Project Deliverable B
Problem Definition, Concept Development, and Project Plan

GNG2101 [D]
Introduction to Product Development and Management for Engineers and Computer Scientists

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Introduction

In this report, our team will analyze and implement client statements from our client meeting on January 17th, 2023 and use these needs to find our interpreted needs. From these needs we will derive our problem statement and our design criteria. To develop our target specifications, our team benchmarked various different arm rehabilitation devices as well as different workout devices to see what currently exist and what tolerable specs these devices have. Once we had defined our problem statement and specs, our team had a structured meeting to help developed possible concepts. Once we had our concepts, we evaluated them against our target specs and combine separate concepts to formulate posible solutions. After re-evaluating the combined, we were able to determine our favoured concept.

Problem Definition

Needs Identification

On January 17th, 2023, our team was able to conduct our initial client meeting with our client. During this meeting, our team was able to acquire statements from the client which we will transform into interpreted need. Our team then was able to rank these needs from 1 to 5 where 1 was deemed to be a very important need while 5 represents a less important need.

Table 1: Clients Statement and Ranked Interpreted Needs

Client Statements	Interpreted Need	Ranking
Left arm has issues locking elbow, and bicep is gone	The device is able to lock in place of the elbow	2
During Workouts, the participant moves all over the room	The device is portable and light	3
Does LES mills body attack 3 times a week	The device is durable	4
Client weighs 195 lbs	The device can support the user	1
Pain is not an issue, Collapses during push ups	The device can support the user	1
Wants to fit in with group	The device is aesthetically pleasing and is minimal design	4
No transition between tracks of workout session	The device is easily portable	3
Grip strength is good but getting into position is a challenge	The device is easily controllable	2
Symmetrical workout such as lifting a bar is challenging	The device can aide the users in completing symmetrical exercises	1

Arm is not able to fully extend	The device is able to increase range of motion	4
Rotation in arm is a difficulty	The device can aide the user in increasing range of motion	4
Can't move arm straight without injuring arm	The device is able to increase range of motion	4
Mobility/Stability is an issue	The device can aide in stabilizing the arm and increase range of motion	3
Shoulder is overcompensating for arm	The device can control and stabilize the shoulder	2

Client Information

During our client meeting on January 17th, 2023, we were able to obtain information on the client which will be used in developing our concepts and design. During the progression of this deliverable, we realized some information on the client was still missing. Both known and unknown information can be seen below in table 2.

Table 2: Known and Unknow Client Information

Known Client Information	Unknown Client Information
● Client weighs approximately 195-200 lbs and 5' 10" tall ● Client cannot lock left elbow ● Client participates in LES Mills bodyattack sessions ● LES Mills bodyattack uses arms for approx. 10 mins per session ● Can not do symmetrical exercise due to left arm injury ● Currently uses yoga block to attempt exercises ● Elbow is restricted ● Pain isn't an issue	● Client's exact range of motion in the left arm. We will measure the range of motion of : ○ Shoulder (Abduction-Adduction) ○ Shoulder (Flexion-Extension) ○ Elbow ○ Forearm (Pronation-Supination) ● Strength in both arm ● Difference in length between both arms

Problem Statement

Our client has a need for a compact and light device to simulate a locking motion in his left elbow while ensuring proper support under continuous load, throughout symmetrical and static movements.

Benchmarking

In this section, our team developed metric and found existing products which are currently used to either increase the range of motion or aid in doing exercises such as push-ups to compare against the metrics.

Table 3a: Metrics

Metrics	Measurement	Units
Cost	Price	$
Size	Volume	m^3
Sizing	Size	Small - XXXL
Range of Motion	Degrees	°
Weight Capacity	Weight	lbs
Device Weight	Weight	lbs

Table 3b: Existing Benchmarked Product

Device Name	**Orthomen Hinged ROM Elbow Brace**	**Slingshot Pushup Band**	**EduExo Pro exoskeleton arm**
Features/ needs met	The device can support the elbow	The device can aid the user in performing symmetrical movements	This device can aid in symmetrical movements and stability
Pros	- Has a lockout function on brace - Has an adjustable range of motion dial - light and comfortable material - Enables elbow stability	- moderate support at the base of the pushup movement - Deeper you go in a pushup, the more assistance you get - Comfortable with double ply chest portion - designed to avoid shoulder injuries with bodyweight movements	- Full exoskeleton with shoulder and elbow support with 3 degrees of freedom - force sensor, elbow sensor, EMG sensor can help measure muscle output/activity - Metal structure and joints allow for proper load management
Cons	- Not ideal for exercise movements - Offers no support for completing pushup movements - Not cost effective	- Doesn't compensate for the difference in height and range of motion for the 1 arm - No progressive overload mechanism once strength develops	- Very expensive and hard to obtain - A bit bulky and possibly uncomfortable to wear for frequent use - New startup so lack of experience/reviews
User feedback	- "Brace is comfortable. Straps can be cut to proper fit; the velcro tabs are	- "it has made a tremendous difference in my ability to do push ups	This product is a new device in the market (startup) thus there is a

	removable to accomplish this. Adjustment of the flexibility is straightforward enough." - " I could not stabilize my elbow with the sling, but once I place the elbow brace on I was able to limit my movement and decreasing my pain."	and tricep push ups! " - "What I like is how the band bounces you back into place automatically" - "Started a w being barely able to do 10 reps....after 2mnths w the slingshot and being disciplined in my daily workout...im up to 40x3."	lack of user reviews
Cost	154 $	72$	2314$
Metrics & Properties	- dimensions: 36.58 x 14.73 x 12.45 cm; - Weight: 635g - Flexion: 0-120° - Extension: 0-90°	- sizing: XS-3XL - bodyweight: 120-300lbs - Item weight: 288g	- force sensor: 10kg - Materials: CNC parts, Metal sheets, plastics, textiles - 3 degree of freedom - Motor: 5 Nm feedback serv
Link	Elbow Brace	Slingshot	Exoskeleton

Target Specifications

From our interpreted needs, we are to converted them into target specifications which will in turn be used as design criteria. All similar interpreted needs were grouped for simplicity.

Table 4: Design Criteria Converted from Interpreted Needs

Interpreted Need	Design Criteria
The device is able to lock in place of the elbow	- The device manually lock - The device is rigid enough to support weight
The device is portable and light	- Maximum Device weight/size (lbs)
The device is durable	- Device length of life
The device can support the user	- The device can support 200 lbs
The device is aesthetically pleasing	- Minimal Design - Aesthetic
The device is easily controllable	- Simple design usage - User Friendly - Controllability on exercise movements
The device can aide the users in completing symmetrical exercises	- Proper shoulder stability - Support for eccentric and concentric movements
The device can control and stabilize the	- Device ensures proper exercise form

shoulder	- Can support appropriate load (lbs)

Table 5: Target Specifications

Design Specifications	Relation	Target Value	Units	Verification Method
Functional Requirements				
Support appropriate weight/loads	>=	200	lbs	Analysis
Stabilize the shoulder	=	yes	N/a	Prototype and Test
Controllability during exercise movements (eccentric +concentric movements)	=	yes	N/a	Test if the device can easily be locked, can easily descend (Can spring contract, expand), and easily controlled by client
Allow for symmetrical exercises using proper form	=>	yes	N/a	Testing with various exercises and positioning
Constraints				
Fits user's arm	=	yes	N/a	Test
Support client's body weight	=	195	lbs	Stress Analysis
Non-Functional Requirements				
User Friendly and simple setup	<=	1	mins	Through testing, the client is able to easily use the device for his exercise movements. The

				device is simple to put on/off or move into position
Maximum Device size/weight (portability)	<=	10 1	Lbs m^3	Test
Manual Lockout feature	=	yes	N/a	Prototype and Test
Durability (device length of life)	>=	100	Operational hours	Highly Accelerated Life Testing (HALT)
Aesthetic and minimal design	=	yes	N/A	Through feedback from the client's perspective in the prototype phase

Concept Development

Sub-System Concepts

Vertical Movement

Concept 1: Spring

Concept 1 for vertical movement involves using a spring to add a force to help the client get back up from a push up by storing the energy gained by the user compressing the spring with the downward motion of a push up and this energy is released as the client begins the upward motion of the pushup

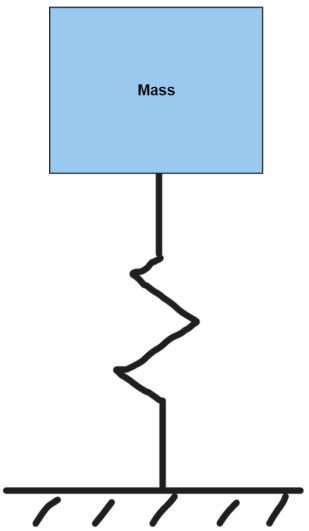


Figure 1: Conceptual Spring Pushing up a Mass

Concept 2: Damper

Concept 2 for vertical movement involves using a spring and damper to add a force to get back up which is very similar to the spring but a springs motion oscillates when the energy is released. To avoid this, a damper can be added to absorb these forces.

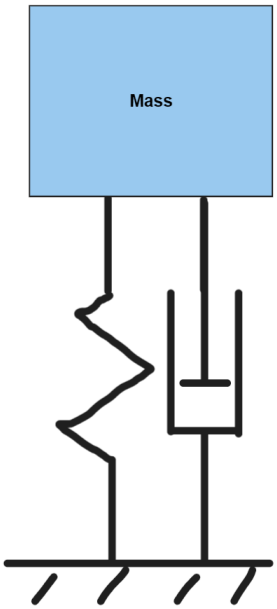


Figure 2: Conceptual Spring and Damper Pushing up a Mass

Concept 3: Piston

Concept 3 for vertical movement involves using a piston cylinder to slowly aid the user get back up when triggered, This concept is troublesome due to the need for pneumatics or hydraulics.

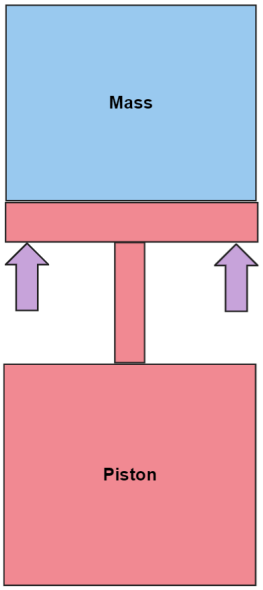


Figure 3: Conceptual Piston Pushing up a Mass

Stabilizing Shoulder/Elbow

Concept 1: Elbow Lock

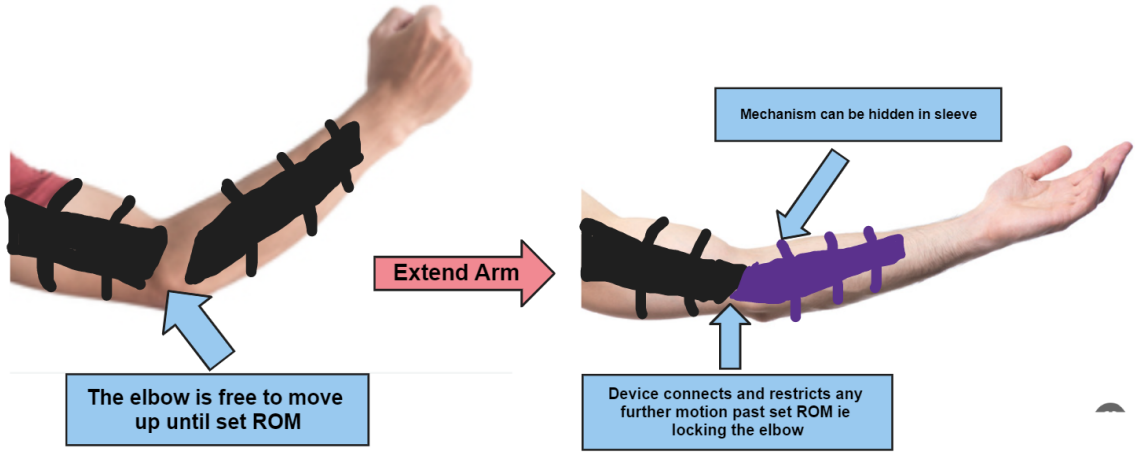


Figure 4: Elbow locking mechanism

This concept revolves on helping the client lock his elbow to reduce the amount of force needed when his arm is fully extended. This concept works on the same principle a folding chair uses. When you have a folder chair, the leg swings out up until a certain point where it hits the other leg which locks and restricts its motion as seen in figure 5. This mechanism could be hidden in a sleeve for aesthetic reasons.

Figure 5: Chair locking Mechanism

Concept 2: Shoulder Platform

Concept 2 involve stabilizing the users shoulder so the user does not need to focus any force on keeping his shoulder where it should be and he can focus fully on the motions of the arm.

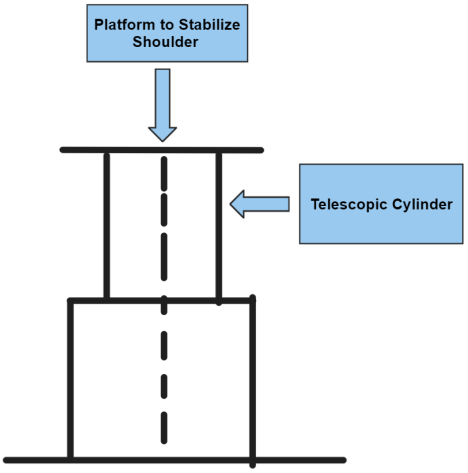


Figure 6: Shoulder Platform

Concept 3: Elbow Compression Sleeve

Concept 3 involves the use of an external compression sleeve located at the elbow joint. The elbow compression sleeves enable blood flow and healthy circulations throughout the joint. These sleeves offer protection to possible elbow pain/injuries by protecting the arm muscles and tendons. These are often utilized during pressing and pushing movements.

Reducing Difference in Arm Length

Concept 1: Handle

Concept 1 involves setting a handle at a known height (difference in length between arm 1 and 2) to account for the difference in height. This handle can be fixed to an externally attached device or a device attached to the arm.

Concept 2: Yoga Blocks

Concept 2 involves using an already owned yoga block to aid a device which is attached to the users arm to counteract the difference in length between the 2 arms.

Concept 3: Triangular Block

Concept 3 is very similar to concept 2 but by changing the geometry of the block, the user can choose the desired height of the second arm by using a triangular shape block since a triangle a sloped edge.

Initial Solution Concepts

Concept 1

The first developed concept is comprised of solutions from our 3 sub-sections listed above. The first subsection is the left side of figure 1. It is the handle system of adjustable height which can be used to customize the device to the exact difference in length between the 2 arms. The second subsection is the spring and damper system which during the concentric movement of a push up will provide support on the way back up. The spring and damper will be pinned to the outer fixture. The third subsystem is the shoulder support platform which will be pin to the spring and damper and will provide stability during a push-up. An added feature in this design is the lock on the platform. This lock can be used to enable different exercises such as the plank or mountain climbers. Figure 7 represents a simple sketch of this concept.

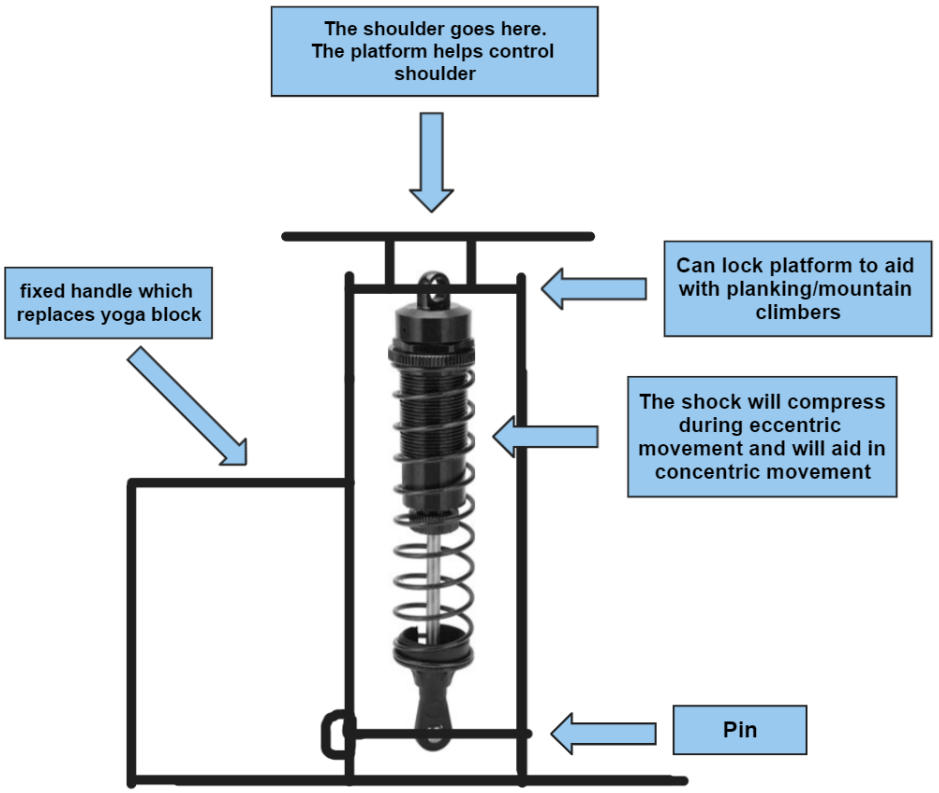


Figure 7 : Stationary Push-up/Plank aide Concept

Concept 2

The second developed concept is comprised of 3 sub-sections. The first subsection consists of the portion to compensate for the difference in height between the two arms. To allow for a simple design, the yoga block will be used during the designed movements. The second subsection is the spring and damper system which will be attached to the arm. The spring and damper will be attached to the third sub-system, a supportive sleeve on the clients left arm. The positioning of the spring is located near the elbow joint to allow for the best load transfer (simulating a lockout) to the rest of the arm. The spring will allow for support upon the eccentric part of a pushup movement. An additional feature in this design is also the lock on the spring/damper portion/connection. This lock can be used to enable different exercises such as the plank or mountain climbers as it allows for adequate support on these static movements. Figure 8 represents a simple sketch of this concept.

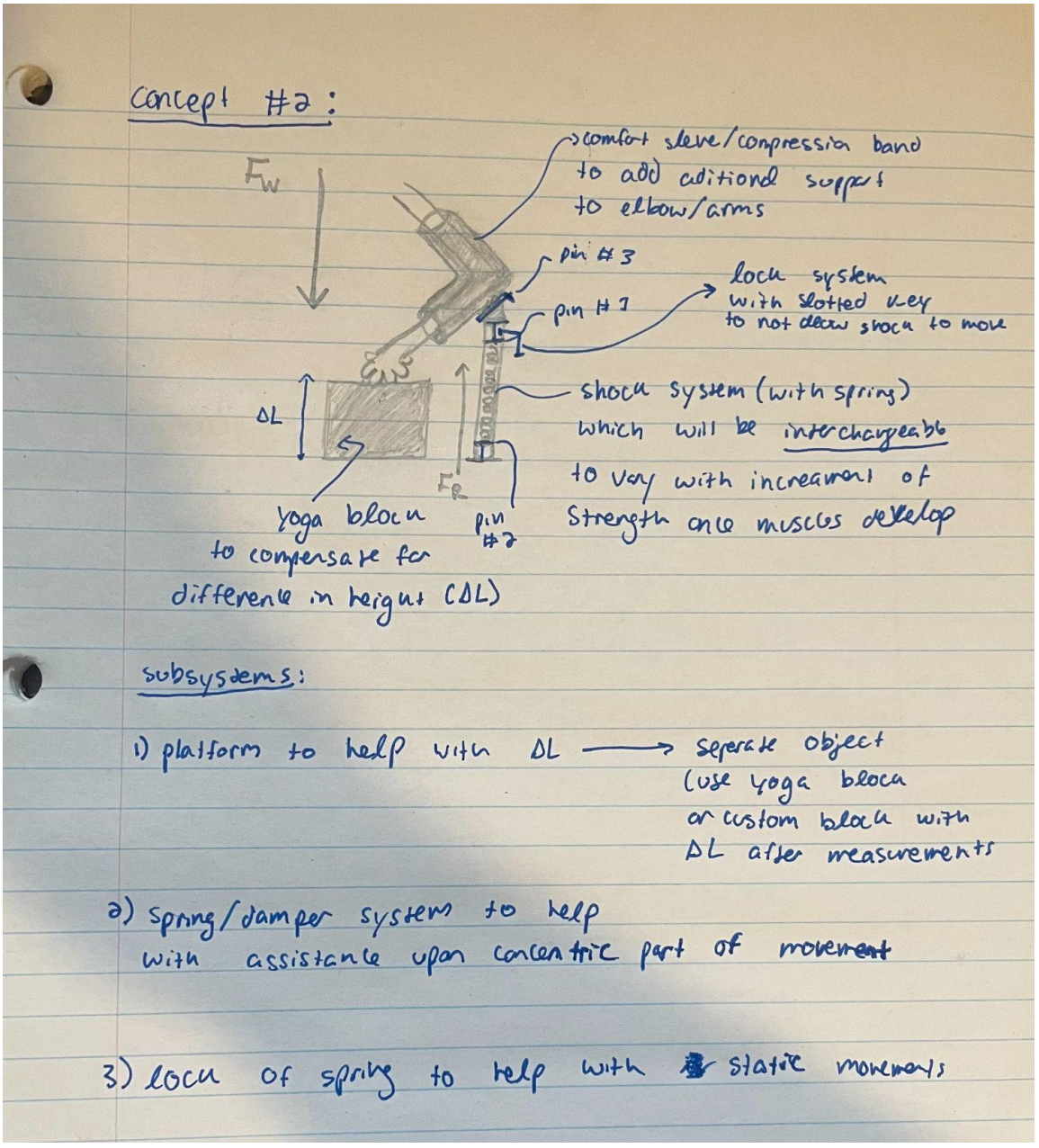


Figure 8: Concept 2

Concept 3

Spring Block

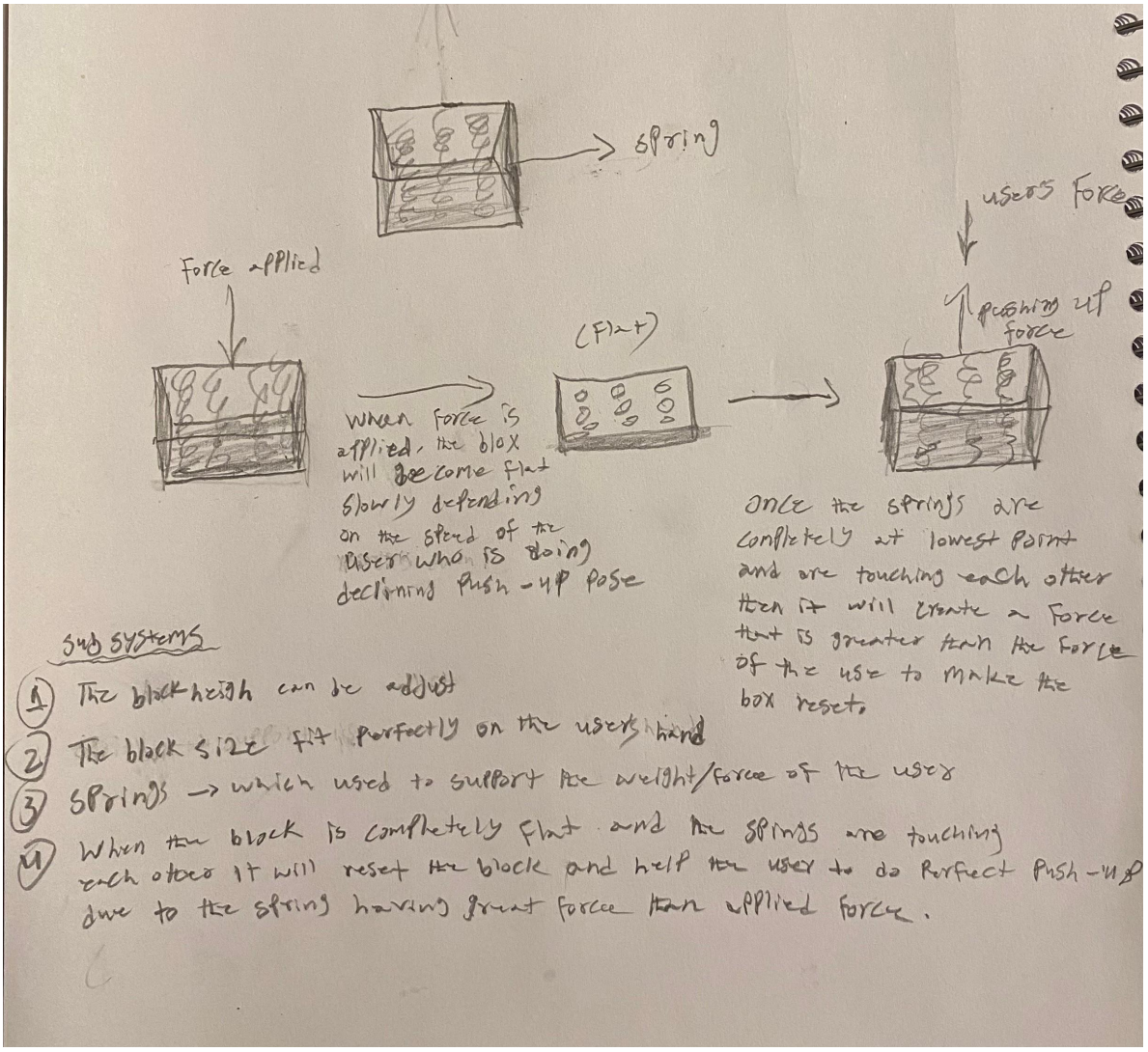
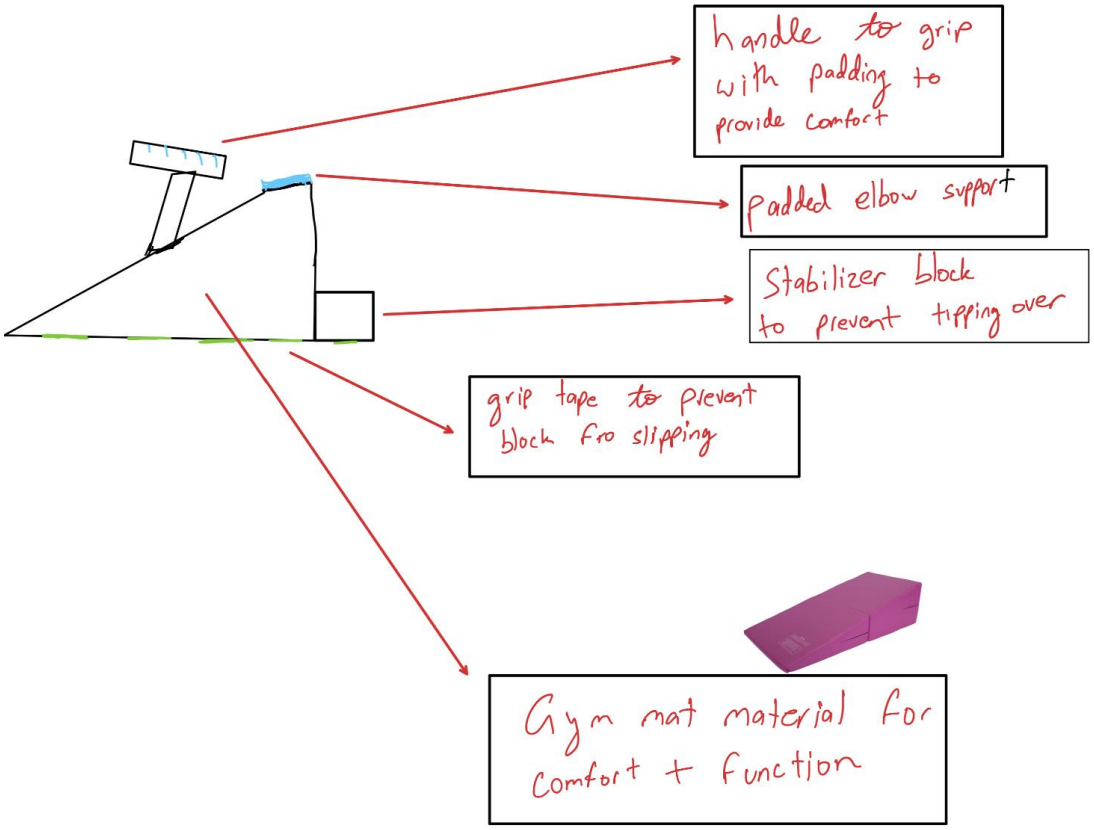


Figure 9: Concept 3

The objective of this concept is to make sure that each shoulder of the client has the same length and to help the client to do push-ups with a perfect pose. This concept is similar to yoga block but is more advance and has more stuff that is very useful to the client. The way this block work is that when somebody is doing the declined push-up pose with the block, a force is applied to the block which causes the block to shrink and become flat. The speed that it takes for the block to become flat is similar to the speed of the person who is doing the declined push-up. After the user does the declined push-up pose, the spring inside the block touches each other which leads to them having a greater force than the applied force and that causes the block to reset itself. The resetting part helps the user to be able to do the inclined push-up without having any shoulder problems and it helps the client's arm to be matched. There're 4 subsystems for this concept. The first subsystem is the height of the box which can be adjusted based on the different lengths between the client's arm. The second subsystem is the size of the block which will be suitable for the client's hands. The block will match the hand of the client perfectly. The third subsystem is the springs which are inside the box and they're used to support the weight of the client and help him do

decline/incline push-up poses. The fourth subsystem is the force which will make the block shape return to normal and that force needs to be adjusted based on the weight/force of the use and how many springs there should be in order to create a greater force that will make the block return normal at the end of the decline push-up pose.

Concept 4



Subsystems.

(1) Stabilizer block to prevent the device from slipping or tipping backwards due to weight applied.

(2) Padded handle to allow client with an elevated place to grip to allow for symmetrical exercise.

(3) Grip tape and padding adds a level of comfort and security for the client.

The purpose of this design concept is to allow the client to perform symmetrical static exercises with the help of a mat and handle device. The concept includes a triangular shaped gym mat with an affixed rod and handle mechanism to allow for gripping. The client may use their left arm to grip onto this elevated handle and perform their exercises. The handle is equipped with a soft padded material and is fixed directly to the base of the mat to allow for maximum stability. The concept also includes a flat surface at the top of the triangular mat to allow for the client to rest their elbow and perform a more even push-up with their right hand. This flat surface includes some more padding for the comfort of the client's elbow. The underside of the entire mechanism includes some grip tape to prevent any sliding or slipping while the product is being used. This also acts as a fail safe to prevent any accidents or injuries caused by the product.

The three subsystems outlined above work collectively to provide an adequate solution to the client's needs. Precise measurements could also be utilized to better optimize the positioning of the handle and elbow rest. The materials used in this concept would be easy to obtain and can be purchased for a relatively low cost, hence the concept is within the allocated budget.

Analysis of Concepts

The chart below outlines the rankings given to specific design criteria present in each initial concept. As a team, the weighting of each criteria was created based on its interpreted need ranking and then ranked on a scale of 1 to 5 (with 1 being the highest rating, and 5 being the worst). By using a weighted average, the final scores were calculated and compared against one another. The one with the lowest total score (concept 1) was chosen to be our global solution since it performed the best while being tested against the design criteria.

Table 6: Concept AnalysisPrototype Concepts

Design Criteria	**Criteria Weights**	**Concept 1**		**Concept 2**		**Concept 3**		**Concept 4**	
Proper Weight/load Support	0.15	2	0.3	3	0.45	3	0.45	3	0.45
Shoulder Stability	0.1	1	0.1	5	0.5	5	0.5	5	0.5
Controllability during exercise movements	0.2	2	0.4	3	0.6	2	0.4	3	0.6
Allows for symmetrical exercises with proper form	0.05	2	0.1	2	0.1	3	0.15	2	0.1

Fits Users Arm	0.05	3	0.15	1	0.05	1	0.05	2	0.1
User Friendly with a simple startup	0.1	2	0.2	4	0.4	2	0.2	2	0.2
Portable (maximum weight/size)	0.1	4	0.4	2	0.2	3	0.3	3	0.3
Appropriate Lockout Function	0.1	2	0.2	3	0.3	4	0.4	3	0.3
Durability (Length of life for device)	0.1	2	0.2	4	0.4	4	0.4	3	0.3
Aesthetic and minimal design	0.05	4	0.2	4	0.2	3	0.15	4	0.2
Final Scoring =		2.25		3.2		3		3.05	

Conclusion

In conclusion, our team chose to select concept 1 with some features implemented from the other concepts as concept 1 was by far the better concept when analyzed against the design criteria. Concept 1 was not perfect and other concepts provide features concept 1 did not have so we decided to implement some of them into concept 1 to improve the design. A con of concept 1 was that the circular handle may cause some difficulties when gripping the device so we took the grip take idea from concept 4 to improve. We decided to add a wide base to the device to increase the stability of the device and we decided to make the spring interchangeable as it was in concept 2 to make the device more versatile in different situations. The pro's of this device are that it will stabilize the shoulder, provide support during the concentric motion in a push-up, will help with doing push-ups, planking and mountain climbers, is simple to use and build, and it a versatile device. The cons of this device are that it doesn't reinforce the ROM of the arm and the elbow isn't supported but this device should help the user build muscle in the arm. This concept should be able to complete every target specification listed above in table 4 except for locking the elbow but this device does not stop it from occurring either so an add-on device could be design to accomplish this.

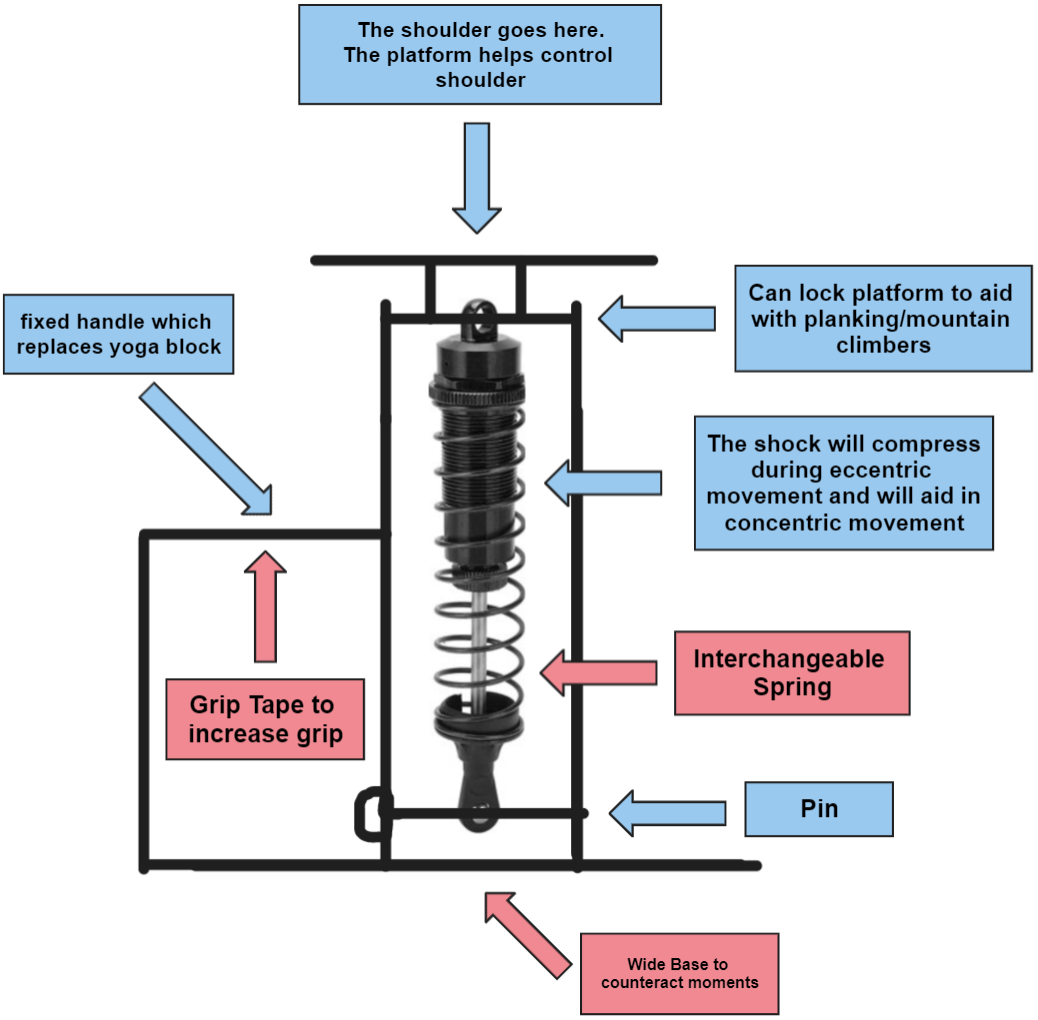


Figure 10: Chosen Concepts

Project Plan

In this deliverable, our team updated our project plan to include milestones and task dependencies. Our wrike gantt chart can be found below by following the link. All task which were already completed were marked as complete.

Wrike Link;
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=6GZxBNumy3OR6dft1kIYi9hUemG4Uf1n%7CIE2DSNZVHA2DELSTGIYA