Flying Squirrel

Jonathan Avila, Ryan Donnellan, Justin Joy, Owen Kehl, Joey Mathews

NAU

NORTHERN ARIZONA UNIVERSITY

Background and Problem Statement

- More than 795,000 strokes occur per year in the U.S., 610,000 of which are first or new [1]
- Survivors suffer neurological damage, and often struggle with mobility
- The *Hamster* assuages mobility issues by exercising arm movement in patients
- Designed as a more affordable, at-home alternative to other complicated rehabilitation devices
- The *Flying Squirrel* adds vertical motion while remaining within similar parameters
- Sponsored by Dr. Razavian, who specializes in robotics and control algorithms

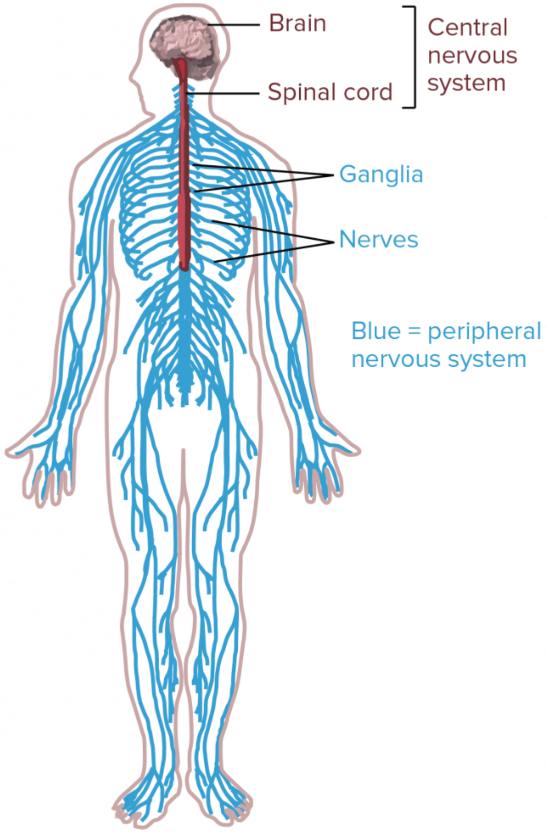


Figure 1: Human Nervous System

Black Box Model

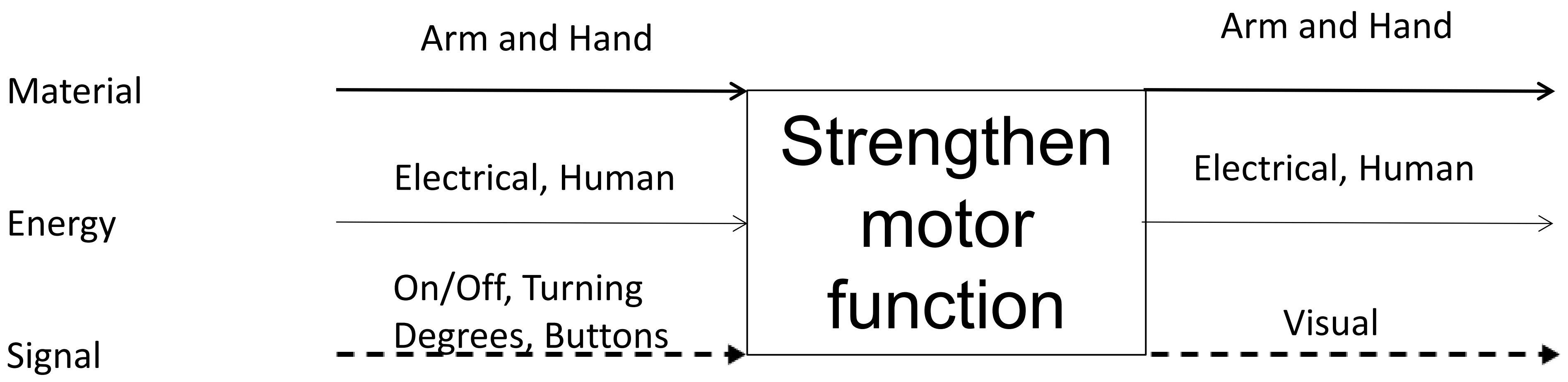


Figure 2: Black Box

Functional Decomposition

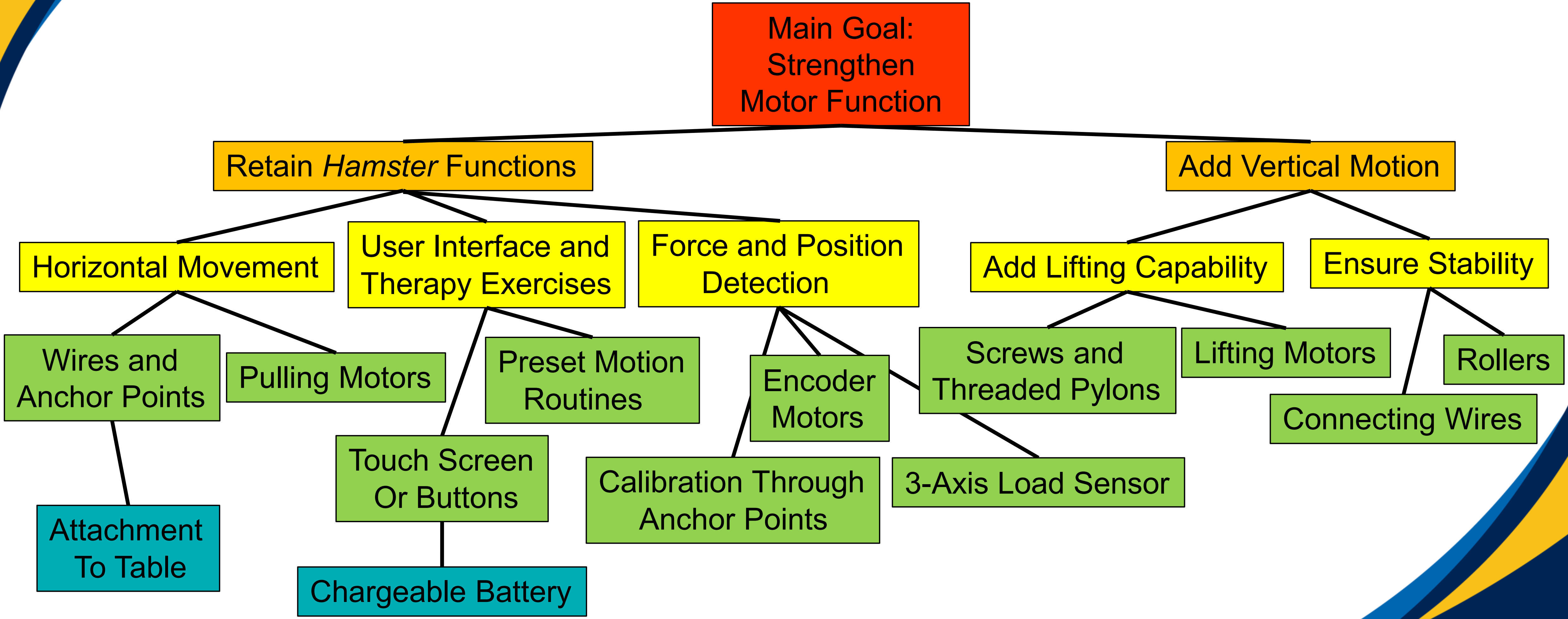
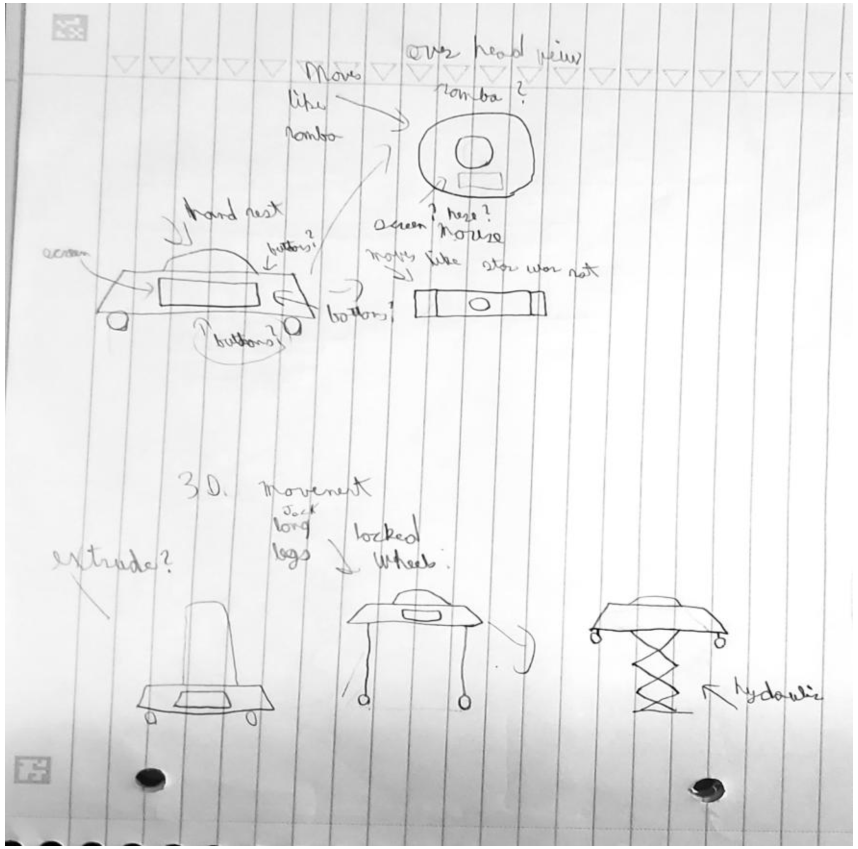


Figure 3: Functional Decomposition

Concept Generation 1

During first client meeting, Dr. Razavian requested the team to complete the first concept generation.

John



Ryan

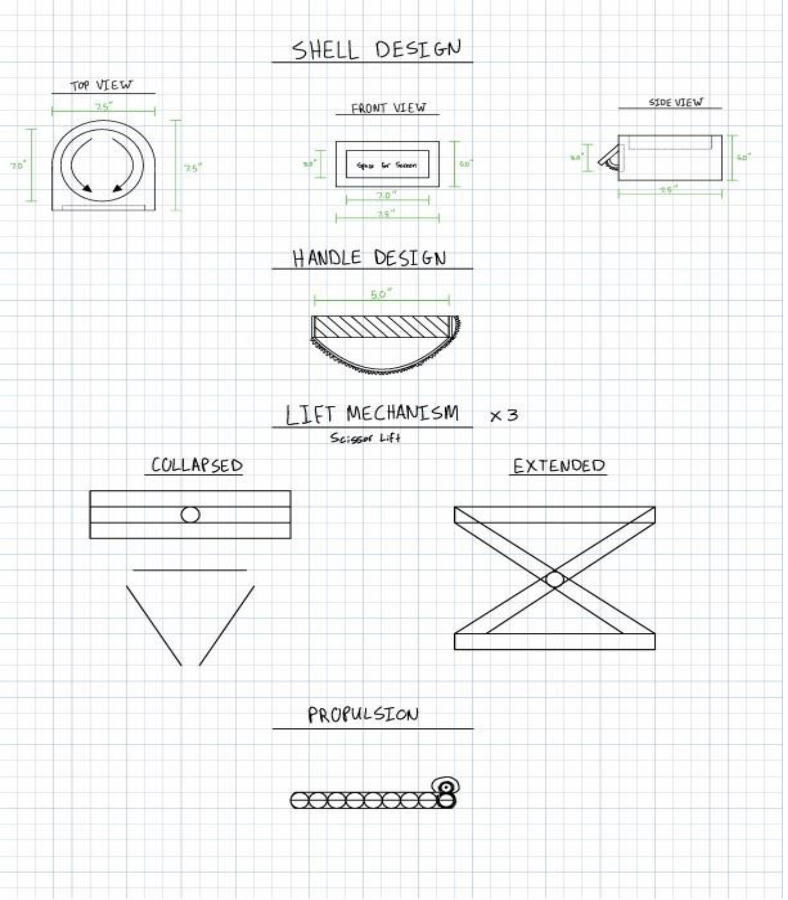
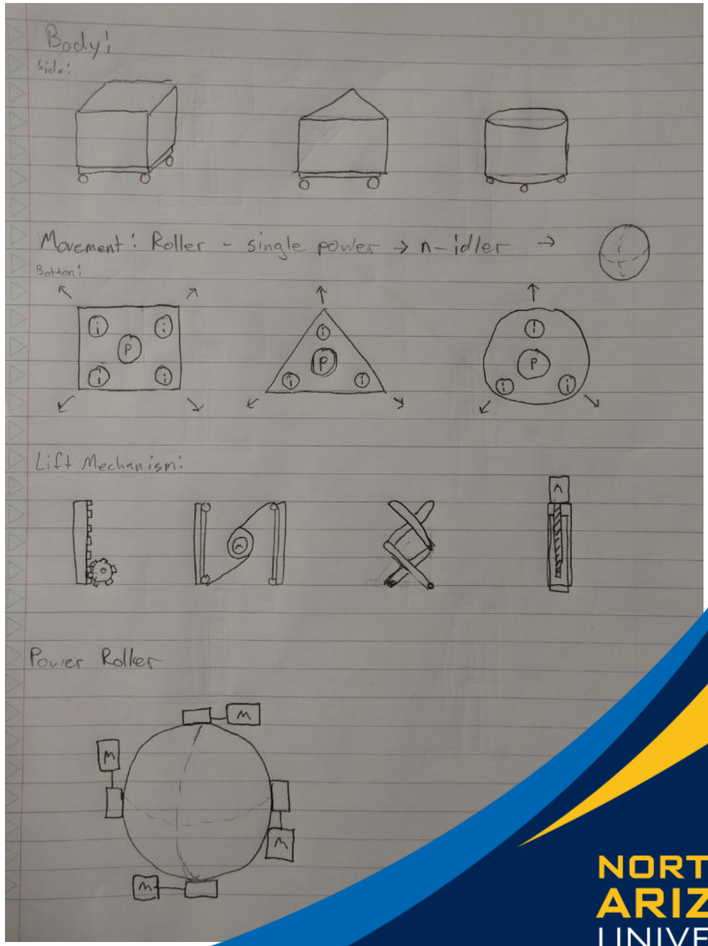


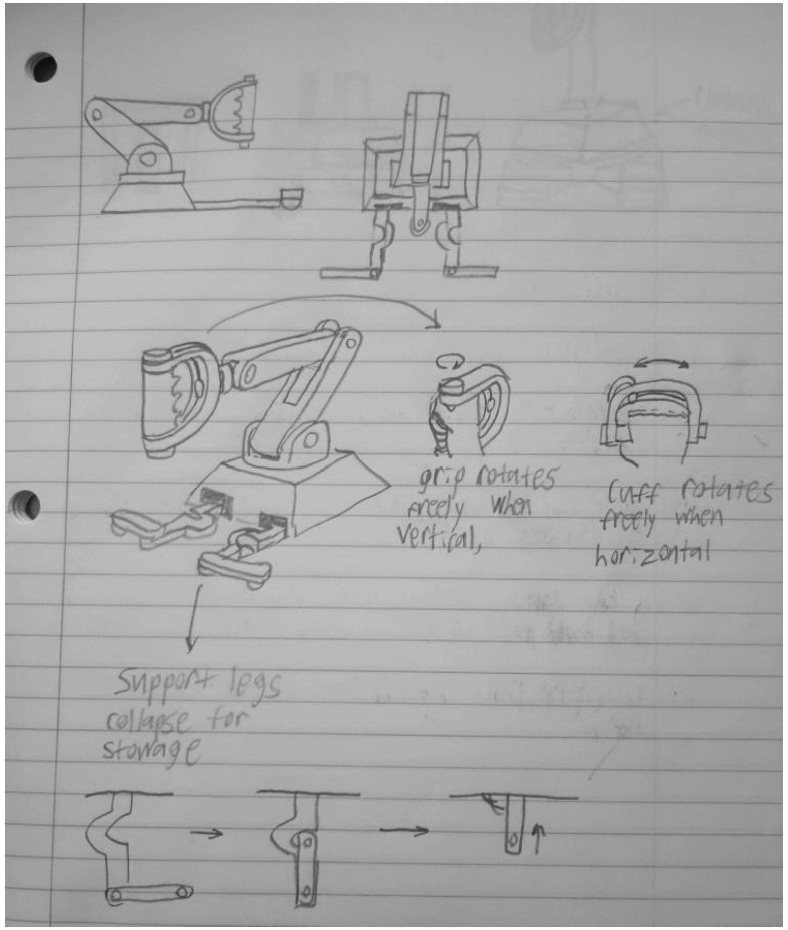
Figure 4-6: Concept Gen. 1

Justin



Concept Generation 1

Owen



Joey

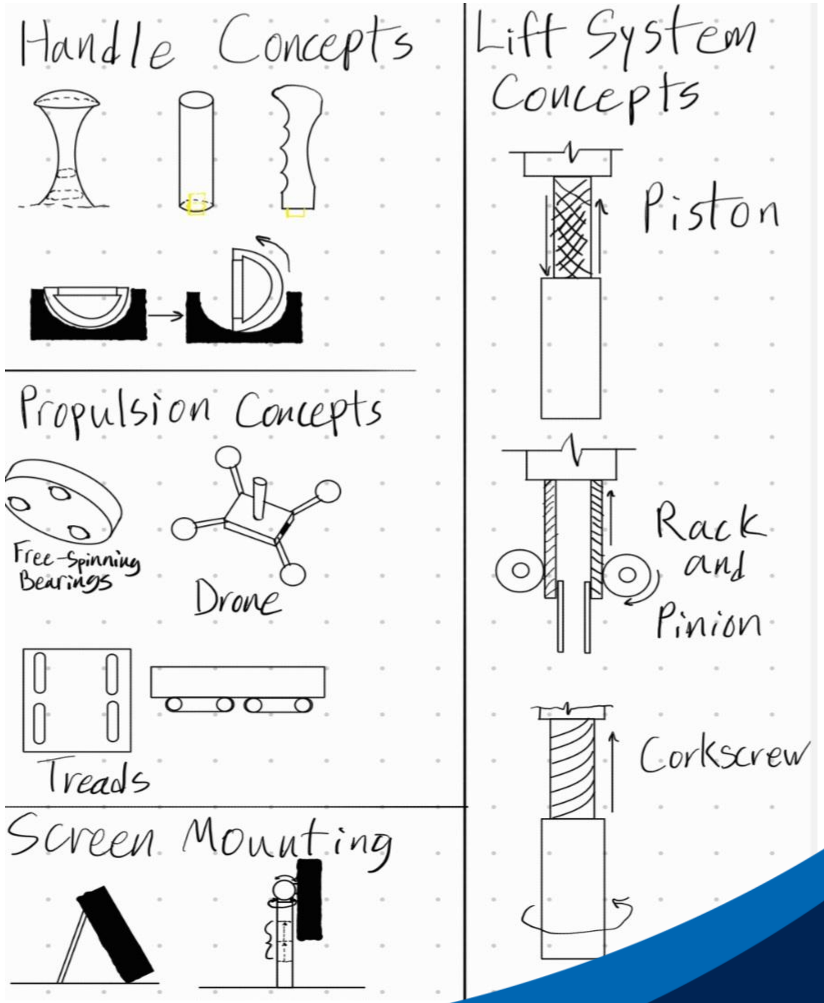


Figure 7-8: Concept Gen. 1

Client Concept Generation

Dr. Razavian

- Presented cable driven robot to the team
- Handle below body
- Asked team for 2nd concept generation based on cable driven concept
- Pros and Cons with 1st concept

Pros

- Rollers
  - Direction speed changes
- Lift
  - Screw
  - Rack/Pinion

Cons

- Moment
  - Lack of control
- Robotic Arm
  - Expensive
- Tracks
  - Limited mobility

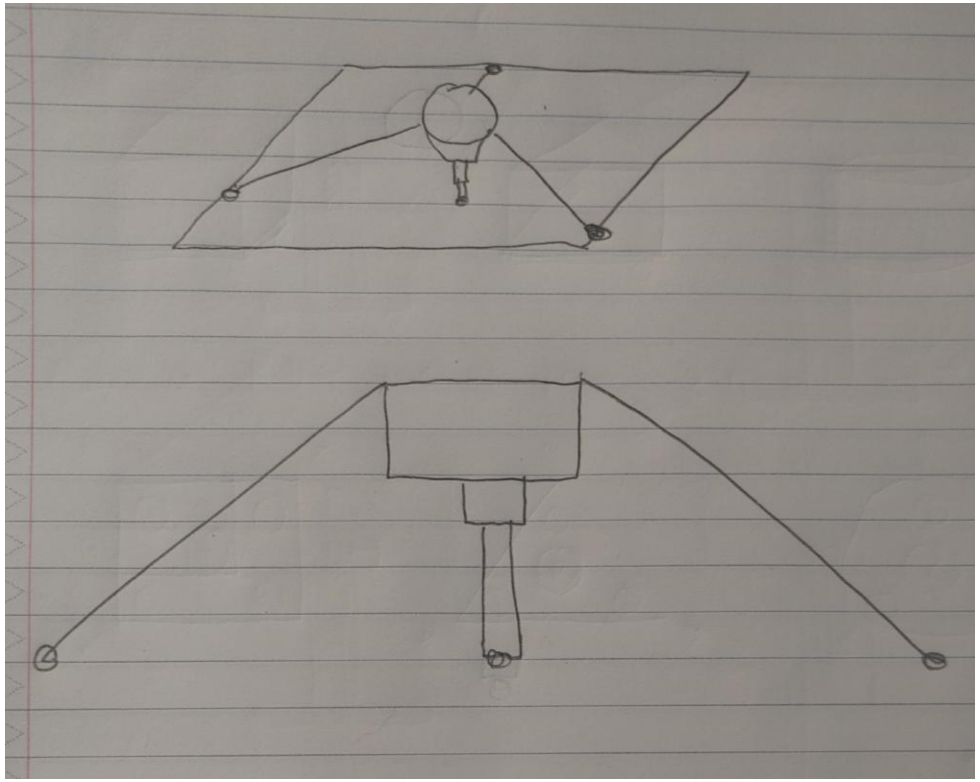
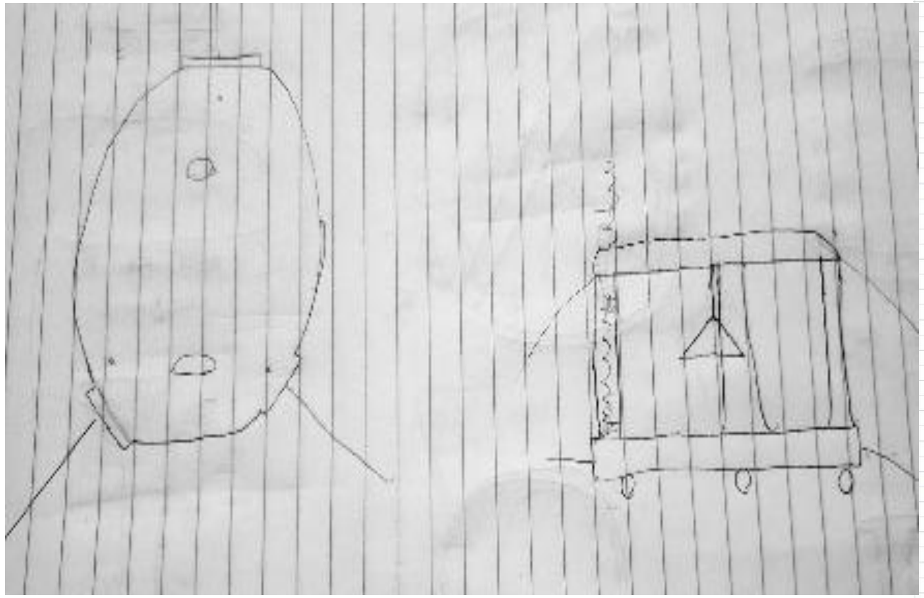


Figure 9: Client Concept

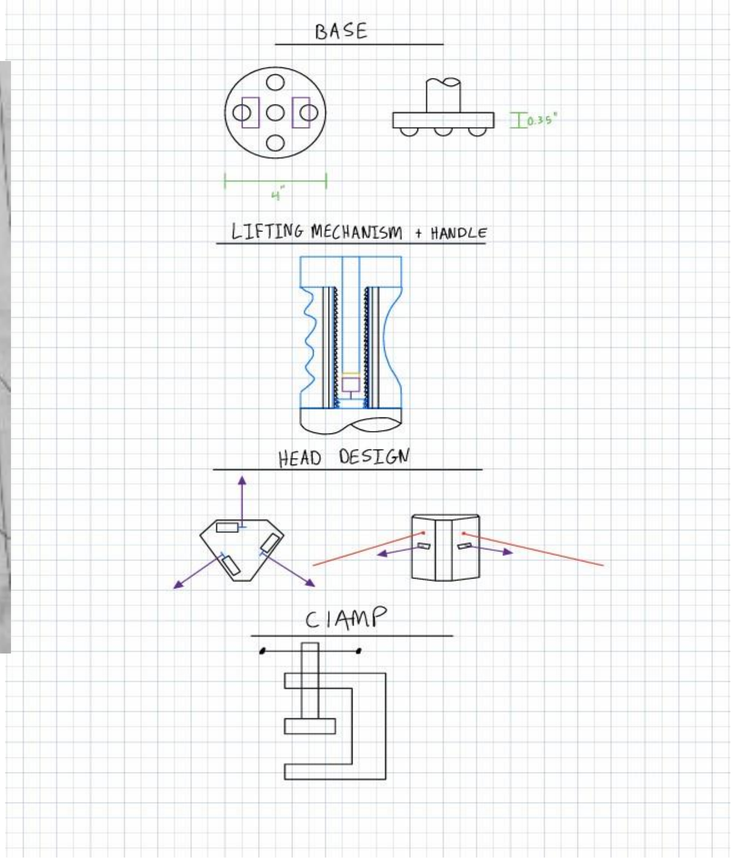
Concept Generation 2

During second client meeting, Dr. Razavian requested the team to complete a second concept generation based on the cable driven design.

John



Ryan



Justin

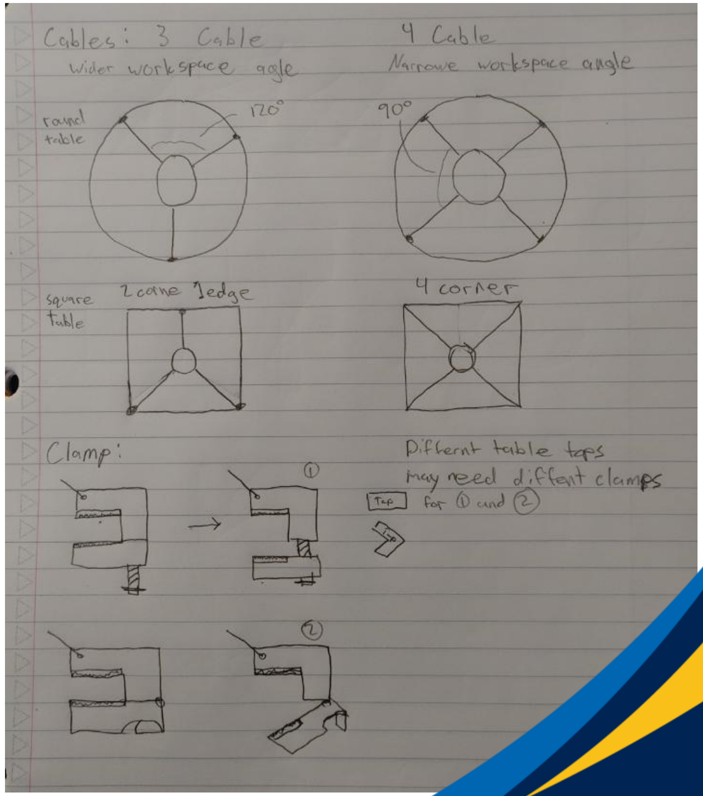
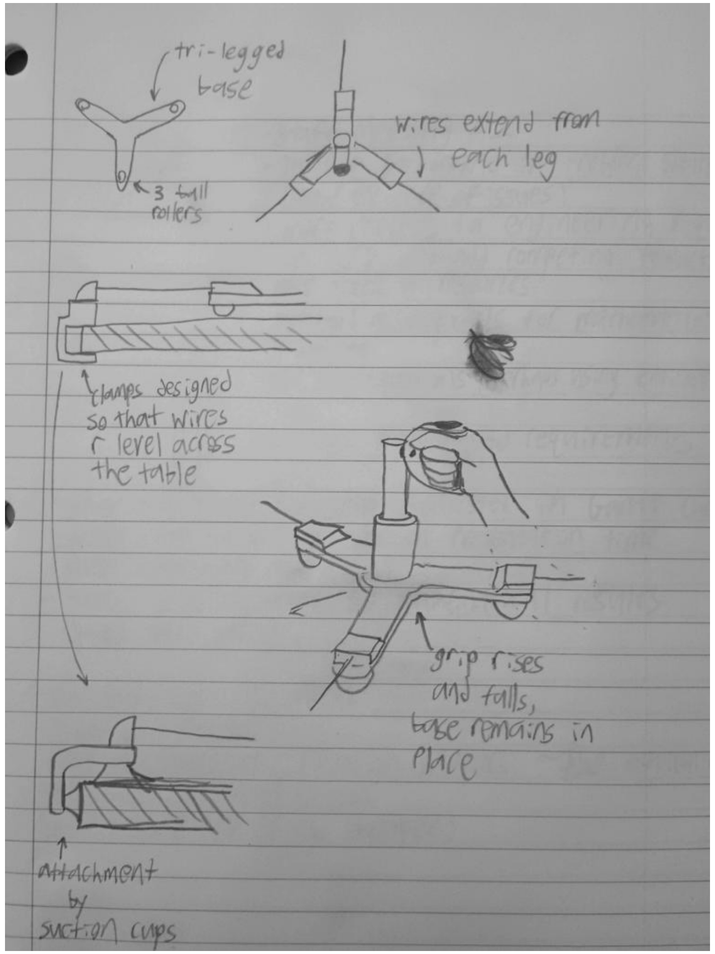


Figure 10-12: Concept Gen. 2

NORTHERN ARIZONA UNIVERSITY

Concept Generation 2

Owen



Joey

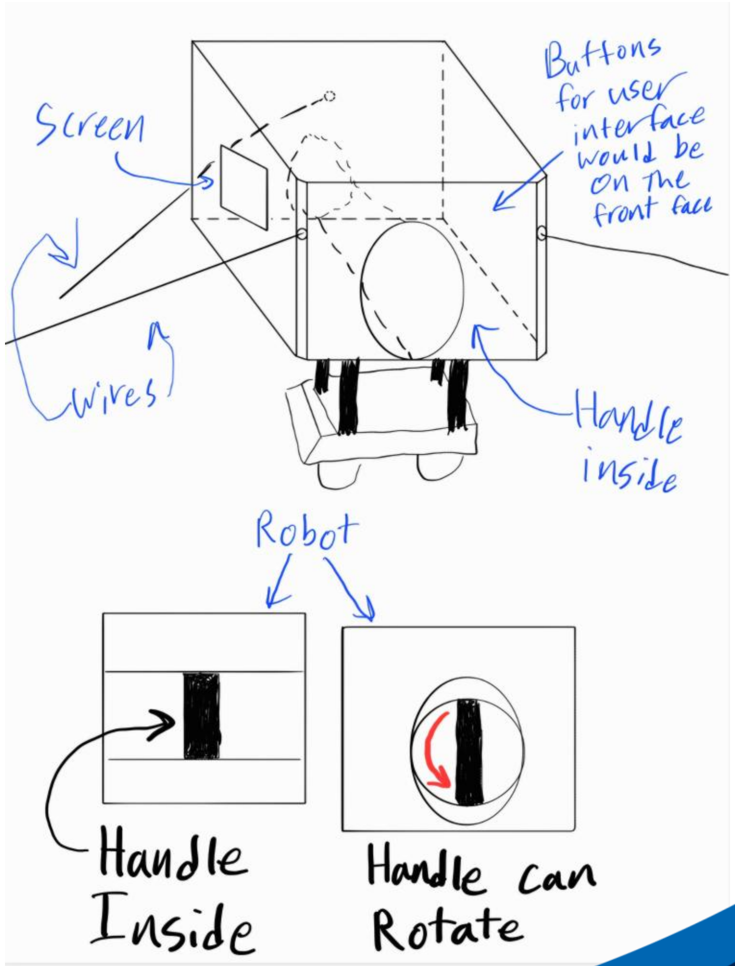


Figure 13-14: Concept Gen. 2

NORTHERN ARIZONA UNIVERSITY

Client Concept Generation

Dr. Razavian

- Provided feedback on concepts for cable driven designs
- Addressed obstacles
  - Cable clamp/cup
  - Design for 4 different table-tops
    - Small round
    - Small square
    - One-edge desk
    - Large shop table
  - Calibrations with cable angles
- Requested CAD model
- Cables need to be mounted on upper section of robot

Pros

- Lift mechanism
- Base can host hardware
  - Batteries
  - Control modules
  - Rollers
  - Lift motor

Cons

- Need clamps for different table types
- Lower cables do not prevent moment as efficient as higher cables

NORTHERN ARIZONA UNIVERSITY

Engineering Calculations

Maximum Motor Torque Estimates

Guiding Assumptions:

(1) Cable tension is maximum required force (10 N = 2.24809 lbf)

(2) Only accounting for one motor

(3) Robot is in Equilibrium

(4) Cable's winch is 1 inch in diameter

$\tau = F*r$

$\tau = 0.127 Nm = 0.0937\ lbf\text{-}ft$

Adjusted Torque with a Factor of Safety of 2 (Suggested by Dr. Razavian):

$\tau_{adjusted} = F.O.S. * \tau$

$\tau_{adjusted} = 0.254\ Nm = 0.1874\ lbf\text{-}ft$

Validation

We are writing a script in MATLAB to calculate the torque applied to all three motors simultaneously at every position within the robot's area of play. This will be used to find the maximum torque for each motor. The maximum torque is predicted to be close to our torque estimation.

NORTHERN ARIZONA UNIVERSITY

Engineering Calculations

Angle to Anchor Point

Guiding Assumptions:

(1) Static anchor points,

(2) equal length wires

Equation

θ = arctan(y / x)

Moving 2in right and 2in up, wire length = 12in

Line 1: 11.31° ccw

Line 2: 13.63° cw

Line 3: 2.84° ccw

Validation

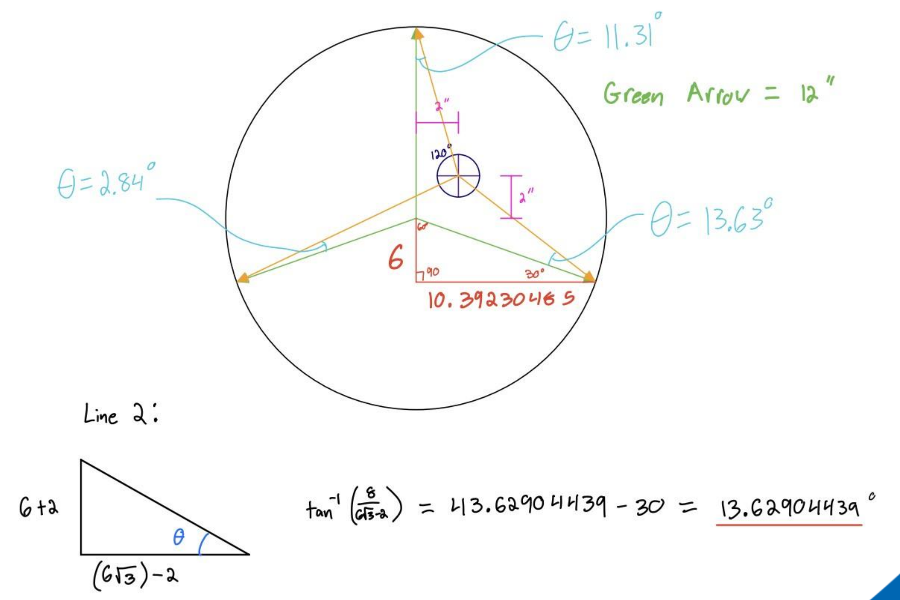


Figure 15: Anchor point validation

Engineering Calculations

Minimum Tension in Cables

Assuming cable is clamped 12 inches away from device.

Equation ∑MA=0 can be used for 2 cases

- Cables attach at top and bottom
  - ∑MA=0: TxL+FxL=0
  - **T=2.2lbs**
- Cables only attached to top
  - ∑MA=0: TxL+FxL=0
  - **T=2.2lbs**

Validation

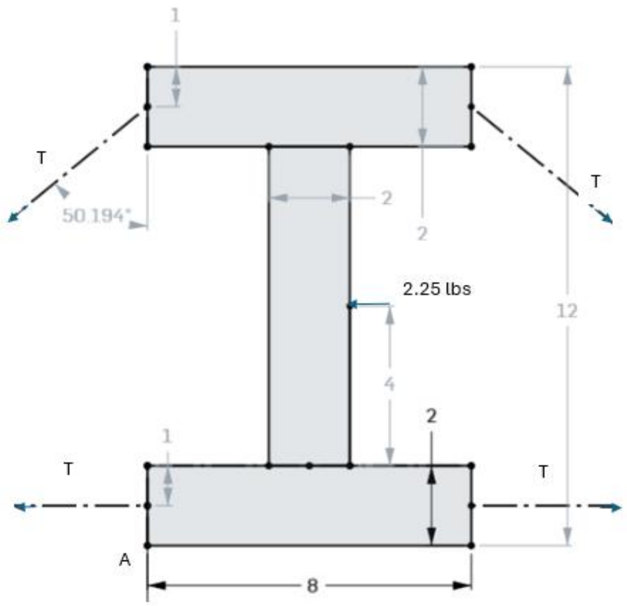


Figure 16: FBD validation

NORTHERN ARIZONA UNIVERSITY

Engineering Calculations

Downward Force From Wires

- y= height difference between robot attachment pt and anchor attachment pt
- x= distance from robot to anchor or connecting line between anchors
- D= diameter of robot (assume 8”)
- Necessary horizontal force equals 10N
- Assume y= 7” and x= 1” minimum
- Instance 1:
  - Fy= 70.55N downward
- Instance 2:
  - Assume 3’ between anchor pts
  - Fy= 14.55N downward

Validation

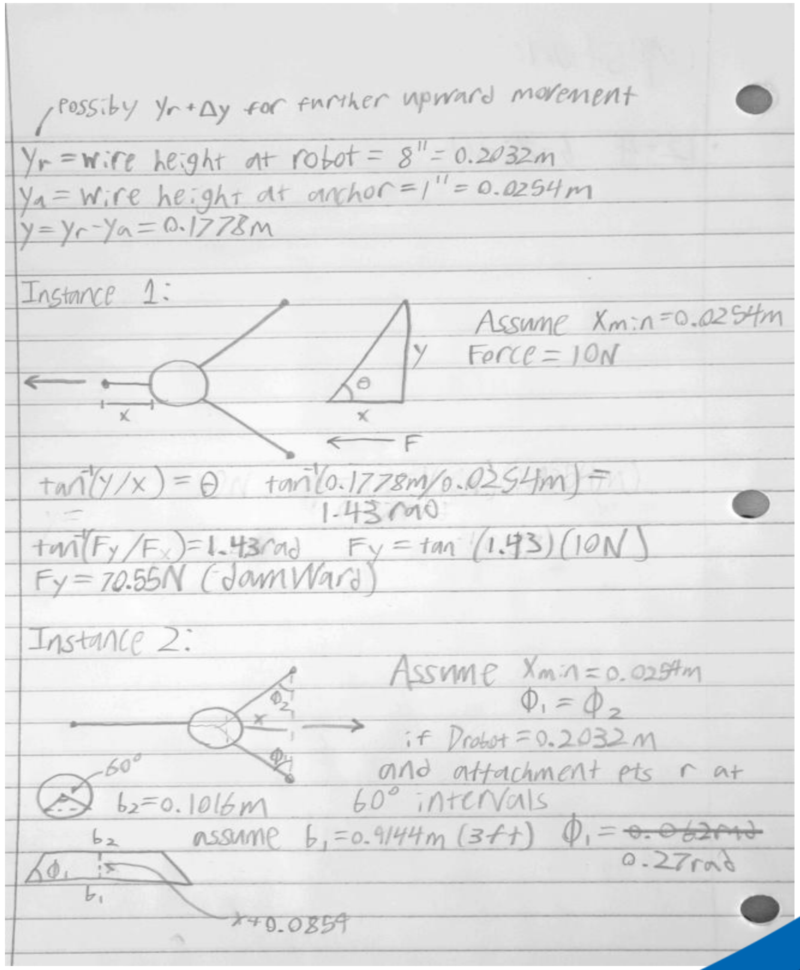


Figure 17: Downward force validation

Engineering Calculations

Wire Max Stress

Explanation

To find the robot at its max stress, we will test it at what a worst-case scenario could be.
That would be ten newtons acting on a single wire.

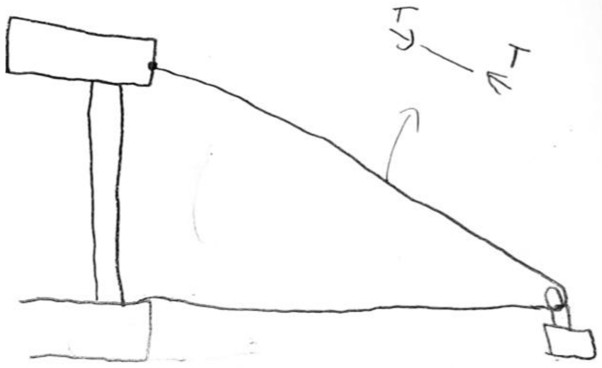
T=10N

Equation

Stress=F/A=T/A

Stress=26,308 MPa
Wire rated strength is 214,114MPa

Validation



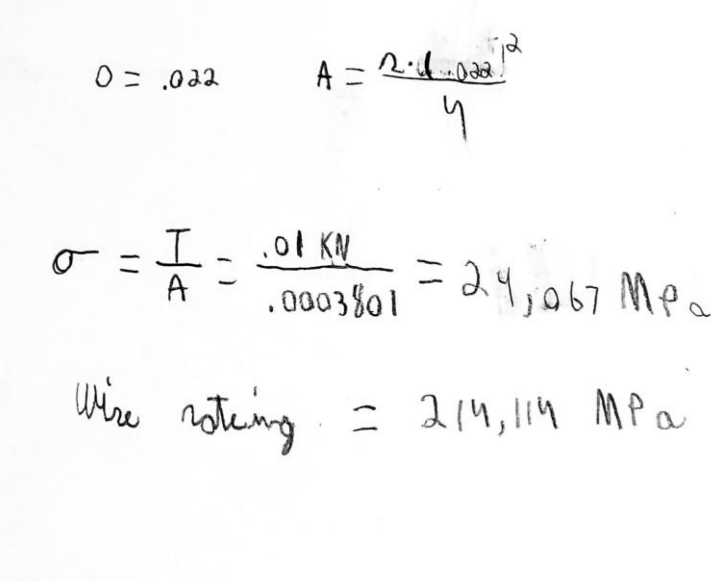


Figure 18: Stress force validation

Calculations Table

Calculations Table			
Equation	How it's applicable.	What requirements these equations meet.	How we validated the answers obtained.
$t = I * Ah$	Calculating minimum battery required to achieve desired run time.	Minimum run time of 30 minutes.	Obtained average power draw from online sources and used those to calculate time
$\theta = \arctan(y / x)$	Calculating position of robot as it moves closer to boundary	Position accuracy of 0.1mm	Solved equations by hand and used scale model to test angles
$S=(F*nf) / A = (T*nf)/ A$	Calculates the minimum amount of stress our cable needs to able to withstand	To be able to withstand 10 N of Force	By finding the amount stress induced we can select an appropriate wire
$\sum MA=0$	Calculates the minimum amount of tension in cables	Minimum tension needs to be 2.2lbs or nearly 10 N	Using structural analysis, the equation can be solved by hand
$\tau = F*r$	Calculates the estimated maximum applied torque	Finding a motor that can output the required 10 N of force	Using a MATLAB script to calculate the torques at all positions the robot could be at
$\tau_{adjusted} = F.O.S. * \tau$	Calculates the estimated maximum applied torque using the factor of safety	Finding a motor that can output the required 10 N of force accounting for a factor of safety	Using a MATLAB script to calculate the torques at all positions the robot could be at
$M= MP_{hm}g(L(1-0.5P_{hl}))+ MP_{fm}g(L(0.5P_{fl}+P_{al}))+ MP_{am}g(L(0.5P_{al}))$	Calculates net upward force needed to move an extended arm	Moving user's hand with an upward force of 10 newtons	Used human body mass percentages and solved by hand
$F_y= F_t*\cos(\theta)$	Calculates downward force due to wire tension	Applying 10N force in horizontal and vertical directions	Solved by hand using force diagrams and position assumptions

Table 1: Calculations Table

Pugh Chart

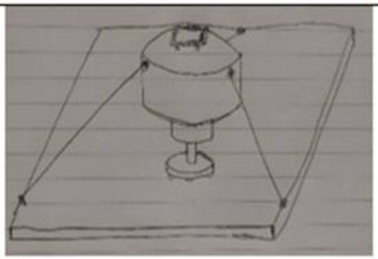
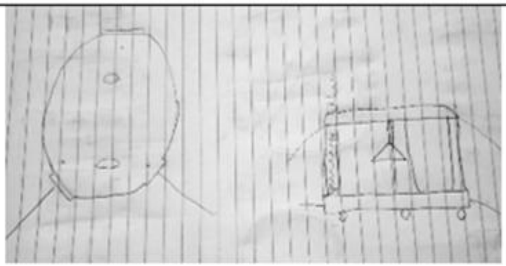
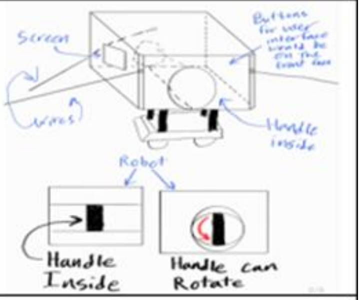
Criteria			
Design	1	2	3
Production cost	+ Smaller device	S	Datum
Speed of the Robot	-It has a smaller base to work with	+The base and double wire allow for fast accurate movement	Datum
Device Size	+ It has a small frame	+ it is more compact than the Datum	Datum
Position Tracking	S	S	Datum
Force	-Smaller base to account from moment	S	Datum
User Friendliness	-Setup difficulties from base size and user touchscreen.	+It has a fast and easy set up with a screen	Datum
Total +	2	3	
Total S	1	3	
Total -	3	0	

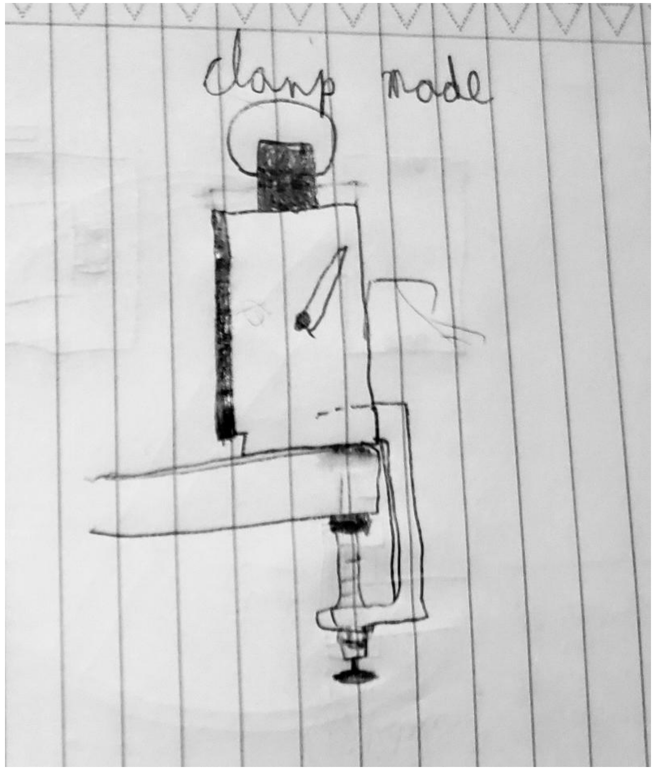
Table 2: Pugh Chart

Design 2 is our best design according to the Pugh Chart

Concept Generation 3

John

- Hybrid C Clamp and Suction anchor point



Joey

- CAD Rough Draft

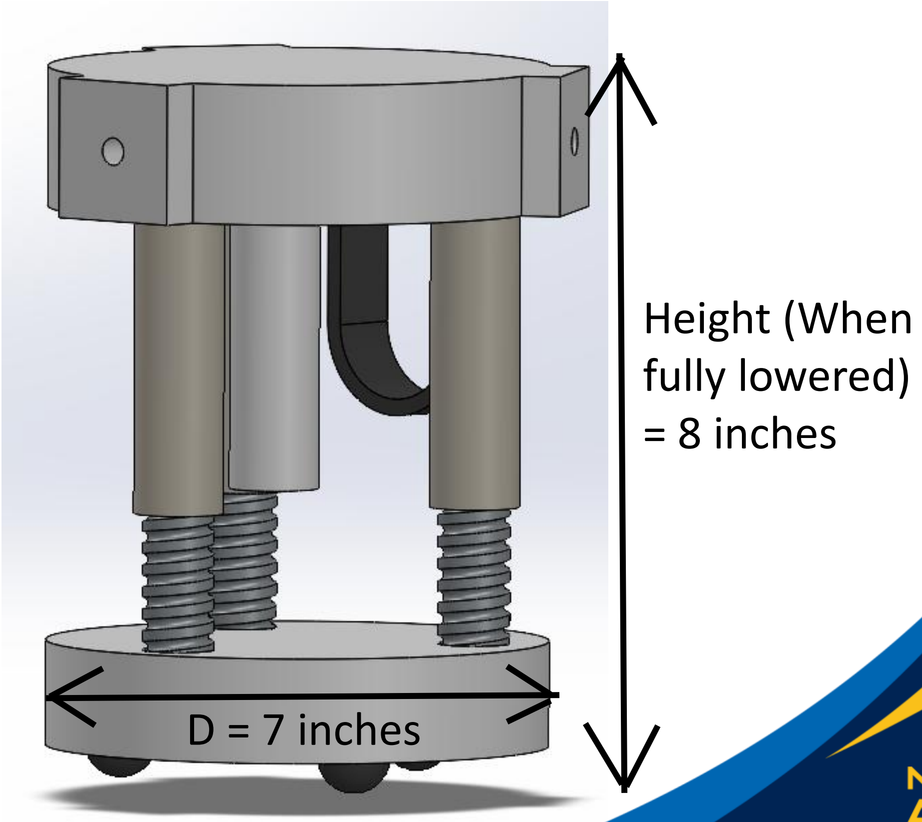
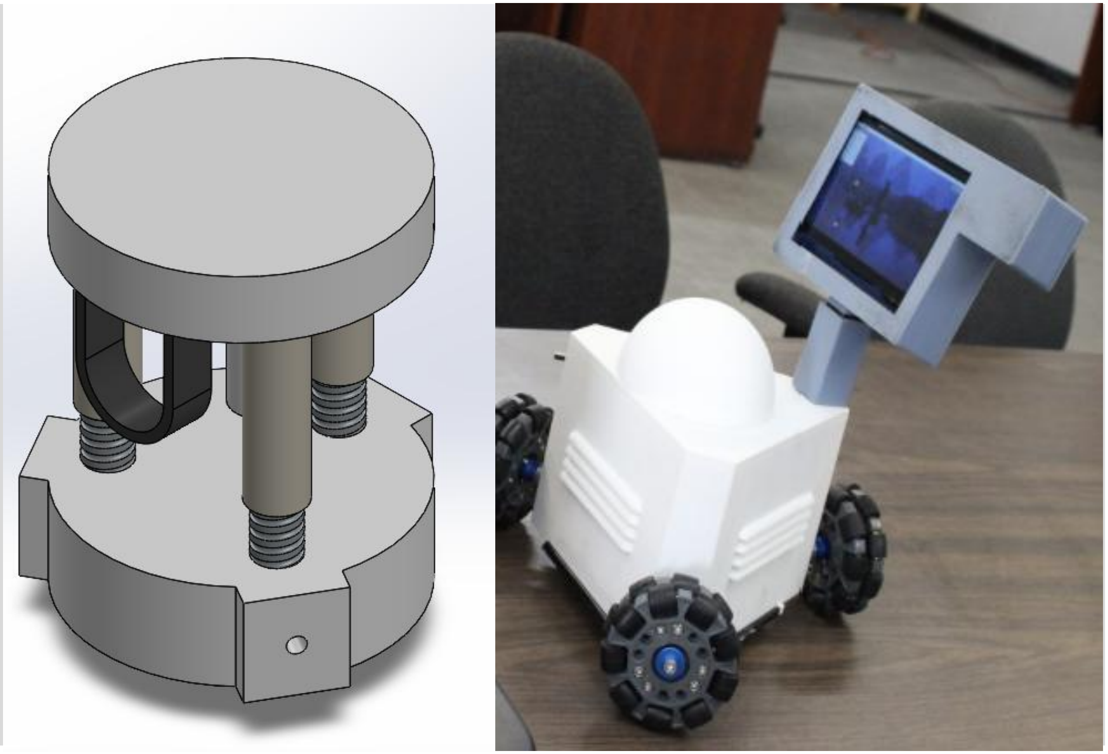


Figure 19-20: Clamp and CAD Model

NORTHERN ARIZONA UNIVERSITY

Benchmarking



Current CAD iteration compared to Hamster

Comparison to Other Products

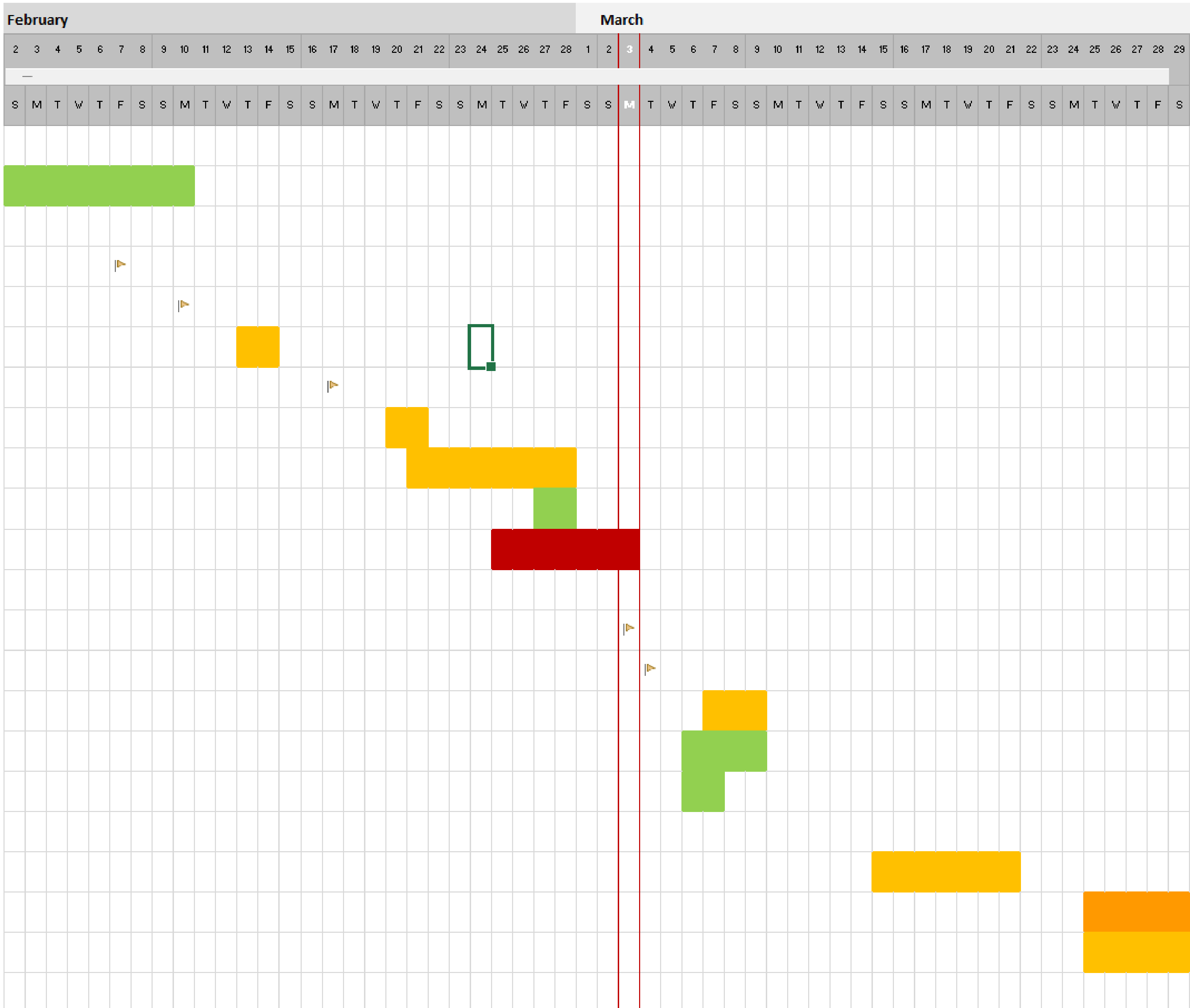
- Compact in stowed configuration
- More affordable than other available models
- Easily moveable for setup
- Conceivably fast setup process
- Comparatively simple motion design
- Provides partial arm support
- Provides vertical motion

NORTHERN ARIZONA UNIVERSITY

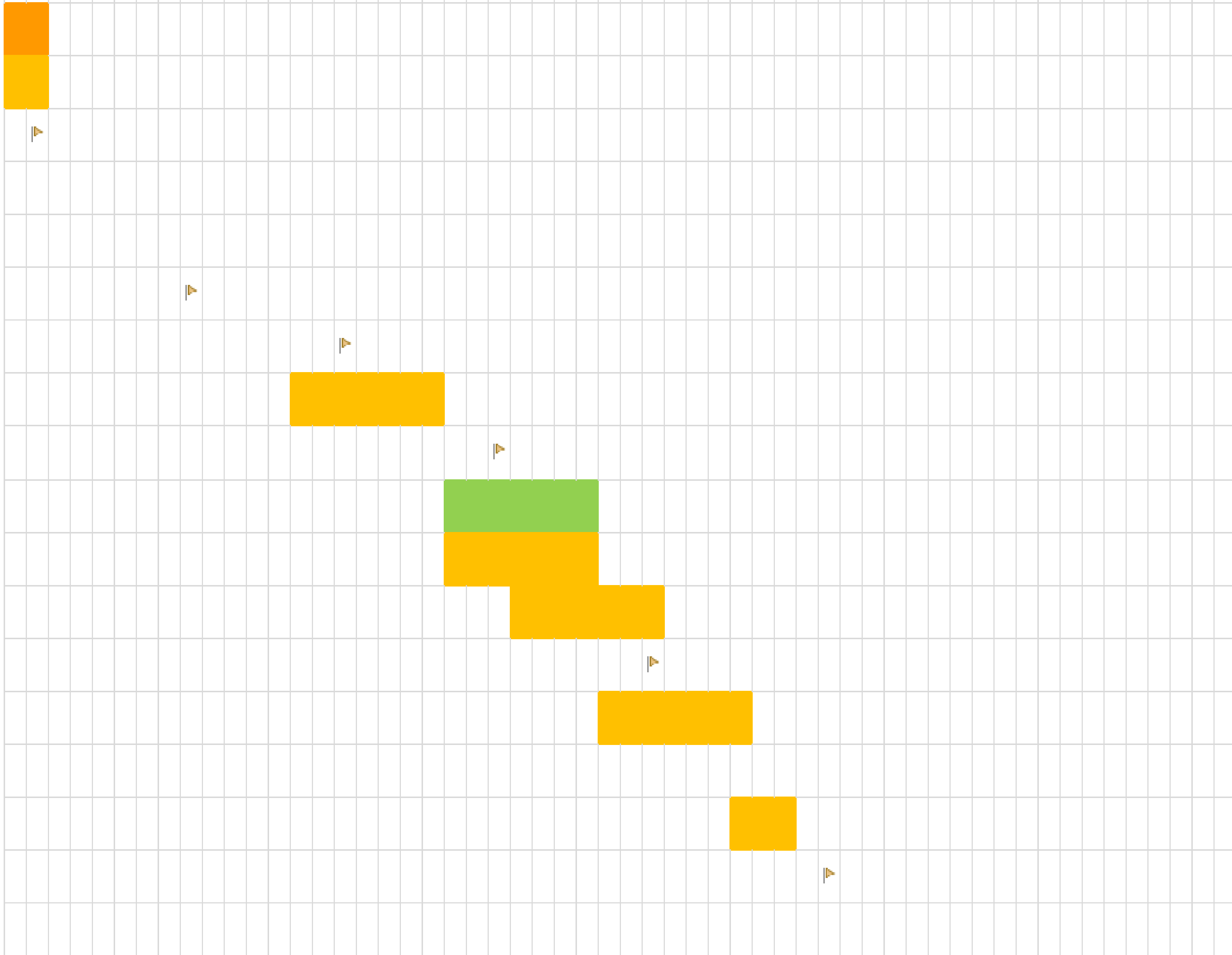
Project start date: 2/2/2025

Scrolling increment: 0

Milestone description	Category	Assigned to	Progress	Start	Days
February					
Presentation 1	On Track	All	100%	2/2/2025	9
First Client Meeting	Milestone	All	100%	1/30/2025	1
Second Client Meeting	Milestone	All	100%	2/7/2025	1
2nd Staff Meeting	Milestone	All	100%	2/10/2025	1
Third Client Meeting (New Concept Generation)	Low Risk	All	100%	2/13/2025	2
3rd Staff Meeting	Milestone	All	100%	2/17/2025	1
Fourth Client Meeting	Low Risk	All	100%	2/20/2025	2
Self Learning Homework	Low Risk	All	100%	2/21/2025	8
Fifth Client Meeting	On Track	All	100%	2/27/2025	2
Presentation 2	High Risk	All	70%	2/25/2025	7
March					
Team Feedback 2	Milestone	All	0%	3/3/2025	1
Peer Eval 2	Milestone	All	0%	3/4/2025	1
Report 1	Low Risk	All	0%	3/7/2025	3
Website Check 1	On Track	Joey	90%	3/6/2025	4
Sixth Client Meeting	On Track	All	0%	3/6/2025	2
Staff Meeting 5	Milestone	All	0%	3/17/2025	1
Analysis Memo	Low Risk	All	0%	3/15/2025	7
1st Prototype Demo	Med Risk	All	0%	3/25/2025	7
Presentation 3	Low Risk	All	0%	3/25/2025	7
Team Feedback 3	Milestone	All	0%	3/31/2025	1



1st Prototype Demo	Med Risk	All	0%	3/25/2025	7
Presentation 3	Low Risk	All	0%	3/25/2025	7
Team Feedback 3	Milestone	All	0%	3/31/2025	1
April					
Peer Eval 3	Milestone	All	0%	4/1/2025	1
Staff Meeting 7	Milestone	All	0%	4/7/2025	1
Staff Meeting 8	Milestone	All	0%	4/14/2025	1
Report 2	Low Risk	All	0%	4/12/2025	7
Final Staff Meeting	Milestone	All	0%	4/21/2025	1
Final CAD and BOM	On Track	All	10%	4/19/2025	7
HW4-Individual Analysis	Low Risk	All	0%	4/19/2025	7
2nd Prototype Demo	Low Risk	All	0%	4/22/2025	7
Proto Demo Feedback	Milestone	All	0%	4/28/2025	1
Project Management for 486C	Low Risk	All	0%	4/26/2025	7
May					
Website Check 2	Low Risk	All	0%	5/2/2025	3
Final Peer Eval	Milestone	All	0%	5/6/2025	1

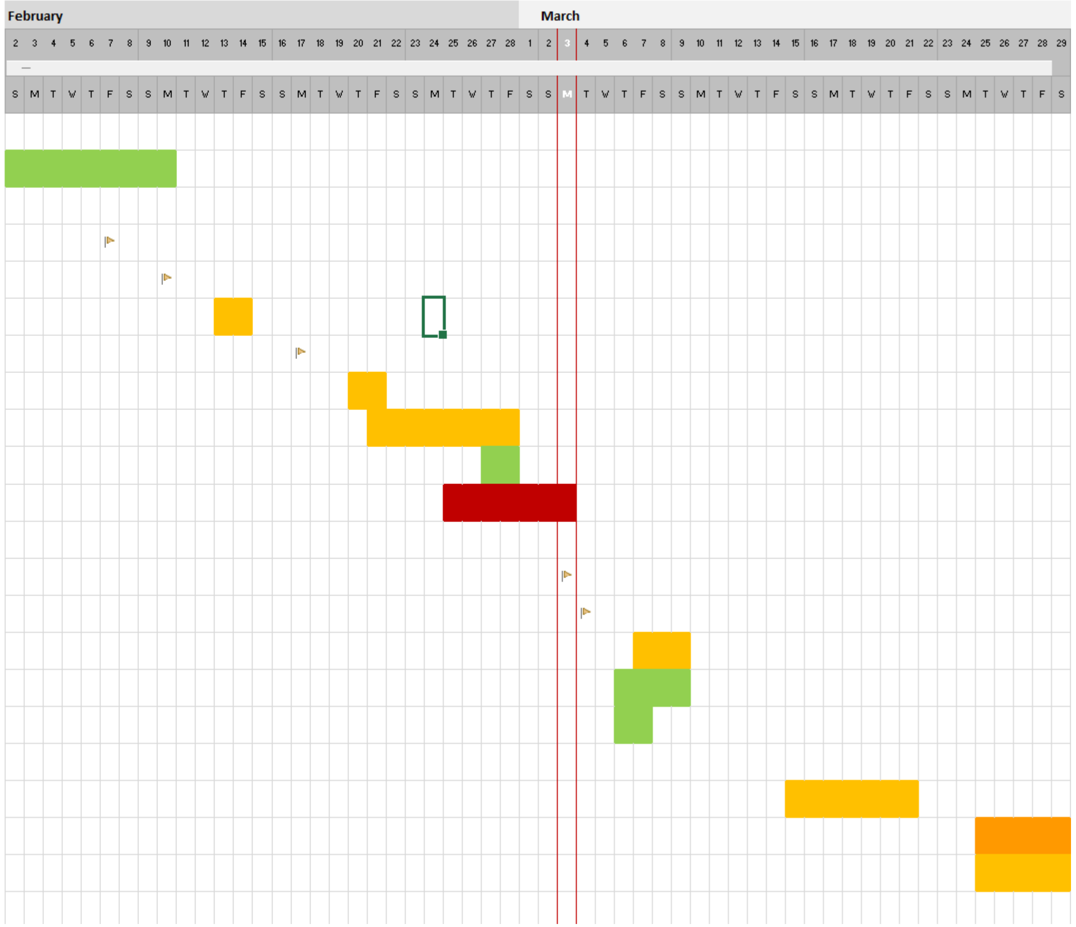


Gantt Chart and Schedule

Project start date: 2/2/2025

Scrolling increment: 0

Milestone description	Category	Assigned to	Progress	Start	Days
February					
Presentation 1	On Track	All	100%	2/2/2025	9
First Client Meeting	Milestone	All	100%	1/30/2025	1
Second Client Meeting	Milestone	All	100%	2/7/2025	1
2nd Staff Meeting	Milestone	All	100%	2/10/2025	1
Third Client Meeting (New Concept Generation)	Low Risk	All	100%	2/13/2025	2
3rd Staff Meeting	Milestone	All	100%	2/17/2025	1
Fourth Client Meeting	Low Risk	All	100%	2/20/2025	2
Self Learning Homework	Low Risk	All	100%	2/21/2025	8
Fifth Client Meeting	On Track	All	100%	2/27/2025	2
Presentation 2	High Risk	All	70%	2/25/2025	7
March					
Team Feedback 2	Milestone	All	0%	3/3/2025	1
Peer Eval 2	Milestone	All	0%	3/4/2025	1
Report 1	Low Risk	All	0%	3/7/2025	3
Website Check 1	On Track	Joey	90%	3/6/2025	4
Sixth Client Meeting	On Track	All	0%	3/6/2025	2
Staff Meeting 5	Milestone	All	0%	3/17/2025	1
Analysis Memo	Low Risk	All	0%	3/15/2025	7
1st Prototype Demo	Med Risk	All	0%	3/25/2025	7
Presentation 3	Low Risk	All	0%	3/25/2025	7
Team Feedback 3	Milestone	All	0%	3/31/2025	1



- Prepare 1st report
- Continue client meetings
- Flesh out CAD model
- Perform further motion and force calculations

NORTHERN ARIZONA UNIVERSITY

Budget

Current Project Budget	$3750
anticipated expenses	-$1350
Actual expenses to date	-$65
Resulting Balance	$2385

Table 2: Budget

Fundraising

The Go fund me page is going to be open in the upcoming weeks.

On top of this we are working with ASME to do a fundraiser with a local restaurant for additional funds.

Bill of Materials

	Item	Quantity	Cost Per Unit ($)	Final Amounts($)
1	3-axis force sensor	1	750	750
2	Optical encoder motors	4	50	200
3	18650 Battery	3	25 (sold in 4 pack)	25
4	Braided Fishing Line	1	30	30
5	Circuits and wires	1 Sold as a set	45	45
6	Misc. Electronics and plastics	1	100	100
7	Stainless Steel Ball Bearings	1 sold in large set amounts	6	6
8	Suction Mechanism	3	15	45
9	C clamps	3	5	15
			Final Subtotal=	1216

Table 3: Bill of Materials

Notes to Consider

Dr. Razavian asked that we include a force sensor and because of the price has informed us the production budget limit is no longer $1000

NORTHERN ARIZONA UNIVERSITY

Thank you!

NORTHERN ARIZONA UNIVERSITY


Question?
NORTHERN ARIZONA UNIVERSITY

Resources

[1] “Stroke Facts.” CDC. https://www.cdc.gov/stroke/data-research/facts-stats/index.html (accessed February 23, 2025).

NORTHERN ARIZONA UNIVERSITY