Final Tests and Demo

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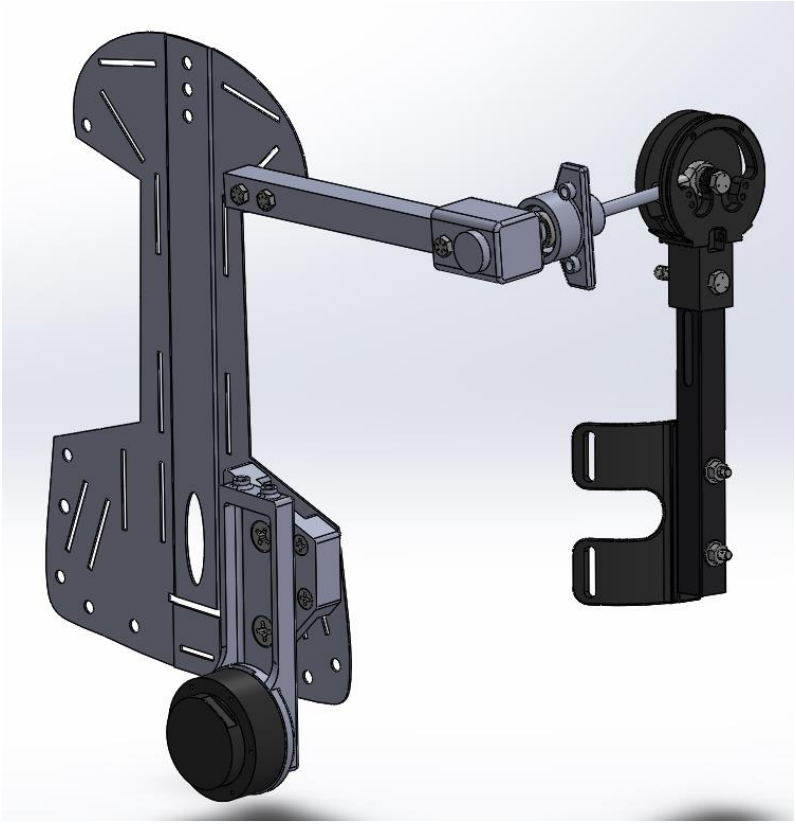


QFD

		Technical Requirements						Customer Opinion Survey				
Customer Needs	**Customer Weights**	Bowden Cable Actuation	Revise Dr. Lerner's Previous Pulley Design	Device can be independently operated away from stationary machinery	Design Must weigh less than 6 lbs.	Design must protrude less than 10cm (3.94in) from the body	Design must increase timed ability to hold a weight in front of the user using their shoulder-arm complex	*1 Poor*	2	*3 Acceptable*	4	*5 Excellent*
Cable Actuated	5	9	3	3	1	1	9	B	C	A		
Utilize a Pulley	5	3	9		3	3	9	AB		C		
User Operable	3	3		9	3	1		B	A	C		
Lightweight	4	1		3	9					AB	C	
Low-Profile	4	3	1	3	3	9					A	BC
Assist Shoulder Endurance	5	9	9			3	9					ABC
Technical Requirement Units		N/A	N/A	N/A	N	N/A	N/A					
Technical Requirement Targets		Bowden Cables	N/A	Remote Controller	< 6 lbs	< 10 cm	15% Increase					
Absolute Technical Importance		130	109	66	77	74	135					
Relative Technical Importance		2	3	6	4	5	1					

Customer & Engineering Requirements

CUSTOMER REQUIREMENTS	ENGINEERING REQUIREMENTS	INITIAL TESTS	FINAL TESTS
CR1 - Cable Actuated	Bowden Cable Actuation	Is it cable actuated?	N/A
CR2 - Utilize a Pulley	Use Dr. Lerner's Pulley Design	Is a pulley used to create torque?	N/A
CR3 - User Operable	Operate independently of stationary machinery	N/A	Can the user operate the device independently of stationary machines?
CR4 - Lightweight	Weigh < 6 lbs.	Does the device weigh less than or more than 6 lbs.?	N/A
CR5 - Low-Profile	Protrude < 10cm (3.94in)	Does the device protrude less than 10cm (3.94in) from the user's body?	N/A
CR 6 – Increase Endurance/Reduce Fatigue	15% Increase in time to hold an object	N/A	Does the device improve endurance by reducing arm fatigue?

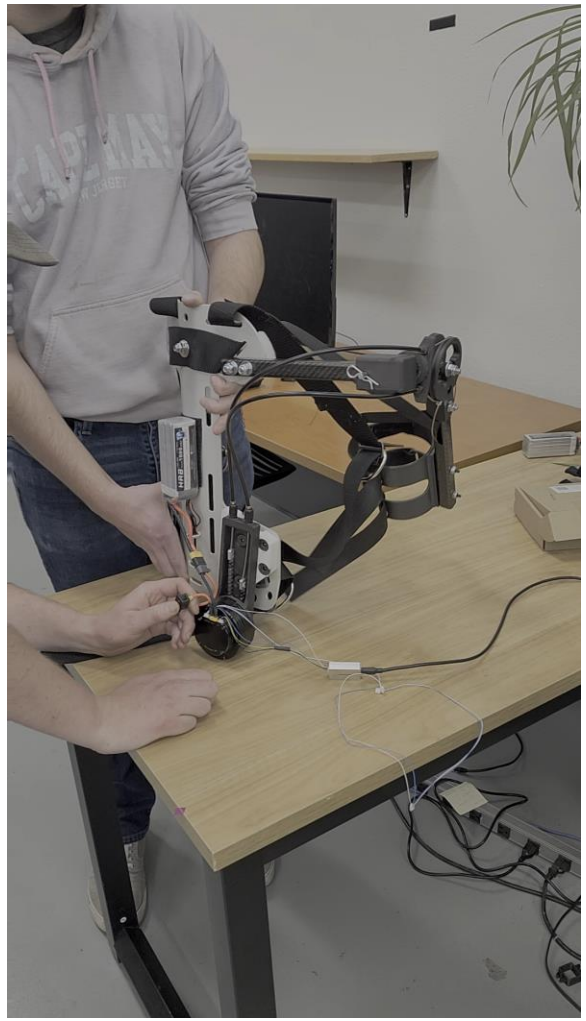
Testing Summary Table

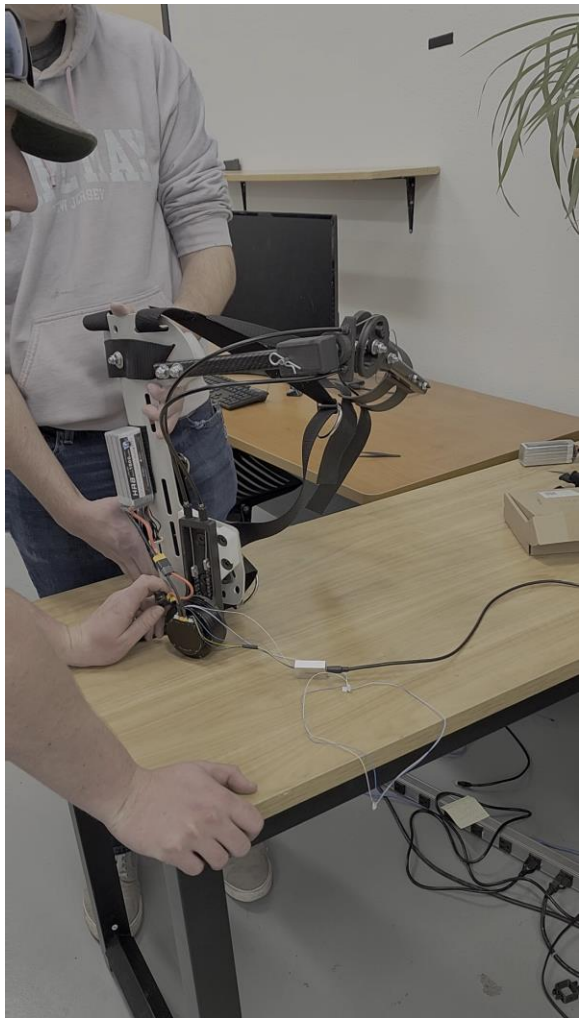
Experiment/Tests	Relevant DR's
Ex 1 – Cable Actuation	ER1
Ex 2 – Pulley Utilization	CR1, ER2
Ex 3 – Weight Tests	CR3 and CR4
Ex 4 – Protrusion Measurements	CR3 and CR5
Ex 5 – Endurance/Fatigue Tests	CR 1, CR 2 and ER 2

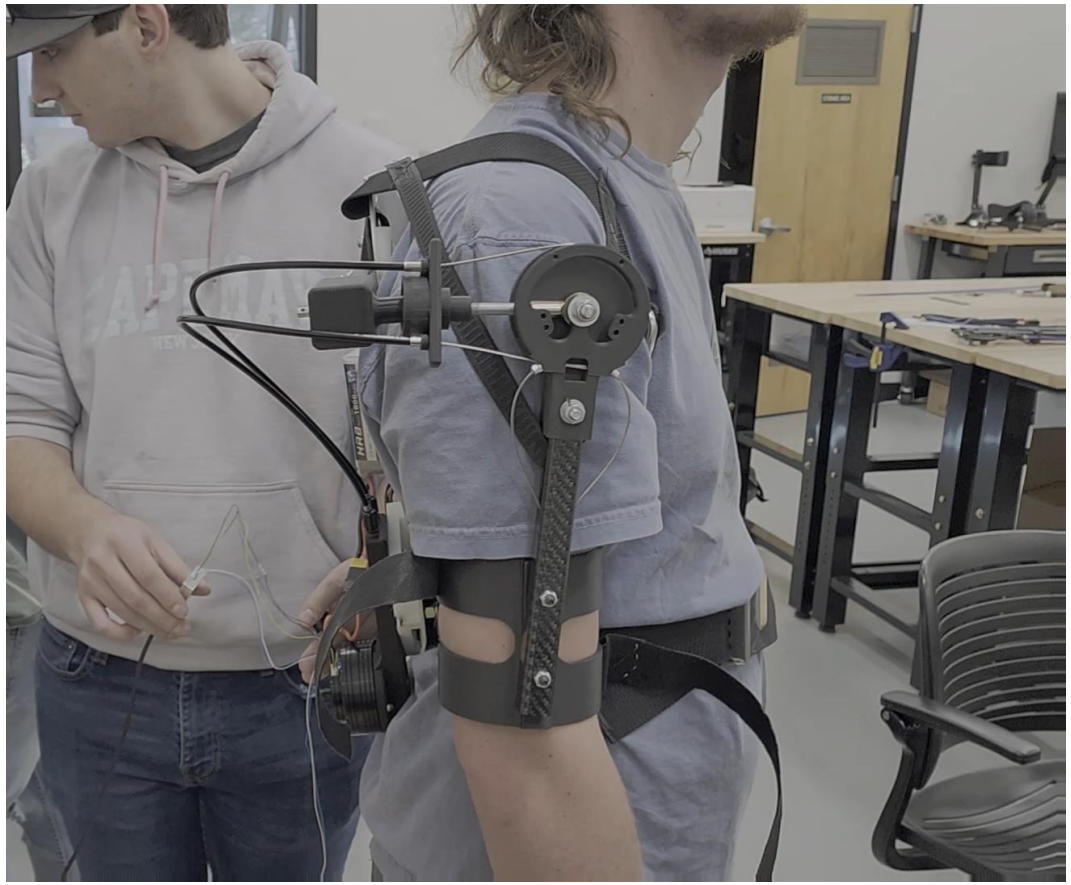
Summary of Experiments

Experiment 1 – Cable Actuated	Does the system use Bowden cables?
Experiment 2 – Pulley Driven	Is the system driven by a pulley?
Experiment 3 – User Operable	Can the device be worn freely?
Experiment 4 – Weight Measurements	Is the device less than six pounds?
Experiment 5 – Protrusion Measurements	Does the device protrude less than 10cm (~4inches)
Experiment 6 – Endurance/Fatigue Tests	Was there a 15% increase in endurance while the device is active?

Initial Testing







Testing Iterations

Figure 1

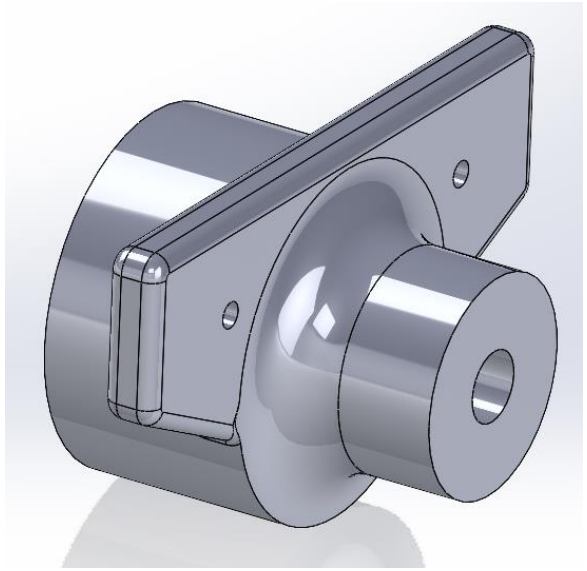
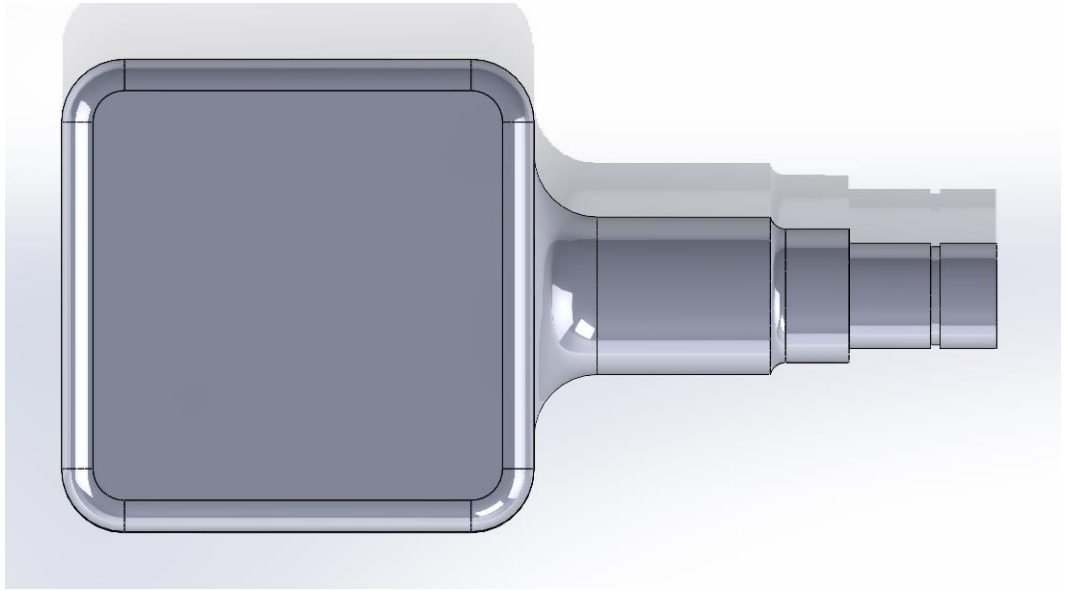


Figure 2

- Originally printed out of non-reinforced Onyx. Inadequate printing pattern that allowed for shearing shown in Figure 1.
- New design, Figure X, adds a fillet to the base of the all-thread interface for minimized stress concentration. Printed out of Onyx inlaid with Carbon Fiber. Printed perpendicular to the force direction.

- Shaft originally printed out of PLA. Designed as one piece. Inadequate design allowed for extruding shaft to shear.
- New shaft, Figure 4, machined out of an aluminum bar. More structurally sound and secure.

Figure 3



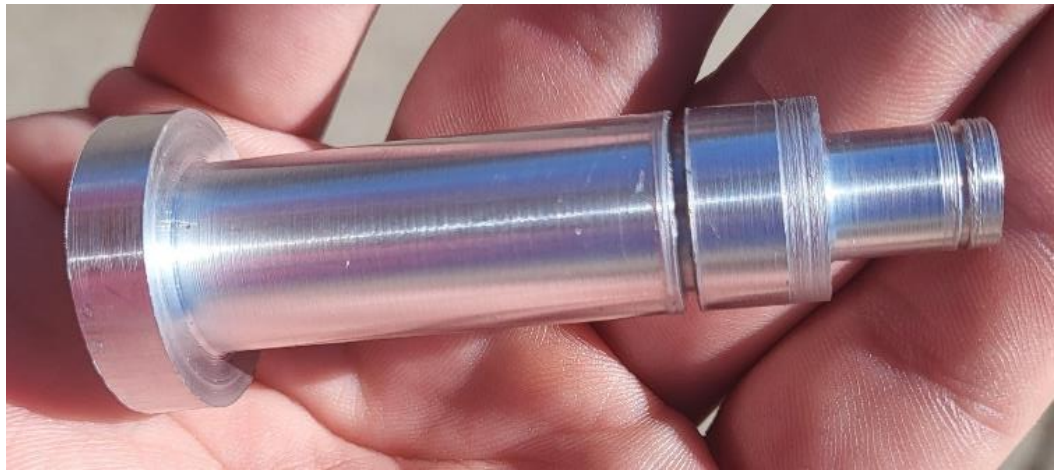
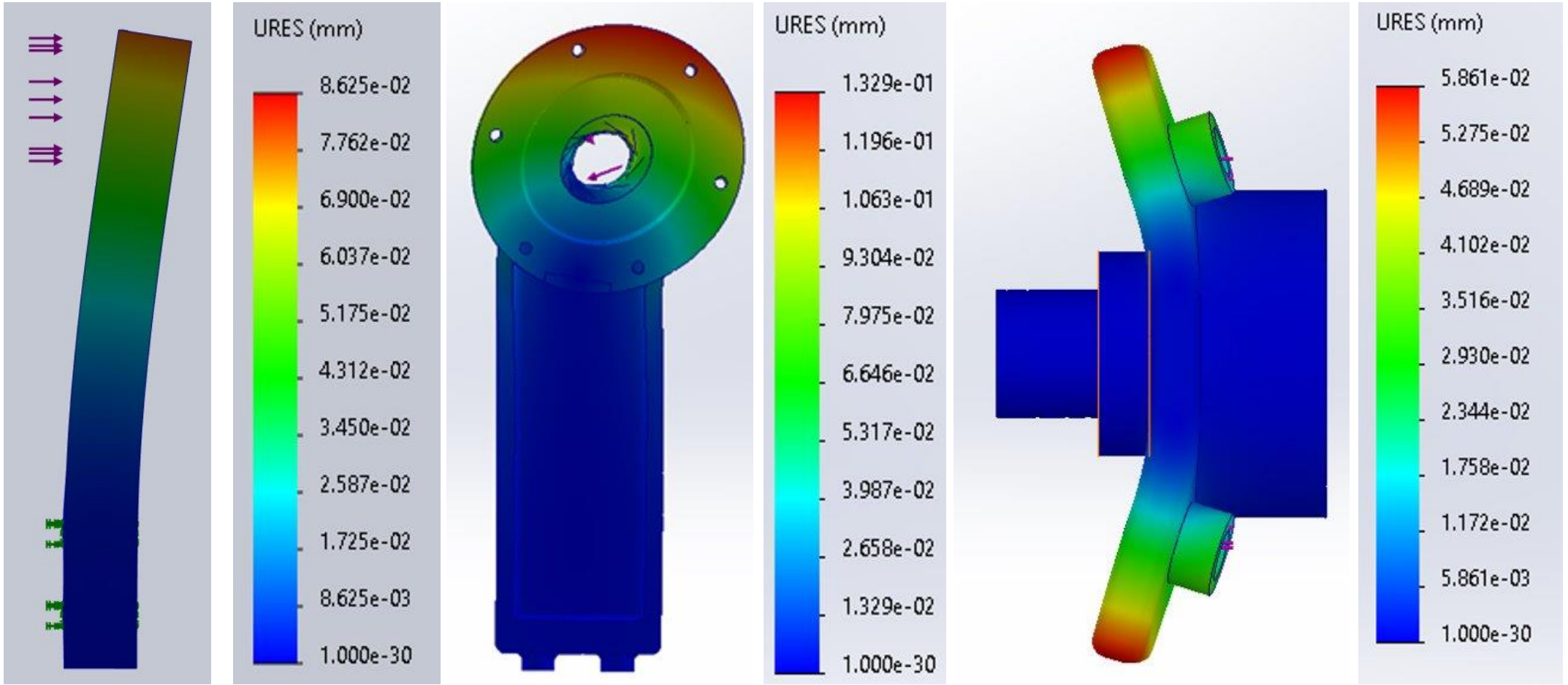


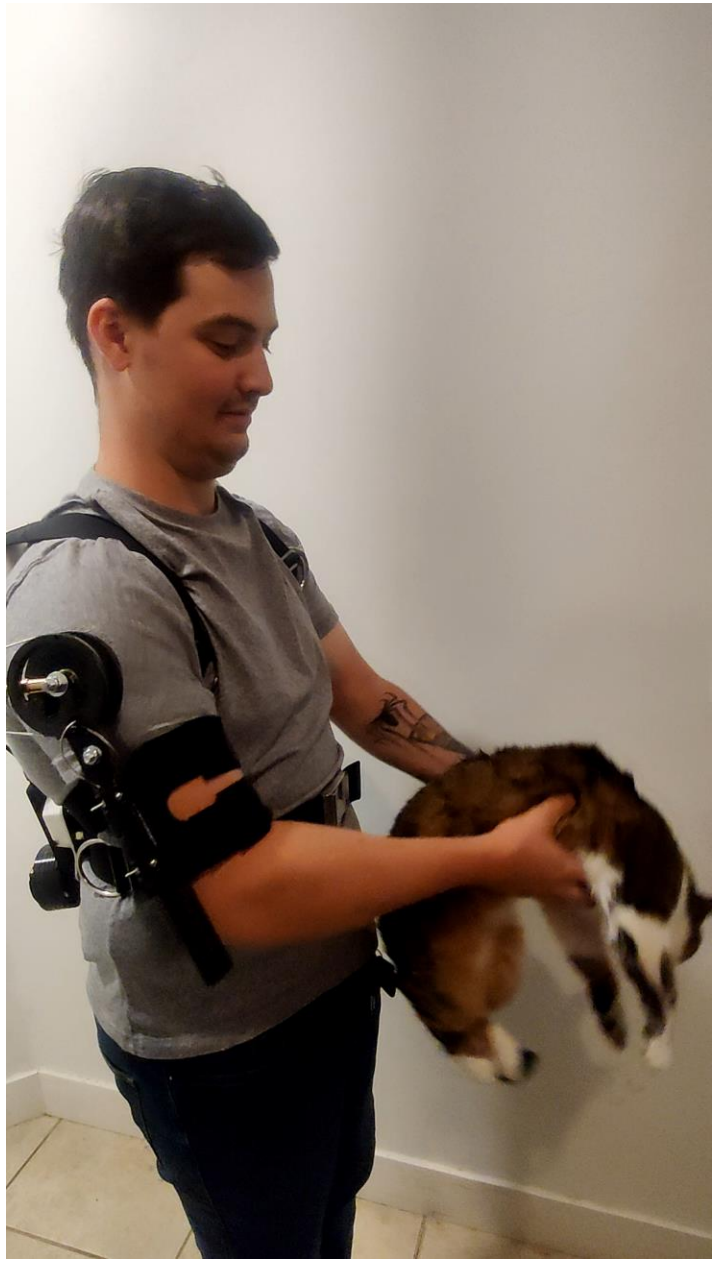
Figure 4

Finite Element Analysis



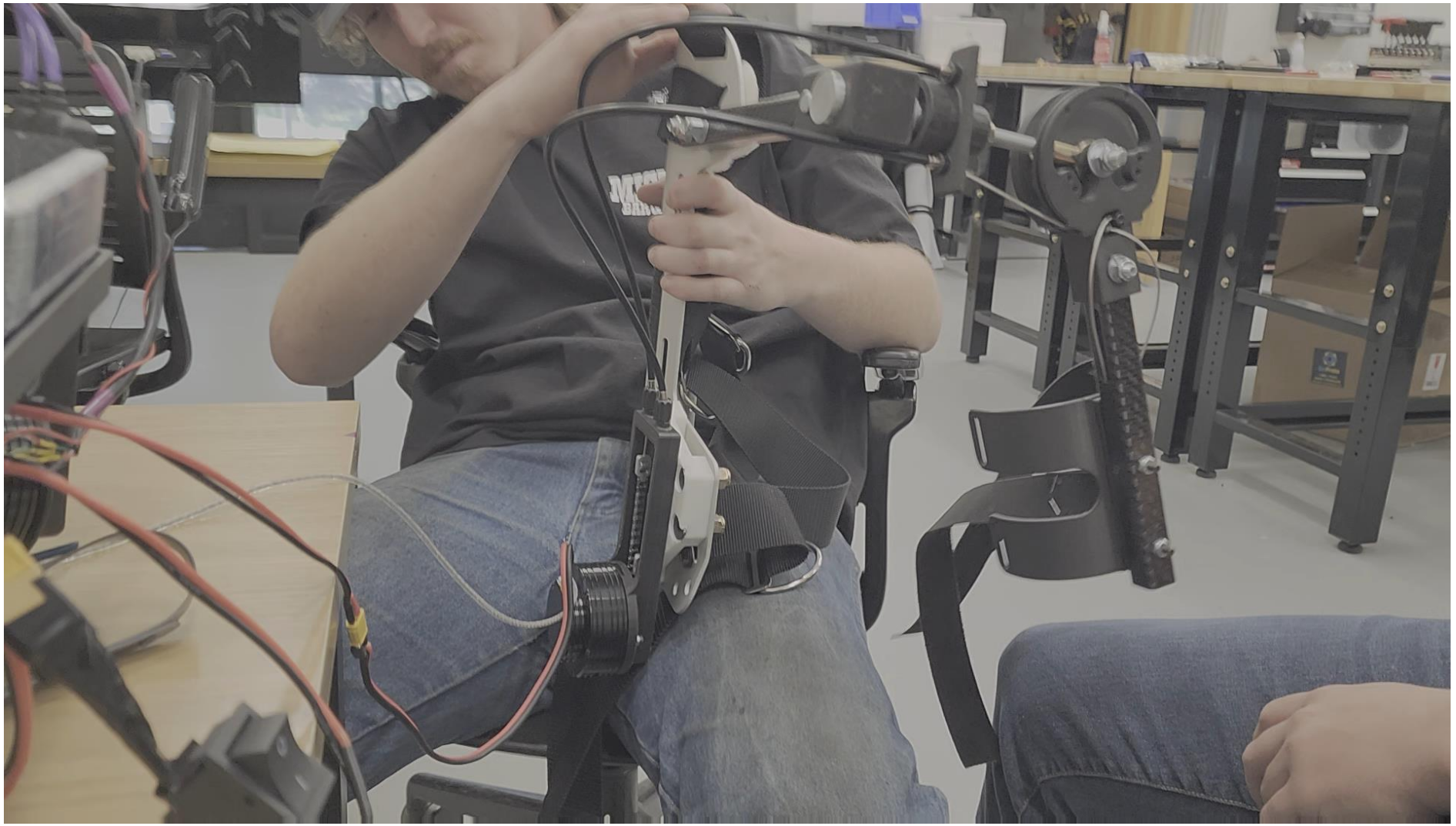
From left to right: Carbon fiber square tubing, motor mount (Oynx) and Bowden cable termination block (Oynx)

Final Testing – DOF and Movement



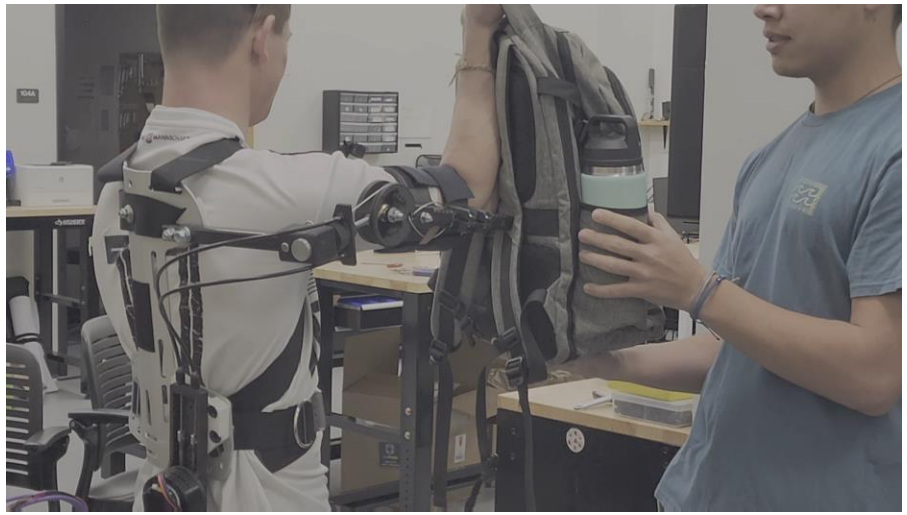
Final Testing – Protrusion and Weight Measurements

Final Testing – System Actuation

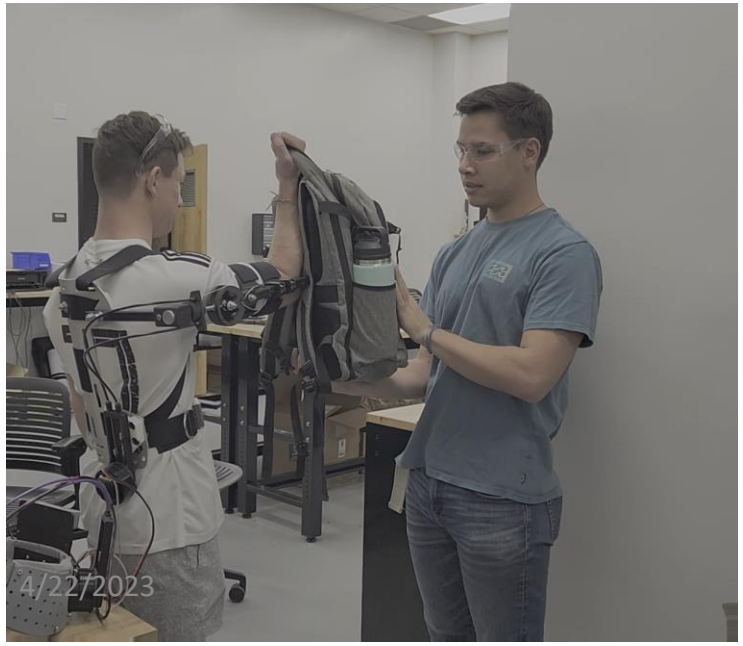


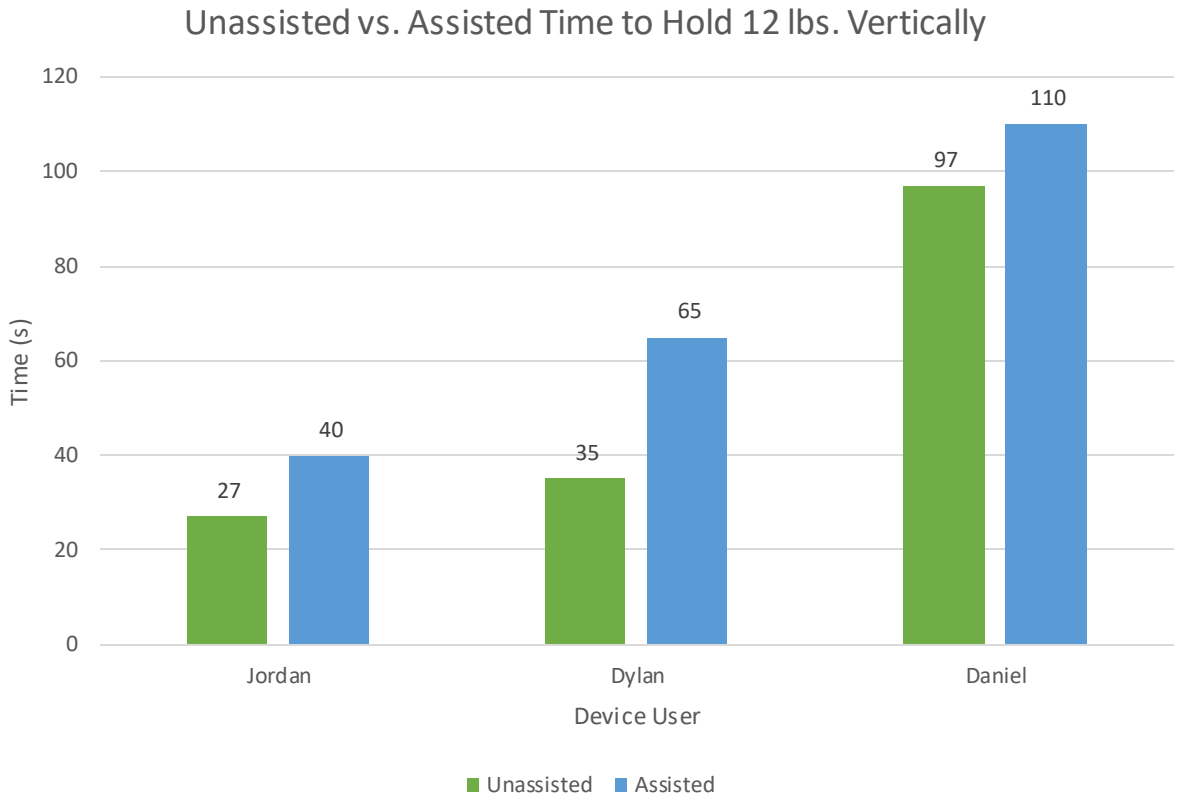
Final Testing - Endurance

Unassisted:



Assisted:





- During this test, the motor was outputting 7 N-m of torque which was roughly 21 N-m of torque at the shoulder.
- The device on increased the time held by the following percentages:
  - Jordan – 48.14% increase
  - Dylan – 85.71% increase
  - Daniel – 13.40% increase
  - Average – 49.08% increase

Specification Sheet

Table 3: ER Summary

Engineering Requirement	Target	Tolerance	Measured/Calculated Value	ER Met? (Yes or No)	Client Acceptable? (Yes or No)
Bowden Cable Actuation	N/A	N/A	N/A	Yes	Yes
Revise Dr. Lerner's Pulley Design	N/A	N/A	N/A	Yes	Yes
Lightweight	< 6 lbs.	+ 4 lbs.	5.5 lbs.	Yes	Yes
Low-Profile	< 10 cm (3.94 in.)	Maximum 10 cm	~ 4.5in or 11.43cm	No	Yes
Independently Operable	Independently Controlled	N/A	N/A	No	Yes
Increase in time to hold an object	15% Increase	Minimum 12.5%	Average of 49% Increase	Yes	TBD

Future Work

A Two Arm System:

This will help stabilize the device and produce results for the initial, but discontinued, pull-up test.

Fail Safes:

Although the output power from the motor is easily controlled it would be reassuring to have immediate stops that disable the device past a certain limit.

Increased Mobility:

Currently, the rear Carbon Fiber bar makes the device to rigid to raise the arm laterally or move fluidly. Increasing the range of motion while applying torque in the correct direction will broaden the opportunities for this project.