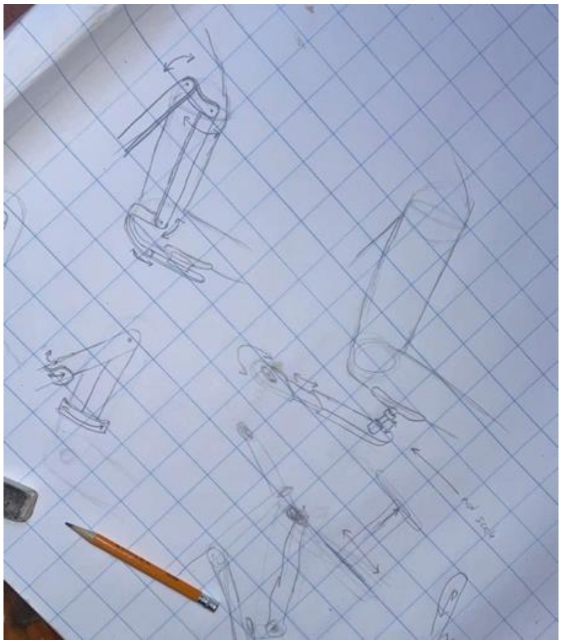
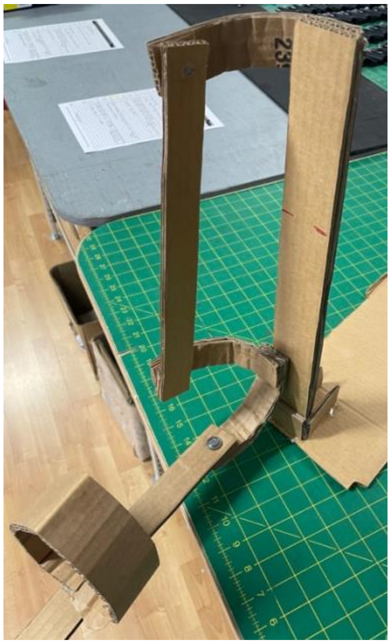
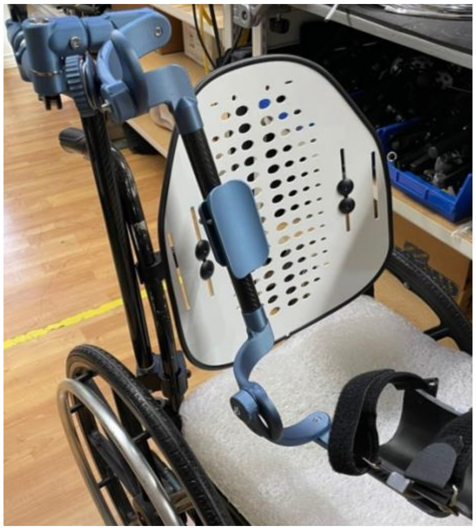




Summer 2024 Mobile Arm Support Project Summary



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Executive Summary

The project goal is to create a mobile arm support for people with reduced arm function that is low cost, has a sleek, low-profile design, and is seamless and simple to use. The current prototype uses rubber bands to generate tension within the tube that runs along the upper arm, and cables transfer this force through torque arms to generate lift for the shoulder and elbow forward rotation joints. The primary next steps for further prototyping are to add support to the shoulder abduction and elbow rotation joints, add additional arm interface pads for the upper arm and shoulder, and design internal mounting pegs to have the rubber bands concealed within the upper arm tube.

Background Context


SaeboMAS


Jaeco Wrex MAS


Kinova MAS

Reduced arm strength and/or loss of muscular control can result from several neurological conditions like Parkinson's disease, Multiple sclerosis, ALS, Stroke, or muscular distrophy. Mobile arm supports (MAS) assist people with reduced arm function to perform various tasks. They typically mount to wheelchairs or tables, and usually have an armrest to support the user's arm. The ideal function of a mobile arm support is to fully support the user's arm throughout their range of motion in a smooth and seamless way, enabling them to perform tasks they would have found challenging or impossible otherwise.

Anatomy of the Current Design

A 3D scan of the current assembled prototype can be viewed in a browser at https://lumalabs.ai/capture/431611f4-7abb-4e69-83c9-bb7d136bd235.

Shoulder Position Adjustment

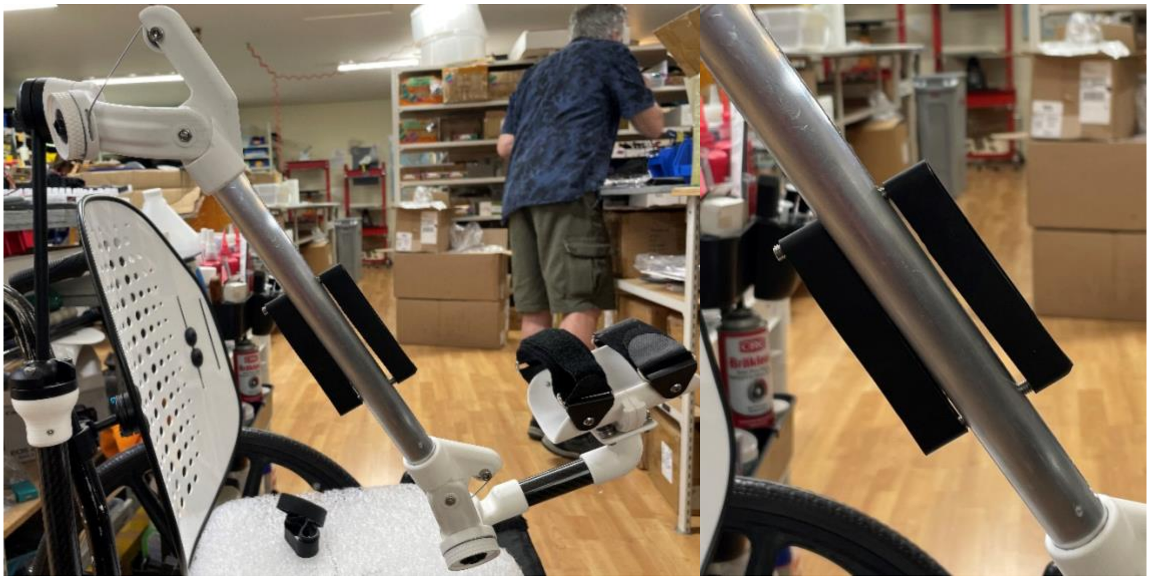
A set of two ball-and-socket joints allow the arm to be positioned in line with the user’s shoulder, in combination with a height adjustment mechanism built into the carbon fibre tube below.

Shoulder Bend

This 90-degree bend has two rotation joints at its ends, to allow for shoulder abduction (swigning upwards to the side), and forwards rotation (swinging upwards to the front). In combination, this allows for complete freedom of movement of the shoulder joint.

Tension Element

The tension element sits in the middle of the tube that runs along the upper arm, and pulls on cables connected to both ends. External rubber bands are the current tension element:



Torque Arms

The torque arms guide the cables attatched to the tension element away from the axes of rotation of the shoulder and elbow joints, creating torque around those joints:

Ratcheting Cable Tensioners

The knobs built into the shoulder and elbow bends allow adjustment of the tension cables. They have ratcheting mechanisms so that they hold their position once tightened but can also be released easily by flipping the ratchet dial in the center of the knob.

Elbow Bend

This 90-degree bend aligns with the user’s elbow joint and allows for elbow internal/external rotation (swinging elbow inwards and outwards), and forward rotation (swinging elbow upwards and downwards).

Forearm Pad

The forearm pad holds the user’s forearm and allows for wrist rotation using four bearings that ride along a rail.

Past Lessons, Current Status, and Next Steps

Force Generation

The current prototype uses rubber bands to generate tension, which is then transferred through cables to generate torque and assist forward rotation of the shoulder and elbow. The below table outlines the pros and cons of different force generation methods that have been tested:

Force Generation Method:	**Pros**	**Cons**
Spring Steel Tension Spring	- Compact (can easily fit inside upper arm tube) - High longevity compared to elastomers	- Hard to find a spring with the required tension and length extension capabilities (see below) - Hard to replace inside upper arm tube
Surgical Tubing Tension Spring	- Compact - Easy to source	- Low force generated does not support full arm weight - Hard to replace if internal
Torsion “Mouse Trap” Spring	- Compact as can be integrated within joints - High longevity	- Available springs are far too weak - Hard to source compact torsion springs with high required torque - Difficult to integrate torsion spring into a bearing joint
Rubber Band Tension Spring	- Easy to replace - Easy to source - Can generate very high force using multiple bands - Easy to for physiotherapists s and assistants to dial in tension	- Current external implementation is not compact or aesthetic - Implementation of sleek internal rubber band system will require design of a carriage system and cover hatch
Gas Piston Tension Spring	- Compact - Can have high enough force to fully support an arm	- Force and dimension requirements make for difficult sourcing, or expensive custom springs

Within the current cable system for forward shoulder and elbow support, the tension element pulling on the cables must have a minimum length of around 10cm, and a maximum length of greater than 22cm. The force required from the tension element is around 200N. Currently, the tension element must more than double in length to provide a full range of motion to both joints. This is likely impossible with gas springs due to the rigid geometry of the housing and piston. The torque arms could be shortened to enable a gas spring to be used; Shorter torque arms will require more force from the tension element but won't require as much lengthening.

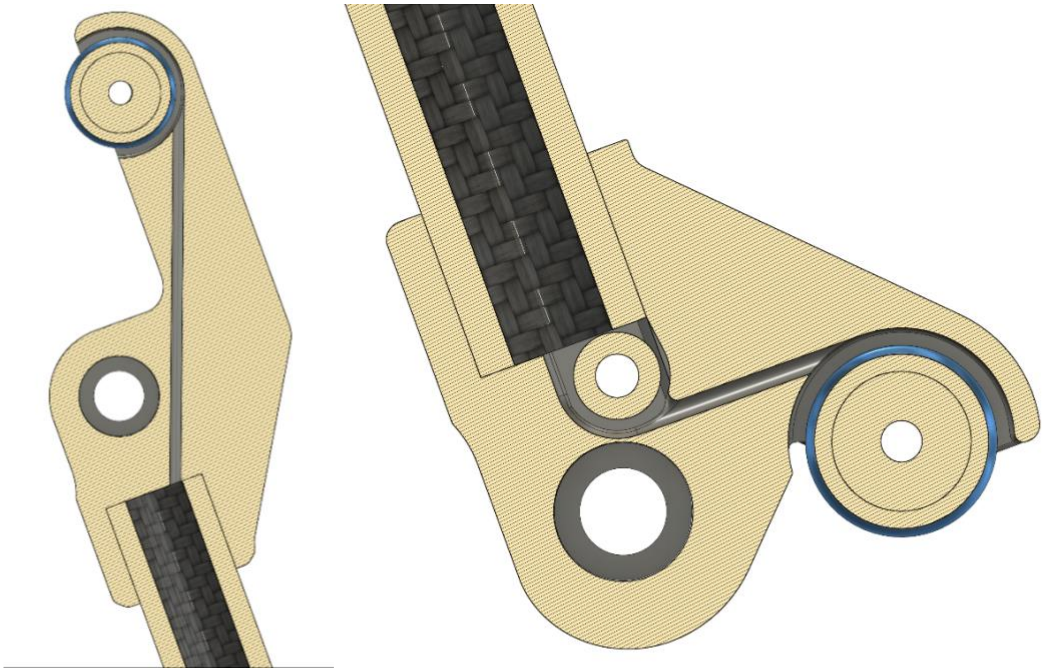
The most promising option is the rubber band system. One reason is that it is easy to adjust the amount of support to match the weight of the arm, unlike the other methods. The ratchet knob system can change the tension by stretching the tension element, however this can't be the primary method of tension adjustment; Using the ratchet knobs to increase the tension will move the ends of the tension element closer to the ends of the space the tension element can move within. This can begin to reduce the range of motion of the arm due to the tension element colliding with the end of the slot / track.

Changing the internal tension of the tension element is required to match the amount of support to the weight of the arm. This can be done easily by adding or subtracting rubber bands. In the case of springs or pistons, it can be done by replacing the tension element with one of a higher or lower internal tension. This would require several different tension options to match the support to a range of arm weights. It would also require easy replacement of the tension element inside the upper tube segment. This can be achieved with mounting pegs inside the upper tube segment accessible via a hatch in the side of the tube. This system could be used with any tension element, while maintaining a sleek external design. Given this, rubber bands appear to be a leading option for further prototypes due to their ease of sourcing and high-tension capabilities.

A feature that should be carried over from the current prototype with external tension elements is the visual indication of tension element endpoints; Misadjusted ratchet knob positions can result in reduced range of motion, and calibrating the position of the tension element is far easier with visual feedback. Calibration involves moving the shoulder joint to its lowest position where the most cable is pulled through the torque arm, and then ensuring that the tension element has not hit the end of its track. After this, the process is repeated with the elbow joint. The tension element endpoints can be made visible either by a transparent window in the upper arm tube, or by small pegs sticking out through a slot in the side of the upper arm tube.

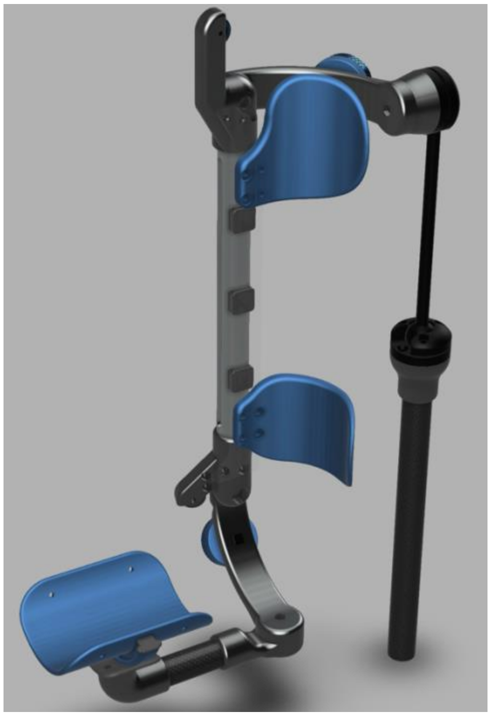
It may be possible to eliminate the cable adjustment system entirely, if rubber bands are the tension element; As each rubber band has relatively low tension, they can be stretched over the mounting pegs even when they are far apart. As more bands are added, the arm support will naturally begin lifting the user's arm. If the cable lengths are correct from the start, they need no length adjustment and the ratchet knobs can be done away with, resulting in a sleeker design with lower complexity and part costs.

Friction Management



The current prototype uses bearings to guide the metal cables over the ends of the torque arms with low friction. As visible on the cross section of the lower torque arm, a simple bushing has been used to guide the cable around a second 90-degree bend within the component. Future prototypes should integrate small bearings to decrease the friction between the cable and this bushing. The cable routing curves should have radii of no less than 1cm, so that the current bicycle brake cable can be bent around and elastically return to its original shape. A more flexible cable would enable smaller radii and therefore smaller bearings. Future prototypes should also adjust the cable routing within the upper torque arm to have the cable run directly into the middle of the upper arm tube.

Arm Pads



Supporting the user's arm in more locations will help maintain alignment with the arm support. As depicted, the upper arm could be supported from the back by an oblong curved pad. The shoulder could lightly interface with a curved circular pad mounted to the inside of the upper bent piece. These pads would help prevent the user's arm from sliding out of the forearm pad when the forearm is angled upwards. Straps going from the upper arm pad around the user's arm are likely unnecessary.

Future prototyping can also explore the possibility of a strapless forearm interface using a latching clasp mechanism to hold the forearm in when closed, and act as a simple arm rest when open. This strapless interface could be combined with a latching mechanism to hold the arm support in the resting position when locked in, that is able to be unlatched by the user to move their arm freely. This would make it feasible to permanently replace a user's arm rest with the mobile arm support.

Support Axes

The current prototype shows promise for the rubber band and cable system to support the forwards lifting of the shoulder and elbow joints. The shoulder abduction joint (swinging up to the side) and the elbow internal/external rotation joint currently have no support, and they may require a different approach due to the limitations of the geometry.

For the elbow rotation joint, a strong torsion spring integrated into the joint would be ideal. The torsion spring would be positioned to exert no force when the elbow is facing straight ahead, so that movement in either direction would be supported to easily return to center. This support is crucial for arm movements where the elbow rotates inwards while the shoulder is raised, such as eating.

For the shoulder joint, a strong torsion spring could also be used. The spring should have enough torque to assist in shoulder abduction to at least 45 degrees but should not be so strong as to force the users arm outwards when they are in the resting position.

Range of Motion Limiting

The ability to decrease the range of motion of individual axes of the arm support is useful for users with a limited range of motion or with loss of muscle control, but has not yet been implemented. The range of motion of the shoulder and elbow forwards lifting joints is currently limited by the torque arms colliding with the elbow and shoulder bend pieces. This means that the shoulder can lift to just below horizontal, and the elbow can go from in line with the upper arm to about 45 degrees past being perpendicular with the upper arm.

The range of motion of shoulder abduction is currently unlimited, however there is also no support in that direction. When a torsion spring is added to the shoulder abduction joint, an adjustable hard stop for that joint should also be added.

The elbow rotation joint is limited to just over 45 degrees of external rotation, due to collision with the lower bent piece. There is no limit on internal rotation, but future prototypes should have a limit of around 90 degrees, or perpendicular to straight ahead.

The ability to freeze the motion of individual axes has also not been implemented and could be integrated into the range of motion adjustment mechanism.

Summary of Next Steps

Some immediate next steps for the prototyping phase of the arm support are as follows:

- Add support to the shoulder abduction and elbow rotation joints
- Add additional arm interface pads for the upper arm and shoulder
- Improve / shrink torque arm design and optimize for milled aluminum
- Design internal mounting peg system for tension elements with easy access hatch
- Redesign componentry for manufacture out of milled aluminum