ECE Team 8 / ME Team 29
Strength Assisting Orthotic

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Presentation Overview

- Project Overview
- Load Modeling
- Mechanical System
- Electrical System
- Safety Analysis
- Conclusion

Project Overview

- Purpose: to design and build a powered orthotic arm.
- An orthotic is an artificial device that is used to increase bio-mechanical efficiency.
- This is an entrepreneurial project, so business applications were kept in mind throughout the design process.

Entrepreneurial Aspect

- Participated in the Engineering Shark Tank Competition, giving a business pitch of our design to a panel of judges.
- Need: Workers that do heavy lifting and are prone to back injury and other such ailments. Many current rehabilitation orthotics are expensive and inaccessible.
- Market:
  - Healthcare
  - Civilian
  - Military

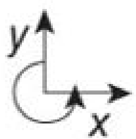
Goals

1) Provide a strength-assisting powered orthotic that will make lifting heavy objects easier.
2) Increase endurance for holding said objects, using a form of actuation to mimic muscles and a frame to add structure.
3) Lift at least 10 pounds with just the power of the orthotic.
4) Give range of motion similar to a human arm.
5) Allow for a large user base.

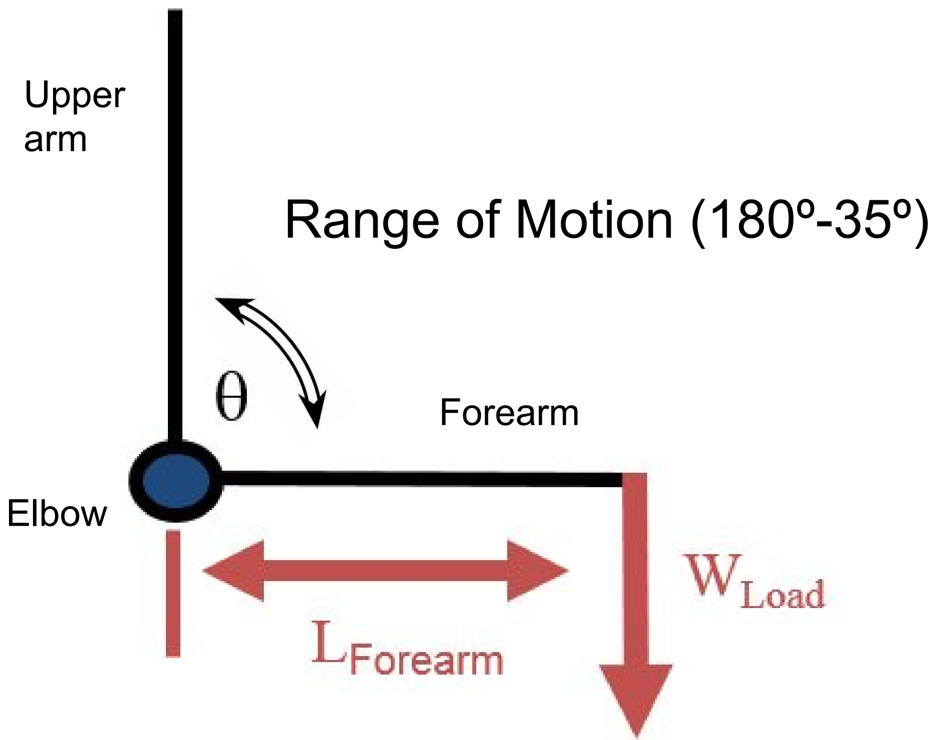
Design

- The orthotic is modular (has easily replaceable parts).
- The orthotic frame was conventionally machined out of aluminum.
- The frame includes a sliding bar to change distance of forearm and upper arm, which allows for a large percentage of the human population to be able to use the orthotic.
- The aluminum frame can’t plastically deform.
- Range of Motion for the orthotic is 180º-35º
- A motor is used as the method of actuation.
- Increased safety mechanisms and fail safes were used.

Modeling the Load to be Lifted



To find the maximum torque needed, the maximum average forearm length will be used as the moment arm.



$\theta = 90°$

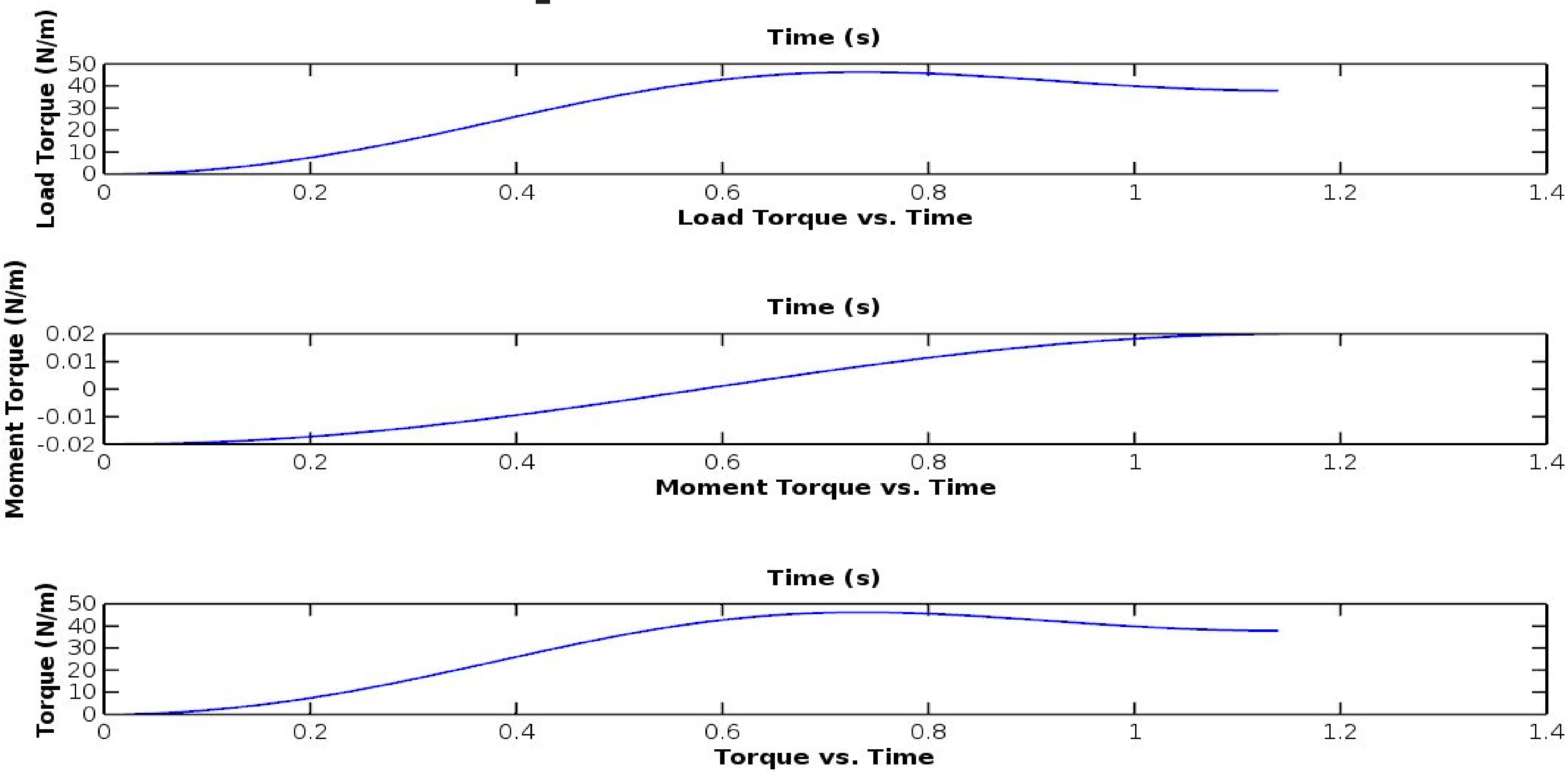
$L_{Forearm\ -\ max} = 52cm$

$L_{Forearm\ -\ min} = 38cm$

$W_{Load} = 21.lbs = 9.52\ kg$

Whitney

Motor Torque Simulation



- Equations used:
  - $\tau = \tau load + \tau moment$
  - $\tau load = m*g*\sin(\theta)*r$
  - $\tau moment = I\theta''$
  - $I = mr^2$

Whitney

Types of Electric Motors

- DC Brushless
  - Higher efficiency due to no loss of energy from friction
  - A lower EF and RF noise
  - Output less heat
- Pancake Motor
  - Designed to be flat, use windings around a disc to provide the EM field.
  - The design allows for the motor to be much more compact than other motors
- Brushed DC Motor
  - Moderate level of control
  - Slower, so more torque
  - Rotates continuously

Brushless Motor

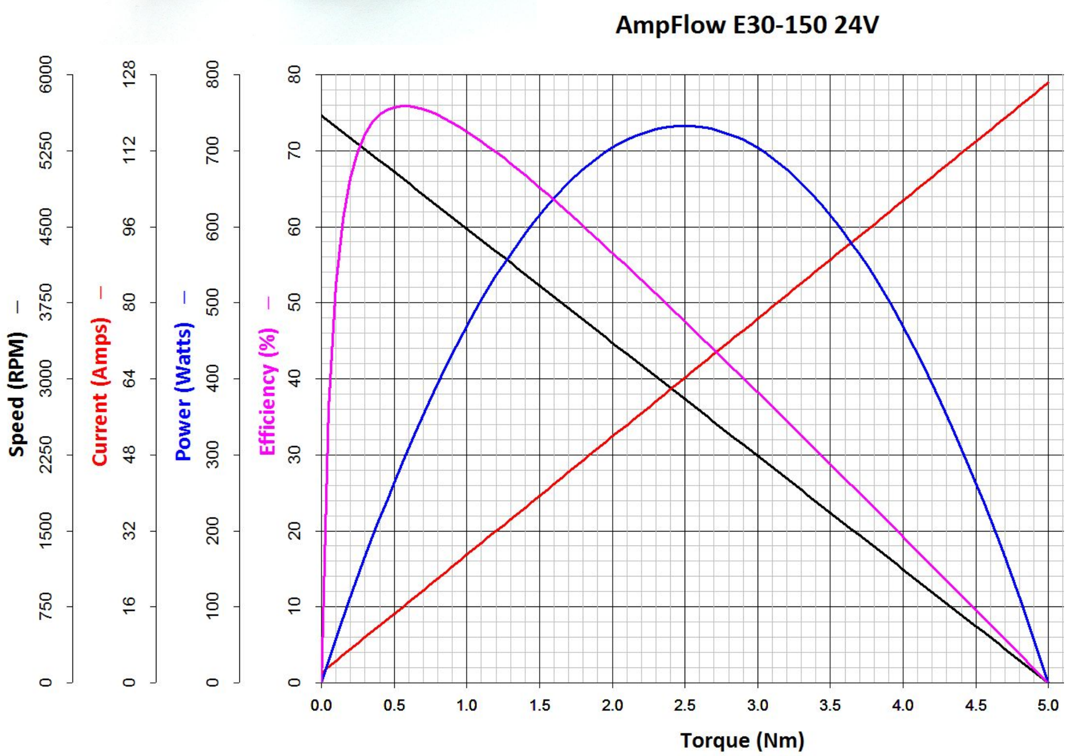
Pancake Motor

Brushed DC Motor

Motor Choice - AmpFlow E30-150

Brushed DC Motor:

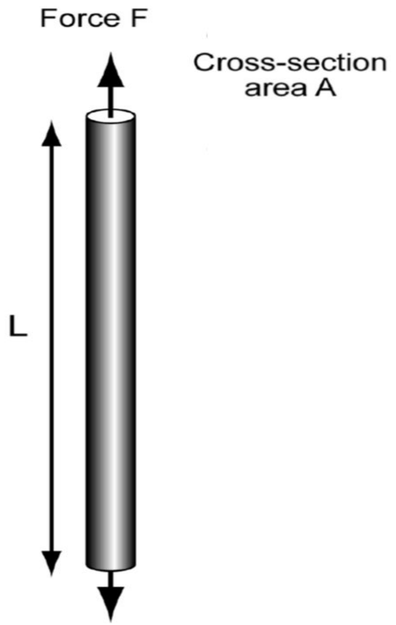
- Stall Torque (Nm)
  - 5.014
- Operating Point
  - .95 Nm
  - 20 A
  - 24 V peak
- Price
  - $79

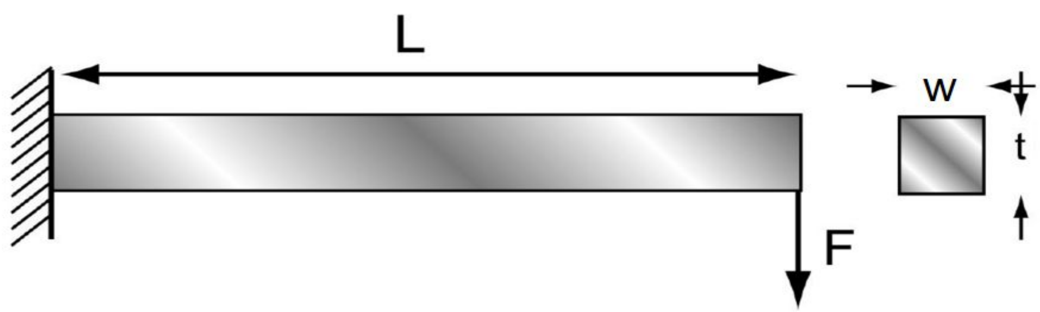


Whitney

Material Selection

For the general design of our orthotic we simulate the arm as a light, strong, stiff Tie rod when the arm is at 180 degrees and simulate the arm as a light, strong, stiff cantilever beam which is end loaded.

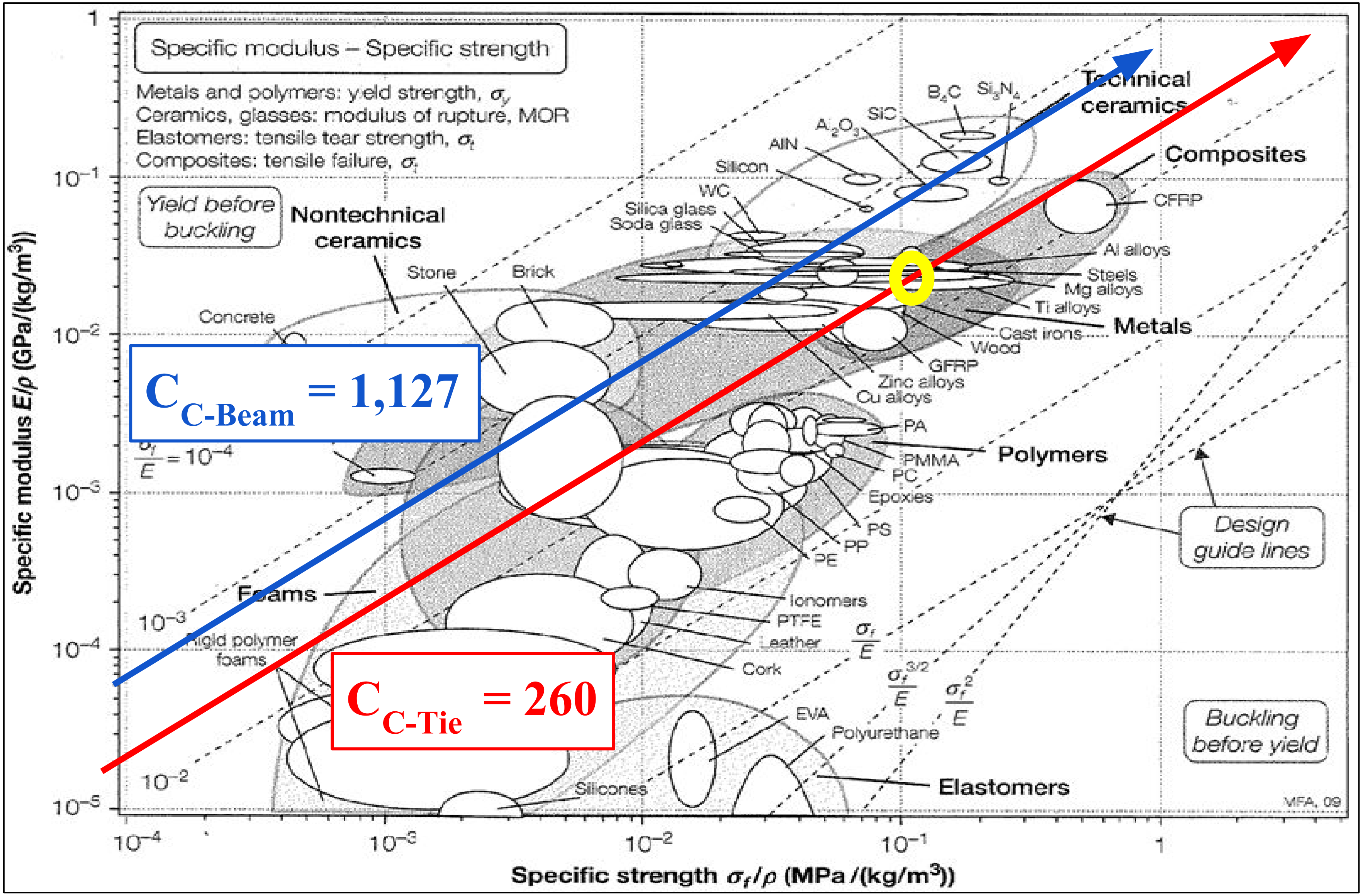




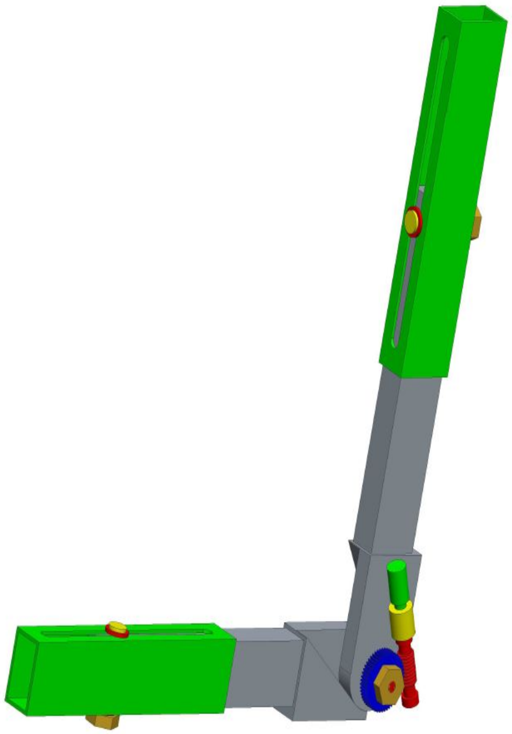
$$\frac{E}{\rho} = \left(\frac{L}{\delta}\right)\left(\frac{\sigma_y}{\rho}\right)$$

$$\frac{E}{\rho} = \left(\frac{4L^2}{6t\delta}\right)\left(\frac{\sigma_y}{\rho}\right)$$

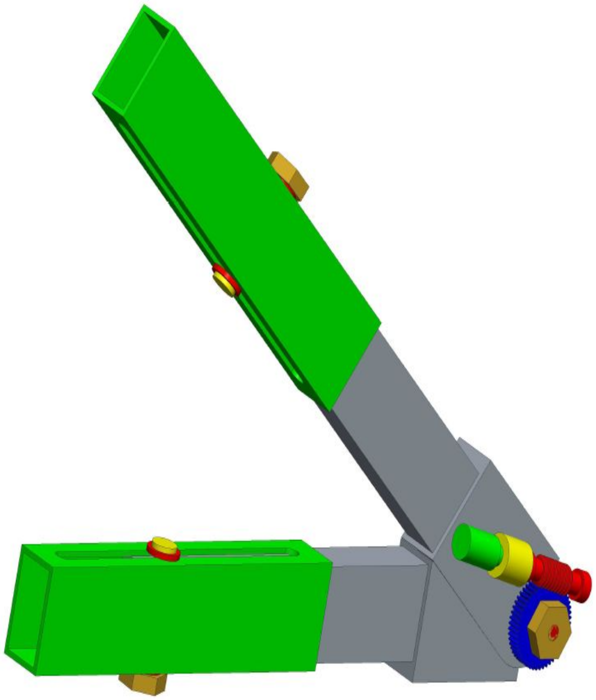
Material Selection (cont.)



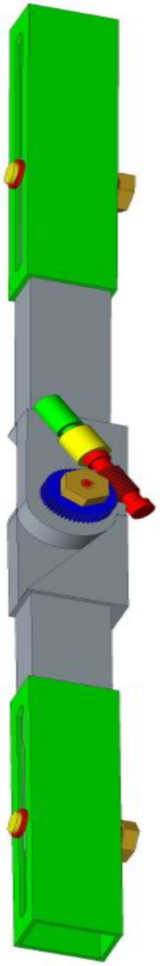
Final Frame Design



Arm at 90 degrees.



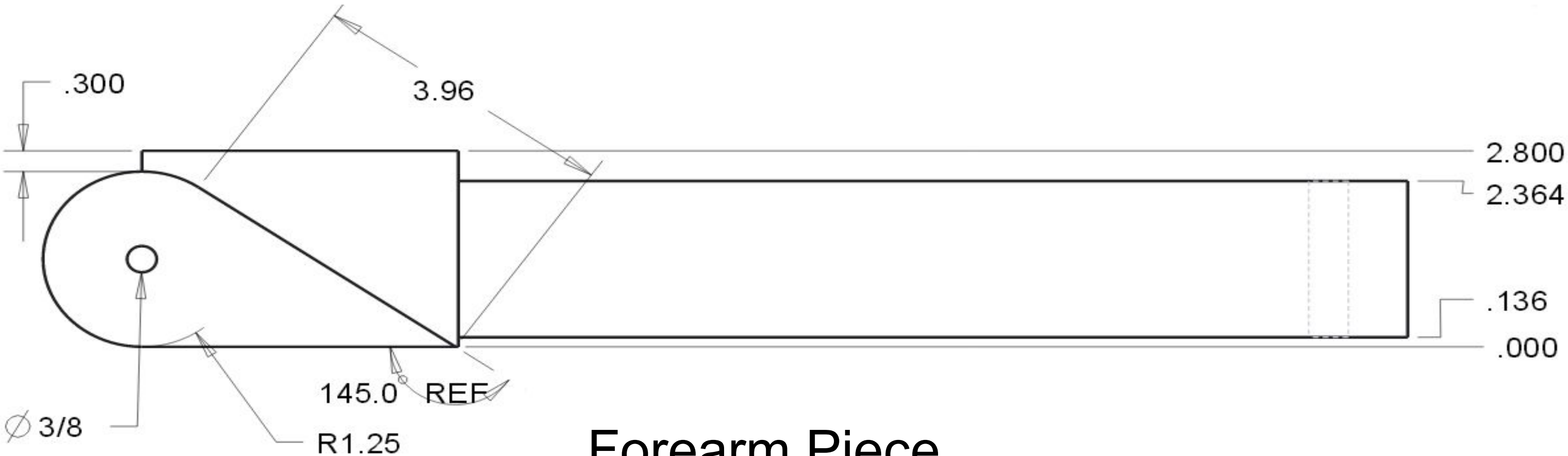
Arm at 35 degrees.



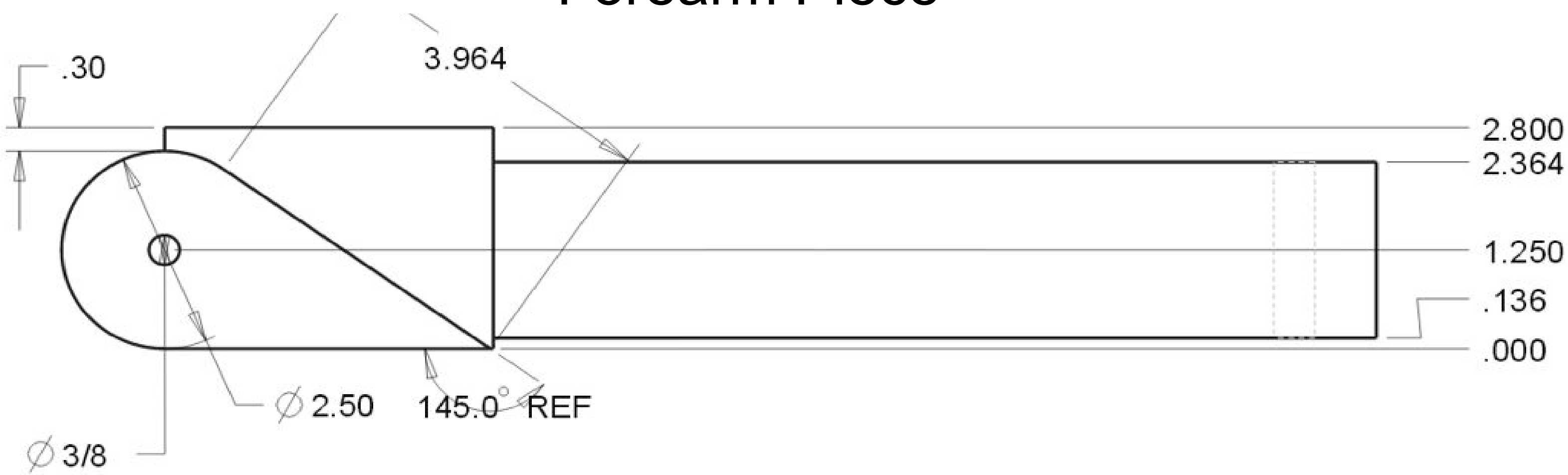
Arm at 180 degrees.

Slapikas

Final Frame Design Cont.

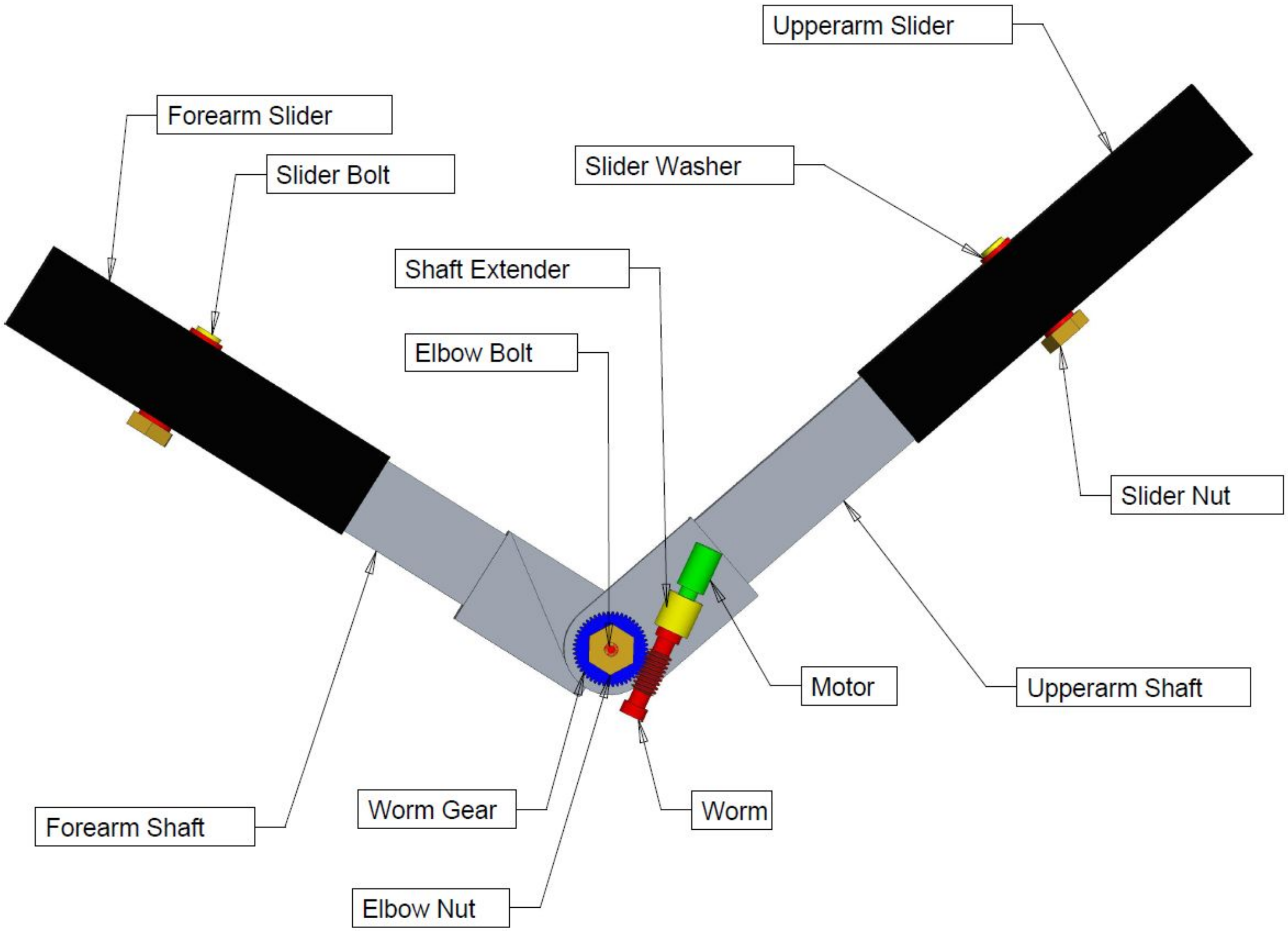


Forearm Piece



Upper Arm Piece

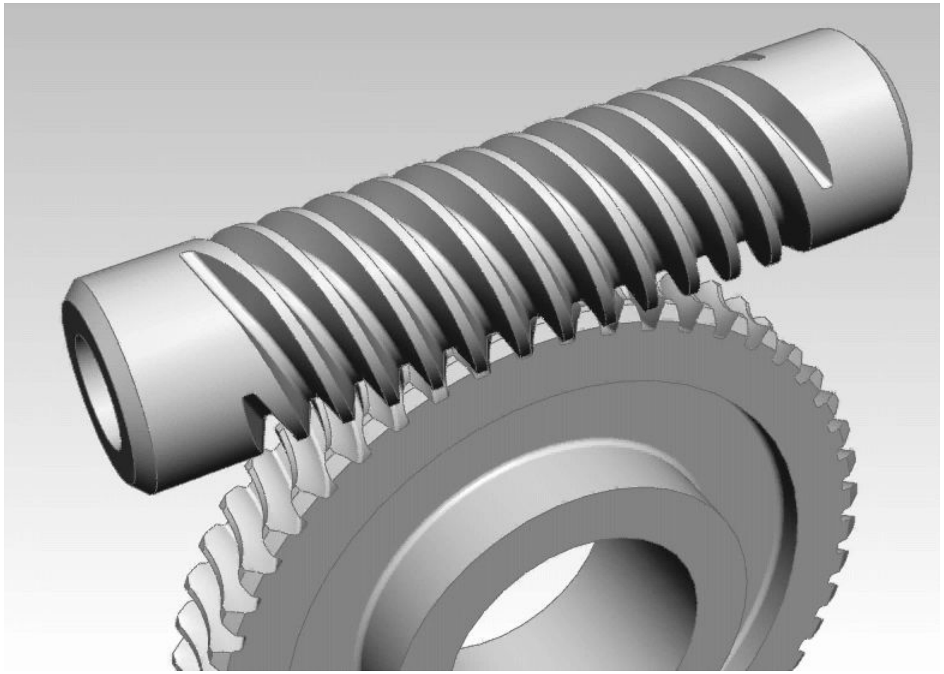
Frame - Fully Labeled



Worm Gear Drive

We chose to apply torque through a worm and worm gear system for several reasons:

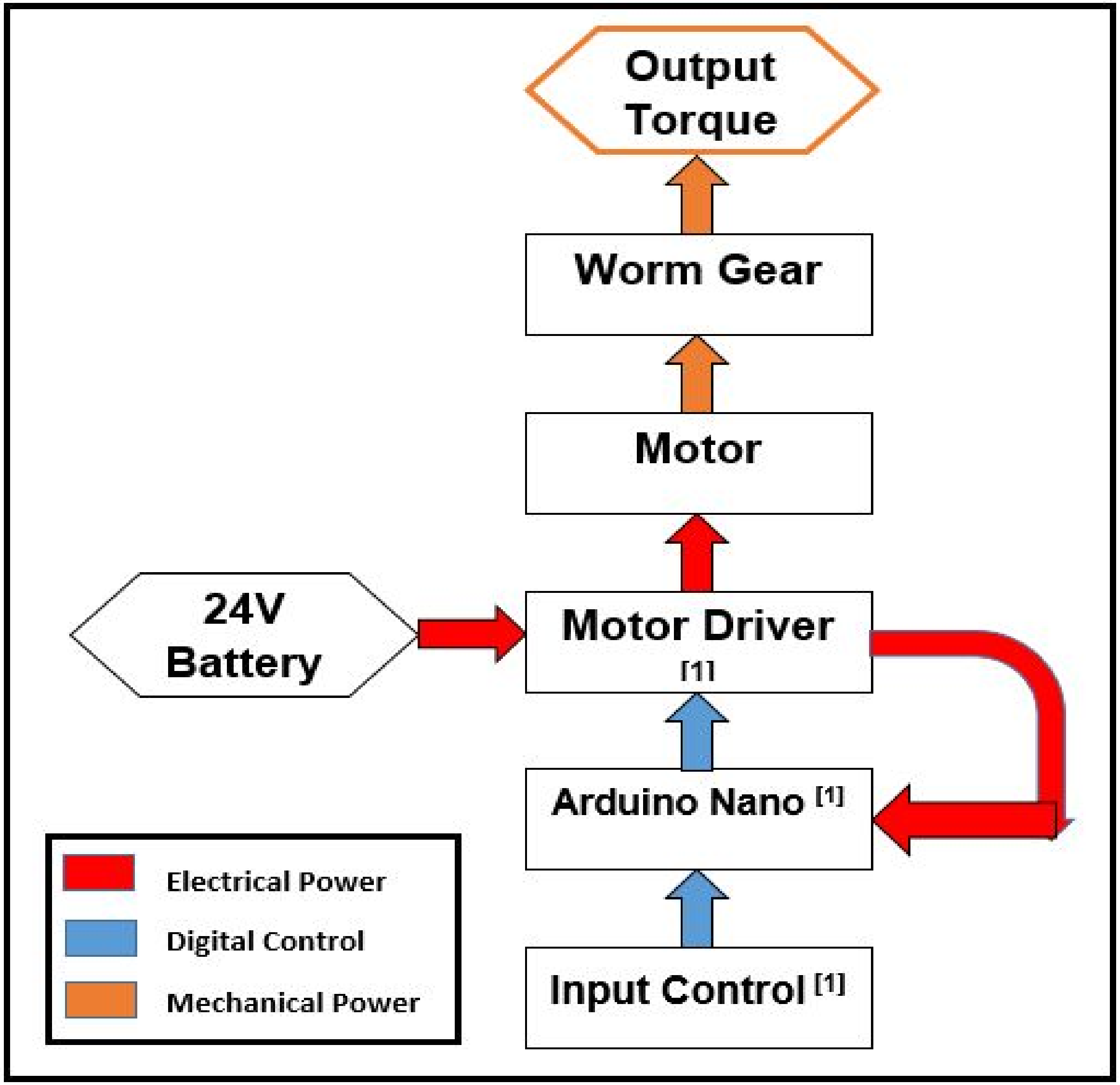
- Reduces motor speed
- Increases torque
- Easier to apply torque through the motor
- Locks the user's arm into position when the motor is not activated



Backpack

- Utilize both straps to spread weight evenly across the back
- Will suspend the weight of the orthotic
- Centers moment of inertia
- Adjust straps so that the bag fits closely to the body and does not sit low below the hips
- Houses the microcontroller, motor driver, voltage regulator, and battery.

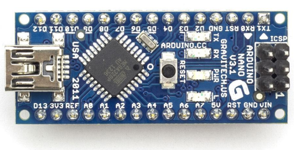
Upper Level System Diagram



[1] Indicates presence of a safety mechanism

Electronics Selection

- Motor Driver - SyRen 50
  - 50 amp continuous current rating
  - 100 amp peak current rating
  - Integrated thermal and adjustable overcurrent protection
- Microcontroller - Arduino Nano
  - Breadboard-friendly development board
  - Simple, cheap, effective
- LiPo 24V 5Ah Battery
  - Will be used at 20 Amps.



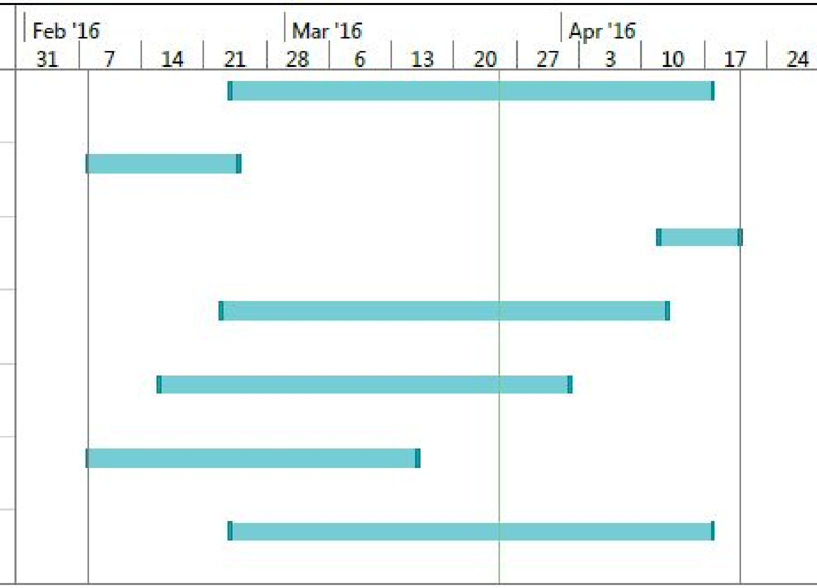
Budget Analysis

Budget for the project was $1,400.

Part	Cost of Design	Money Spent
Arduino Uno Nano	$8.88	$0
DC Voltage Step-down Regulator	$8.36	$0
AmpFlow E30-150 24V	$79	$79
Driver Board	$119	$119
Aluminum	$470	$470
24V Battery	$83	$83
Push Buttons	$4	$0
Worm Gearset	$92	$92
Back Mounted Frame	$100	$100
Mannequin	$221	$221
Total Cost:	$1,176.55	$1,164
Money Leftover		$236

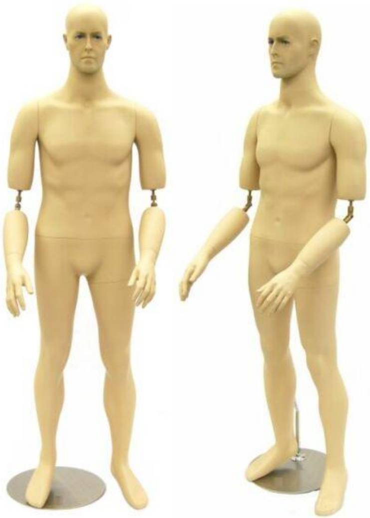
Gantt Chart

ID		Task Mode	Task Name	Duration	Start	Finish
1			Build Frame	39 days	Wed 2/24/16	Sun 4/17/16
2			Test electrical subsystems	13 days	Mon 2/8/16	Wed 2/24/16
3			Final Tests	7 days	Tue 4/12/16	Wed 4/20/16
4			Test mechanical susbsystems	36 days	Tue 2/23/16	Tue 4/12/16
5			Order mechanical parts	34 days	Tue 2/16/16	Fri 4/1/16
6			Order electrical parts	27 days	Mon 2/8/16	Tue 3/15/16
7			Program microcontroller	39 days	Wed 2/24/16	Sun 4/17/16



Safety Analysis

- Potential Problems
  - Motor Overloading
  - Battery Overloading
  - Motor Driver Overloading
  - Movement of arm outside of natural human motion
- Solutions
  - All tests performed in fire-resistant environment, with fire extinguishers present
  - Meticulous testing of set up under multiple test conditions to simulate different use cases
  - Multiple failsafes on each subsystem to ensure immediate shutdown upon dangerous operating conditions
  - Use a mannequin in lieu of a human testing.
- General Safety Protocols
  - At least two testers present during tests: one to perform, one to man the power switch.



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Future of the Project

Year 2 of this project will focus on these objectives:

- Fabricate a motor shaft stabilizer
- Continue work on obtaining safety clearance for human testing from the FSU Safety Department
- Implement a biofeedback sensor input system to replace the current push button system

Conclusion

- A brushed DC motor served as the actuator.
- Aluminum was chosen for the composition of the frame.
- A worm gear drive was used and mounted to the elbow joint.
- The frame went through an iterative design process, leading to the final machined design.
- The electrical system was constructed as designed and tested successfully.
- Construction of the orthotic is almost complete. Mounting the motor to the frame led to difficulty due to its size.

Questions?

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[1] N. Vladimirov, 'Titan Arm', *Titanarm.com*, 2014. [Online]. Available: http://titanarm.com/.

[2] C. Jackson and C. Jackson, 'U.S. Military ‘Iron Man’ Suit Prototype TALOS Debuts in Weeks [Video]', *Guardian Liberty Voice*, 2014. [Online]. Available: http://guardianlv.com/2014/05/u-s-military-iron-man-suit-prototype-talos-debuts-in-weeks-video/.

[3] Plagenhoef, S. "Body Segment Data." *Body Segment Data*. Research Quarterly for Exercise and Sport, n.d. Web. 20 Oct. 2015.

[4] Ahmed, Altayeb Abdalla. "Estimation of Stature from the Upper Limb Measurements of Sudanese Adults." *Forensic Science International* 228.1-3 (2013): n. pag. Web.

[5] Materials selection in mechanical design. By M. F. Ashby, Pergamon Press, Oxford 1992