Below the Knee Exoskeleton

Team: Ryan Oppel (Budget Lead), Alexandra Schell (Team Lead), Nicolas Watkins (Website and CAD Lead)

NAU NORTHERN ARIZONA UNIVERSITY

ER's and CR's

CR's

- CR1: Durable
- CR2: High range of motion
- CR3: Comfortable
- CR4: High battery life
- CR5: Adjustable
- CR6: Lightweight
- CR7: Affordability

ER's

- ER1: Energy efficient
- ER2: Accommodate different shoe size
- ER3: High Torque
- ER4: Supports users of all weight
- ER5: Under 3 kg
- ER6: Temperature of motor
- ER7: Battery Capacity
- ER8: Ingress Protection

QFD

			\swarrow		+								
												Improver Directi	nent on
Design Requirements (;-,-) Customer Requirements		t	different		of all		of motor	ţ	Ingress Protection	Customer Competitive Assessment			
		Energy efficien Accommodate	Accommodate shoe sizes	shoe sizes High torque	Support users weights	Under 3 kg	Temperature o	Battery Capaci		1 Worst	3 2	4 5 Best	
Dur	rable	3		3		6	6	6		9		C AB	
High range of motion 5		5			9							В	AC
Comfortable 4		4		3		3	3	3					А
High battery life 3		3	9		6			9	9				В
Adjustable 3		3		3		6							C A
Light	weight	5			3		9			3			B AC
Affore	Affordability 5								3	3		С В	
Technical Impor	Technical Importance: Absolute		27	30	78	48	75	57	42	57	Α	Caple	x Exo
Technical Importance: Relative			7%	7%	19%	12%	18%	14%	10%	14%	В	Utah	Knee
	v	Vorst: 1				-			B	C	С	ETM	Motor
Design		2	AD		в	C		В	C	В			
Assessment		3	AD		C C	Δ	B			Δ			
rasessment		Best: 5	С	A	A		A						
Target Value		90	0.3	1000	90	2	70	1000	54				
USL		60	0.27		120	3	155		68				
LSL		30	0.22	500	30	1.5		500	52				
Units		mins	m	mNm	kg	kg	С	mAh	IP				

Testing Plan

2 Top Level T	esting Summary	/	Exp3: Ingress Test	ER8: Ingress Protection	Motor and PCB/battery housing,	Probe, Spray bottle, determined by target	
Experiment/Test	Relevant DRs	Testing Equipment Other Recourse Needed		Exp4: Thermal Test	ER6: Temperature of Motor	water Arduino, DAQ, motor & housing	Alternate motor housings
Exp1: Weight and COM	ER5: Under 3kg CR6: Lightweight	Scale	Access to device from Lerner's Lab	Exp5: Final test on human	ER2: Accommodate Different Shoe Size	Assembled device, treadmill	Test Lab
Exp2: Initial run of device	ER1: Energy Efficient	Device, PCB, Battery Motor	Programmed PCB		ER4: Supports Users of All Weight		
ER3: High Torque				ER1: Energy Efficient			
	ER7: Battery Capacity				ER6: Temperature of Motor		
	CR4: High Battery				CR1: Durable		
	Life				CR2: High range of motion		
Exp3: Ingress Test	ER8: Ingress Protection	Motor and	Probe, Spray bottle,		CR3: Comfortable		
		PCB/battery housing, water	determined by target IP rating		CR5: Adjustable		
L	1	1	Į		CR6: Lightweight		

Testing Images

Exp 1: Weight and COM





Exp 1: Comfortability and use.



Testing Images

Exp 3: Ingress Protection





IP (Ingress Protection) Ratings Guide



Specification Sheet

4.1 CR Summary Table

Customer Requirement	CR met? (√or X)	Client Acceptable? (√or X)
CR1: Durable		
CR2: High Range of Motion		
CR3: Comfortable		
CR4: High battery life		
CR5: Adjustable	 Image: A set of the set of the	
CR6: Lightweight	✓	
CR7: Affordability	1	

				-	
Engineering Requirement	Target	Tolerance	Measured/ Calculated Value	ER met? (√ or X)	Client Acceptable? (√ or X)
ER1: Energy efficient	60 mins	\pm 30 mins			
ER2: Accommodate shoe size	.27 m	± .05 m	.22m	~	
ER3: High torque	10 N-m	<u>+</u> 5 N-m			
ER4: Supports users of all weights	90 kg	± 30 kg	90kg	\checkmark	
ER5: Under 3 kg	3 kg	± 1 kg	1.1kg	~	
ER6: Temperature of the motor	70° C	± 70° C			
ER7: Battery Capacity	1000 mAh	± 500 mAh			
ER8: Ingress Protection	IP45	IP44, IP67	IP45	\checkmark	

Percent Complete

Customer Requirements	Engineering Requirements				
 42% Adjustable Lightweight Affordability 	 50% Accommodate shoe size Supports users of all weight Under 3 kg Ingress Protection 				

Thank You!

