ECE Team 10 / ME Team 29
Strength Assisting Orthotic

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10/23/15

About Power-Flex

- Our team is dedicated in designing and building a powered strength-assisting orthotic arm.

- This orthotic will have applications in physical therapy, military use, commercial use, and will be marketed to these groups.

The Business Side

Why build this project?

- It can be used to in numerous jobs and fields:
  - Adding strength to warehouse workers and other such civilian jobs
  - As a rehabilitation tool for people with loss of motion or strength
  - As a soldier enhancing wearable
- It solves real problems:
  - Workers that do heavy lifting and are prone to back injury and other such ailments. This wearable will reduce the risk by taking part of the load.
  - Current rehabilitation orthotics are expensive and inaccessible

Goals

1) Providing a strength-assisting powered orthotic that will make lifting heavy objects easier.

2) Increasing endurance for holding said objects, using a form of actuation to mimic muscles and a frame to add structure.

3) Lifting a minimum weight of a paper cup, with a long-term goal of lifting at least 20 pounds.

What is an Orthotic?

- An orthotic is an artificial device that is used to increase bio-mechanical efficiency.
- Orthotics are different from prosthetics, which are artificial limbs.
- Previous orthotics are bulky and hindersome to natural movements.

Titan Arm

In 2013, engineering students at the University of Pennsylvania developed a powered orthotic called “Titan Arm”.

They accomplished this by using DC motors and a cable drive.

TALOS Exosuit

MIT, DARPA, and U.S. Army Research are developing an exosuit to enhance human abilities.

Its features include assisting lifting with heavy loads, protecting the wearer from bullets, and making use of multiple cameras and sensors.

The current design is bulky and limits natural movement.

Needs Analysis

	Price	Safety	Power	Lifespan	Geometric Mean	Normalized Weight
Price	1	0.2	0.5	0.333333	0.4273	0.0779
Safety	5	1	5	5	3.3437	0.6095
Power	2	0.2	1	0.5	0.6687	0.1219
Lifespan	3.000003	0.2	2	1	1.0466	0.1908

After some analysis, it was decided that the most important needs are Safety, Lifespan, Power, and Price (in order of importance).

Based on this analysis, the primary objective is to develop a user-friendly powered orthotic that is safe, ergonomic, and modular.

Initial Design

The Arm has to be interchangeable (right to left)(left to right).

Sliding bar to change distance of forearm and upper arm

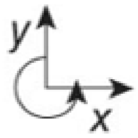
Stiffness of material for the orthotic has to be greater than that of a human forearm (the deflection needs to be almost nonexistent)

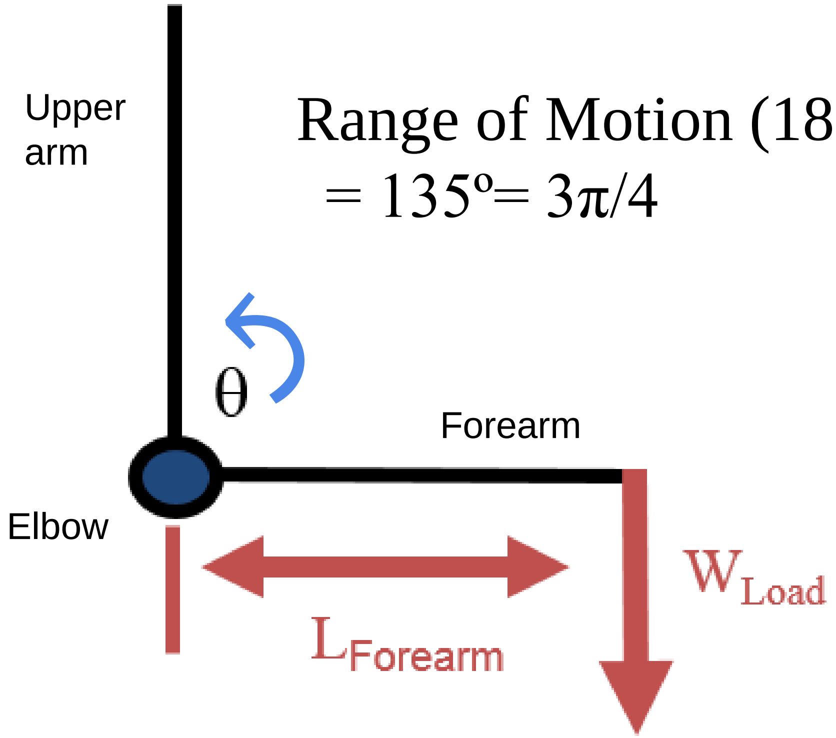
Strength of the material can't plastically deform.

Range of Motion for the orthotic (180º-55º)

Modeling the Load to be Lifted

To find the maximum torque needed, the maximum average forearm length will be used as the moment arm. For the overall design though, the minimum forearm length will be included as well to increase the market base as the design will include a sliding bar.





Range of Motion (180º-55º)
= 135º= 3π/4

$\theta = 90°$

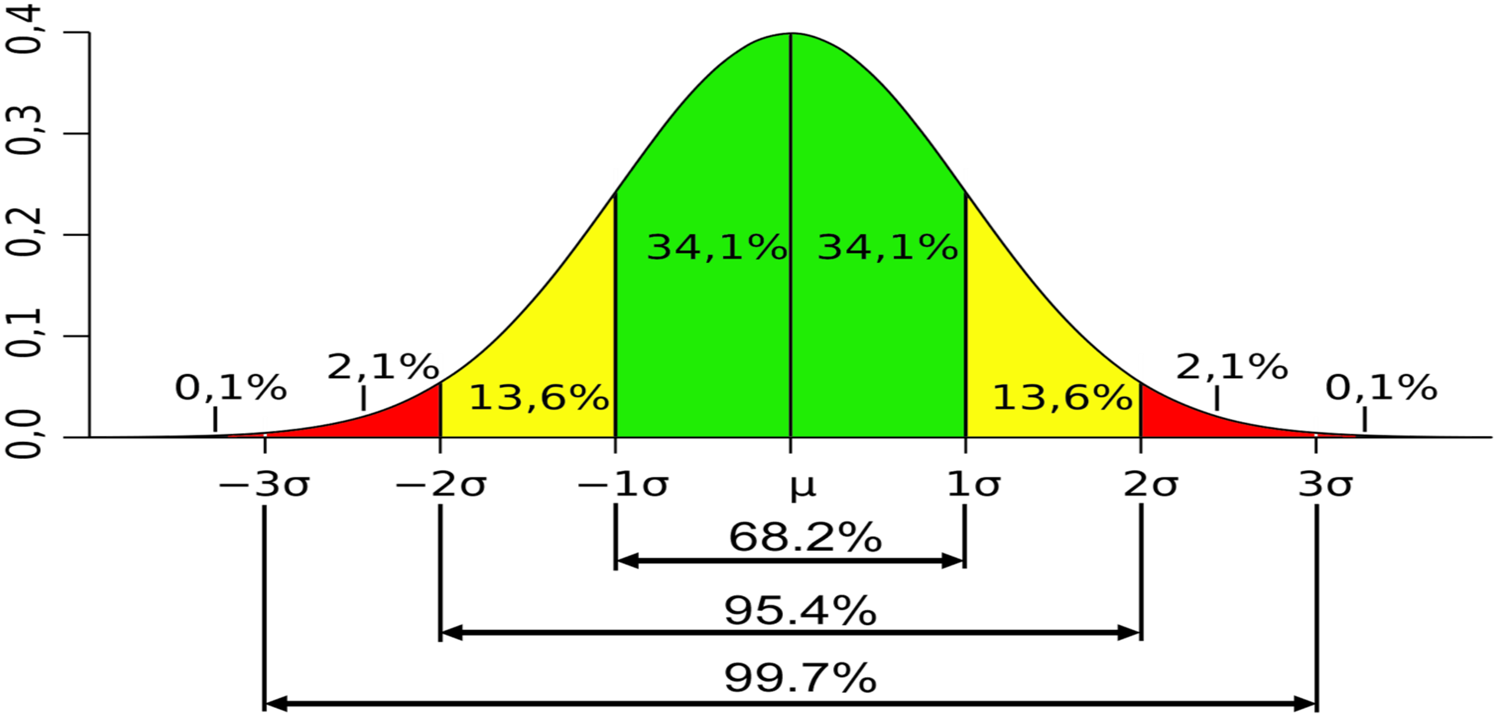
$*L_{Forearm\ -\ max} = 52cm$

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

W_{Load} = 21lbs = 9.52 kg

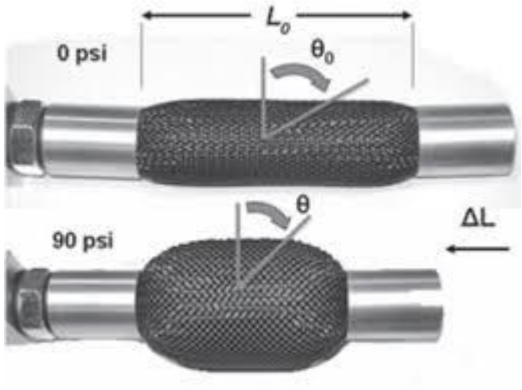
Modeling the Load (Cont.)

*The min and the max arm lengths have a difference of more than two standard deviations of the median. Meaning that over 95.4% of the human population should be able to use the orthotic.



Methods of Actuation

Pneumatic Muscles



Artificial muscles are a relatively new technology with a wide range of applications.

Power-Flex hoped to use this to provide an innovative solution for providing actuation.

It is lightweight, relatively strong, and low in price.

Pneumatic Muscles

Pros	**Cons**
Lightweight	Low Strength Output
Inexpensive	Difficult Control System
Soft	Low Contraction Ratio
Flexible	Requires High PSI
Replaceable	Requires new muscles for change in arm length
Simple	Requires Pressure Safety

We chose not to use this method for several reasons: a low contraction rate, a low power output, and a slow release after contraction. Also, the technology is fairly new without much research behind it.

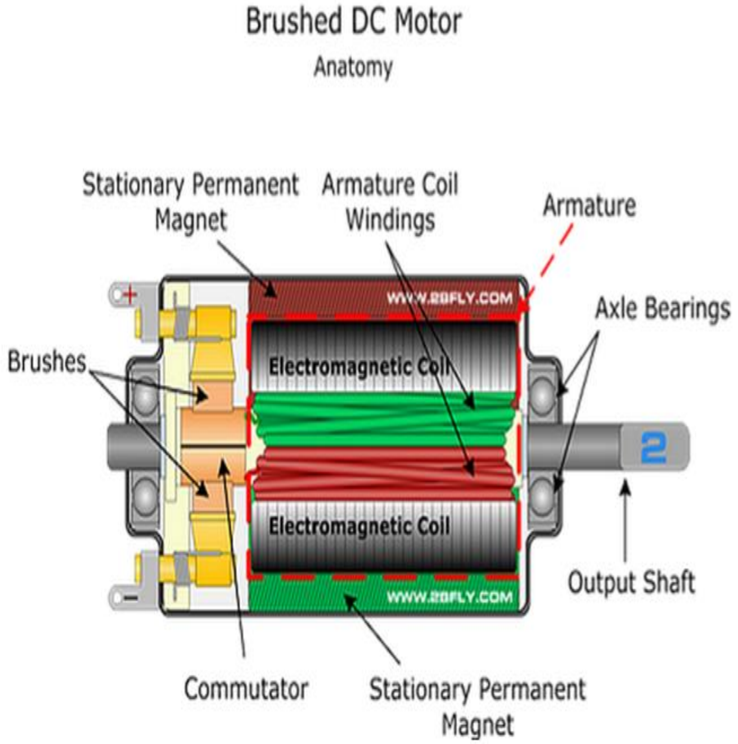
Methods of Actuation

Motors

Motors have a large background of research and with that reliable formulas to calculate needed torque and power.

They are cumbersome, and will make the design heavier and less ergonomic.

Motors are also more expensive, thus making the power arm more expensive and less accessible.



Motors

Pros	**Cons**
Effective	Expensive
Reliable	Heavy
Great Contraction Ratio	Require High Power
Only Needs Electricity	Heat
Relatively Quiet	
Fast	

Our team chose to use motors because they are powerful and have been tested and proven to be effective for a long time period.

Types of Electric Motors

Brushless Motor

- DC Brushless
  - Higher efficiency due to no loss of energy from friction
  - A lower EF and RF noise
  - Output less heat

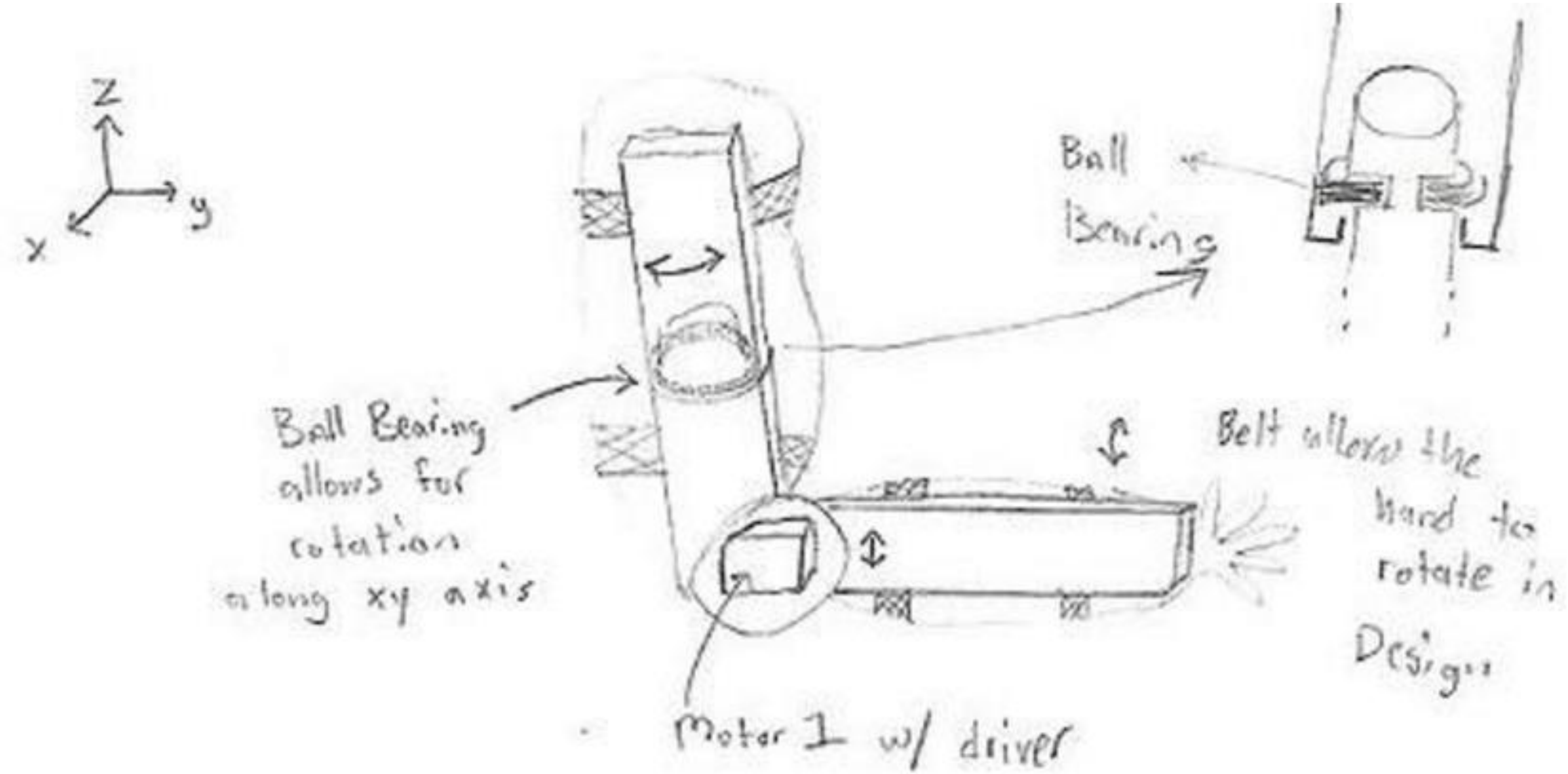
Pancake Motor

- 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 mor than other motors
  - Need to be used at > than 40 kHz due to decreas induction

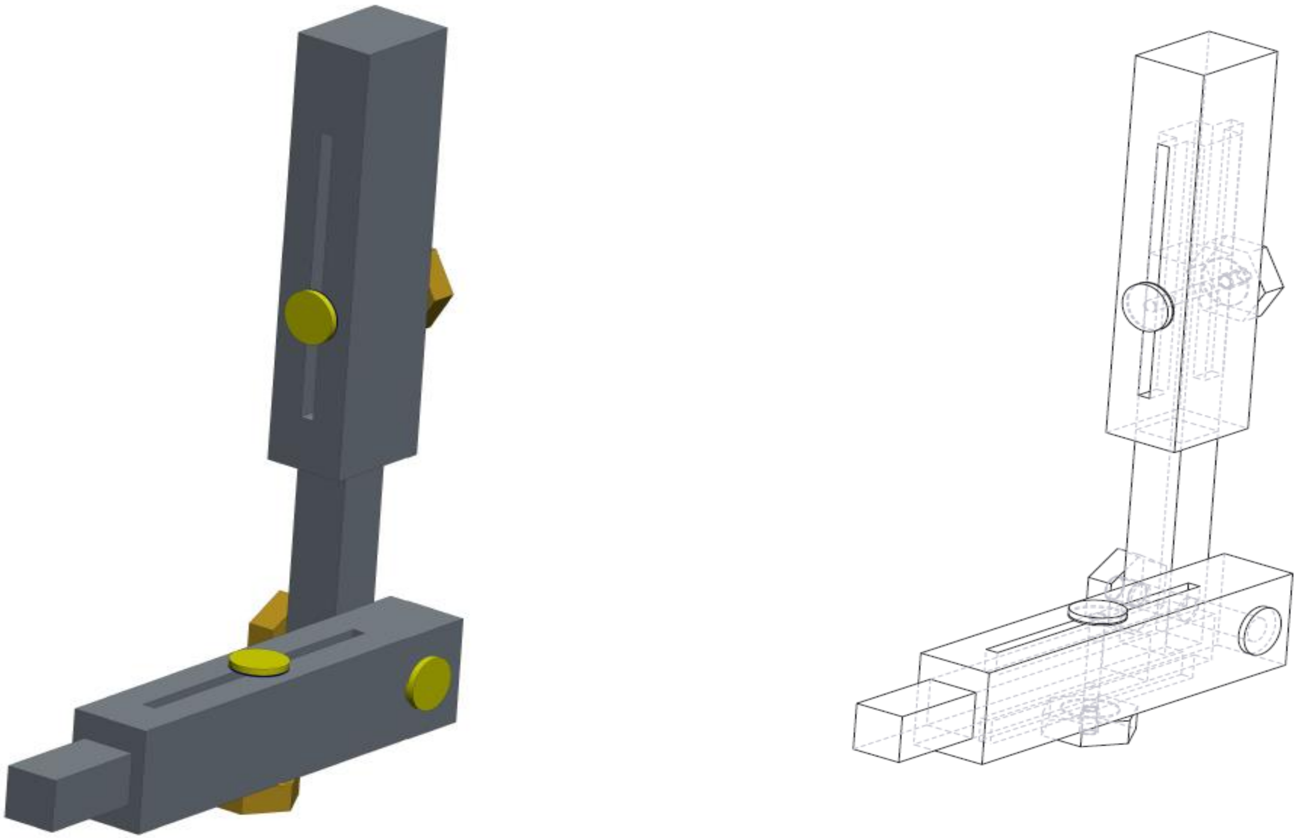
Stepper Motor

- Stepper Motor
  - High level of control

Frame pt 1


z
y
x
Ball Bearing
Ball Bearing allows for rotation along xy axis
Belt allows the hand to rotate in Design
Motor 1 w/ driver

Frame pt 2

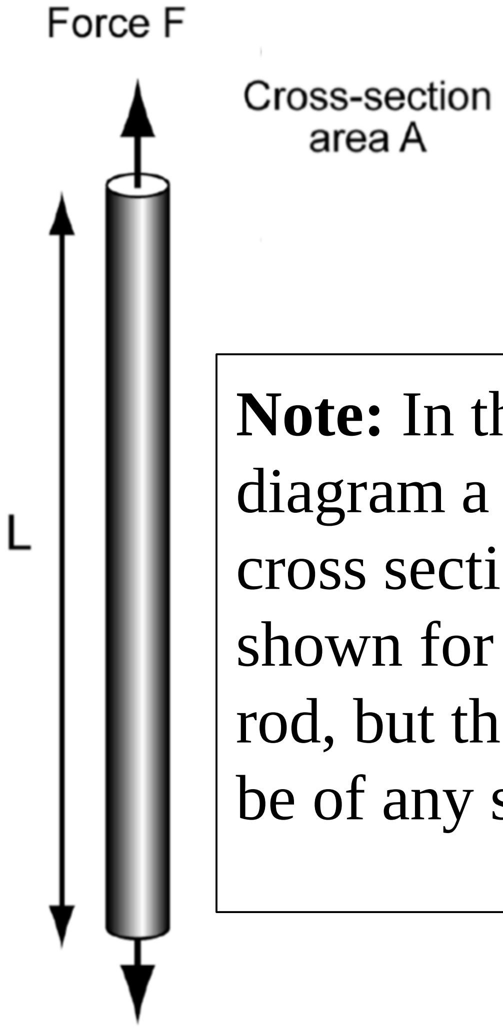


Material Selection

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 to obtain the coupling equation.

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

Where E is the young’s modulus, ρ is the density, δ is the deflection of the tie rod, σ is the yield strength for the material the tie rod, and L is the length of the rod.



Note: In the diagram a circular cross section is shown for the Tie rod, but the Tie can be of any shape.

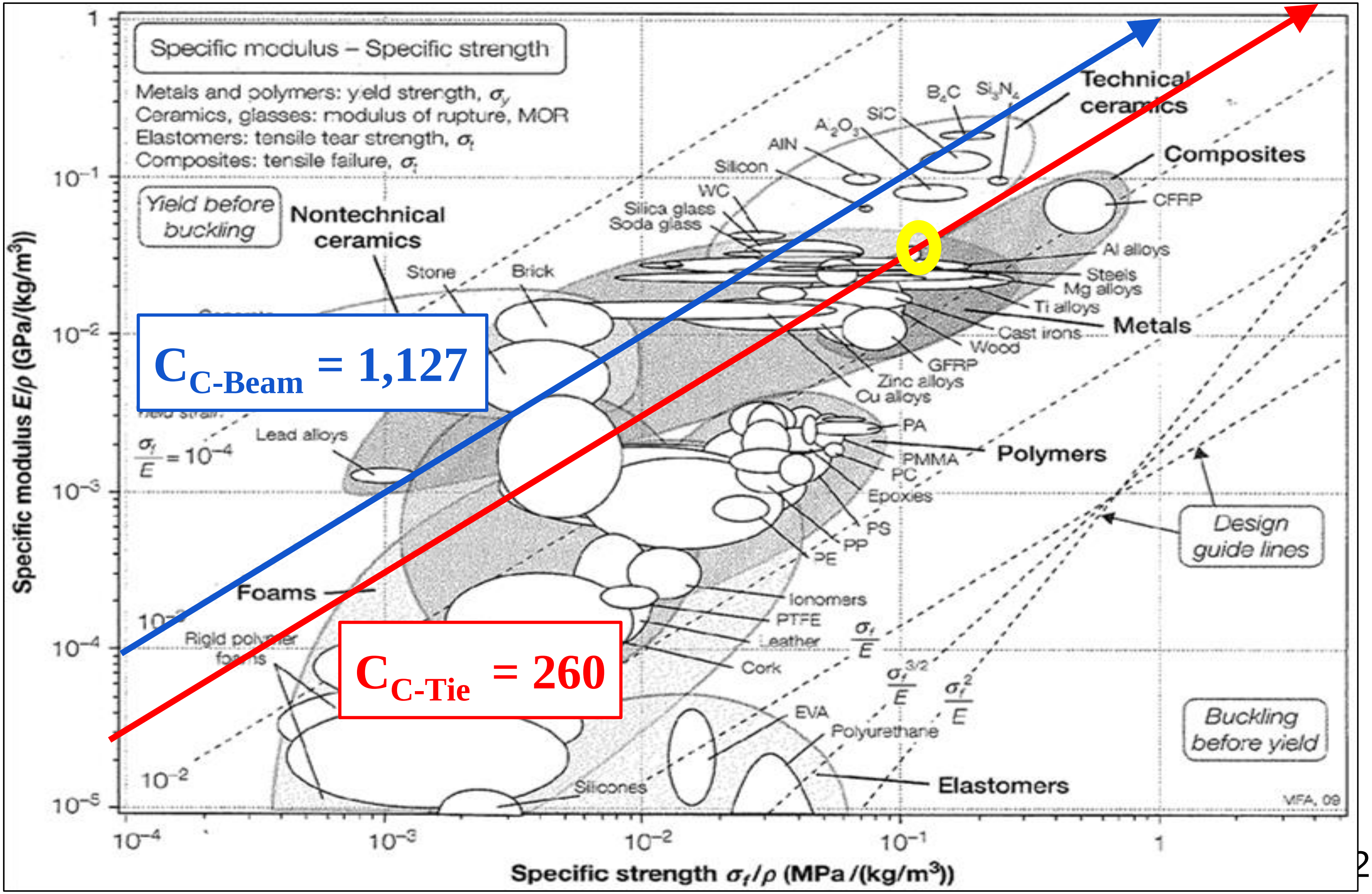
Material Selection (cont.)

Also for when the arm is in movement we can simulate the arm as a light, strong, stiff cantilever beam which is end loaded and the thickness(t) of the beam is known to get its coupling equation.

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

Where E is the young’s modulus, ρ is the density, δ is the deflection of the beam, σ is the yield strength for the material the beam, t is the thickness and L is the length of the beam.

Material Selection (cont.)



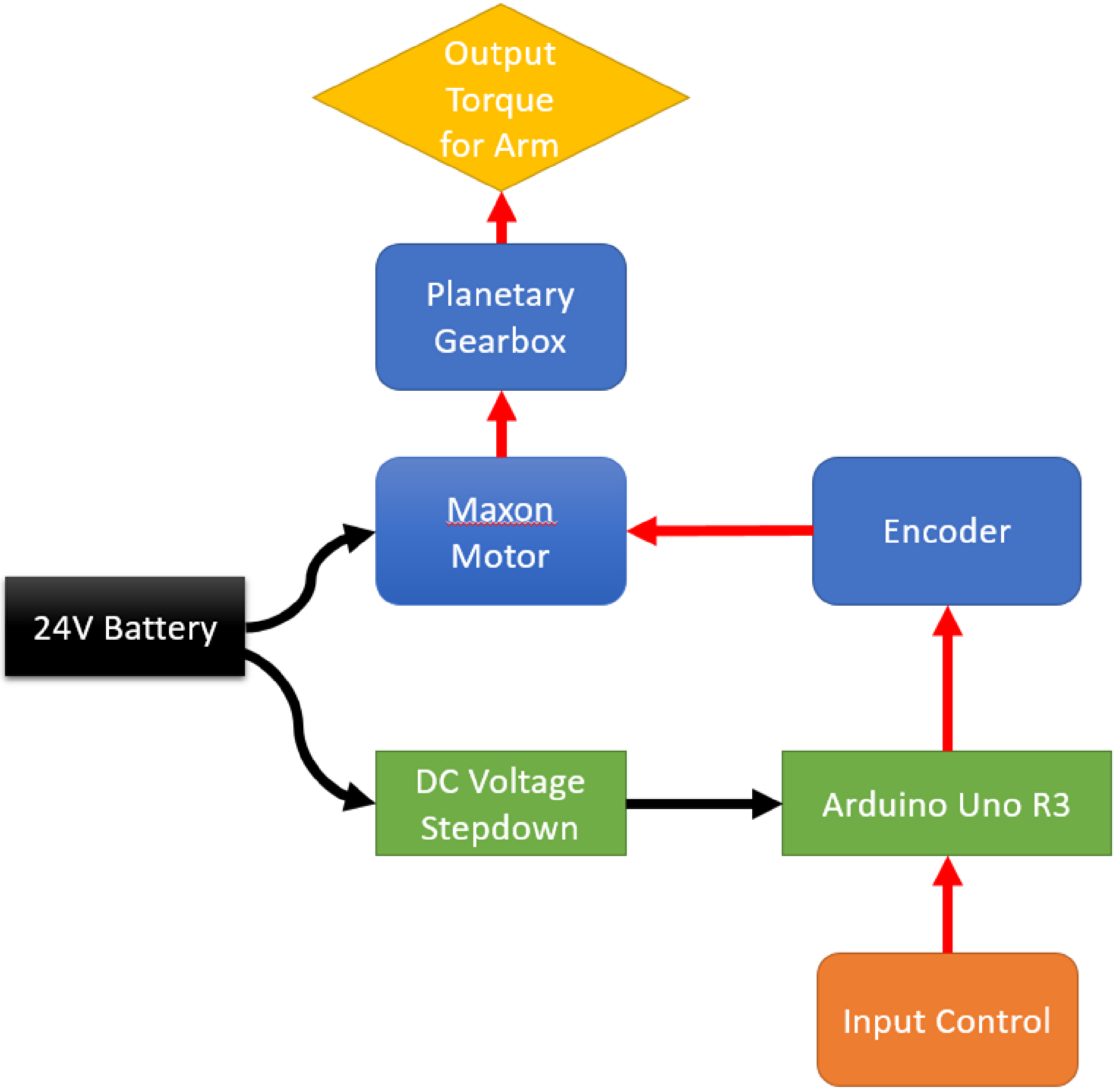
$C_{C\text{-Beam}} = 1{,}127$

$C_{C\text{-Tie}} = 260$

Material Selection (cont.)

Calculation of material Mass and width for Al - alloy		
	m(kg)	**W(m)**
Beam		
Strength	0.218082	0.001808
Stiffness	1.083996	0.008985
Tie		
Strength	0.005592	0.005377
Stiffness	0.006414	0.006167

Overview of the Control System



Why Choose Arduino?

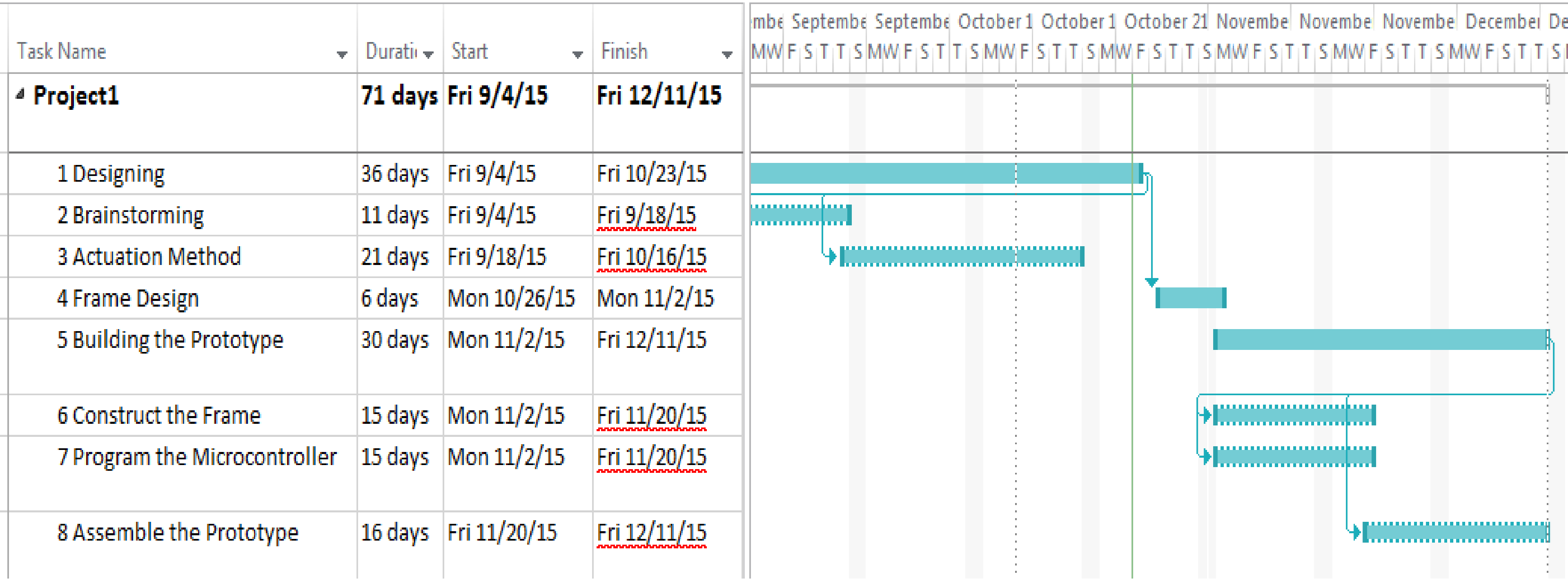
- The Arduino Platform is easy and fast for prototyping .
- When converting from prototype to product, a standard microcontroller will not be used - custom circuits will be designed
- Arduino Platform gives a lot of pre-wiring and free code libraries

Budget Analysis

Budget for the project is $1,400.

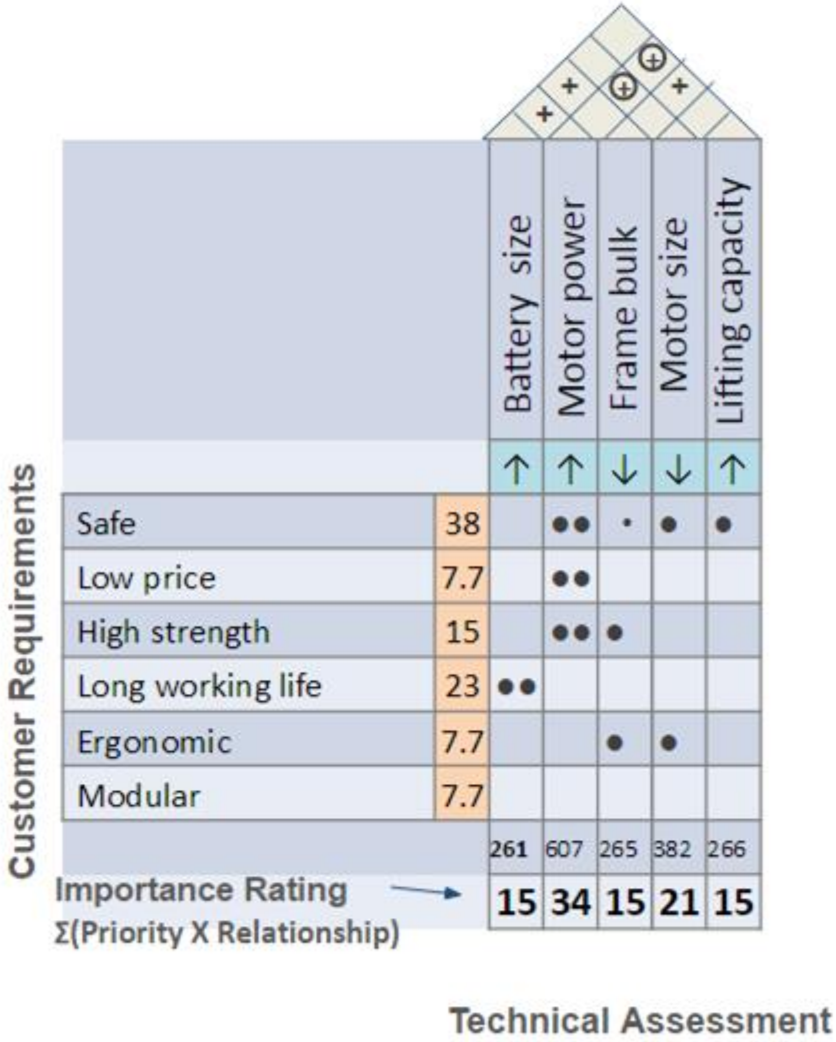
Name	**Price**	**Quantity**	**Total**
24V 6.24 N/m 150 Rpm Pancake Motor + Drivers	$859.25	1	$859.25
Arduino	$8	1	$8
Adjustable DC/DC Stepdown regulator	$10	1	$10
Aluminum Frame [$1.50 -1.70 per kg]	$100	1	$100
24V 5Ah Battery	$110	1	$110
TOTAL COST			**$1087.25**

Gantt Chart



Task Name	Durati	Start	Finish
Project1	**71 days**	**Fri 9/4/15**	**Fri 12/11/15**
1 Designing	36 days	Fri 9/4/15	Fri 10/23/15
2 Brainstorming	11 days	Fri 9/4/15	Fri 9/18/15
3 Actuation Method	21 days	Fri 9/18/15	Fri 10/16/15
4 Frame Design	6 days	Mon 10/26/15	Mon 11/2/15
5 Building the Prototype	30 days	Mon 11/2/15	Fri 12/11/15
6 Construct the Frame	15 days	Mon 11/2/15	Fri 11/20/15
7 Program the Microcontroller	15 days	Mon 11/2/15	Fri 11/20/15
8 Assemble the Prototype	16 days	Fri 11/20/15	Fri 12/11/15

House of Quality



		Battery size	Motor power	Frame bulk	Motor size	Lifting capacity
		↑	↑	↓	↓	↑
Safe	38		••	·	•	•
Low price	7.7		••			
High strength	15		••	•		
Long working life	23	••				
Ergonomic	7.7			•	•	
Modular	7.7					
		261	607	265	382	266
Importance Rating →		15	34	15	21	15

Σ(Priority X Relationship)

Correlations:
- ⊕ Strong Positive
- \+ Positive
- ⊖ Strong Negative
- − Negative

Relationships:
- •• Strongest= 10
- • Strong= 7
- ⊙ Fair= 4
- ○ Weak= 1

Future Plans

- Design way to connect shoulder to upper arm
- Forearm to upper arm gears
- Add computerized controller
- Finalize motor selection
- Design locking mechanism for arm joint
- Do market research

Conclusion

- A powered orthotic has potential to solve real world problems.
- Future developments will begin with finding an appropriate source and supply line for the actuators with the calculated specifications.
- Aluminum will be used for the orthotic frame.
- Our calculations for the necessary materials put us within budget for this project, as far as the prototype is concerned.
- Our calculations predict a 20 pound lifting capacity.

Questions?

[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