Robotic Ankle Exoskeleton

Diego Avila, Emma De Korte, Tre Green

NAU NORTHERN ARIZONA UNIVERSITY

Project Description

- Partnered with Zachary Lerner
- -Partnered with NAU Biomechatronics
- -Develop Ankle Exoskeleton
- -Focus on structure of system (not motor)
- -Aid in walking motion
- -Commonly going to be used for Cerebral Palsy
- -previous trial “did not observe a significant group-level benefit relative to walking without the device. However, [they] did observe a marked benefit for [their] more impaired participants”[1]
- We intend to reiterate parts of their design (bracket, chain to cable, pulley)

[redacted]

Functional Decomposition

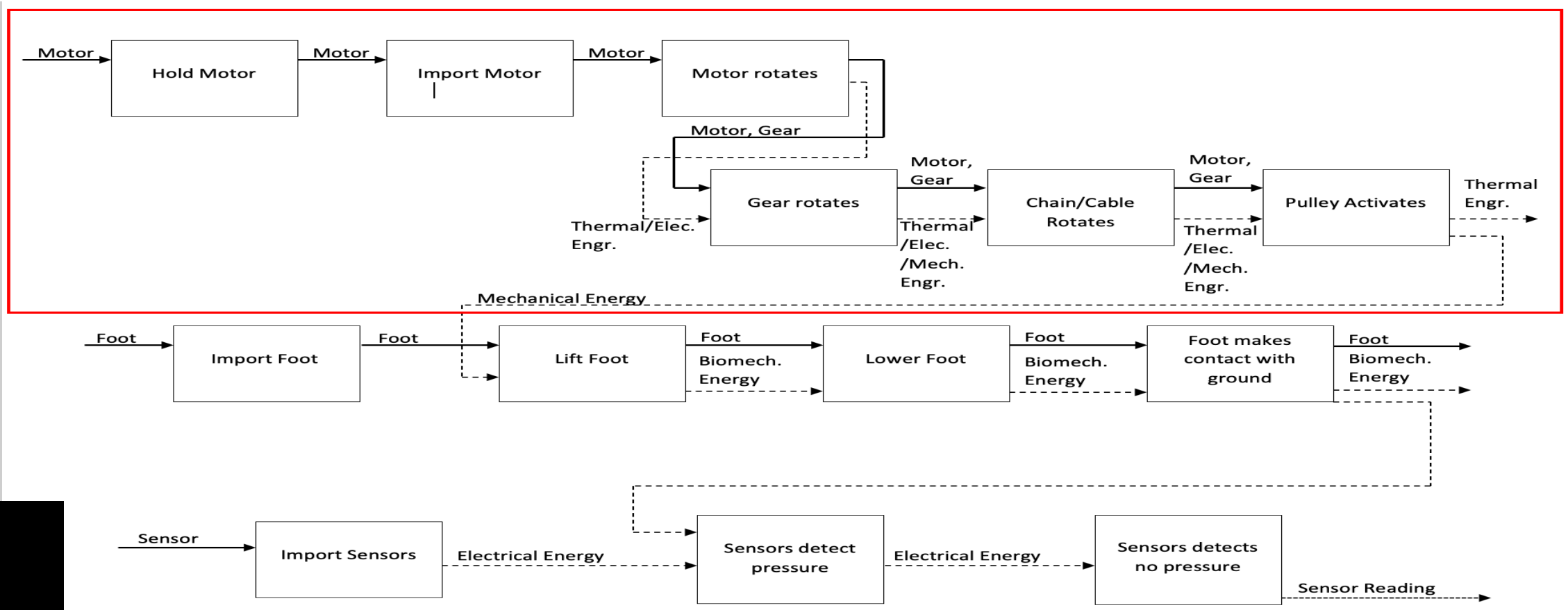
- Black Box Model

[redacted]

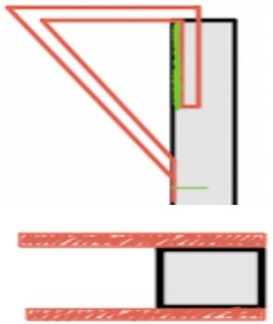
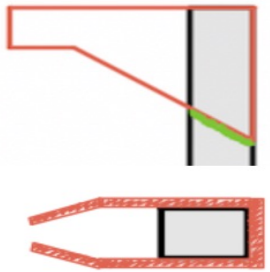
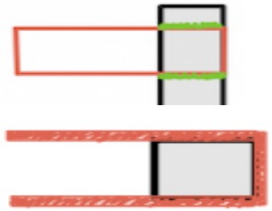
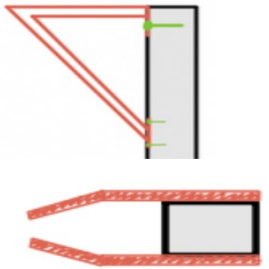
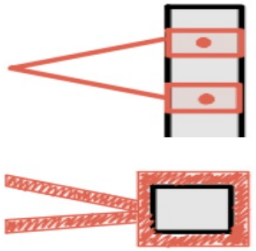
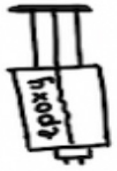
Avila, 2

Functional Decomposition

- Functional Model, Red Box is Team's Focus



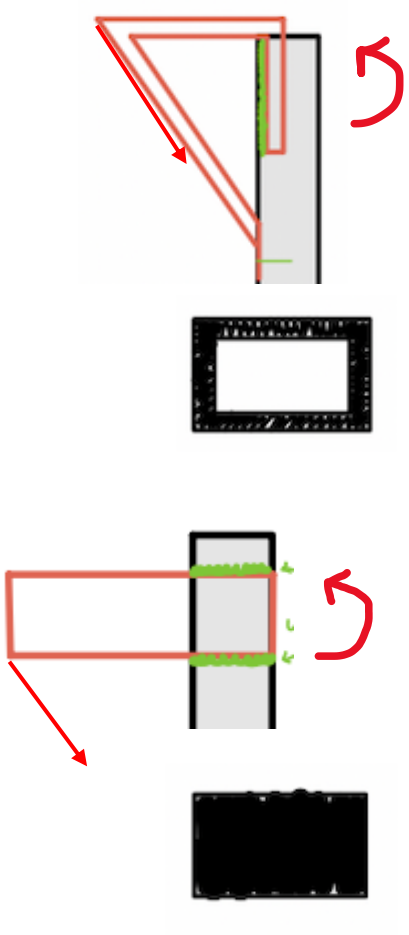
Concept Generation

Subsections	1	2	3	4	5
Bracket Shape, A					
Cross Section, B					
How bracket is mounted, C	 Riveting	 Bolt/screw	 Epoxy		

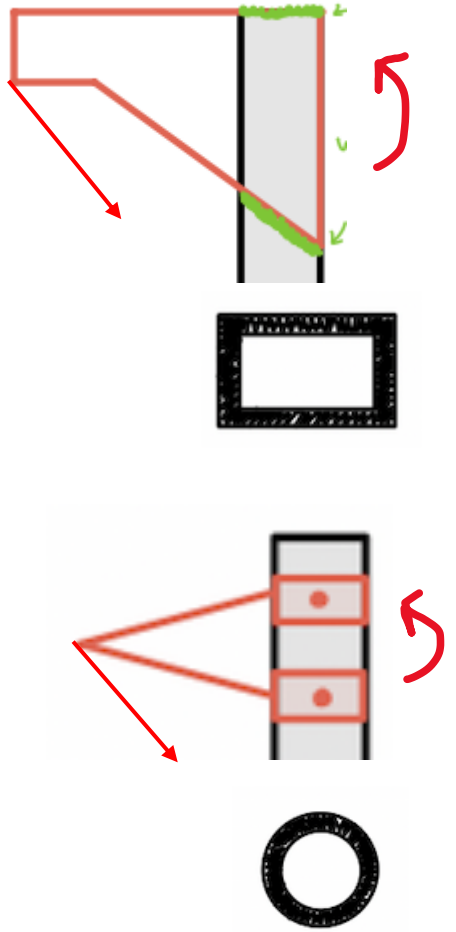
Green, 4

Engineering Calculations

- F=388N (From force calculation on Slide 7)
  - Fx = 388Ncos(45)
    - 274.357N
  - Fy = 388Nsin(45)
    - 274.357N
- The bracket with the highest surface area on the tube will better disperse the force



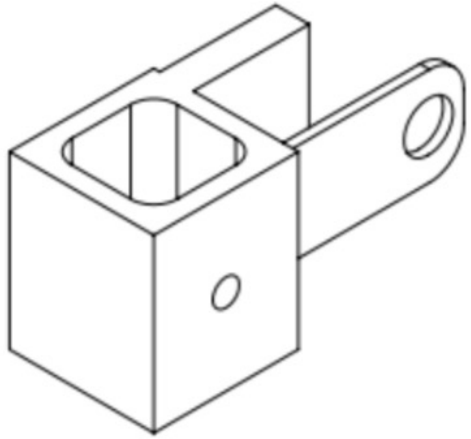
- Assuming a 45º of from the cable pulling downward on the bracket
- There will be a positive moment on the attachment point



Engineering Calculations

- Calculating Shearing force at attachment point to bracket

$$\tau = \frac{F}{A}$$



- F=Torque/ Radius
- Torque= 3.5 NM
- Radius of gear= .009M
- F= 388 N Acting Upwards on the connection

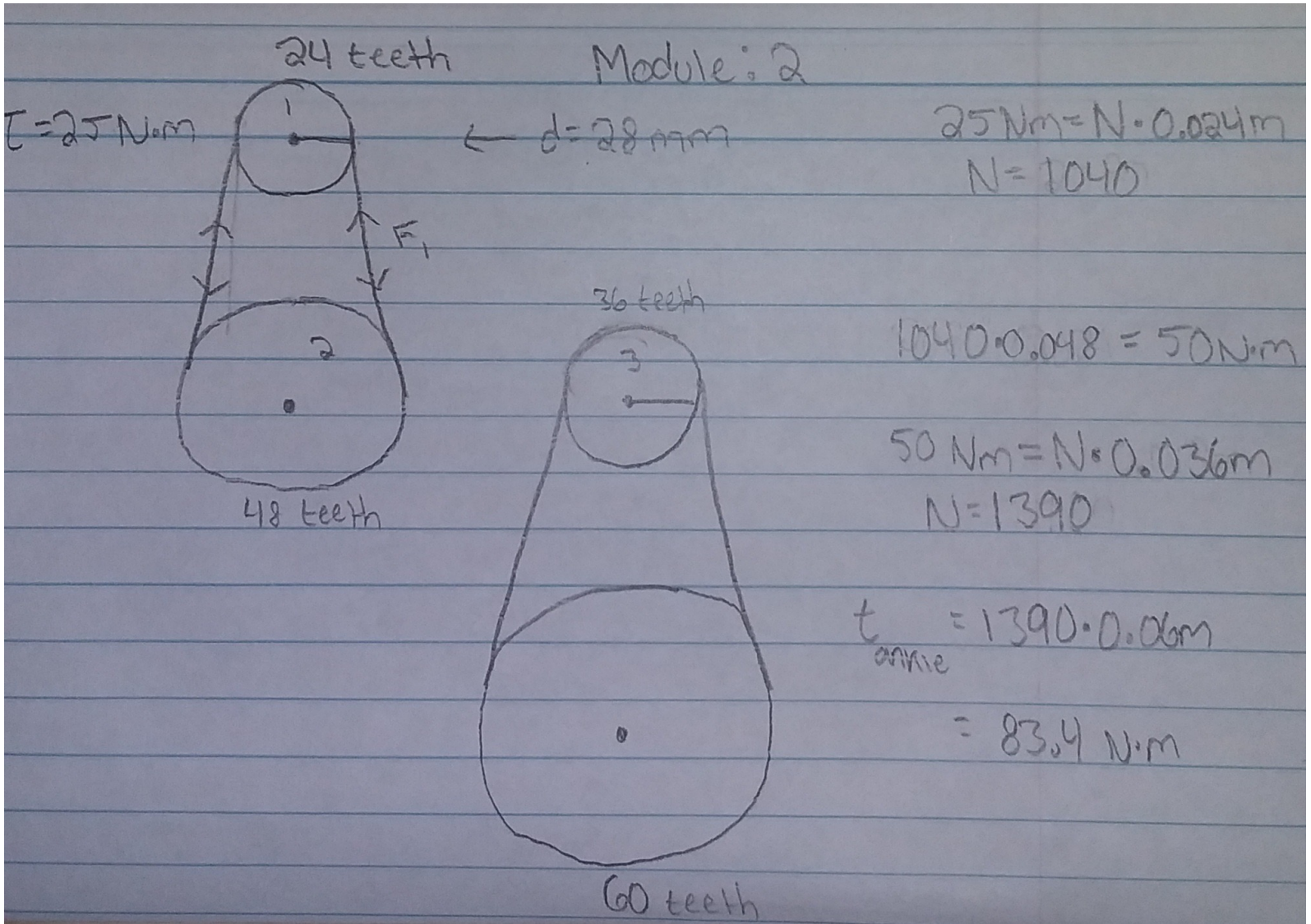
Using a Bolt/Rivet or epoxy

- Fy=388sin(45)=274 N
- factory of safety= 2
- Using trial and error
- Bolt d=9 mm
- Shearing force of bolt= 8.61 N/mm^2
- Ultimate allowable stress of aluminum is 155 N/mm^2

- Epoxy Shear strength = 6.89-137 MPa

Green, 7

Cable Tension

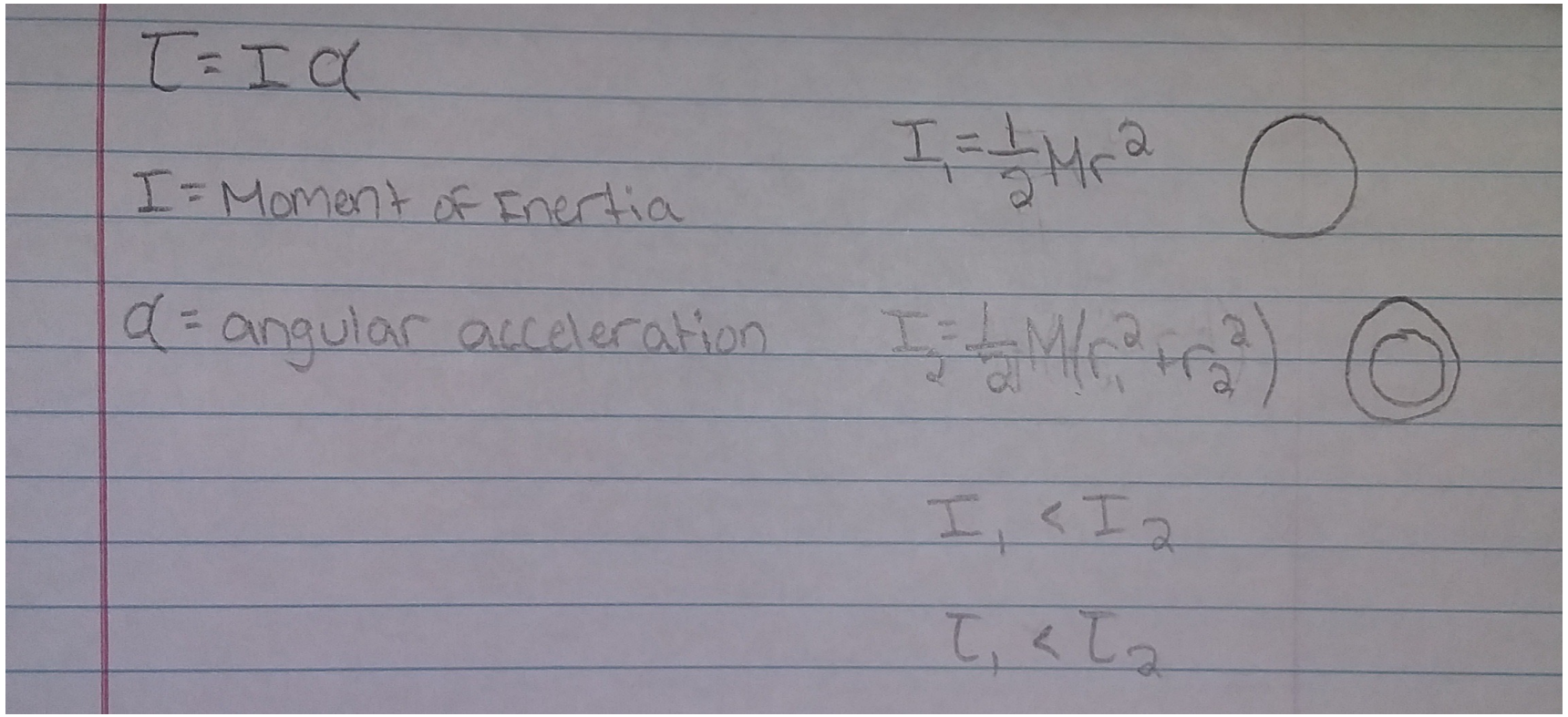


- Given:T1= 25 Nm
- Define module for radius
- F1=T/1R1
- T2=F1*R2
- T3=T2
- F2=T3/R3
- T(ankle)=F2*R4
- 83.4Nm>80.6Nm
- 70 kg patient

[redacted]

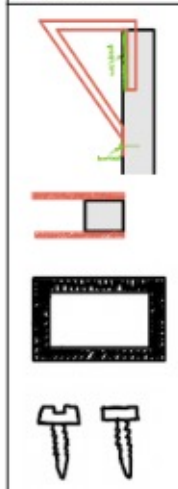
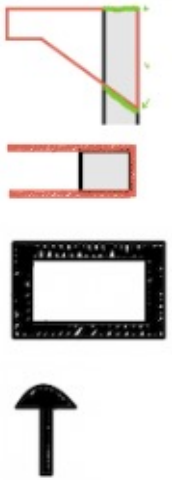
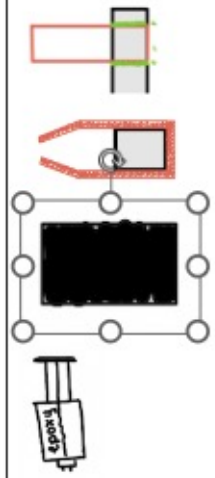
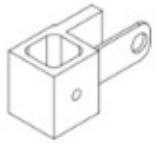
Ideal Cross Section

- Circular cross sections are stronger than square cross sections because they evenly distribute force and are also lighter



- Tubing has a larger moment of inertia than solid shafts, so it requires more torque to produce the same angle of twist

Concept Evaluation: Pugh Chart

Pugh Chart	Design 1	Design 2	Design 3	Design 4	Datum
					
Lightweight	+	+	S	+	datum
Easy to take on and off	N/A	N/A	N/A	N/A	Datum
Durable	+	+	S	S	Datum
Cost Effective	+	-	S	+	Datum
Small in Size, close to body	S	S	S	S	Datum
$\Sigma+$	#	2	0	2	Datum
$\Sigma-$	1	2	0	0	datum
Σs	1	1	3	2	datum

Decision Matrix

- Design 1

		Design (1)		Design (4)	
Criteria	Weight	Score (1-10)	Weighted Scor	Score (1-10)	Weighted Score
Light Weight	0.4	9	3.6	8	3.2
Easily taken on and off	0.05	10	0.5	10	0.5
Durable	0.3	8	2.4	9	2.7
Cost effective	0.15	9	1.35	8	1.2
Small in size	0.1	7	0.7	9	0.9
Total	1		8.55		8.5

CAD Model

Schedule

Presentation 2					
Task 1 - Project Description	Avila, D.	100%	10/8/23	10/10/23	3
Task 2 - Functional Decomposition (Black Box & Functional Model)	Green, T.; De Korte, E.	100%	9/26/23	10/3/23	8
Task 3 - Concept Generation	Green, T.; De Korte, E.	100%	9/26/23	10/3/23	8
Task 4 - Engineering Calculations: De Korte	De Korte, E.	100%	10/3/23	10/6/23	4
Task 4 - Engineering Calculations: Green	Green, T.	100%	10/3/23	10/6/23	4
Task 4 - Engineering Calculations: Avila	Avila, D.	100%	10/3/23	10/6/23	4
Task 5 - Pugh Chart and Decision Matrix	Green, T.; De Korte, E.	100%	10/6/23	10/8/23	3
Task 6 - CAD Model	De Korte, E.	100%	10/8/23	10/10/23	3
Task 7 - Schedule and BOM	De Korte, E.	100%	10/8/23	10/10/23	3
Task8 - Budget	Green, T.	100%	10/8/23	10/10/23	3

Schedule

Report 1	
Task 1 - Project Description	0%
Task 1 - Deliverables	0%
Task 1 - Success Metrics	0%
Task 2 - Customer Requirements	0%
Task 2 - Engineering Requirements	0%
Task 2 - House of Quality	0%
Task 3 - Benchmarking	0%
Task 3 - Literature Review	0%
Task 3 - Mathematical Modeling	0%
Task 4 - Functional Decomposition	0%
Task 4 - Concept Generation	0%
Task 4 - Selection Criteria	0%
Task 4 - Concept Selection	0%
Task 4 - Proof Read Content	0%

Presentation 3	
Task 1 - Project Description	0%
Task 2 - Design Description	0%
Task 3 - Design Requirements	0%
Task 4 - Engineering Calulcations	0%
Task 5 - Design Validation	0%
Task 6 - Schedule & Budget	0%

- The team is currently behind schedule

Budget

- Current Budget is 4000 dollars
  - $2000 per leg
- Our Current Expense are 0
- Estimated budget based
  - Based on previous projects final design is 1,646 dollars
  - Our largest expense will be our motor ≈ $773 and Gearbox ≈ $300+
  - We can expect our final design to be around that value, while the rest of the money will go toward prototyping.

Fundraising is 400 dollars and will discuss with Lerner

Green, 14

Bill of Materials

Current Bill of Materials			
Part	Manufactor/Source	Quantity Per Unit	Cost Per Unit
Bracket (Aluminum 6061-T6, 12"x12"x0.09")	OnlineMetals.com	1	$15.62
3" Pulley	E-Rigging.com	1	$13.49
Cable (5/16")	Midwest Unlimited	1	$0.48
Chain (1ft, 05B, 8mm Pitch)	McMaster-Carr	1	$9.00
Sprocket (05B, 8 Teeth)	McMaster-Carr	1	$13.05
Motor	Lerner	1	-
Calf Cuff	Lerner	1	-
Carbon Fiber Tubing	Lerner	1	-
Footplate	Lerner	1	-
Sensors	Lerner	?	-
Motor Mount	Lerner	1	-
Computer Chip	Lerner	1	-
		Total:	$51.64

De Korte, 15

- [1]-[5]

Any Questions?

Thank you

NAU NORTHERN ARIZONA UNIVERSITY

References

- DOI 10.1109/TBME.2021.3137447, IEEE Transactions on Biomedical Engineering
- BDYNAS. (2020). *SHIGLEY'S MECHANICAL ENGINEERING DESIGN, 11TH EDITION, SI UNITS* (11th ed.). MCGRAW-HILL EDUCATION (AS.
- *Overview of materials for Epoxy Cure Resin*. Overview of materials for epoxy cure resin. (n.d.). https://www.matweb.com/search/datasheet_print.aspx?matguid=956da5edc80f4c62a72c15ca2b923494
- *Shear and tension capacity of stainless steel bolts*. British Stainless Steel Association. (n.d.). https://bssa.org.uk/bssa_articles/shear-and-tension-capacity-of-stainless-steel-bolts/
- *Fully active chain and sprocket ankle exoskeleton for Rehabilitation Assistance*. BIOMECHATRONICS LAB. (n.d.). https://www.ceias.nau.edu/capstone/projects/ME/2022/22F_P12BiomechLab/Documents.html

•[1] "Carr," McMaster, https://www.mcmaster.com/products/iso-05b-roller-chain/roller-chain-trade-number~05b/pitch~8-00-mm/pitch~8-mm/ (accessed Oct. 13, 2023).
•[2] "Carr," McMaster, https://www.mcmaster.com/products/sprockets/roller-chain-trade-size~05b/roller-chain-trade-number~05b/number-of-teeth~8/ (accessed Oct. 13, 2023).
•[3] "Vinyl coated galvanized aircraft cable," Midwest Unlimited - Fall Protection, Rigging, Safety, Tools & Gear, https://www.midwestunlimited.com/vinyl-coated-galvanized-aircraft-cable.html?gclid=Cj0KCQjw1aOpBhCOARIsACXYv-ekyylepabf2ei68ZHEzA4kCwEG1g1--feHyIdb-LVHZbuBDGGAEXsaAmdmEALw_wcB (accessed Oct. 13, 2023).
•[4] "0.09" aluminum sheet 6061-T6 -part #: 1244," Order 0.09" Aluminum Sheet 6061-T6 Online, Thickness: 0.09", https://www.onlinemetals.com/en/buy/aluminum/0-09-aluminum-sheet-6061-t6/pid/1244?variant=1244_12_12&CAWELAID=120293320000164164&CAGPSPN=pla&CAAGID=&CATCI=&gclid=Cj0KCQjw1aOpBhCOARIsACXYv-ct5sBiMrJhjND37nKEeXQ04xsKSsNvMzEY5fkzbxEyxRh0l3QyqLIaAvYOEALw_wcB (accessed Oct. 13, 2023).
•[5] "Zinc plated sheaves with bushings, imported," E, https://e-rigging.com/products/zinc-plated-sheaves-with-bushings-imported?variant=39745732378697&gclid=Cj0KCQjw1aOpBhCOARIsACXYv-cbu7LiyxL81QyLjph4uLlEF8JF09NGLSBaSPZn34g6arZJwjd5BhIaAhlXEALw_wcB (accessed Oct. 13, 2023).