X-Chair:
Autonomous Wheelchair Restraint Adaptations

Client: Mr. Keith Wanta
Team Members: Marissa Harkness, Ben Lawonn, Jonathon Murphy, Naman Patel, Jenna Warden
Advisor: Mitchell Tyler

Overview of Presentation

- Client Information
- Problem Statement
- Motivation
- Background
- Product Design Specifications
- Final Design
- Goals
- Fabrication
- Testing Plan
- Discussion
- Budget
- Timeline
- Acknowledgments
- Questions

Client Information

- Mr. Keith Wanta
  - Works as a Senior Programmer Analyst in the Biostatistics and Medical Informatics Department at the UW-Madison School of Medicine and Public Health
  - Diagnosed with Spinal Muscular Atrophy (SMA) Type 2

Problem Statement

- Client is unable to safely enter and operate standing wheelchair
- Movement has many benefits - blood flow, digestion, bone health, which are less obtainable when mobility is restricted
- Existing standing wheelchair supports enable mobility but lacks autonomous accessibility
- CNA and licenced physical therapists can facilitate productive device usage but are too costly

Motivation

- 75 million wheelchair users worldwide [1]
- 3.3 million wheelchair users in United States [2]
- Allows users to move into position that is normally unattainable
- Allows for increased blood flow and movement

Background

What is Spinal Muscular Atrophy (SMA) [1]

- Impacts voluntary movement of muscles

Benefits of being in upright position vs sitting [1]

- Increased blood flow
- Stretching and exercising muscles

Current Problems in standing wheelchair supports

- Difficult to secure in place
- Requires help during entry and exit

Product Design Specifications

Client requirements:

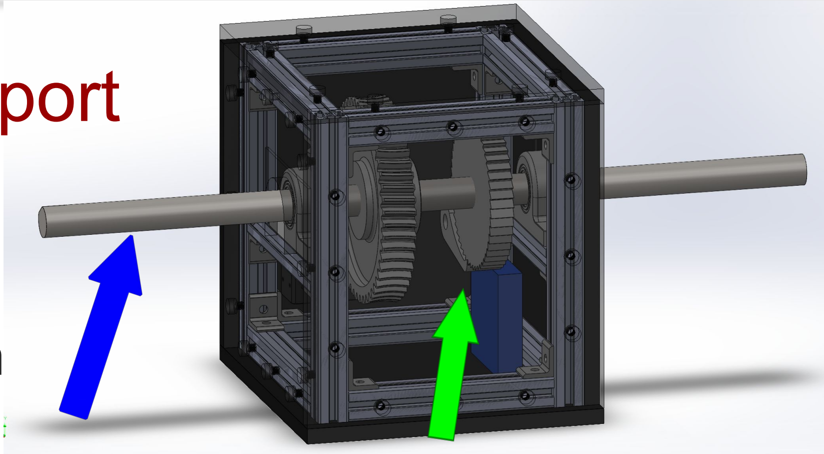
- Motorized, accessible controls for individual device operation
- Must safely secure the user in the upright position
- Cannot interfere with entering and exiting wheelchair via ceiling lift
- Must enable restroom usage while in the upright position

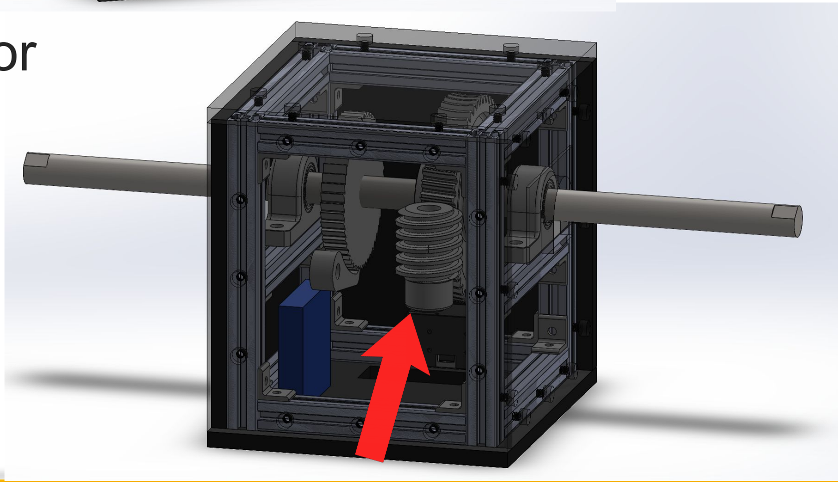
Design requirements:

- Both supports obtain the correct position with 100% accuracy
- Functionally effective over duration of 15 hours
- Supports must enter position within 30 second period
- Controls and failsafes must operate correctly with 100% accuracy

Final Design - Chest Support

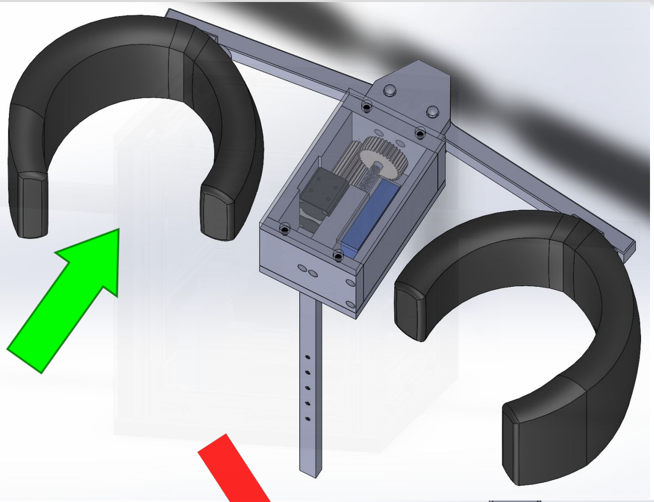
- Central Shaft
  - Moved via worm gear
  - Locked via ratchet system
- Worm Gear
  - Driven by DC brushless servo motor
  - Provides torque multiplication and prevents static backdrive
- Ratchet Gear Lock
  - Ensures dynamic system stability
  - Driven via linear actuator

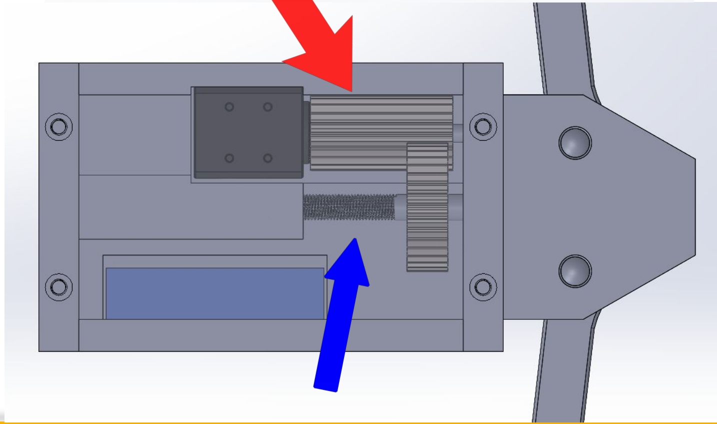




Final Design - Leg Support

- Support Arms (Pinion)
  - Adjustable pad positioning
- Gear Stock System
  - Driven by DC brushless servo motor
  - Enables threaded bolt to move via threading/unthreading
- Threaded Bolt (Rack)
  - Adjusts support arms via threading/unthreading
  - Secures support arms during dynamic and static operation





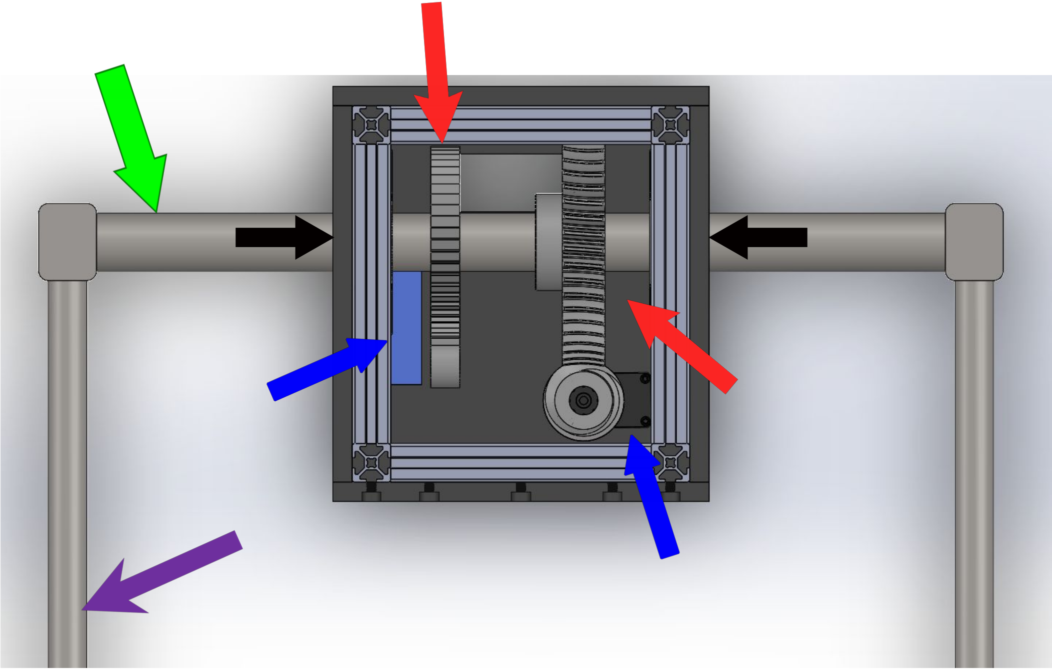
Goals

- Fabrication
  - Conduit prototype via client's design
  - Chest support system
  - Leg support system
- Testing
  - Chest support system
  - Leg support system
- Possible Iterations
  - Based on testing results

DEPARTMENT OF Biomedical Engineering
UNIVERSITY OF WISCONSIN-MADISON

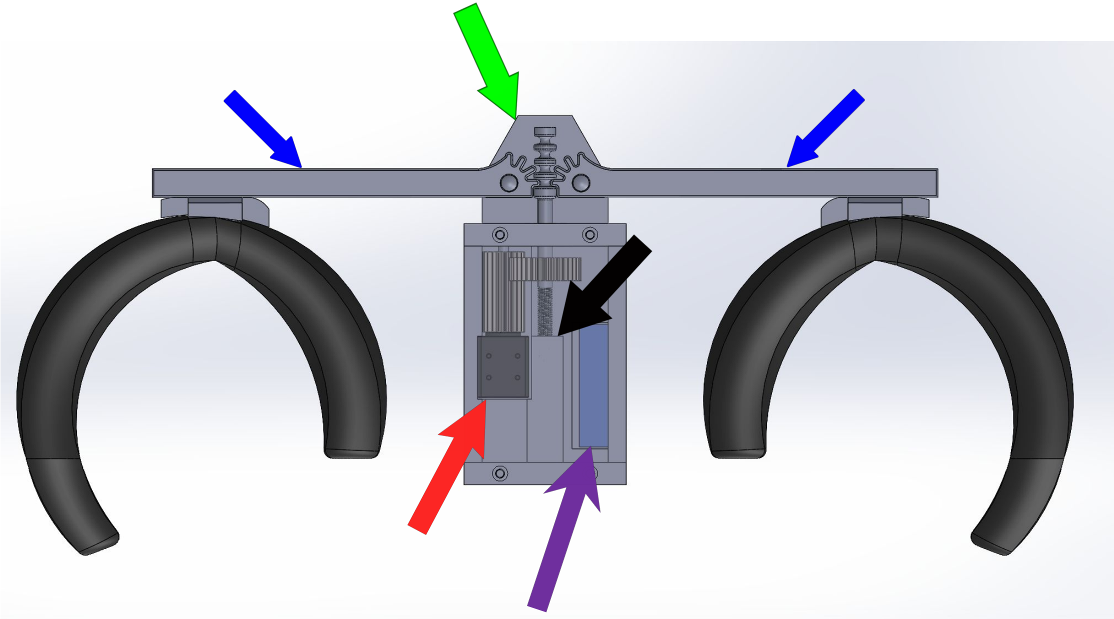
Chest Restraint Fabrication

- Chest Restraint Assembly
  - Over the head bar
  - Chest pad
- Shaft Assembly
  - Shaft, gears, bearings
- Box
  - Framework
- Electronics
- Plates
  - Hinge/latch and catch
- Mount and connect assemblies



Leg Restraint Fabrication

- Box
  - Plates
- Support Bar
- Front Holder
- Support Arms
  - Threaded support
- Electronics
  - Microcontroller
  - Motor



DEPARTMENT OF
Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Testing Plan - Code

- Button to Rotation Communication
    - Tests proper execution of the rotation of motors when the corresponding button is being pushed
        - “go/ no go” test
    - Expecting 100% Accuracy
- Activation Time
    - Tests the activation and relaxation time
    - Goal time: 30 +/- 5 seconds
        - T-test with 95% confidence interval ranging from 25-35 seconds

[2]

DEPARTMENT OF
Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

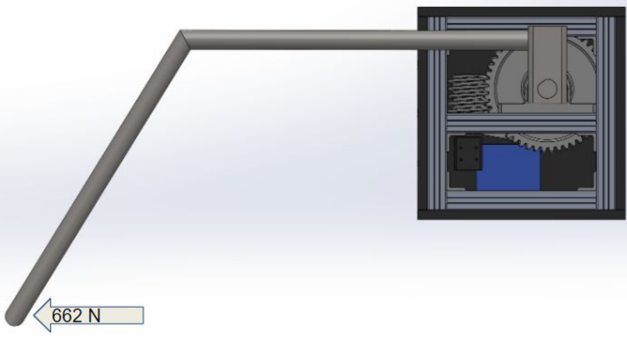
Testing Plan - Code Continued

- Locking Mechanism Verification
  - Ensures that the supports will not move when an American Disability Association compatible switch is flipped
    - "go/ no go" test
  - Expecting 100% accuracy
- Hall Effect Sensor Calibration and Implementation
  - Calibrated using a magnet
    - When the magnet reaches 10mm from the sensor, the motor will turn off
      - "go/ no go" test
  - Once the magnet is attached to the device, after passing a set limit, the device will stop moving
    - "go/ no go" test
    - Expecting 100% accuracy

[3]

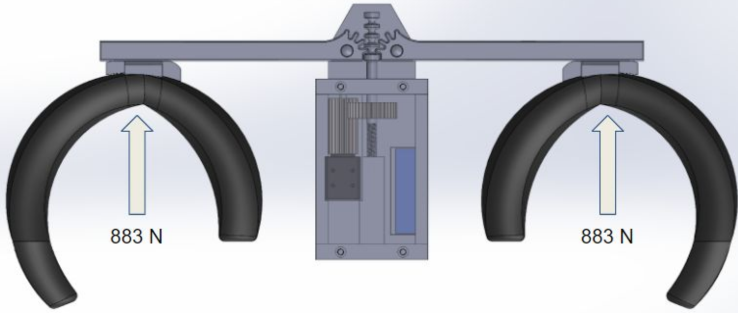
DEPARTMENT OF
Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Testing Plan - Chest Support



- Final Position Repeatability
  - Measuring the angle of rotation of the chest bar to determine the repeatability of the support's final location
    - T-test with 95% confidence interval with a range of +/-3°
- Maximal Stress and Timed Stress
  - Loading the chest bar in the horizontal direction, surpassing 662N (75% of our Client's weight in that direction)
  - Using the same weights from the maximal stress test, load the chest bar for 15 hours
    - T-test with 95% confidence interval with an average no lower than 30 seconds

Testing Plan - Leg Support



- Final Position Repeatability
  - Measuring the angle of rotation of the leg supports to determine the repeatability of the support's final location
    - T-test with 95% confidence interval with a range of +/-3°
- Maximal Stress and Timed Stress
  - Loading both leg supports in the horizontal plane, surpassing 883N (100% of our Client's weight in that direction)
  - Using the same weights from the maximal stress test, load the chest bar for 15 hours
    - T-test with 95% confidence interval with an average no lower than 30 seconds

Discussion

- Transportation and Storage
  - Box with attached foam padding mold to house devices
  - Anti-static foam to protect electrical components
- Technical Documentation
  - User operation manual
  - Electrical components service manual
  - Electrical and physical safety warnings

Budget - Past Expenses

- PVC pipe and connectors - $9
- Nucleo Microcontroller - $11
- Aluminum Plates - $100
- 80/20 Extrusions - $27
- L-brackets - $63
- Pillow Block Bearing - $72
- Rotary Shaft - $22
- Hardware (nuts, bolts, washers) - $44
- TOTAL: $348

Budget - Future Expenses

Chest Support (subject to change)

- Steel Worm Drive - $48
- Cast Iron Worm Gear - $99
- Ratchet Gear - $77
- Ratchet Pawl - $40
- DC Brushless Motor - $99
- Motor Controller - $20
- Motor Controller Expansion Board - $30
- TOTAL: $413

Leg Support

- DC Brushless Motor - $230
- Motor Controller - $20
- Motor Controller Expansion Board - $30
- Carbon Steel Gear Stock - $46
- Stainless Steel Spur Gear - $25
- Support Arm Stock - $20
- TOTAL: $371

DEPARTMENT OF Biomedical Engineering
UNIVERSITY OF WISCONSIN-MADISON

Timeline

March 26th, 2021

April 7th, 2021

April 21st, 2021

April 28th, 2021

Fabrication:

Working with TEAMLABs to produce the chest and leg support prototypes by March 26th

Testing:

Both support systems will undergo tests by April 7th

Improvements:

- Timing
- Restraint comfort
- Other

Final Deliverables:

- Final fabrication
- Written report
- Final Presentation

DEPARTMENT OF
Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Acknowledgments

A special thanks to…..

- Our Client: Mr. Keith Wanta
- Our Advisor: Mr. Mitch Tyler
- BME Director: Dr. John Puccinelli
- BME Department

Questions???

References (in order)

[1] "Disabled People in the World in 2019: facts and figures," Inclusive City Maker, 24-Oct-2019. [Online]. Available: https://www.inclusivecitymaker.com/disabled-people-in-the-world-in-2019-facts-and-figures/. [Accessed: 28-Sep-2020].

[2] "Wheelchair Users," Physiopedia. [Online]. Available: https://www.physio-pedia.com/Wheelchair_Users#:~:text=In the United States of,new wheelchair users every year.&text=However, they all need an appropriate wheelchair. [Accessed: 28-Sep-2020].