Project 11: Arm Exoskeleton

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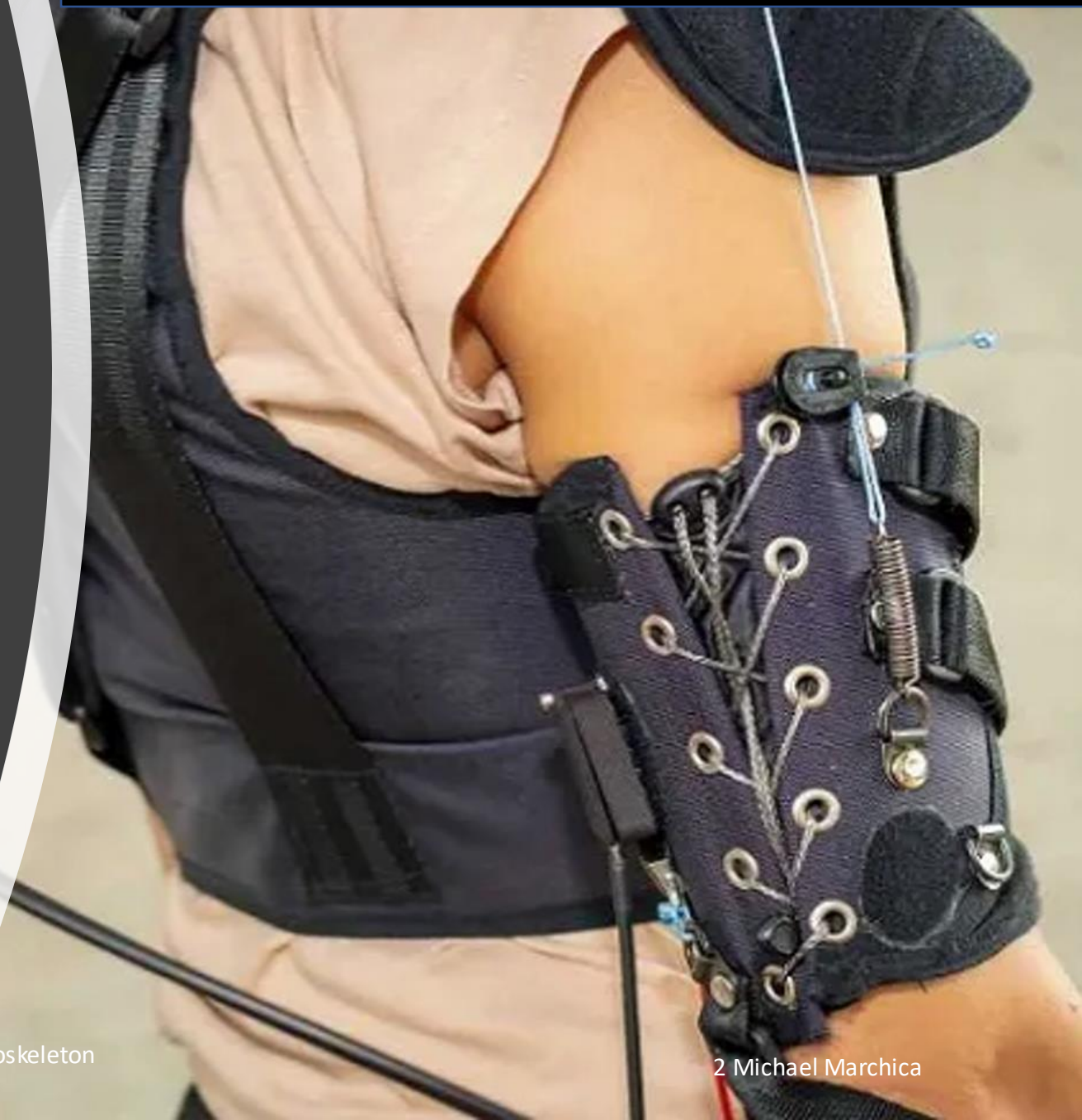
Photo Provided By: ETH Zurich

Description of Project

- To design and improve upon the upper body arm exoskeleton called the Myoshirt, designed by ETH Zürich. The suit will assist the user's task of completing pull-ups and other daily activities.
  - Increase the number of pull-ups by 20%.
  - Lightweight: Must be < 6lbs
  - Low profile: Cannot extrude >10 cm off the body.
- Client: Dr. Zachary Lerner
- Sponsor: W.L. Gore
  - Budget: $3,750

Photo provided by: ETH Zurich



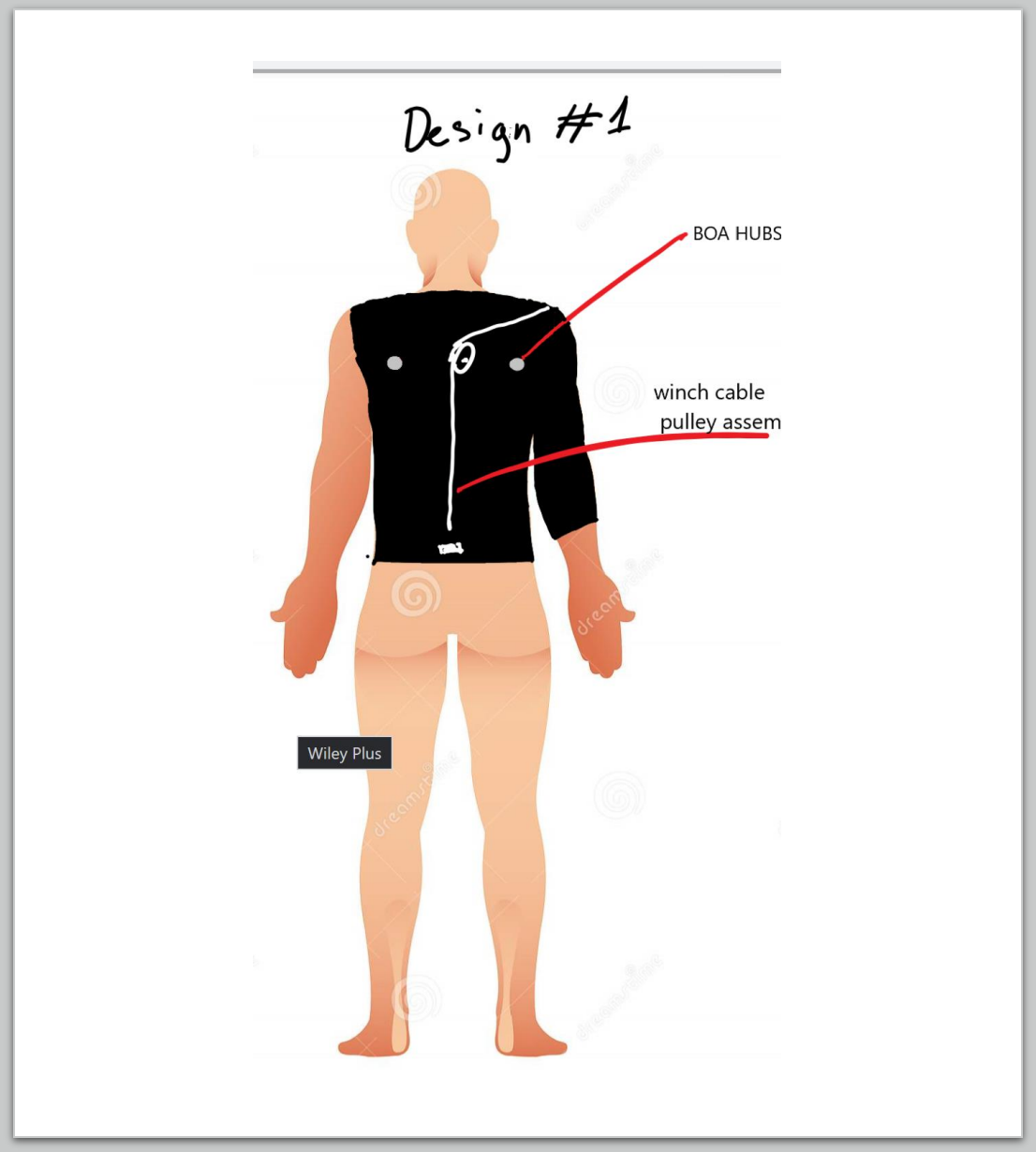
Inputs:		Function:		Outputs:
Pull-up Bar (Solid)	---------->	Increase the amount of pull-ups someone can do by 20% when wearing the exomuscle suit	---------->	Pull-up Bar (Solid)
	---------->		---------->	
Gravity (PE)	---------->		---------->	
Battery Energy (Electrical Energy)	---------->		---------->	Waste Energy (Thermal Energy)
Ground/Bar Forces (Mechanical Energy)	---------->		---------->	Ground/Bar Forces (Mechanical Energy)
Actuation (Mechanical & Electrical Energy)	---------->		---------->	
	---------->		---------->	
Operator Input (Control)	---------->		---------->	Operator Status (Control)
ON/OFF Switch	---------->		---------->	ON/OFF Switch
Analog signals (Lights)	---------->		---------->	Analog signals (Lights)

Black Box Model

- Aid in Concept Generation:
  - View on different forces within the system
    - Allows for design to better accommodate this
  - Broad overview of tasks/problems needed to solve

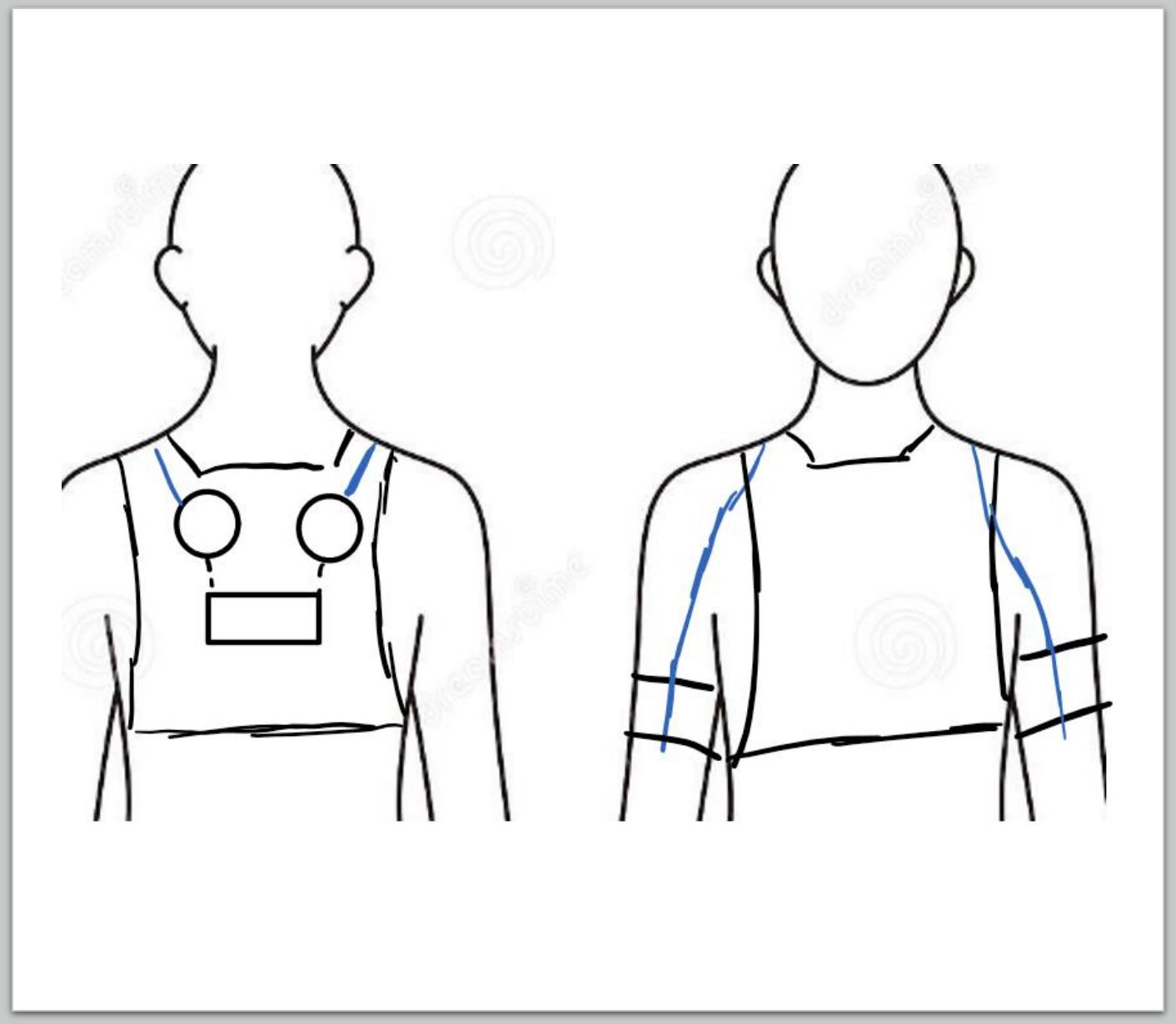
Design 1:

- Description
  - Simple One-armed design with cable bracing BOA system for scapula reinforcement. Cable operated contraction method.
- Advantages
  - One motor and lightweight design.
- Disadvantages
  - Single-arm system
  - Lacks adequate assistance for both arms to provide even stable support for pull up.



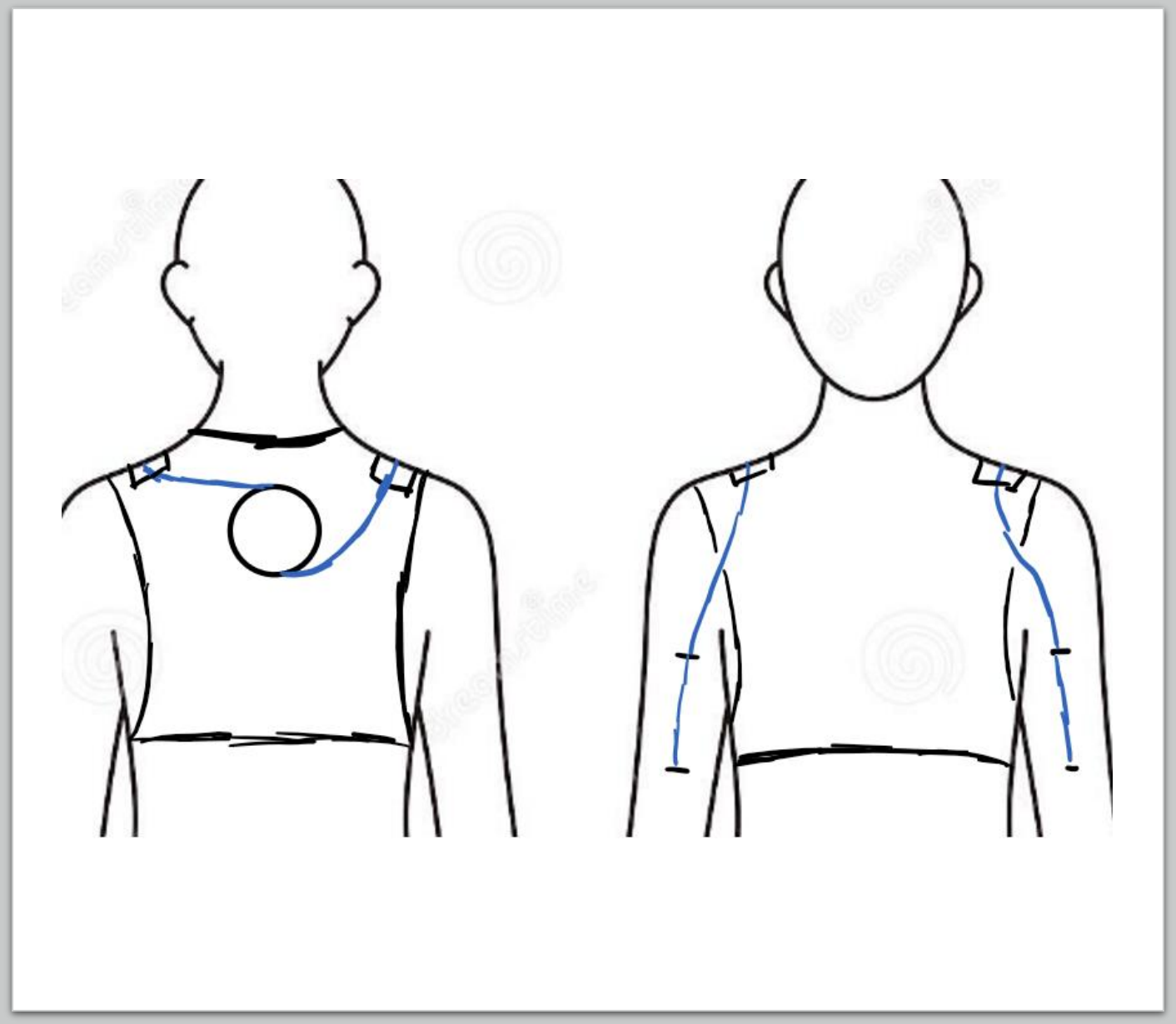
Design 2:

- Description
  - This design uses two motors mounted on each shoulder to control servo arms.
  - The servos will mimic a winch system that will control a wire mounted with two anchor points.
  - Use of Arduino Uno to control speed.
- Advantages
  - Simultaneous actuation of each motor
- Disadvantages
  - Possible safety issues



Design 3:

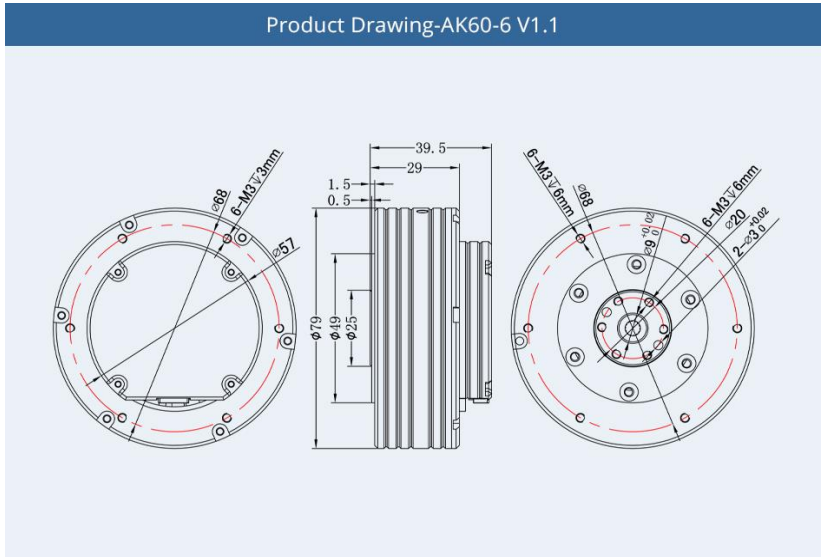
- Description
  - Motorized spool on back coiling wire in both directions
- Advantages
  - Only needs one motor and is a lightweight design
- Disadvantages
  - The hand pressure plate may be hard to disengage safely so need a better design

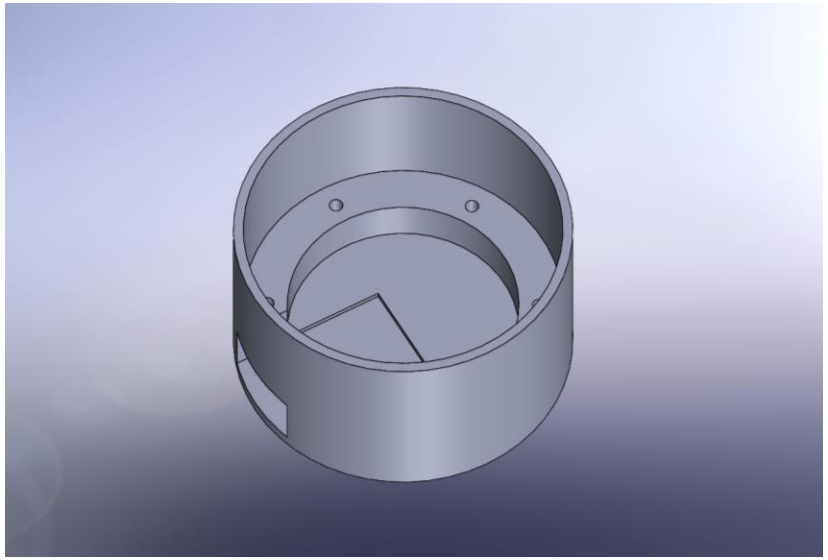


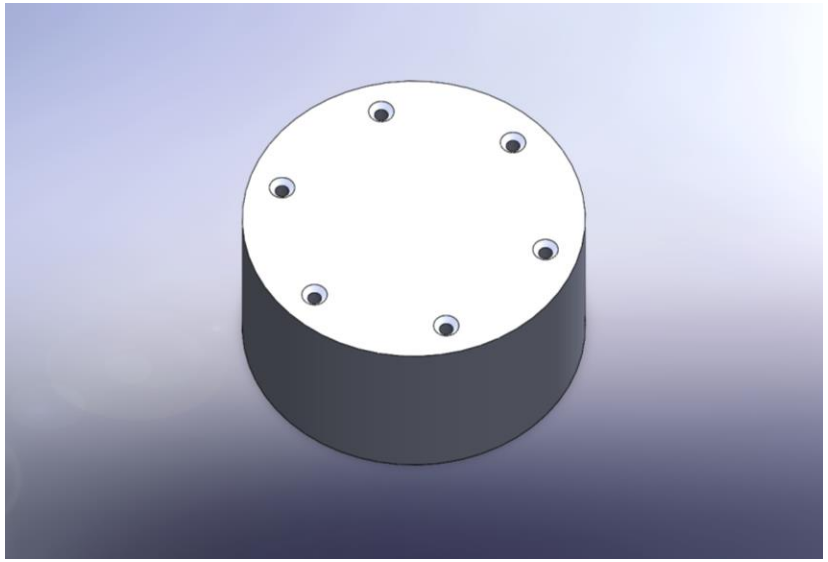
Motor Specifications

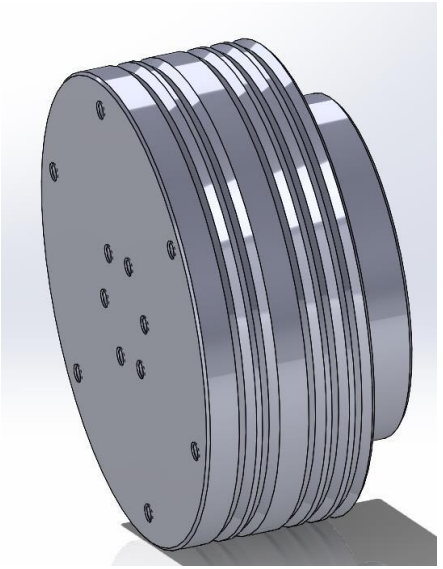
Specifications-AK60-6 V1.1			
Weight(g)	368	Ke(V/rpm)	0.012
Voltage(V)	24	Km(Nm/√w)	0.15
Rated Torque(Nm)	3	Number of Pole-Pair	14
Peak Torque(Nm)	9	Resistance Phase to Phase(mΩ)	605±5
Max Speed@Rated Torque(rpm)	220（Output）	Inductance Phase to Phase(uH)	415±10
Rated Current(A)	4.5	OD(mm)	Φ79
Peak Current(A)	13.5	Height(mm)	39.5
Kt(Nm/A)	0.113	Max torque weight ratio(Nm/kg)	24.46
Kv(RPM/V)	80	Reduction ratio	6:1

SOLIDWORKS Models: Motor & Mount









Concept Evaluation - Pugh Chart

- Through the Pugh chart the team was able to narrow down their designs.
  - Designs were compared to one another through a 'datum' and given a scored based on this.
- Why use a Pugh Chart?
  - A Pugh Chart allowed the team to compare their designs and decide on the most optimal one.

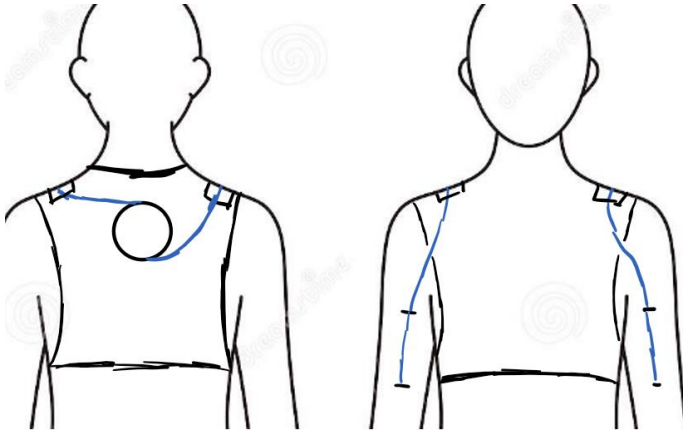
Pugh Chart						
Selection Criteria	Datum	Design 1	Design 2	Design 3	Design 4	Design 5
Lightweight	Datum	S	+	+	-	-
Portable	Datum	S	S	S	S	S
Low Profile	Datum	S	+	+	-	+
Comfort	Datum	+	+	S	S	-
Stability	Datum	+	-	+	+	S
Overall Saftey	Datum	S	-	S	-	S
Total +	Datum	2	3	3	1	1
Total -	Datum	0	2	0	3	2
Total S	Datum	4	1	3	2	3
Score	Datum	2	1	3	-2	-1

Key		
+	positive	1
-	negative	-1
s	neutral	0

Concept Evaluation - Pugh Chart Continued

- Designs 1, 2 and 3 came out on top in the Pugh Chart.
- Customer Needs:
  - Lightweight
  - Low profile
  - Overhand pull-up style
  - Free arm motion
  - Two handed pull-up is preferred
- With these customer needs in mind, designs 1, 2 and 3 will be discussed.

Concept Evaluation - Design Matrix



Engineering Req	Weight	Design 1		Design 2		Design 3	
		Raw	Weighted	Raw	Weighted	Raw	Weighted
Lightweight	0.2	7	1.4	8	1.6	8	1.6
Portable	0.2	6	1.2	7	1.4	7	1.4
Low Profile	0.2	8	1.6	7.5	1.5	8	1.6
Comfort	0.1	7	0.7	8	0.8	7	0.7
Stability	0.15	6	0.9	2	0.3	6	0.9
Overall Saftey	0.15	6	0.9	6	0.9	5	0.75
Total (Out of 10)	1		6.7		6.5		6.95

Budget Planning - BOM

Item Description	Quantity	Units	Individual Cost	Total Cost
Wire - Continuous Flex Cable	1	100ft	$0.40	$0.40
Motor	2	1	$298.90	$597.80
Elastic Latex Fabric (Black, Braided)	1	36ft	$13.35	$13.35
3D Print Filament - Onyx	1	800cc	$190.00	$190.00
3D Print Filament - Carbon Fiber	1	50cc	$150	$150
Pressure Sensor	1	2	$10.00	$10
Lithium-polymer Battery	4	1	$17	$68
Nylon Parachord	1	100ft	$11	$11
Number of parts	12			
Total	$1,040.55			

Budget Planning

- Based on the BOM roughly $100 will be used to make the prototype design
- $1040 will be used for the final design. This includes the robotic and electrical components not included in the prototype
- Most parts come in large quantities and will be transferred to each model.
- The rest of the budget will be used for replacing broken parts, testing, machining/fabricating, tools, and misc.

Type	Prototype	Final Design
Materials	$102.75	$1040.55
Manufacturing	$100.00	$200.00
Emergency funds	$300.00	$750.00
Total	$502.75	$1990.55

References

1. “The myoshirt - daily life assistance for the Upper Limb,” – *Sensory-Motor Systems Lab | ETH Zurich*. [Online]. Available: https://sms.hest.ethz.ch/research/current-research-projects/wearable-robots-for-assistance-and-rehabilitation/The%20Myoshirt.html.
2. M. Dežman, T. Asfour, A. Ude, and A. Gams, “Mechanical design and friction modelling of a cable-driven upper-limb exoskeleton,” *Mechanism and Machine Theory*, 08-Feb-2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0094114X22000234.
3. M. A. Gull, S. Bai, and T. Bak, “A review on design of upper limb exoskeletons,” *Robotics*, vol. 9, no. 1, p. 16, 2020.
4. “Design of a cable-driven arm exoskeleton (Carex) for neural rehabilitation,” *IEEE Xplore*. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/6174477.
5. Y. Mao, X. Jin, G. Gera Dutta, J. P. Scholz and S. K. Agrawal, "Human Movement Training With a Cable Driven ARm EXoskeleton (CAREX)," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 23, no. 1, pp. 84-92, Jan. 2015, doi: 10.1109/TNSRE.2014.2329018.
6. S. J. Ball, I. E. Brown and S. H. Scott, "MEDARM: a rehabilitation robot with 5DOF at the shoulder complex," 2007 IEEE/ASME international conference on advanced intelligent mechatronics, 2007, pp. 1-6, doi: 10.1109/AIM.2007.4412446. https://ieeexplore.ieee.org/abstract/document/4412446?casa_token=e0lWWl4IxXQAAAAA:u5Rq0V6dipilwatyKnxLa13brHBOScWb49DvS
7. H. Ki et al., "Kinematic Data Analysis for Post-Stroke Patients Following Bilateral Versus Unilateral Rehabilitation With an Upper Limb Wearable Robotic System," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 21, no. 2, pp. 153-164, March 2013, doi: 10.1109/TNSRE.2012.2207462. https://ieeexplore.ieee.org/document/6252060
8. *AK60-6 V1.1_AK series dynamical modular_robot dynamics_t-motor store-official store for T-Motor Drone Motor,ESC,Propeller*. [Online]. Available: https://store.tmotor.com/goods.php?id=1201.
9. T. Petrič, L. Peternel, J. Morimoto, and J. Babič, “Assistive arm-exoskeleton control based on human muscular manipulability,” *Frontiers*, 01-Jan-1AD. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fnbot.2019.00030/full.
10. X. Li, W. Li, and Q. Li, “Method, design, and evaluation of an exoskeleton for lifting a load in situ,” *Applied Bionics and Biomechanics*, 25-May-2021. [Online]. Available: https://www.hindawi.com/journals/abb/2021/5513013/.
11. “Design, fabrication, and control of an upper arm exoskeleton … - WVU.” [Online]. Available: https://researchrepository.wvu.edu/cgi/viewcontent.cgi?article=7677&context=etd.
12. “Ssl.umd.edu,” *ssl.umd.edu*. [Online]. Available: https://ssl.umd.edu/.
13. “An Exoneuromusculoskeleton for self-help upper limb rehabilitation …” [Online]. Available: https://www.liebertpub.com/doi/10.1089/soro.2020.0090.
14. C. Vavra, “Exoskeleton helps arm-based physical therapy,” *Control Engineering*, 07-Feb-2022. [Online]. Available: https://www.controleng.com/articles/exoskeleton-helps-arm-based-physical-therapy/.
15. “The rise of the exoskeletons | machine design.” [Online]. Available: https://www.machinedesign.com/mechanical-motion-systems/article/21831817/the-rise-of-the-exoskeletons.
16. D. Chakarov, I. Veneva, M. Tsveov, and T. Tiankov, “New exoskeleton arm concept design and actuation for haptic interaction with virtual objects,” *CyberLeninka*, 01-Jan-1970. [Online]. Available: https://cyberleninka.org/article/n/223018.
17. “DataSpace: Atlasarm: An exoskeleton arm for muscular rehabilitation patients and beyond,” *Princeton University*. [Online]. Available: https://dataspace.princeton.edu/handle/88435/dsp0176537397p.


Questions?