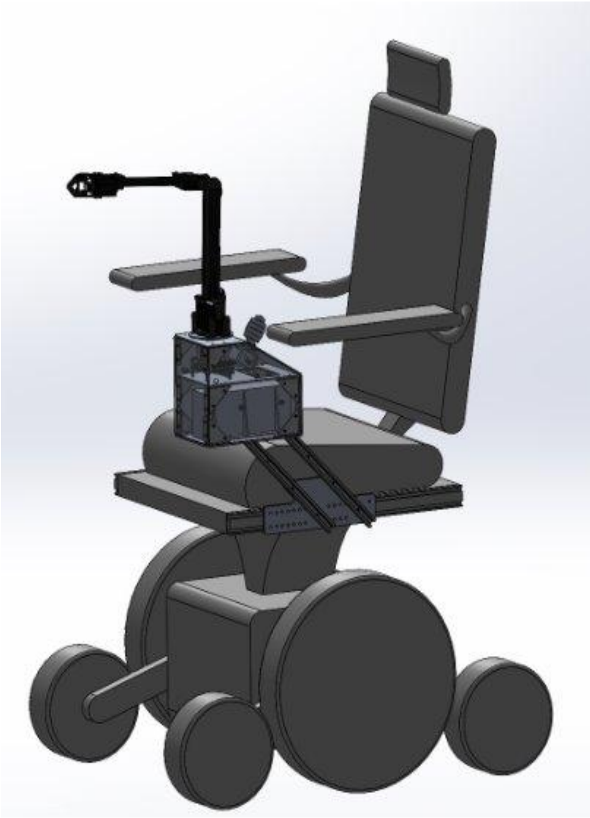
- Push an ADA complaint elevator button
- Retrieve and bring a drink to the user from a user programmed location, then return the drink to this location

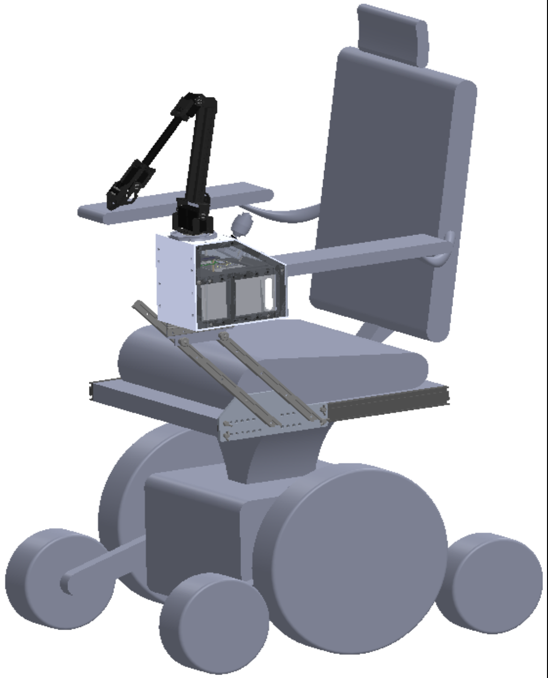


Summary of Changes Since CDR

CDR

- **Structure:**
  - Corner Brackets
  - Mounted Middle Plate
- **Mounting:**
  - Rigid Mounting to Rails
- **Electronics:**
  - ESP32
- **Material:**
  - Aluminum
  - 3D Printed Plates
- **Waterproofing:**
  - Heat Shrink



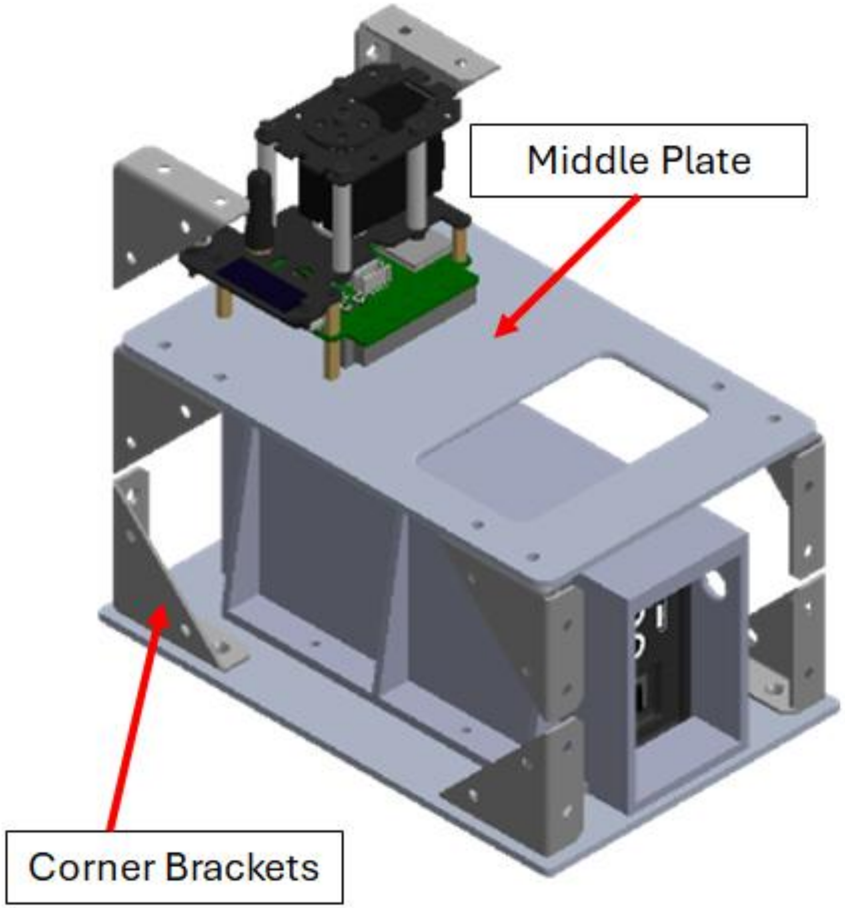


Current

- **Structure:**
  - 3D Printed Frame
  - Integrated Middle Plate
  - Nut-Inserts
- **Mounting:**
  - French Cleat Mounting Assembly
- **Electronics:**
  - ESP32
  - Protoboard
  - Header Pins
  - Adafruit Feather v2
  - Buttons and Switches
- **Material:**
  - Acrylic Plates
- **Waterproofing:**
  - Boot
  - Sleeve
  - 3D printed Ring

Since CDR – Structure

CDR

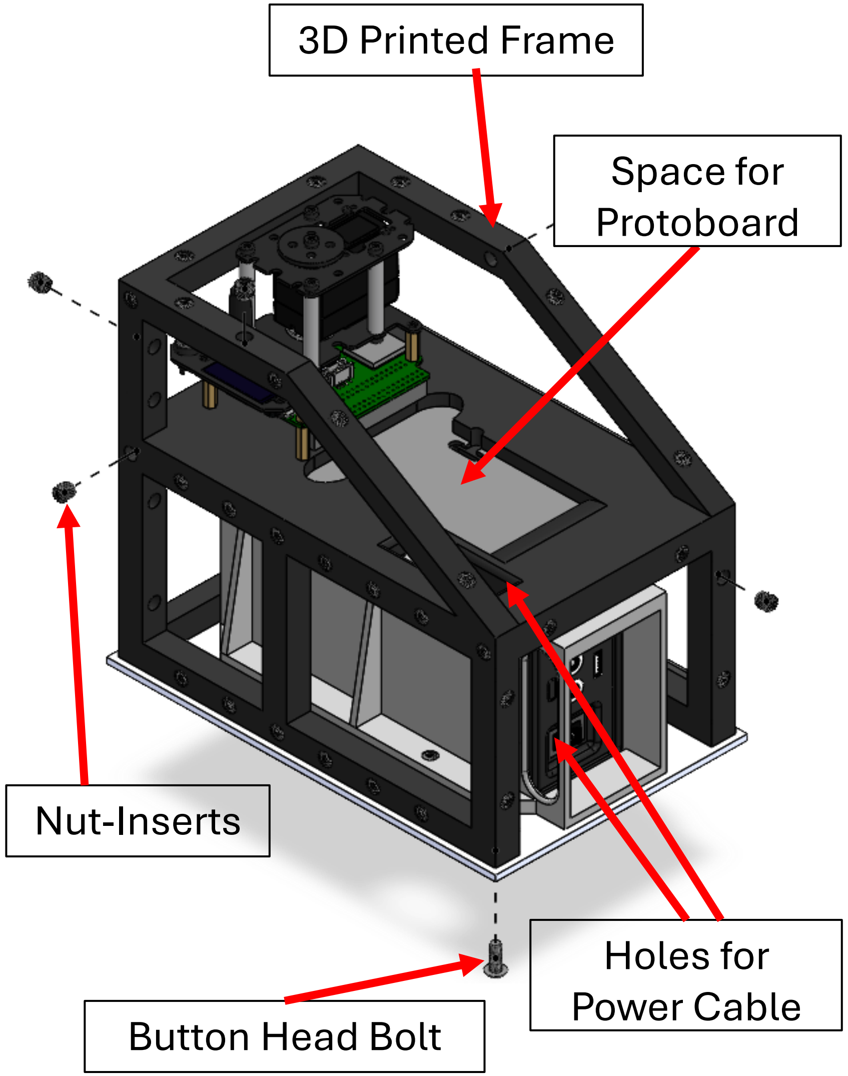


Change:
- Corner Brackets to 3D Printed Frame
- Nuts and bolts to Nut-Inserts
- Middle plate integrated

Reason:
- Assembly/disassembly time reduction
- Maintenance access
- French Cleat installation access
- Protoboard installation access

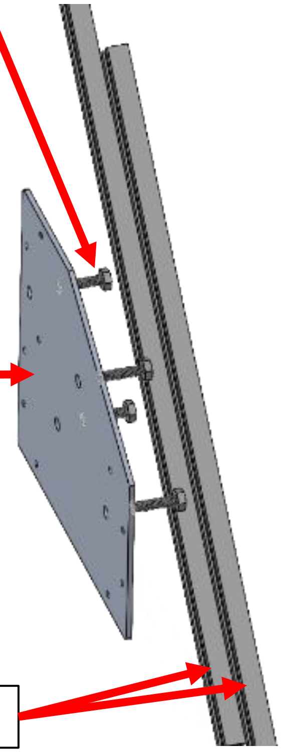
Impact:
- Significant reduction in installation time
- Simplifies installation process
- Delay due to 30-hour print time

Current



Since CDR – Mounting System

CDR

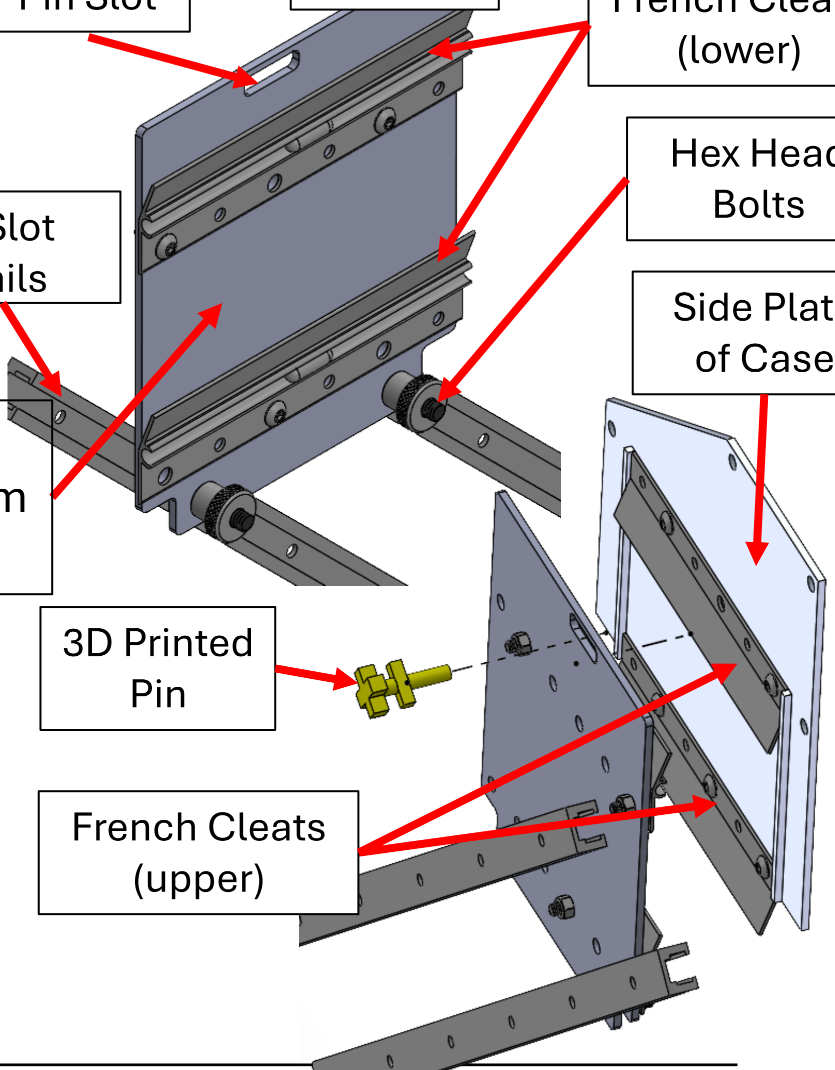


Change:
- Rigid Mounting of Case Side Plate to French Cleat Mounting System
- 1/8” Aluminum Mounting Plate
- 3D Printed Pin

Reason:
- Sponsor Team Requirement to be able to move case quickly and easily.
- Pin prevents case from being bumped off

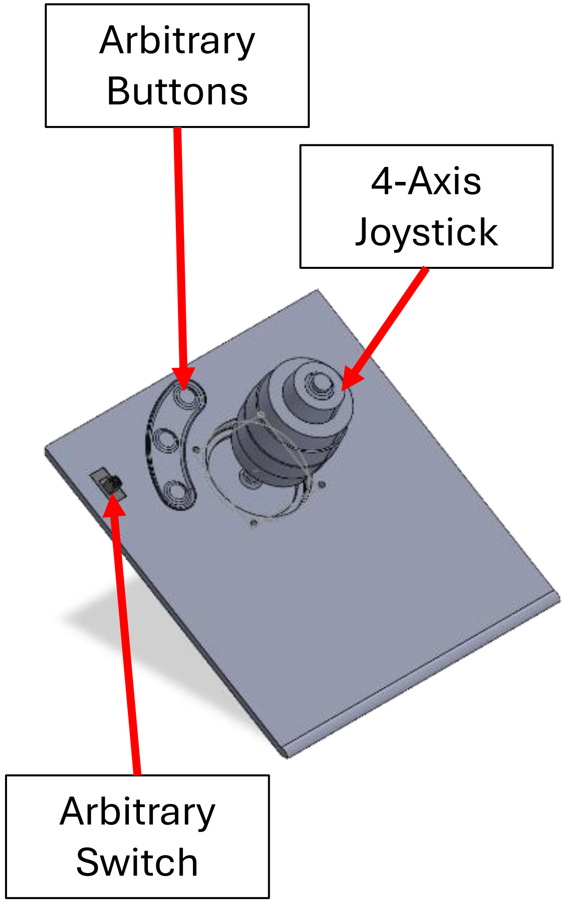
Impact:
- Significant reduction in installation time
- Simplifies installation process
- Increases transportability
- Delay due to booked Plasma Cutter

Current



Since CDR – Electronics

CDR

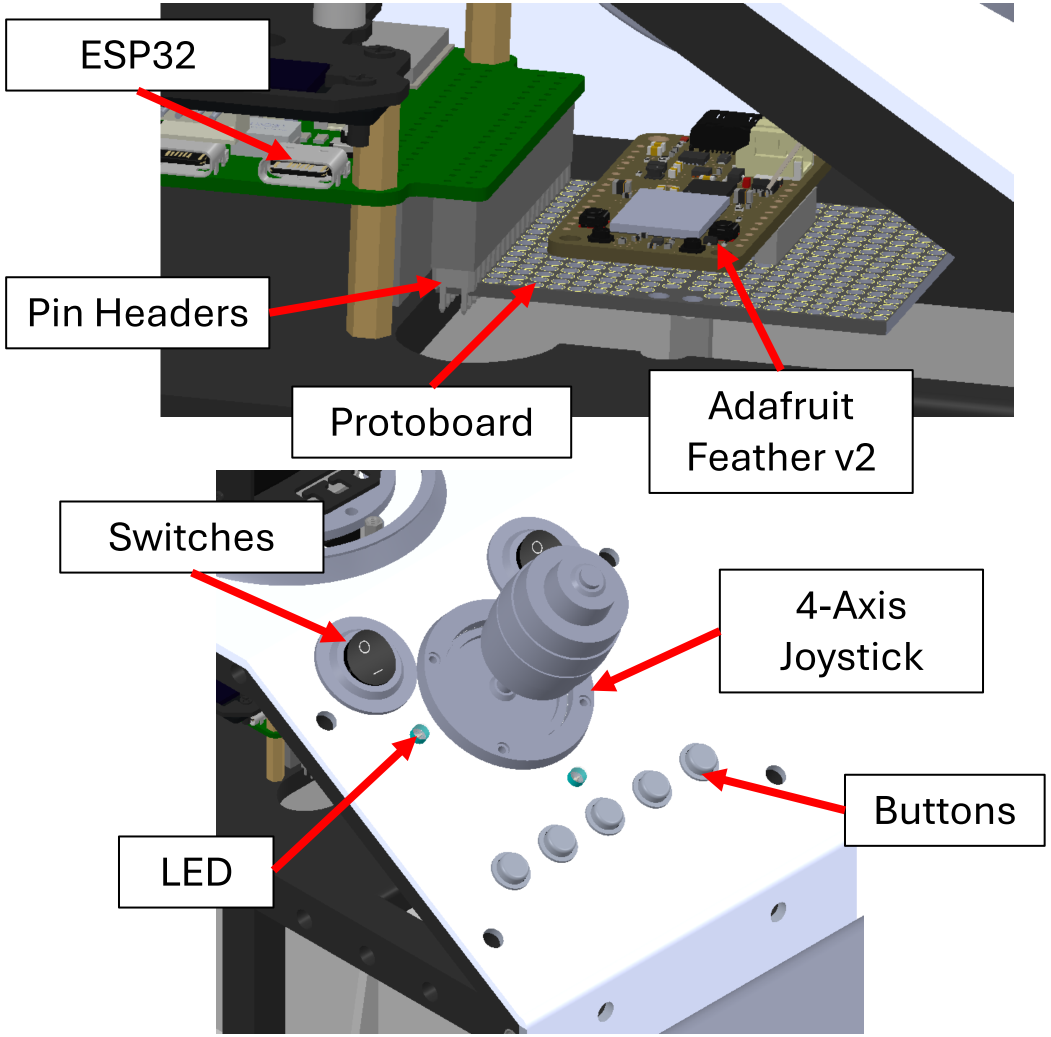


Change:
- Added Adafruit Feather v2
- Added protoboard with pin headers
- Added Switches
- Added Buttons
- Added LEDs
- Removed Arbitrary Buttons and Switch

Reason:
- Can't exclusively use ESP32, feather allows for analog communication
- Protoboard and pin headers allow for easy and sturdy connections
- Switch and buttons added per sponsor team request

Impact:
- Much easier to understand user interface
- Delay due to reprint of frame to fit protoboard
- Delay laser cutting diagonal plate due to multiple changes to fit buttons, switches, and LEDs

Current



Since CDR – Waterproofing

CDR

Heat Shrink to Cover Exposed Joints

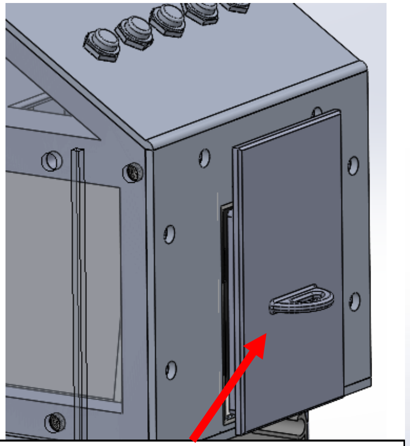
Change:
- Heat Shrink to Leather Boot and Sleeve
- Added Battery Cover
- Added 3D Printed Ring

Reason:
- Heat Shrink wasn't durable or malleable enough
- Waterproof boot allows for 360-degree base rotation
- Waterproof sleeve is malleable enough to allow 180-degree servo rotation
- Battery needed a cover to prevent water damage
- Easy installation and application

Impact:
- Entire robot arm and its electronics becomes waterproof
- Amazon order was lost, causing delay

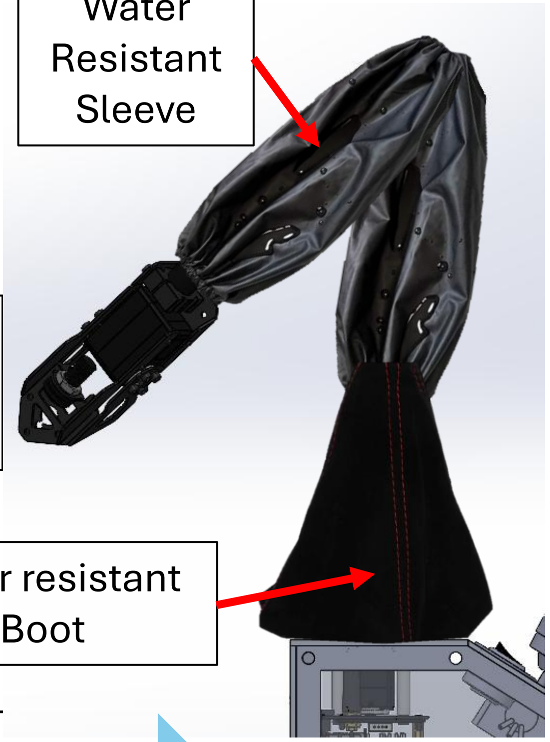
Current

3D Printed Ring to Protect the Top of the Case



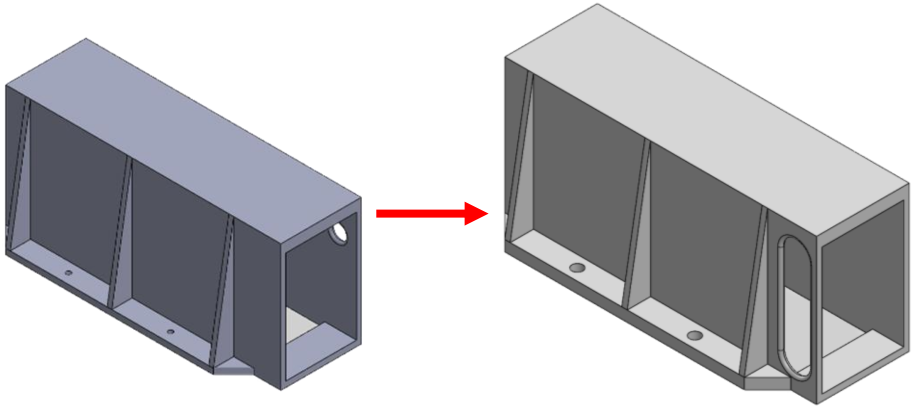
Press Fitted Battery Cover to Protect Inner Chamber

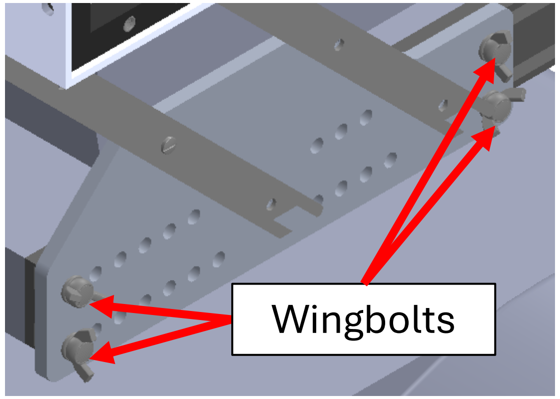
Water Resistant Sleeve

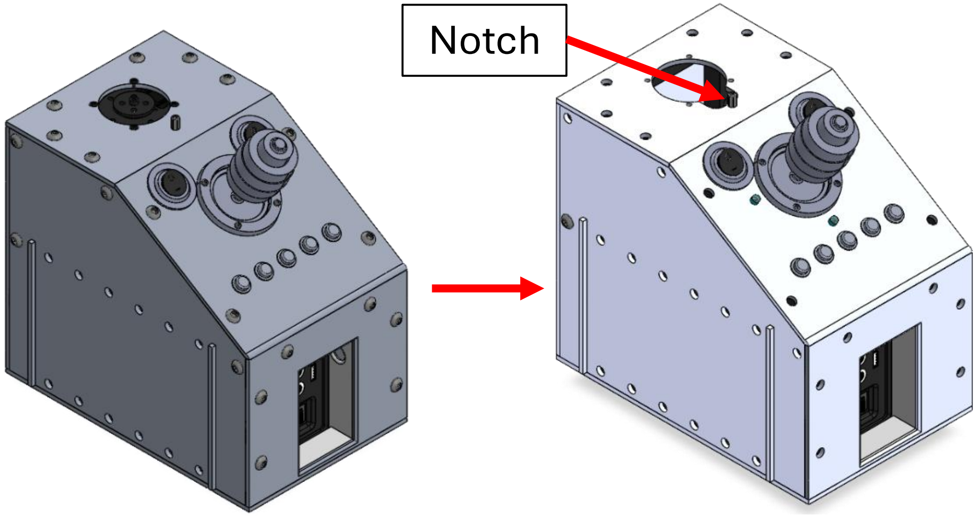


Water resistant Boot

Since CDR: Miscellaneous







Battery Case:

- Hole was too small to allow wires through
- Hole swapped sides to provide more optimal path to the ESP32
- Made more space in the battery case due to battery unevenly wobbling on flat ground

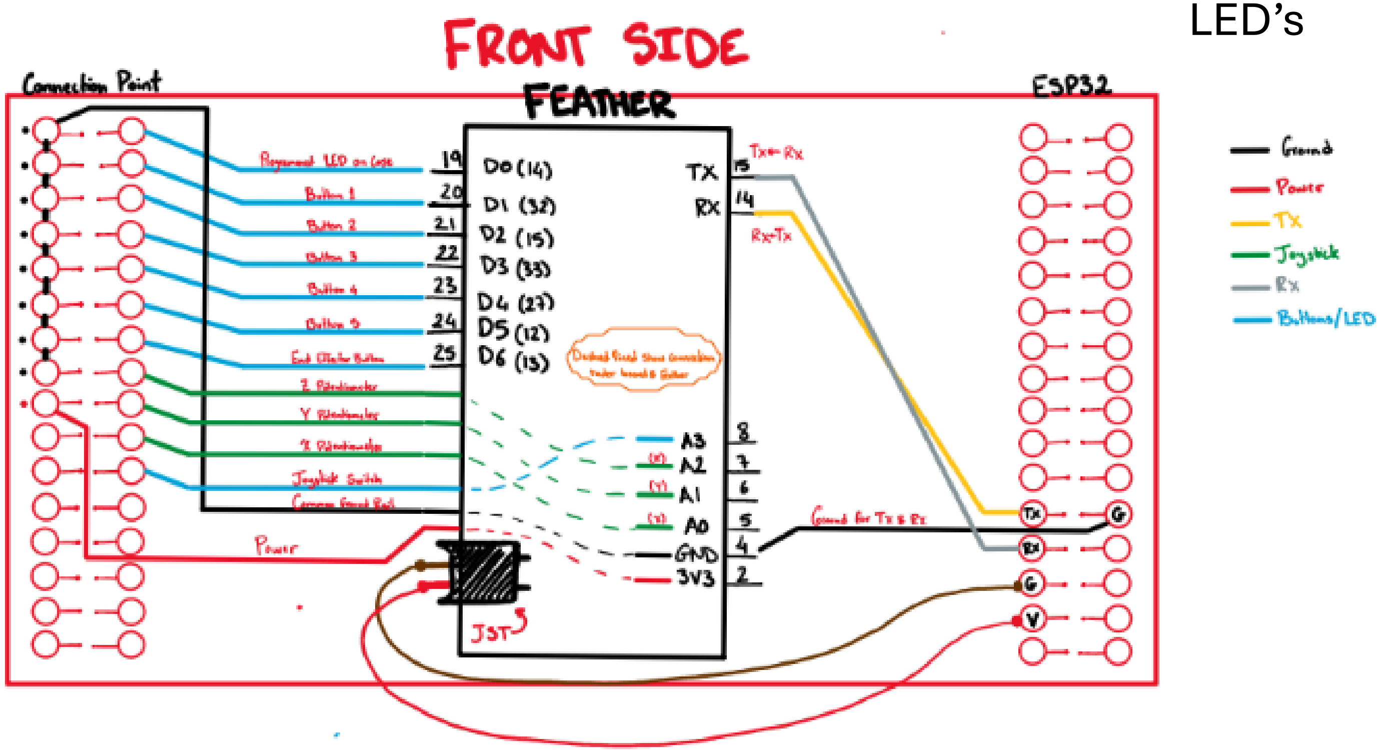
Unitrack Mounting Assembly:

- Replaced M6 flat head bolts with wingbolts to allow user to easily remove assembly

Electronics Case:

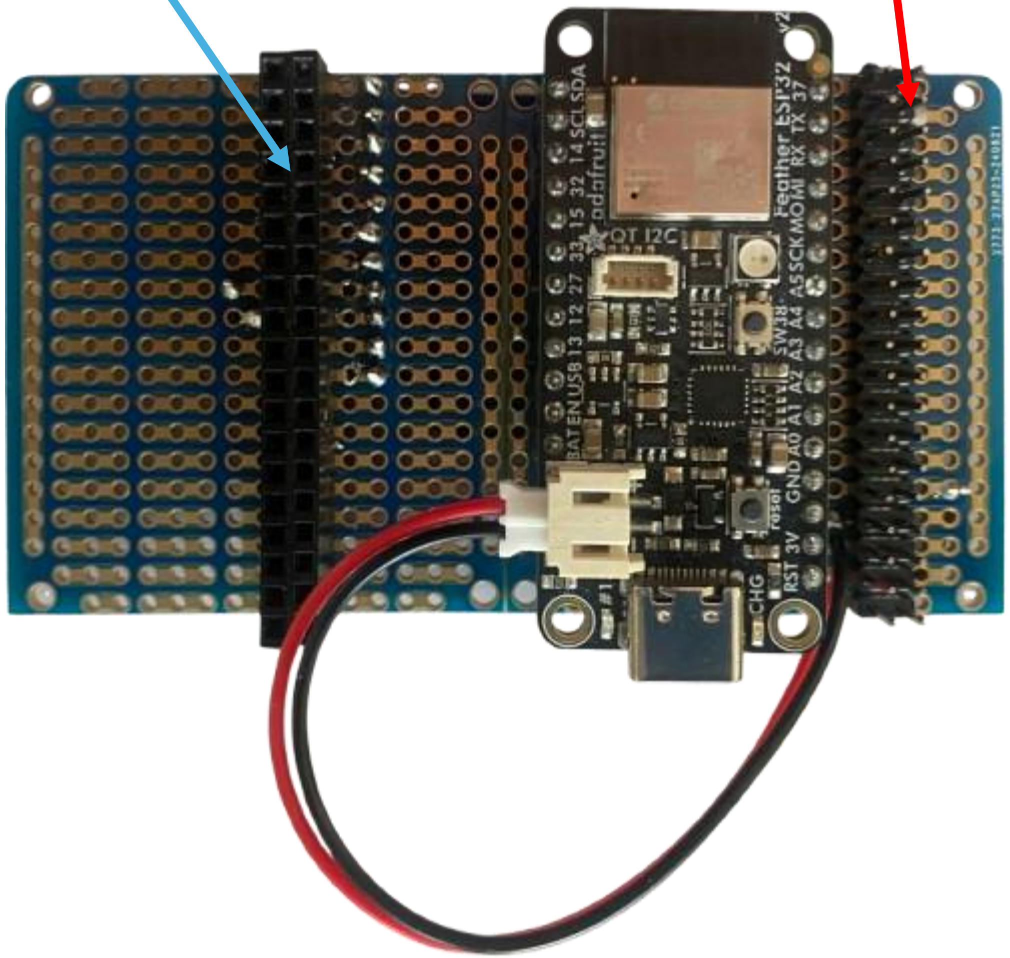
- Plate material changed from aluminum/ABS filament to acrylic
- Notch cut into top plate to allow wires through

Overview of the Brains of the System : Protoboard and Feather

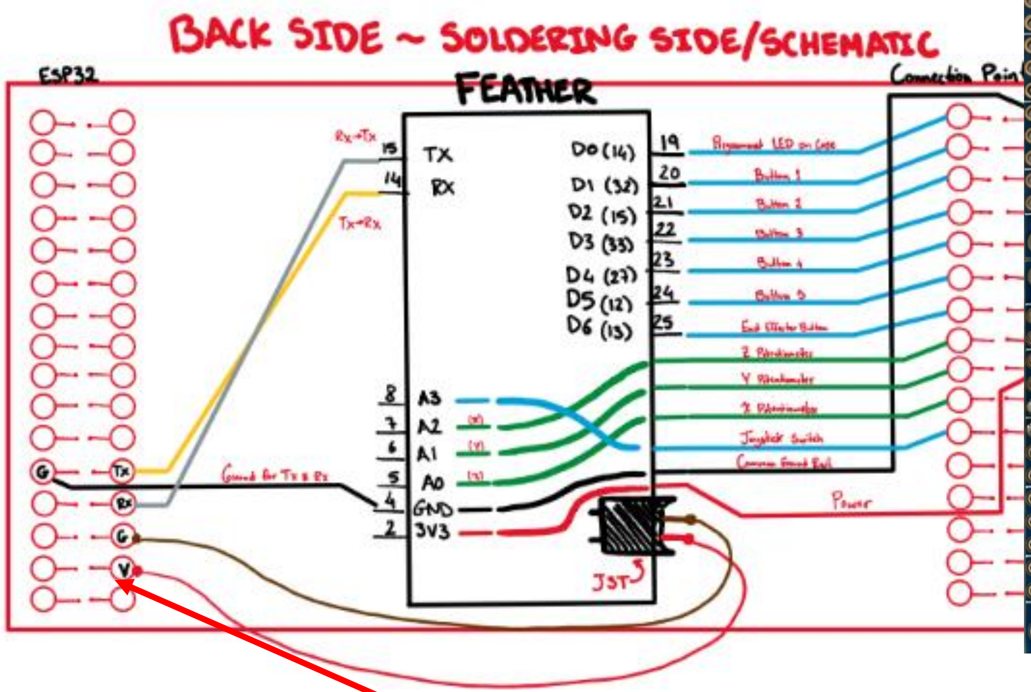


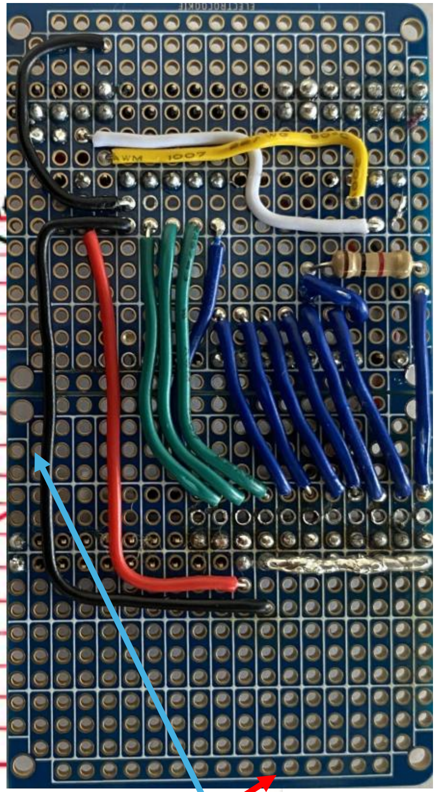
Plugs for attaching buttons, joystick and LED's

Plugs into robot



Overview of the Brains of the System : Protoboard and Feather

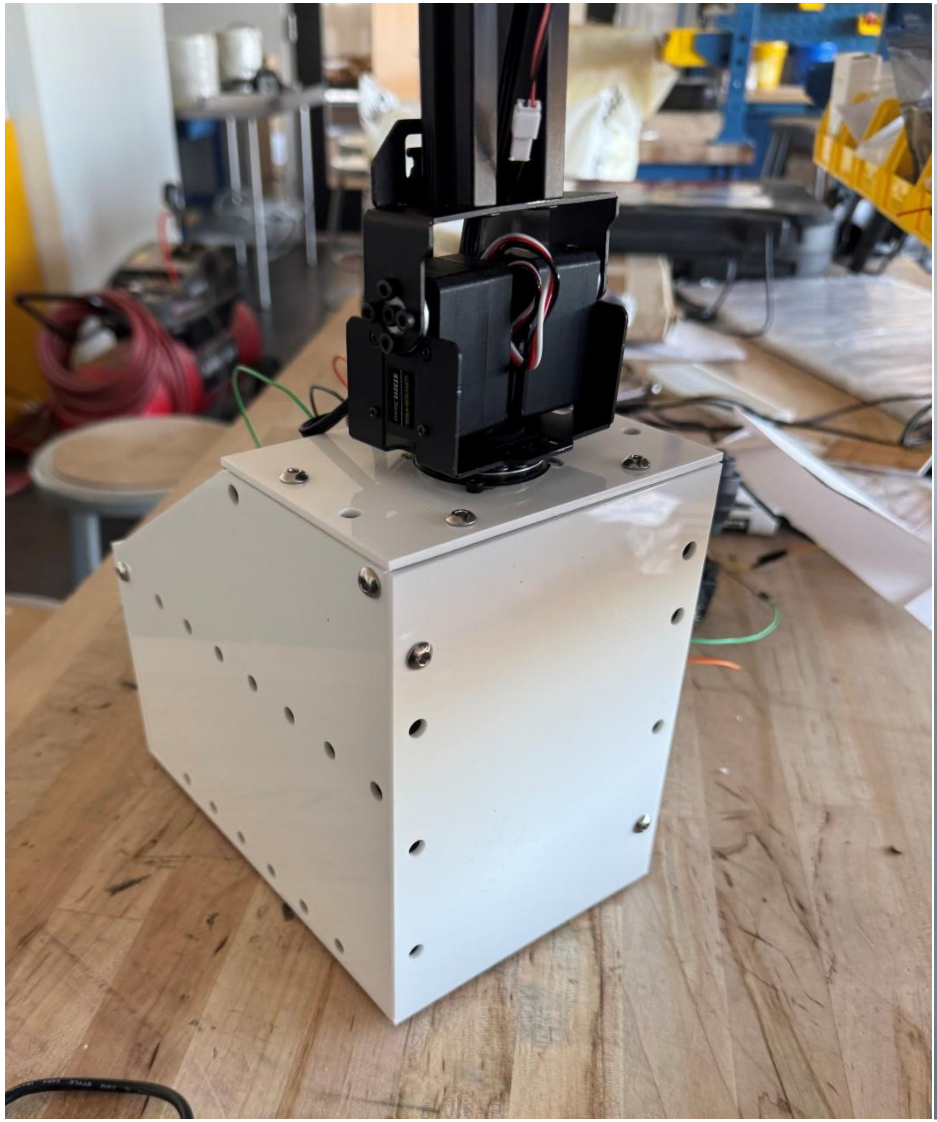




Plugs into robot

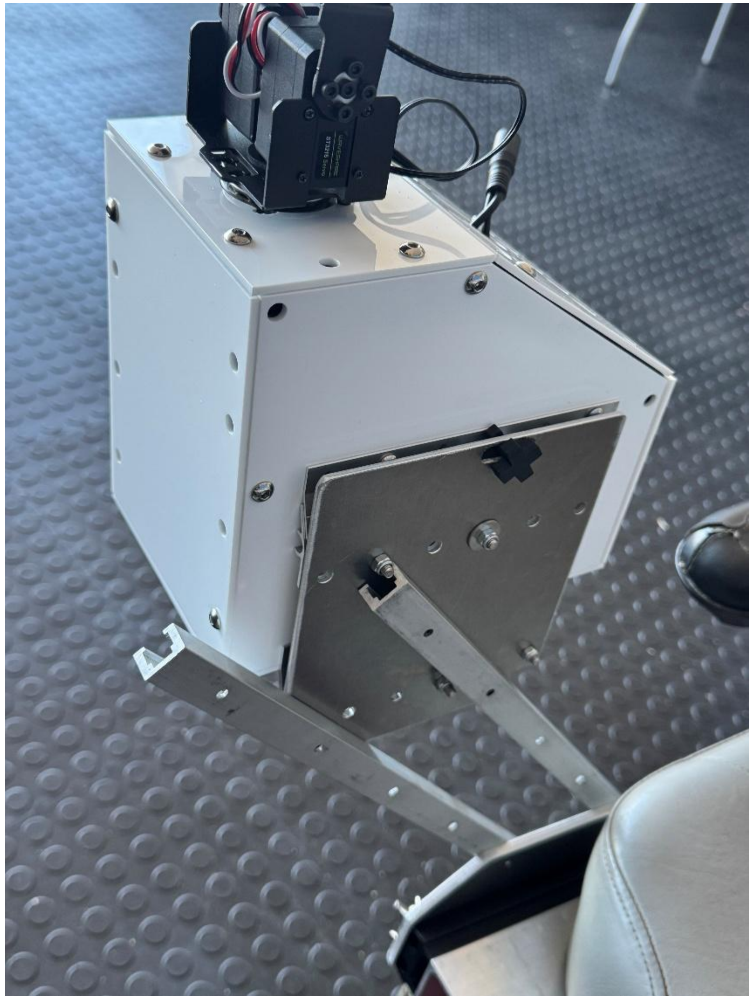
Attachments for peripherals

System Overview



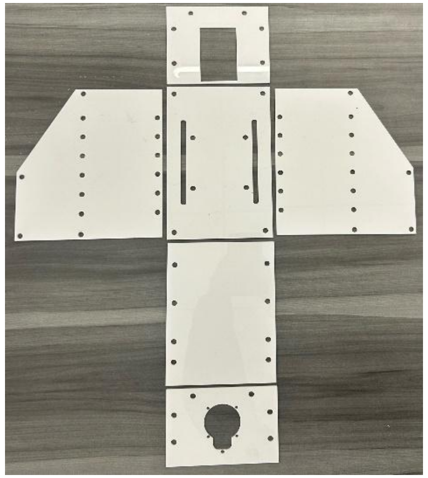
Background | Solution Summary | **Build Progress** | Test Readiness | Project Management

Mounting the System onto the Test Wheelchair



Background | Solution Summary | **Build Progress** | Test Readiness | Project Management

Electronic Casing


Acrylic Panels

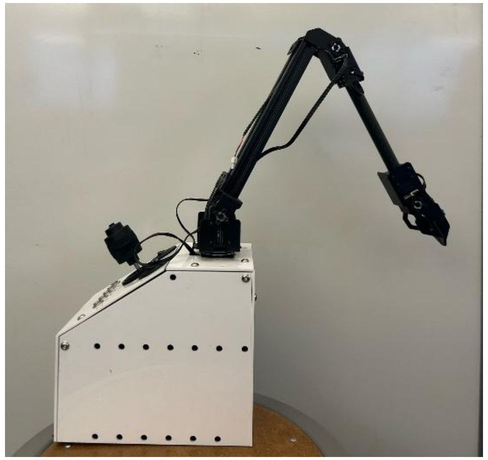

Stopper


Battery Case

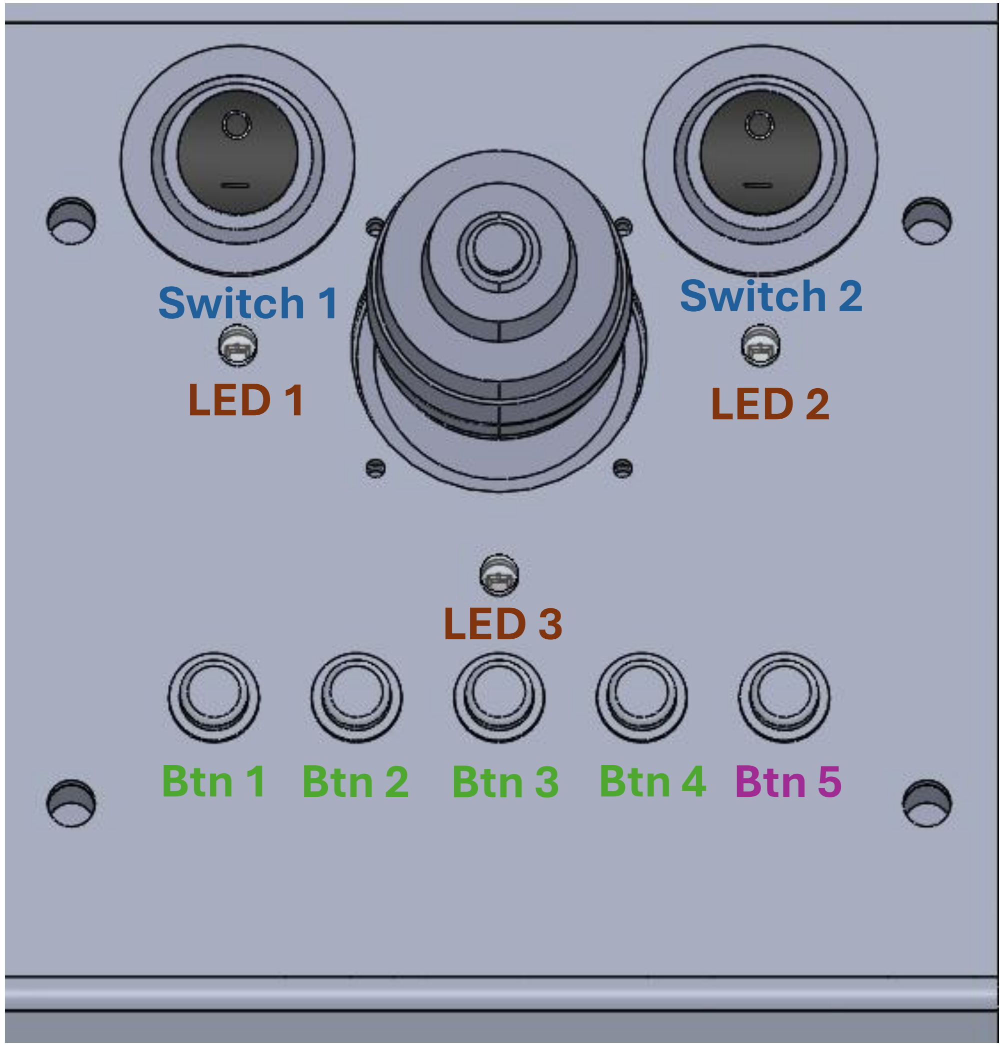

Battery Cover


Corner Frame


Waterproofing Well


Assembled System

User Control Interface



Switch 1: Powers all components
Switch 2: Controls power to the joystick

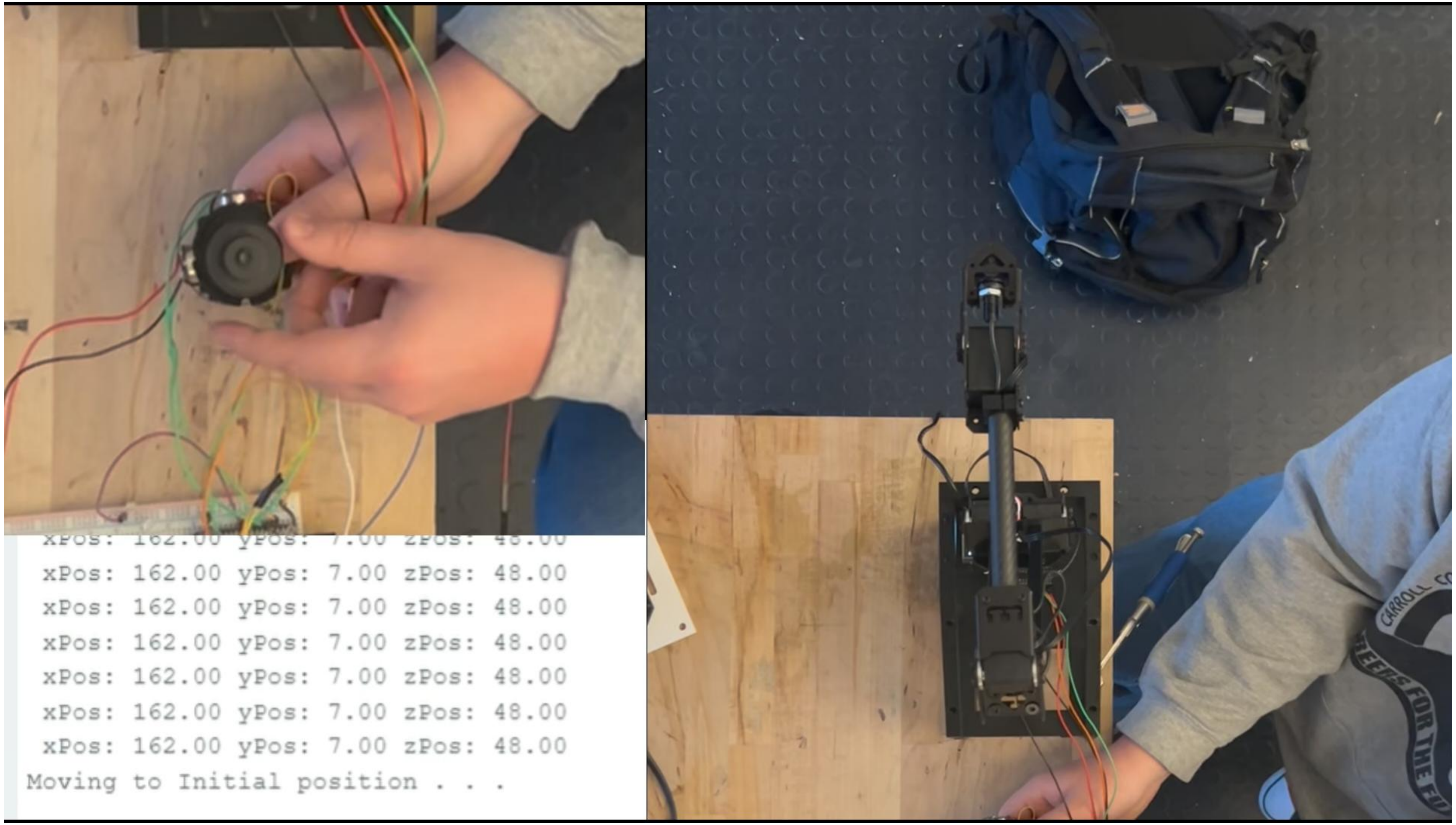
LED 1: Indicates switch 1 is on
LED 2: Indicates whether the joystick is getting power (switch 2 on/off)
LED 3: Status LED indicating what functions are running

Button 1: Used for programming and moving to the ready position
Button 2: Used for programming and running the drink function
Button 3: Used for programming and moving to the first stow position
Button 4: Used for programming and moving to the second stow position

Button 5: An extra button to be used for saving another position or turning off and on the light on the end effector

Current Layout follows a standard for wheelchair joystick and buttons

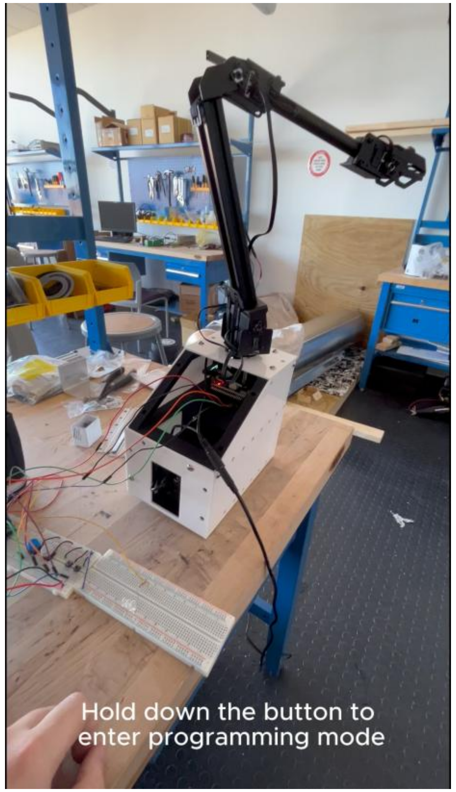
Controlling Robotic Arm with the Joystick



Programming a Location: High Value Function

A brief video showing how a position is saved:

- **Holding** a button for five seconds puts it into **programming mode**
    - In this mode, you move the arm to the location you want to store, and hit the same button to store this location
- **Pushing** a button moves the arm to the **saved location**
    - This location is saved across shutdowns, and can be reprogrammed by holding the button and repeating the above bullet

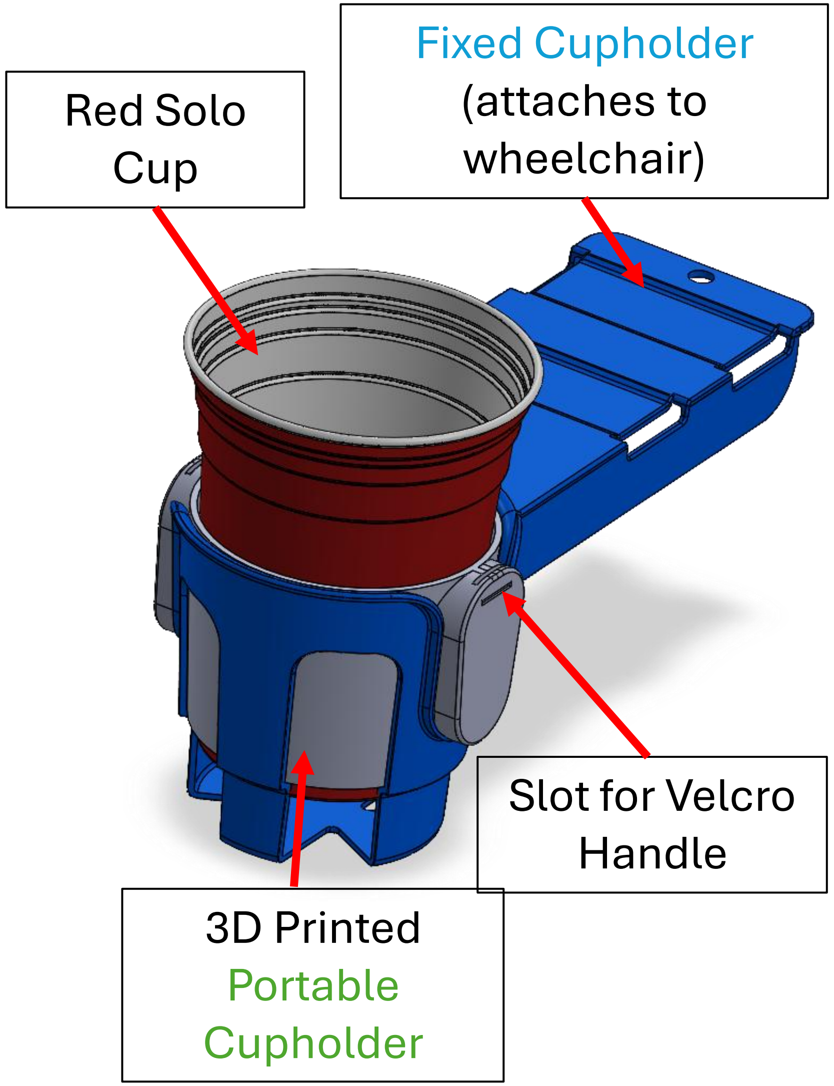


Drinking Function

The portable cupholder rest within the fixed cupholder and the robotic arm picks up the drink via the portable cupholder handle

Figure 2: Paracord Portable Cupholder

Figure 3: Leather Portable Cupholder



Programmed Drinking Function

The user programs two locations for the drinking function:

- The drink position in the cupholder
- The position in front of the users face

No other positions are programmed, the path for this function utilizes a “safe spot” as a midpoint between the two programmed positions

Currently, this safe spot is the “ready/home” position that the user programs with button 1; however, this may be changed after more testing and feedback

With the ability to program specific locations, and the logic in place to complete our high value functions, we are another step closer to fully completing the requirements for our system

Key Requirements

Technical Requirement ID	Requirement	Verification Method	Status
TR 1.1.0	The robot shall be controlled manually by a joystick and should have the ability to program automatic functions accessed through a button push	Test	Completed
TR 1.2.0	The robot shall have no more than six degrees of freedom to reduce the complexity of controls	Inspection	Met with robot arm choice
TR 1.3.0	The robot shall have an operating radius that spans a minimum of 5 inches to a maximum of 2 feet from mount location with 180 degrees of rotation total	System Test	Met with robot arm choice
TR 1.4.1	The battery that powers the robot arm shall last 24 hours between charges	Analysis	Completed

Key Requirements (Continued)

Technical Requirement ID	Requirement	Verification Method	Status
TR 1.3.1	The device should be able to reach and depress elevator buttons and the handicap door button between 35" and 48" as specified by ADA standards	Analysis	Completed
TR 1.3.2	The system shall have an accuracy of +-10mm while at full extension	Analysis and test	Analysis Completed – test scheduled for April
TR 3.0.0	The robot shall be installed in less than one hour and should be operational within thirty minutes of installation	Test	In progress – test scheduled for April
TR 5.3.0	The robot shall have safeguards against unexpected de-energization	Inspection	In progress - Test scheduled for April

Test 1 – End Effector Max. Length Accuracy

TR 1.3.2:
The system shall have an accuracy of +-10mm.

Importance:
This test ensures our system is compliant with the ADA standard 407.2.1 stating the minimum dimension of a button should be ¾ in.

Method:

- Test will be completed in Gilbert senior design space
- Equipment needed:
  - Robotic Arm System
  - Motorized Wheelchair
  - Whiteboard (Plane surface)
  - Tape measure (Larger distance movement)
  - Calipers (Smaller distance movement)

Measured Variables:

- End point displacement L_n

Test 1 – End Effector Max. Length Accuracy (Continued)

Summarized Procedure

1. Robotic arm is powered, and end effector extends to whiteboard at its maximum length 35” from ground.
2. Point P_1 is drawn at the contact between the end effector and white board
3. Joystick is incrementally moved one-unit to the right targeting y axis motion where point P_2 is drawn
4. Measure distance L_1 between P_1 & P_2
5. Joystick is incrementally moved one-unit upwards targeting z axis motion where point P_3 is drawn
6. Measure distance L_2 between P_2 & P_3 and diagonal distance L_3 between P_1 & P_3
7. Review measured distances and compare to maximum tolerance.
8. Repeat test at 48” from ground moving powered wheelchair as needed.

Safety Concerns

- Robotic arm joints are set to $30kg.cm$. To avoid injury, keep away from joints during testing

Expected Outcomes

The end effector displacement at should fall below 10mm at its maximum extension length.

Test 2 – End-Effector Max. Load Capacity

TR 1.1.4:

The arm should be able to bring a drink of weighing 470g to a specified location in front of the user.

Purpose:

Determine the maximum allowable weight of a drink, including container and liquid, that may by carried by the robotic arm.

Method:

- Location: Gilbert senior design space
- Equipment: Waveshare RoArm (incl. table edge fixing clamp and 12V 5A power supply), scale, portable cupholder, fixed cupholder, plastic container (w/ lid and straw), water source, and UI (joystick or computer)

Measured Variables:

Load Capacity: 0.5kg (~1.1lbs)	
Max. Distance:	0.5m (~1.6ft)
Repositioning Precision:	±4mm (~0.1in)
Servo Rotation Speed	40rpm (no torque limit)

Test 2 – End-Effector Max. Load Capacity (Continued)

Summarized Procedure:

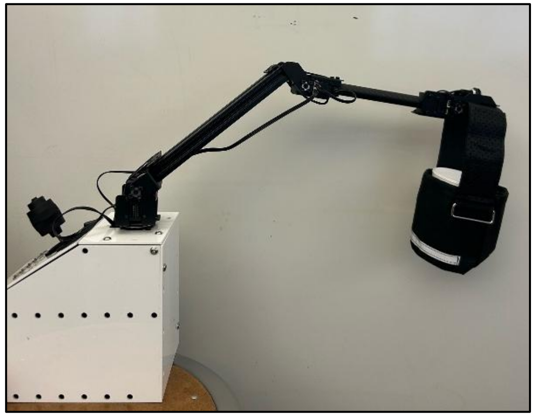
1. Clamp robotic arm to stable surface then connect power and setup UI for robotic arm
2. Mimic/record robotic arm's motion drink function positions (xyz) using UI
3. Measure/record weight of drink and place into portable cupholder; portable cupholder should be already placed in fixed cupholder
4. Position cupholders at the initial position of the drink function then initiate drink function
5. Observe/ record system behavior; determine if system is stable or unstable
6. Repeat steps 3-5 and increase weight by 0.1kg until system is determined to be unstable

Safety Concerns:

- Proper power supply
- Electronics are encased in waterproof material
- Users and computers are outside arm's reach

Expected Outcomes:

- The arm will be able to lift and carry a 400ml drink along the drink function path



Test 3 – Restricted Motion Compliance

TR 5.2.0:
The robot shall have physical or program safeguards to prevent it from reaching undesired locations.

Importance:
Because the system is working in close proximity of the user, safeguards are required to prevent unintentional contact

Method:

- Test will be completed in Gilbert senior design space
- Equipment needed:
  - Robotic Arm System
  - Motorized Wheelchair
  - Connected Laptop

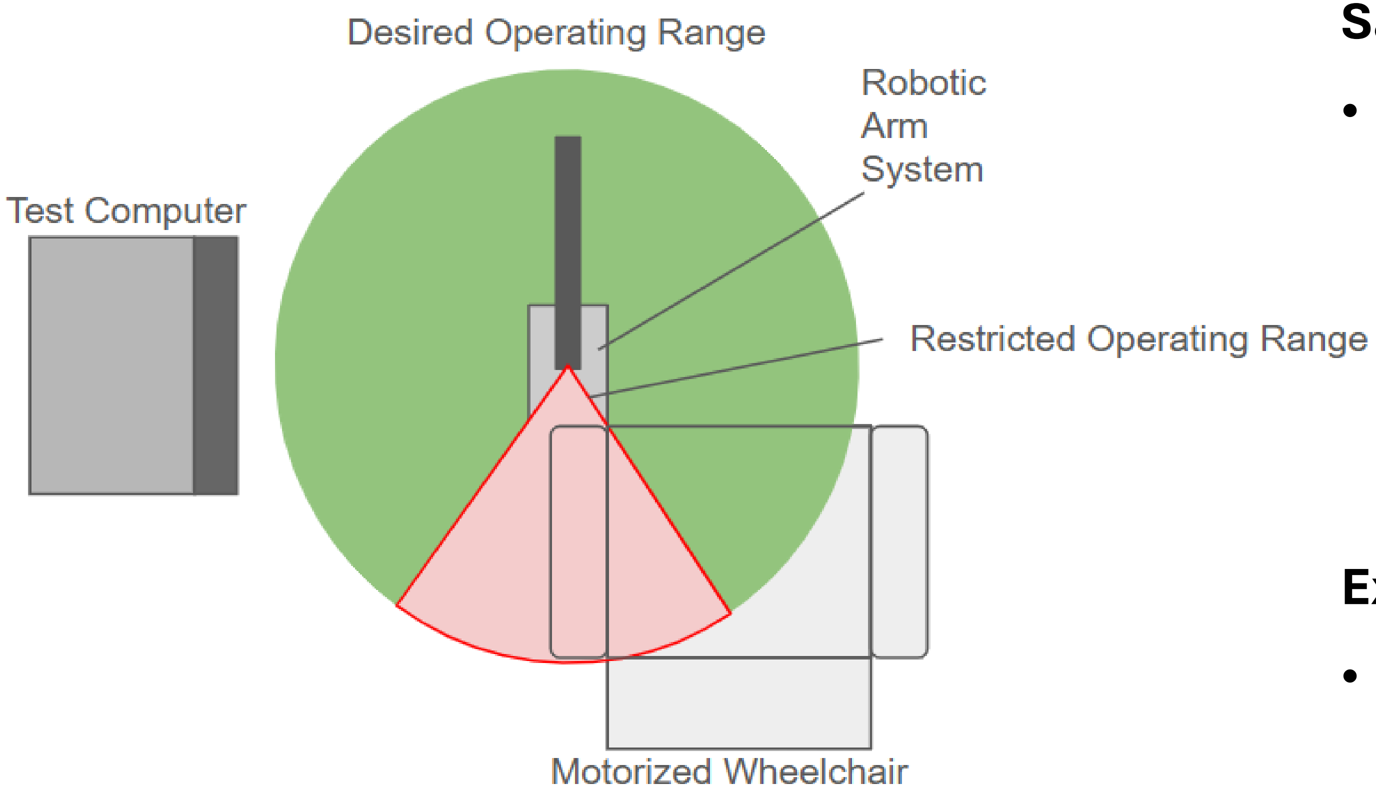
Measured Variables:

Variable	Type	Manufacturer	Model #	Uncertainty
Px	Magnetic Encoder	Waveshare	Built-in (12-bit)	±0.088° (angular) / ±4mm (linear)
Py	Magnetic Encoder	Waveshare	Built-in (12-bit)	±0.088° (angular) / ±4mm (linear)
Pz	Magnetic Encoder	Waveshare	Built-in (12-bit)	±0.088° (angular) / ±4mm (linear)

Test 3 – Restricted Motion Compliance (Continued)

Summarized Procedure

1. Power on the system
2. Confirm data read
3. Initiate arm motion
4. Test Positive Arm limits
5. Test Negative arm limits
6. Test Edge Case Use
7. Repeat steps 3-6 at medium and maximum speed



Safety Concerns

- The arms speed can be high when moving at maximum velocity, it is advised that testers stay out of its range of motion during the test

Expected Outcomes

- The arm will be unable to enter the restricted operating range

Test 4 – Installation and Operation Time

TR 3.0.0:
The robotic aid shall be installed in less than one hour and should be operational within thirty minutes upon installation

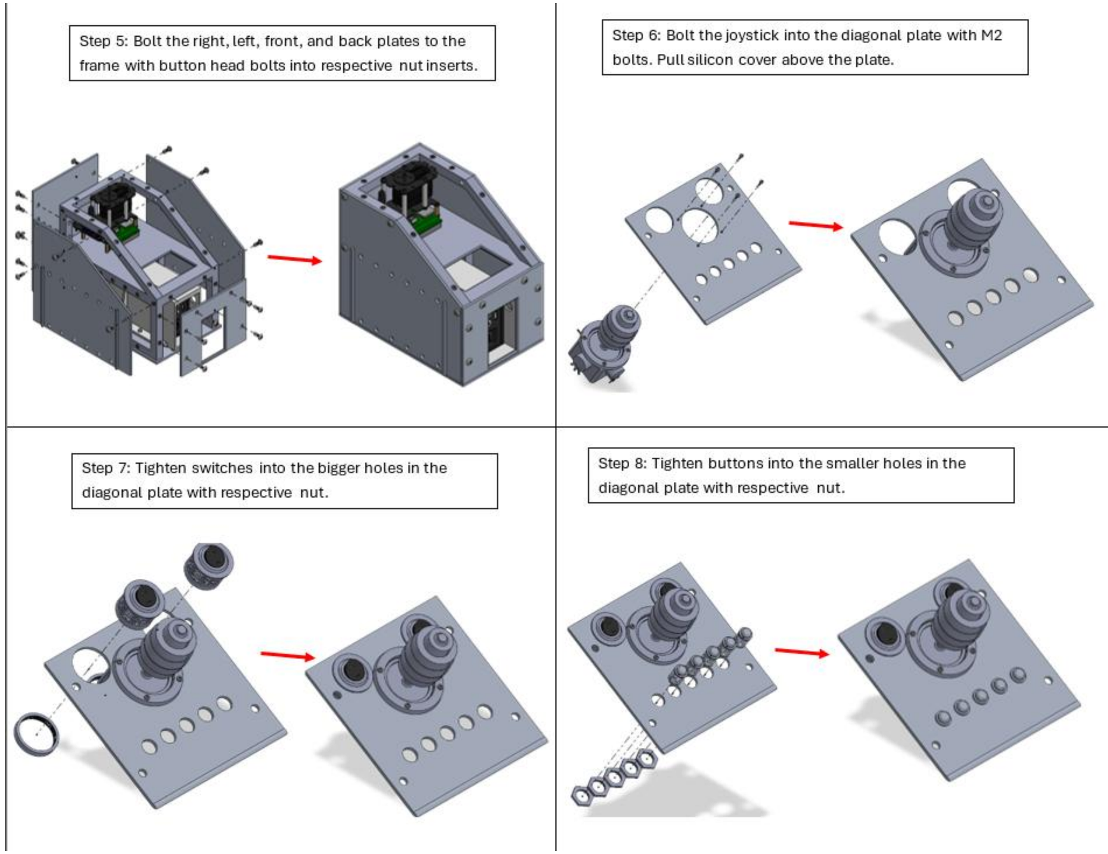
Importance:
This test ensures the system isn't too complex for the customer to use or operate

Method:

- Test will be completed in Gilbert senior design space
- Equipment needed:
  - Robotic Arm System
  - Mounting System
  - Motorized Wheelchair
  - Timer
  - Allen Wrenches/Screwdrivers

Measured Variables:

- Time to installation: T_{in}
- Time till operational: T_{op}



Test 4 – Installation and Operation Time (Continued)

Summarized Procedure:

1. Attach the mounting plate to the Unitrack with square nuts and m6 wingbolts
2. Position rails at a 45-degree angle over respective threaded holes in the mounting plate and secure with 18-8 pan head bolts.
3. Assemble the French cleat system to the 45-degree rails with hex head screws and ¾” locknuts
4. Place electronics case with the top French cleats onto the bottom French cleats, and secure with the pin.
5. Record the time taken as T_{in}.
6. Flip the switch on the battery and ensure the buttons, switch, and joystick all properly manipulate the robotic arm.
7. Record the time taken as T_{op}.

Safety Concerns:

- Proper power supply
- Electronics are encased in waterproof material
- Proper tools and training are supplied

Expected Outcomes:

- The robotic aid will be installed in under an hour and will be operational within 30 minutes.

Test 5 – Maintenance Time

- **TR 3.1.0:** The system shall have maintenance work completed in less than three hours

- **Importance:** Since the system is used for daily tasks, removal from the end user for an extended time is not ideal

Method:

- Test will be completed in Gilbert senior design space
- Equipment needed: Drill/screwdriver, Timer, Allen key, Bucket for Screws
- Additional test equipment: Soldering Iron, Solder, Electrical Tape, Wire Caps, Zip Ties – only if necessary for maintenance

Measured Variables:

Start Time	(00:00 AM/PM)
End Time	(00:00 AM/PM)
Elapsed Time	(Hours: Minutes: Seconds)

Test 5 – Maintenance Time Steps and Outcomes

Summarized Procedure

1. Acquire robotic system and tools
2. Begin timer, record start time
3. Perform maintenance activities described in test plan
4. Once maintenance completed, power on system and verify normal system operation
5. Stop timer and record end time and elapsed time from stopwatch

Safety Concerns:

- Possibility of poking oneself on solder locations – exercise caution during inspection
- Possibility of burning oneself if resoldering loose joins – exercise caution during maintenance
- Possibility of hair getting caught in drill if used – tie hair back before performing inspection

Expected Outcomes:

Expected Outcome	P/F Limit
1.5 Hours	3 Hours
Problems that yield the system inoperable and require a more in-depth inspection are out of the scope of this test	

Schedule – Where we are as of TRR

Task Name	% Comp	Start	Finish	Predecessors	Duration
Solder the protoboard according to the drawings, then wire together the buttons, switches, and joystick onto the protoboard.	85%	Fri 2/28/25	Mon 3/3/25	90	2 days
Place electronics in the acrylics plates and assemble the "case" portion of the system	50%	Tue 3/4/25	Wed 3/5/25	91	2 days
Test custom cup and cupholder options for refinement after TRR	50%	Thu 3/6/25	Mon 3/10/25		3 days
Receive Aluminum plates and manfuacture on plasma cutter and CNC	0%	Mon 3/3/25	Tue 3/4/25		2 days
Perform Test 1-3 according to developed test plans	75%	Thu 3/6/25	Thu 3/6/25	92	1 day
Mount the assembled arm and frame to the wheelchair	**94%**	**Thu 2/6/25**	**Mon 2/17/25**		**8 days**
Order Hardware to Modify the Jazzy test wheelchair for our test fit - receive parts	100%	Thu 2/6/25	Wed 2/12/25		5 days
Attach the unitrack to the wheelchair	100%	Thu 2/13/25	Thu 2/13/25	97	1 day
Modify the armrest to represent the Permobil	75%	Fri 2/14/25	Mon 2/17/25	98	2 days
Attach the system to the wheelchair	50%	Wed 3/5/25	Thu 3/6/25	94,98,99	2 days
Spring Test Readiness Review Presentations	0%	Tue 3/4/25	Thu 3/6/25		3 days
Spring Break	0%	Sat 3/8/25	Sun 3/16/25		7 days

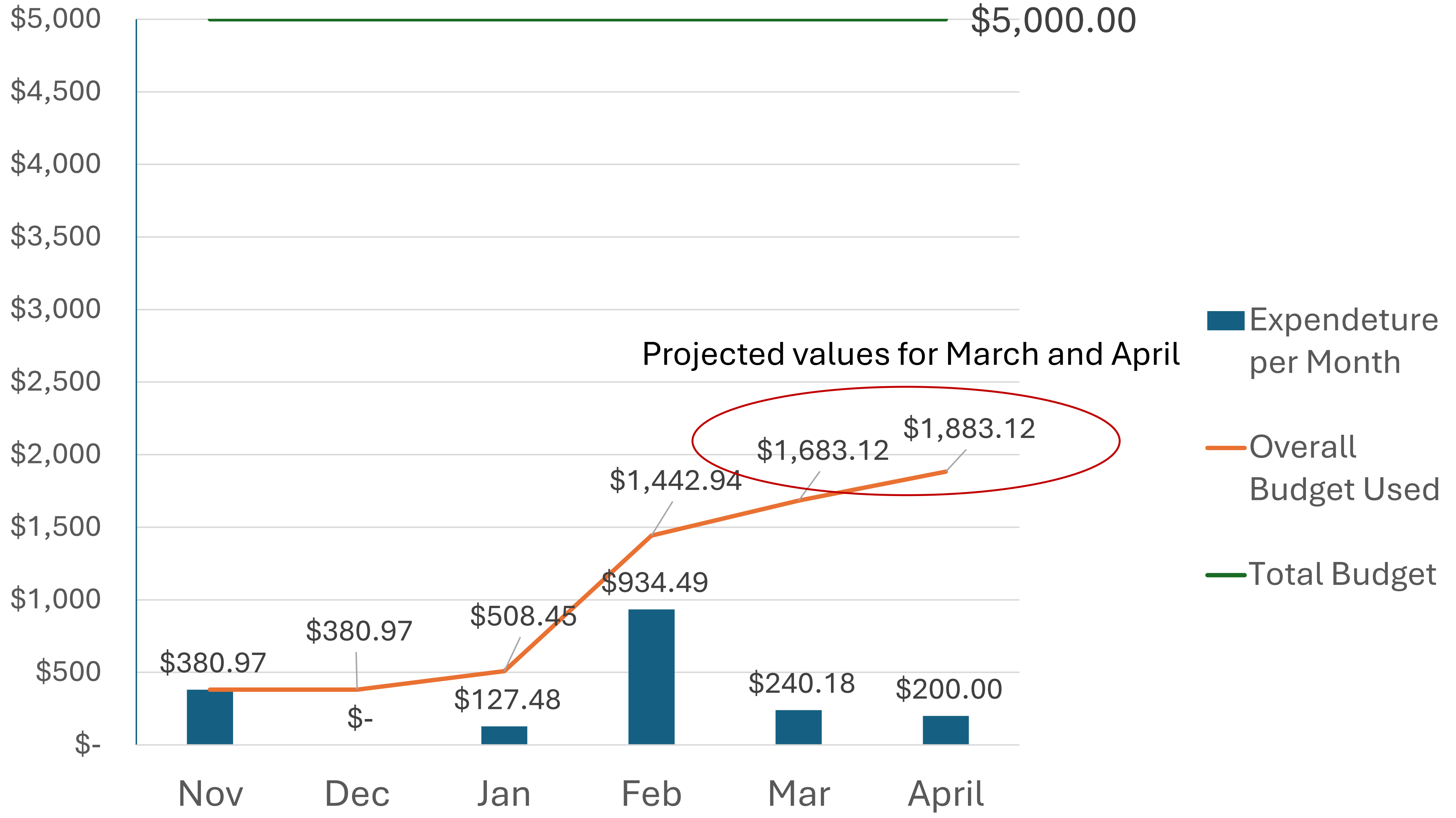
- Currently on progress despite some setbacks with lost packages and shipment issues
- All major parts have been fabricated, and all major subsystems operational
- Begin to focus on assembly and testing

Schedule – What we're doing when we get back

Task Name	% Comp	Start	Finish	Predecessors	Duration
SRR Preparation	**26%**	**Mon 3/17/25**	**Fri 5/9/25**		**40 days**
Continue to debug code, optimizations	75%	Mon 3/17/25	Fri 4/25/25		30 days
Make connections from buttons, joystick, leds to protoboard, test and verify works according to scematic	30%	Mon 3/17/25	Fri 3/21/25		5 days
Test cupholder solution, determine if current solution is viable, make modifications / optimizations	0%	Mon 3/17/25	Fri 3/21/25		5 days
Fully assemble system, make small modifications if necessary	50%	Mon 3/24/25	Mon 3/24/25	105	1 day
Perform the rest of the test according to test plans	0%	Tue 3/25/25	Wed 3/26/25	107	2 days
Meet with Colin from PPMD and test system on his wheelchair	0%	Mon 3/24/25	Mon 3/31/25		6 days
Impliment feedback from meeting with Colin and make other small optimizations necessary	0%	Tue 4/1/25	Tue 4/8/25	109	6 days
Develop deliverable package for sponsor (Documentation, instructions, parts packages, cad files, electronic files, DMX files, everything)	0%	Mon 3/17/25	Fri 5/9/25		40 days
Spring Final Review Presentations	0%	Tue 4/22/25	Thu 4/24/25		3 days
Capstone Expo	0%	Fri 5/2/25	Fri 5/2/25		1 day

- Focusing on assembly when we get back, all parts are nearly ready for assembly, it will happen quickly
- Once assembly completed, testing the system and getting feedback from end users is the highest priority
- While testing, getting feedback and making changes, team will also work on the deliverables needed for construction, operation, and overview of the system

Team 205 Budget expendeture through the year



Conclusions

Meeting Customer Needs:

- The system will be able to push elevator buttons when mounted on the wheelchair
- The system has the coded logic to have unique positions programmed which will be used to complete the high value function of bringing a drink to the user

What We Have Accomplished:

- Mounted the unitrack to our test chair
- Manufactured the frame and case components of the system
- Coding: Basic logic complete for high value functions, shifting to optimization
- Wiring/Electrical: Permanent structures created/acquired – moving to these structures after spring break

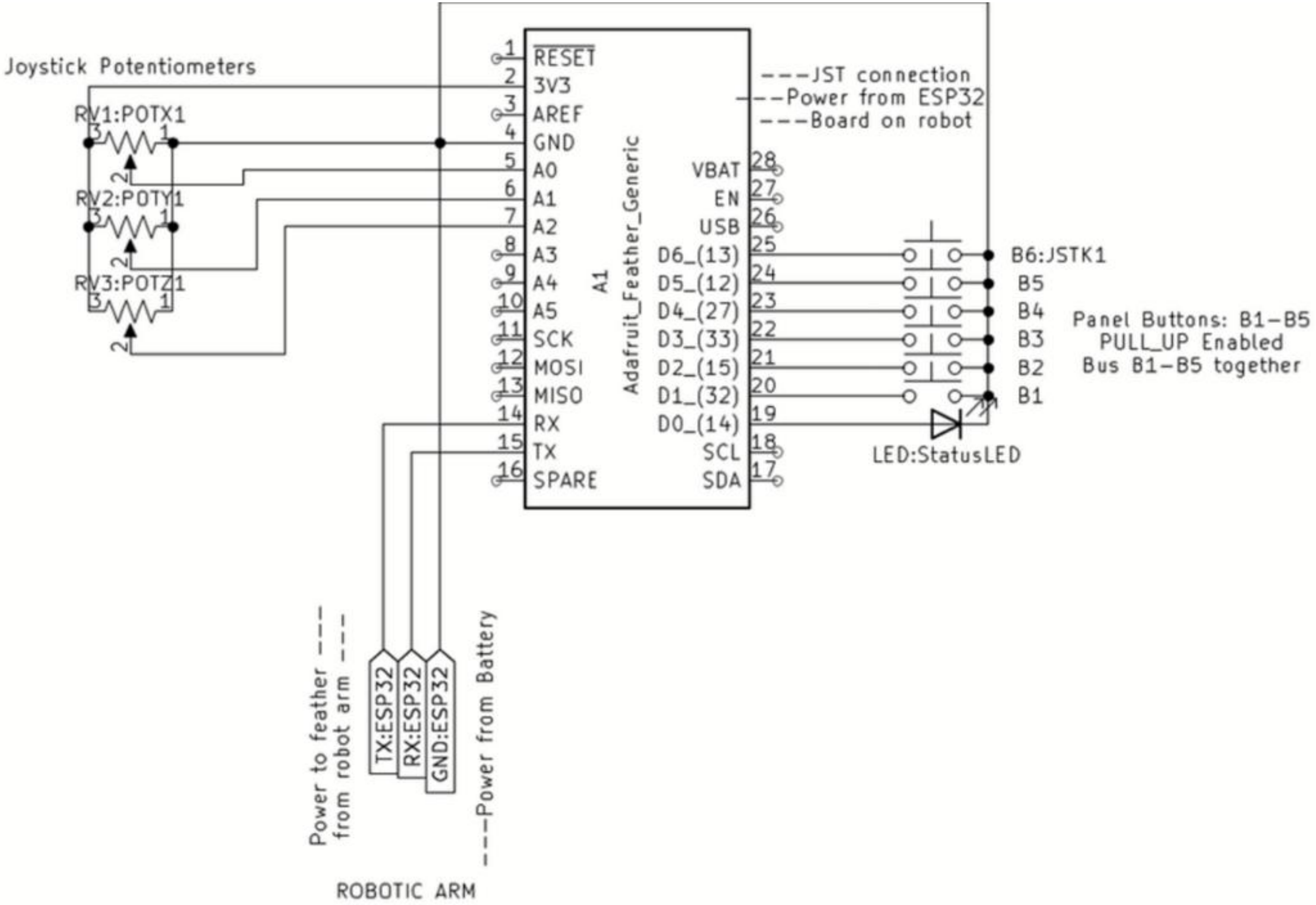
What's left to accomplish:

- Fully assembling system: all major components manufactured and all subsystems operational
- Testing: Perform test once system assembled, get feedback from an end user on system
- Administrative Tasks

THANK YOU FOR LISTENING!

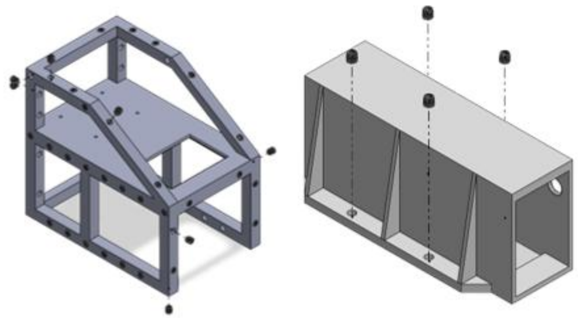
Any Questions for the team?

Appendix 1: Circuit Diagram

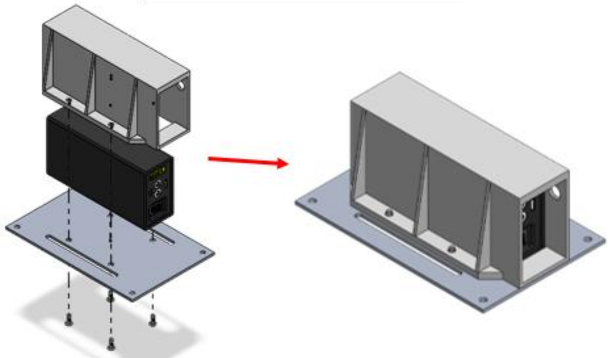


Assembly Manual

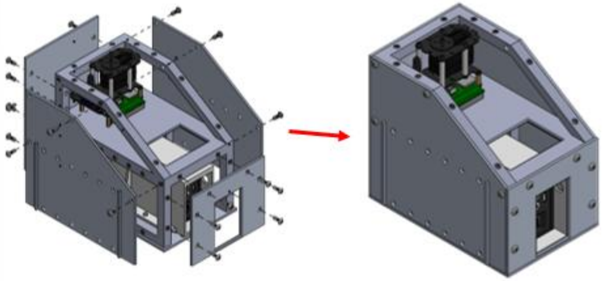
Step 1: Using a soldering iron, put heat nut inserts into all quarter inch holes in the frame and battery case.



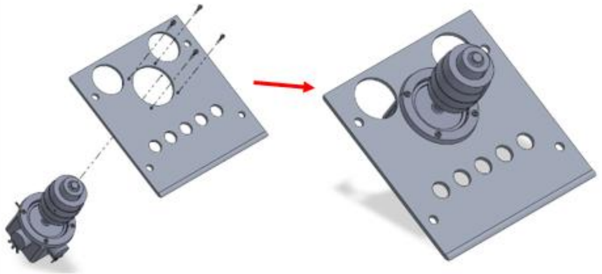
Step 2: Bolt the battery case to the bottom plate with the battery using 4 button head bolts to the nut inserts.



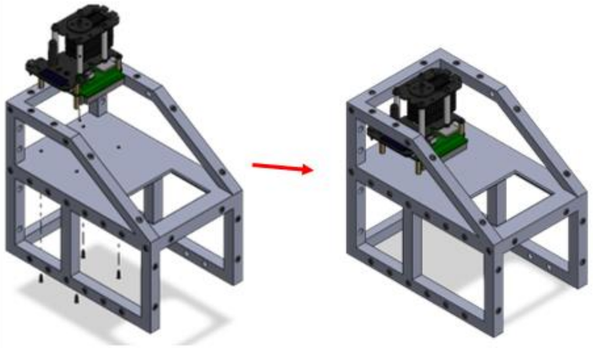
Step 5: Bolt the right, left, front, and back plates to the frame with button head bolts into respective nut inserts.



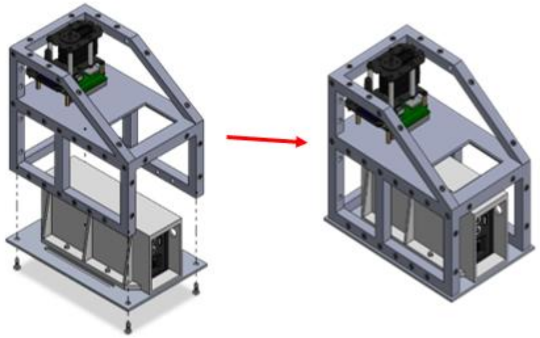
Step 6: Bolt the joystick into the diagonal plate with M2 bolts. Pull silicon cover above the plate.



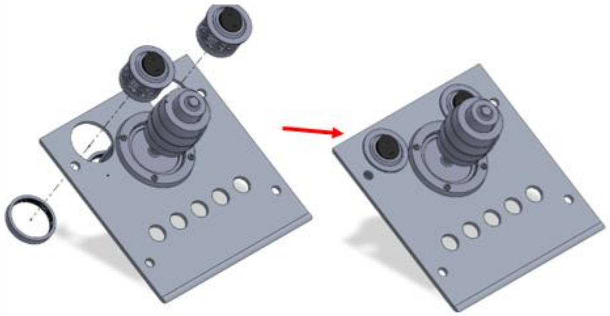
Step 4: Bolt the base of the Waveshare Robotic Arm into the middle plate of the frame using small screws.



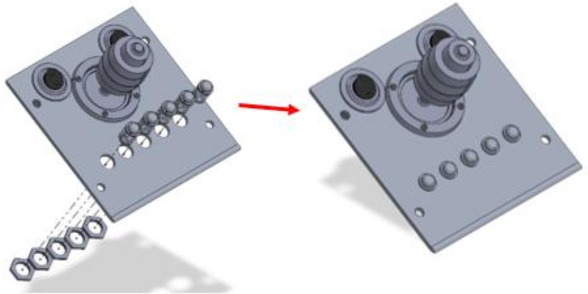
Step 4: Bolt the frame to the bottom plate using 4 button head bolts to the nut inserts on the bottom of the frame.



Step 7: Tighten switches into the bigger holes in the diagonal plate with respective nut.

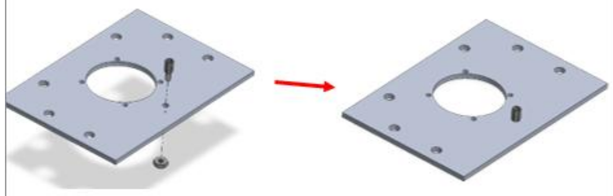


Step 8: Tighten buttons into the smaller holes in the diagonal plate with respective nut.

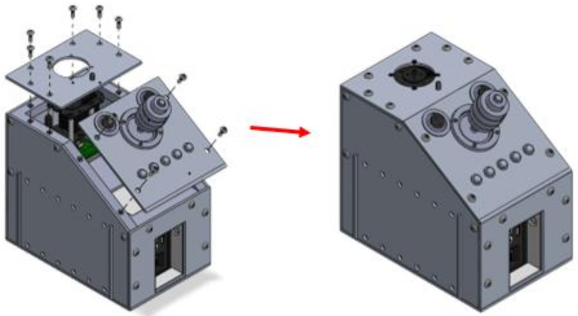


Assembly Manual (Continued)

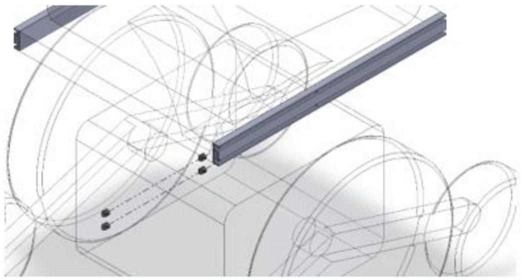
Step 9: Bolt standoff to the top plate in the smaller hole with



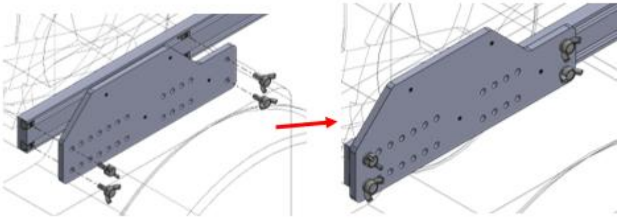
Step 10: Bolt top and diagonal plates into the frame with button head bolts into their respective nut inserts.



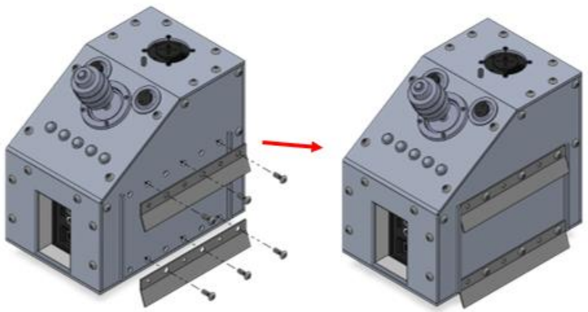
Step 13: On the Unitrack of the Permobil wheelchair, slide the T-slot nuts in.



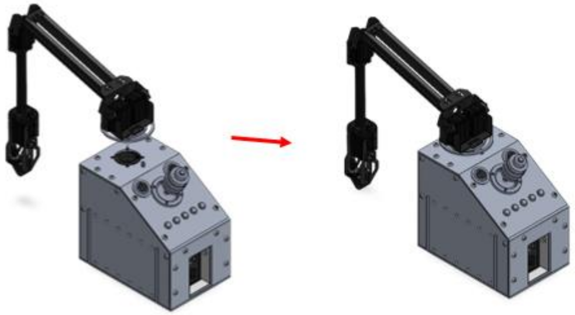
Step 14: Position the 1/4" mounting plate in front of the T-slot nuts and bolt the plate in with wing bolts.



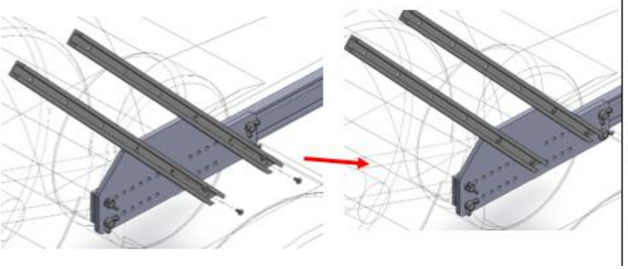
Step 11: Bolt French cleats into the nut inserts in the side of the frame.



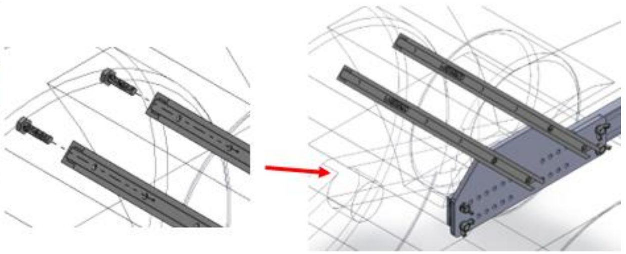
Step 12: Insert the Waveshare Robotic Arm onto its base.



Step 13: Bolt the rails at a 45-degree angle with pan head screws.

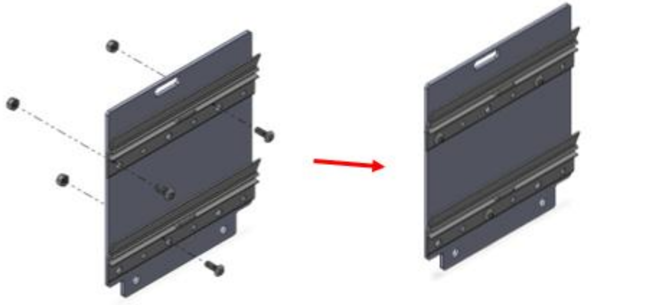


Step 14: Slide the heads of the hex head screws into the rails.

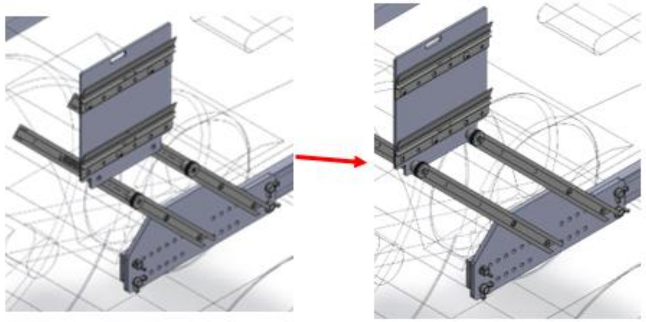


Assembly Manual (Continued Again)

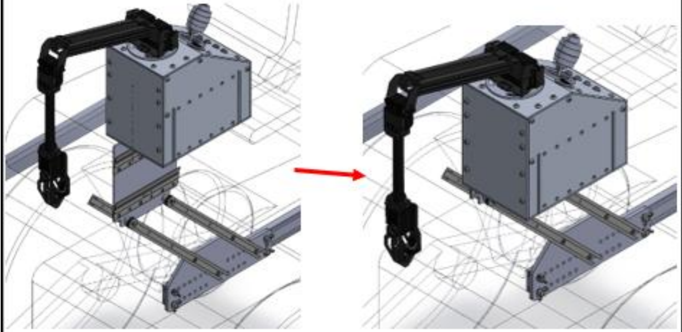
Step 15: To make the connecting assembly, bolt the French cleats onto the connecting plate with button head bolts and M5 button head locknuts



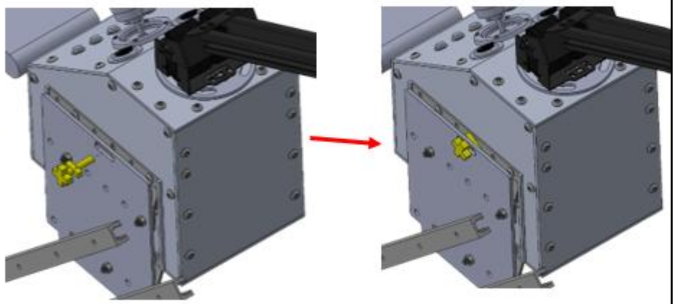
Step 16: Position the connecting assembly over the hex head bolts and secure with 3/4" locknuts.

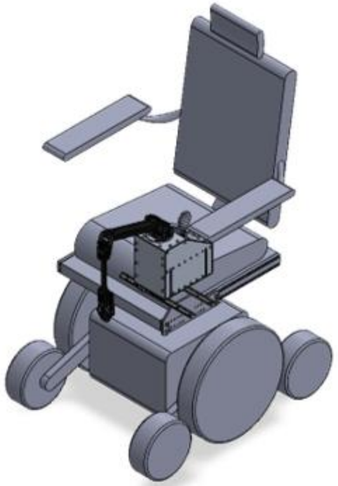


Step 17: Place the case onto the French cleats.



Step 18: To lock the assembly, position the pin in the slot in the connecting assembly and push it until it is flush with the case, then rotate it.





Enjoy

Controlling Robotic Arm