GNG2101

Design Project Progress Update

Group B 2.5

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List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
CAD	computer aided design
DFX	design for ‘X’

Table 2. Glossary

Term	Acronym	Definition

1 Introduction

The task for this project is to design a soft cervical collar that is water resistant and durable. After client meetings, a number of design characteristics were determined, and a few assumptions needed to be made in order to guide the team. These assumptions (currently) include collar size and circumference, adjustability range, and material preferences. As the client was unsure about these aspects, educated assumptions were made, which will be updated and modified as the project continues and the team becomes more familiar with the project.

This document outlines the prototypes made by the group, the testing involved, and the results of the tests. Testing is based on the target specifications created earlier in the semester, with some tests being evaluated on a subjective scale due to the nature of the criteria.

Design constraints will then be created based on prototype testing, and an economics report will be made for the final prototype and product.

2 Prototype 1, Project Progress Presentation, Peer Feedback and Team Dynamics

This section details the creation of the first prototype, the testing that was done, and the conclusions drawn from this. A progress presentation was created and the team debriefed on team dynamics.

2.1 Prototype 1

The purpose of this initial prototype was to determine the comfortability and practicality of silicone for the final product. This was conducted by creating an analytical prototype in CAD and testing using solid works and by use of a physical model that mimics the final product. The physical model was created by sewing a shell out of fabric and filling it with water beads. Water beads were chosen due to their soft nature and similarity to silicone.

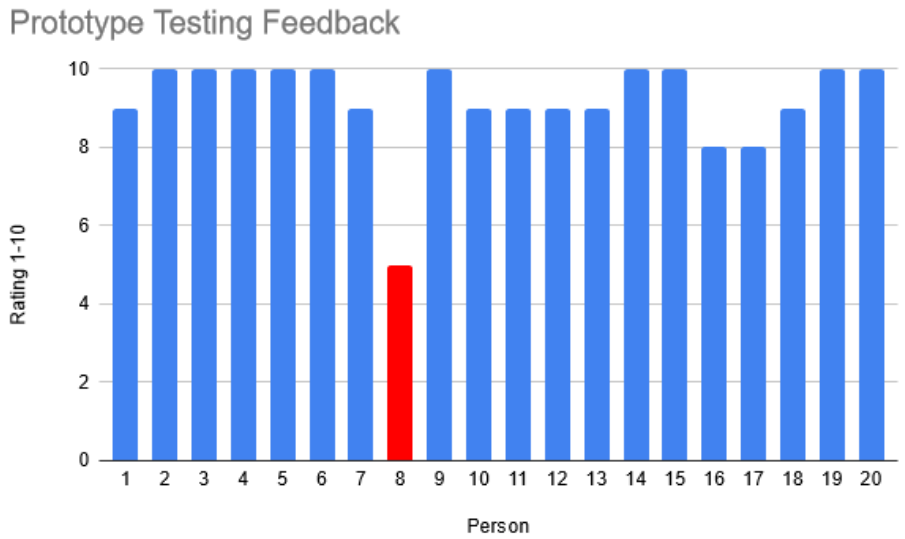
After the prototype (Figure 3) was made, a series of tests were conducted to determine the success of the model. First, a comfortability test was conducted by surveying a number of people who have worn the collar. They were asked to rate their comfortability on a scale of 1-10, with 10 being the most comfortable. Next, a range of motion test was conducted by a group member wearing the collar while performing daily activities. The range of motion of the neck was also tested by measuring the degrees the head can turn while wearing the collar. Motions tested include: turning the head left and right and moving the head up and down (nodding motion).

Table 3. Testing table for prototype 1

Test Number	Reason for Prototype	Evaluation Criteria/D	Level of Prototype	Kind of Prototype	Metrics	Test Description	Analysis Method	DFX

		etermine Measurables						
	Communication, Performance Measurement, Risk Management, Learning/Understanding	*What are you testing with your concept (target measurable attributes)?*	*HiFi/LoFi Focused, HiFi/LoFi Comprehensive*	*Visual, Analytical, Physical*	*What metrics will you test?*	*What specifically will you test*	*Specifically how will you test, include things like duration, sequence of test, equipment, etc.*	*What DFX does this test relate to*
1	Performance Measurement	Subjective comfort of collar	HiFi Focused	Physical	(Score /10)	User comfortability rating out of 10.	Asking people to try on the collar and give a rating	Designing for comfort
2	Performance Measurement	Range of motion	HiFi focused	Physical	Degrees	How many degrees can the head be turned left and right	Having someone wear the collar and move their head.	Designing for comfort
3	performance measurement	load capacity	LoFi focused	Analytical	Kg of force on top of collar.	the load strength of the silicone collar (can it support the average weight of a head)	Simulation in CAD solidworks applying weight to the top of the neck collar.	Designing for durability

Figure 1. Prototype test feedback for comfortability



Average Rating: 9.2/10

Before creating the physical prototype, the group made an assumption that using a silicone base would be comfortable on the user's neck. Additionally, the group assumed that the user of the collar would be able to turn their neck 90 degrees left and right. This is aligned with the DFX of comfortability, allowing for natural neck movement. To confirm this assumption, the group conducted tests by asking potential users to try the physical prototype on and rate it on a scale of 1-10 on comfortability. These results were then averaged, and outlier ratings' reasoning on their rating was noted. To test the range of motion a group member put on the collar and turned their head left and right. The angle was then measured using a ruler as a base point on the user's nose, and a protractor to measure the specified angle the ruler was directed at.

The group also made an assumption that a full silicone base could support the weight of an average human head. To confirm this assumption, the group conducted a simulation in solidworks where weight was applied onto the top resting portion of the neck collar.

Test	Actual Rating	Expected Rating
User comfortability rating average	9.2	8
Range of motion	~90 degrees left and right	~ 90 degrees left and right
Load Capacity	<49 kgf	49 kgf

The expected average rating for user comfortability defined in the target specifications was 8/10. The actual average rating is 9.2/10. This is based on feedback from 20 people. The expected

range of motion defined in the target specifications was 90 degrees left and right. The actual range of motion met the expectations.

A simulation was completed in solidworks that tested the load strength of the neck collar by applying the weight of an average human head onto it. This is shown in Figure 4. After applying the weight, it was clear that the neck collar could not support the expected load capacity, as the area the neck rests on caved in. In future prototypes, considerations will be made for additional support in the collar. This can be done by adding in a plastic middle (encased by the silicone) or by adding thin foam/plastic pieces in the middle area where the head rests.

Figure 2. Physical prototype

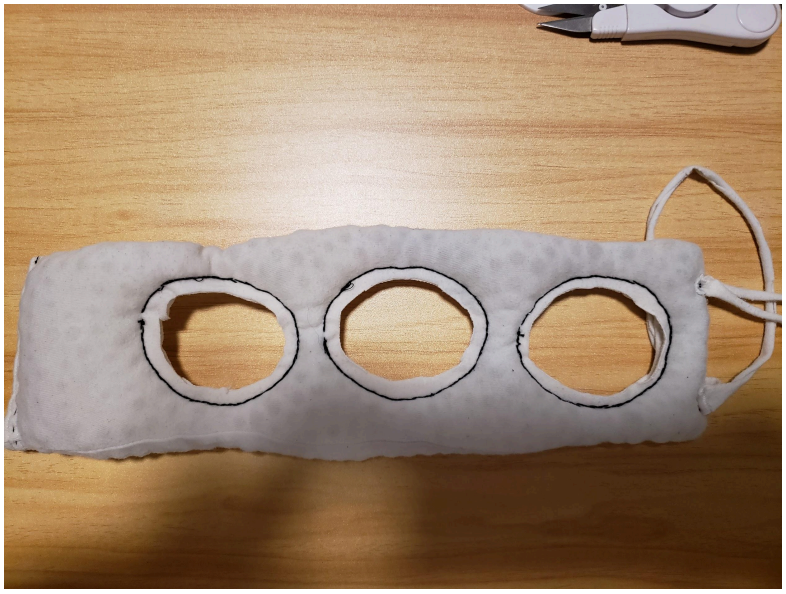
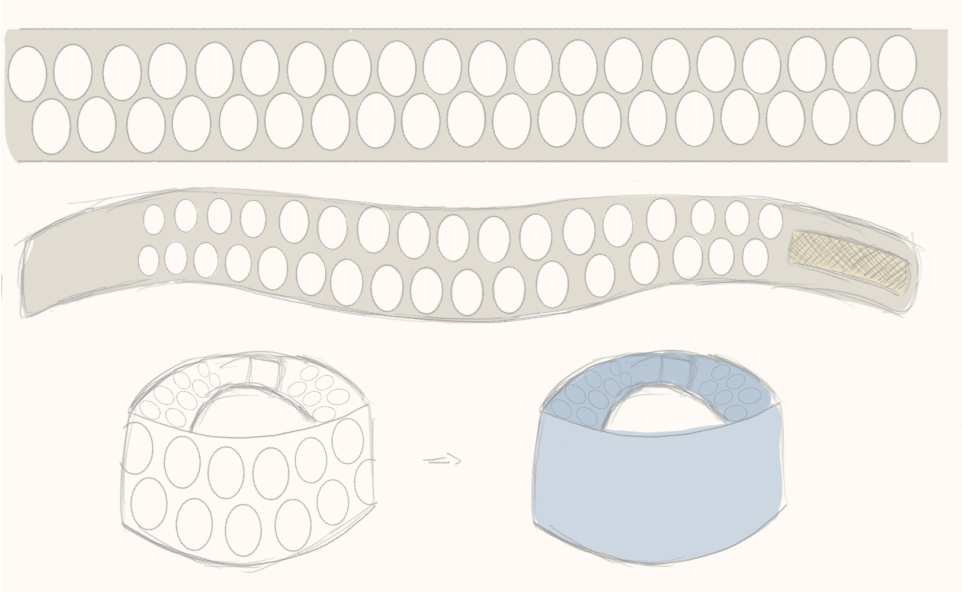
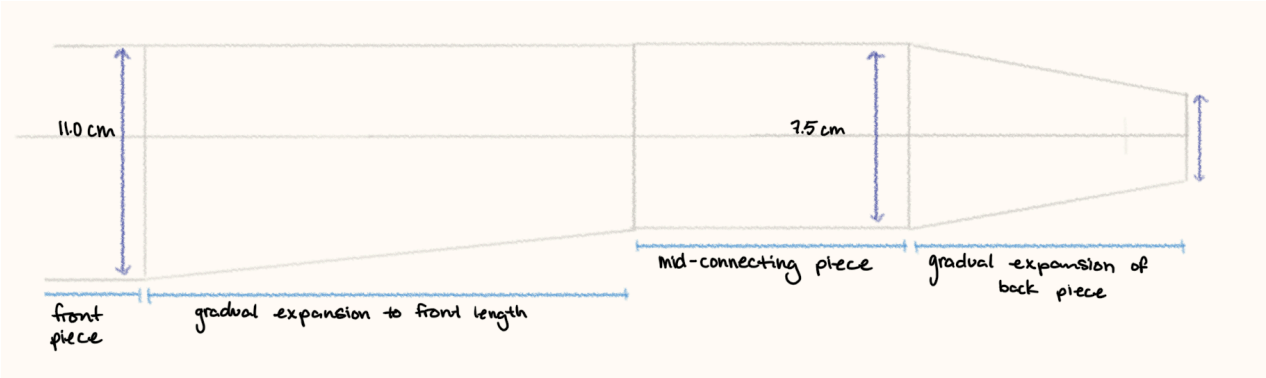


Figure 3. Design concept for the prototype





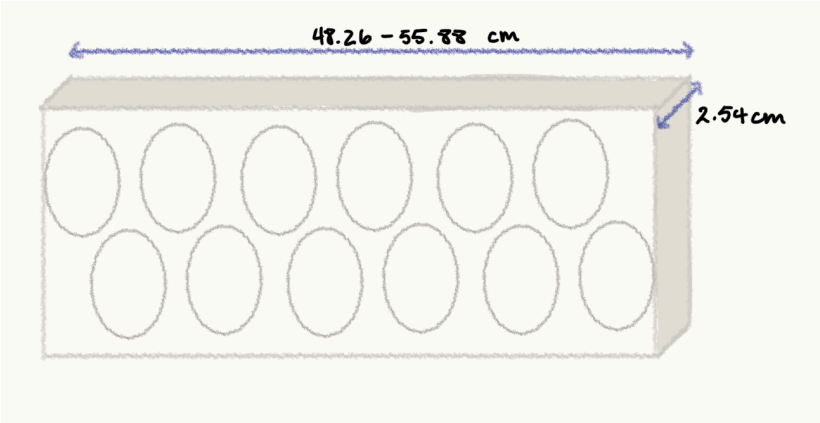
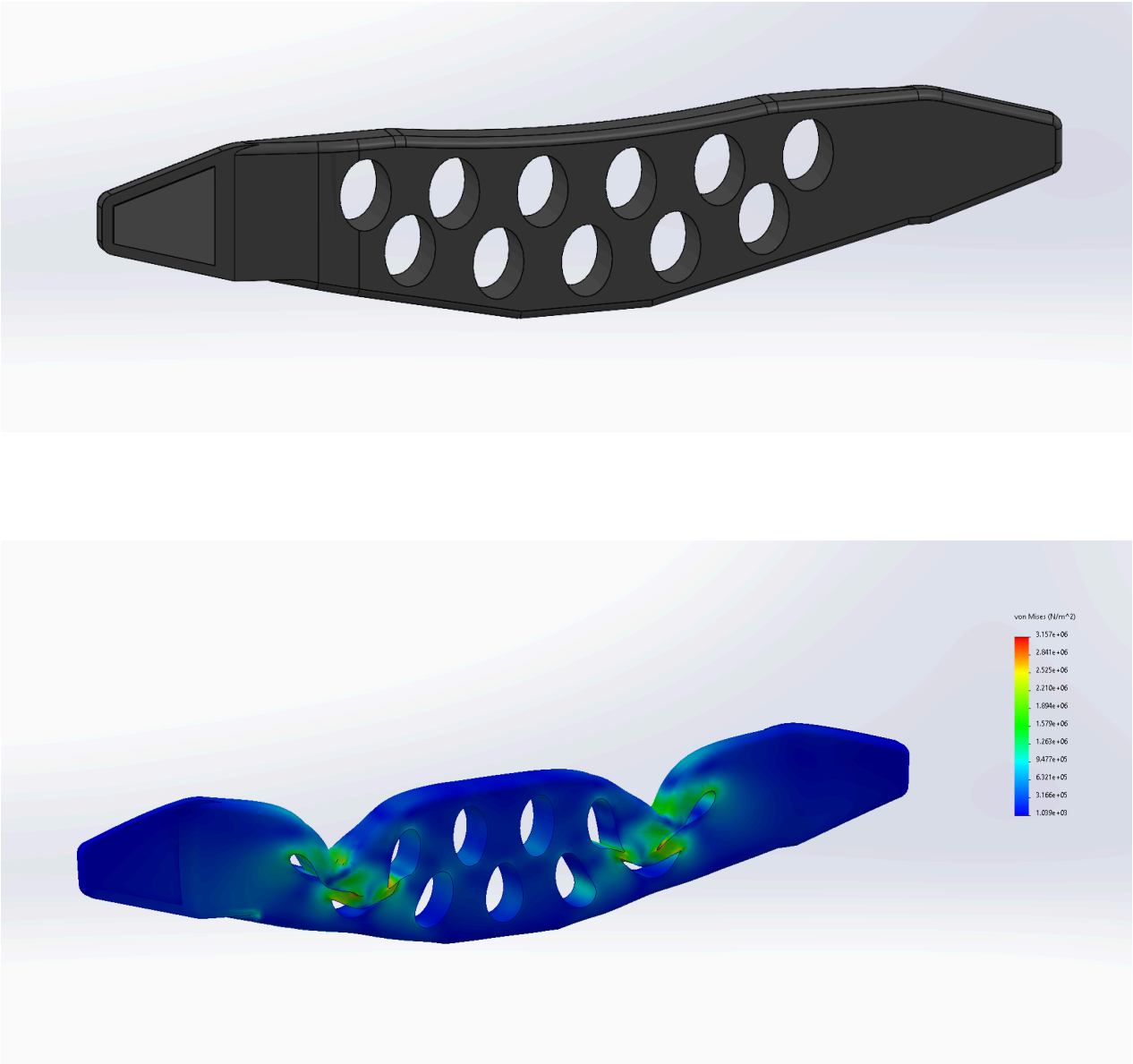


Figure 4. CAD model and simulation for the prototype



2.2 Project Progress Presentation

https://docs.google.com/presentation/d/1NXWXMrdXa608JG9ChDeSmhGy--YNq8_g8FrNJ-_OG7c/edit?usp=sharing

2.3 Project plan update

~ Daniel: Laptop is damaged this week so I was instructed by TA to complete milestones/tasks in a table.

Roles	Assigned To	Start Date	End Date	Due Date
Presentation Slide Deck	All Group Members	Tuesday, October 8th	Monday, October 21st.	Monday, October 21st 11:59PM
Prototype - Idea	All Group Members	Tuesday, October 8th	Monday, October 21st.	Monday, October 21st 11:59PM
Prototype - Physical	Olivia	Tuesday, October 8th	Monday, October 21st.	Monday, October 21st 11:59PM
Prototype - CAD Model	Rowan	Tuesday, October 8th	Monday, October 21st.	Monday, October 21st 11:59PM
Project Plan Update	Daniel	Tuesday, October 8th	Monday, October 21st.	Monday, October 21st 11:59PM

3 Design Constraints and Prototype 2

3.1 Design constraints

The product's two most important design constraints are the comfortability and durability of the soft cervical collar. These DFX factors are important for developing the prototypes as they are a client need and requirement for the final product.

When designing for comfortability, a base of silicone was chosen for the collar due to its soft nature, low skin irritability, and ability to conform to different shapes (neck size, clavicle shape, etc.). For prototype 1, water beads were used to mimic silicone when testing for comfortability, which proved to be successful as shown by the survey results. In future prototypes, using an additional foam layer around the outside has been considered to add more comfort, especially if a harder/more stiff grade of silicone is to be used.

When designing for durability, the team decided that silicone was the best option due to its wide range of stiffness and durable nature. Silicone is resistant to water and chlorine, which makes it the most durable material in an aquatic setting. Additionally, silicone is available in many different stiffnesses, which will allow the proper support needed for a soft cervical collar. In prototype 1, an analytical test was performed on solid works using silicone, and it was found that there are areas where support may not be sufficient with silicone alone. To fix this, the team is considering adding additional supports in the front area of the collar. The supports would be made with reinforced silicone (a thicker area) or by using a separate material encased in silicone. These ideas will be explored in prototype 2.

3.2 Prototype 2

Client Feedback on Prototype 1:

Velcro Usage: The client agreed with this by saying Velcro is preferable for adjustability, but reiterated that superior quality Velcro should be used, one that is strong and durable.

Collar Tapering: The collar should taper and become thinner; the client suggested that the collar must have delicate outlines, and there should be no excess bulk around the collar line.

Padding Considerations: The client was very specific on the thinness of the padding in order not to make the collar bulky. The padding has to be comfortable without the excessive focus on the thickness of the material.

Breathability: The client is fine with the holes on the design for the purpose of breathing but the client wants to know if the collar is designed for swimming only then the holes can be omitted. They fail to consider that the holes are required in a water setting because the client does not sweat.

Material for Comfort: The client said that comfort and ventilation were reasons to use a cotton cover but said that it would not be suitable for swimming. This implies that even though comfort is important the material used in the collar must be taken through its suitability in both comfort and water usage.

Changes to Improve Design for Prototype 2:

Velcro Adjustment: In the same regard, the client indicates that the Velcro should be adjustable, in which high-quality Velcro should be used. It's the material creating Velcro that has to be strong enough as a support yet soft enough to be easily used.

Tapering the Collar: Redesign the collar to be more tapered, reducing its thickness, especially around the edges, to make it look sleeker and less bulky.

Padding Thickness: Reduce the padding thickness to meet the client's desire for a comfortable but non-bulky design. Consider using thin, breathable materials that balance comfort and performance.

Consideration of Holes: Because of the minimal load the collar can withstand when the ventilation holes are present, going forward they will be removed. This is to keep the collar to a minimal width while ensuring it can withstand the estimated load ie. a human head resting on it.

Material for Comfort: The cotton cover also feels comfy but this is not ideal for water-based activities. It may be useful to incorporate a material that is as soft and pliable as it is waterproof for the end product.

Durability Enhancements: These can be reinforced silicone or a combination of a different material (plastic or foam preferably) covered in silicone and used where the neckpiece rests for the load of an average human head increasing the part's durability

Critical assumptions and Testing needed:

1. **Water Weight Retention**

Assumption: The collar will have the least water-absorbent nature, which will retain a maximum of 10% additional weight when it is immersed in water for a long time.

DFX Relation: This assumption is in parallel with Design for Comfort because retaining the collar light after the water experience does not exert extra pressure on the neck. Furthermore, getting it wrong with Design for Portability is also an issue as it would slow down the drying time and storage.

Testing Needed: Subsequent tests should assess water intake to check that the weight increase does not exceed 10% even after some days in water.

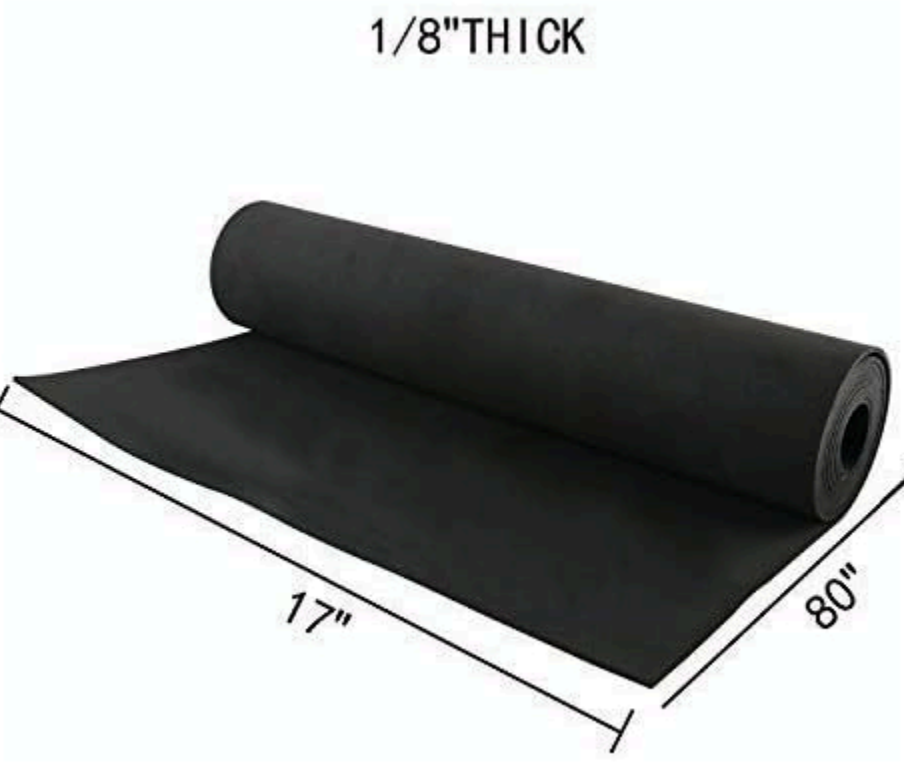
2. **Durability in Harsh Conditions**

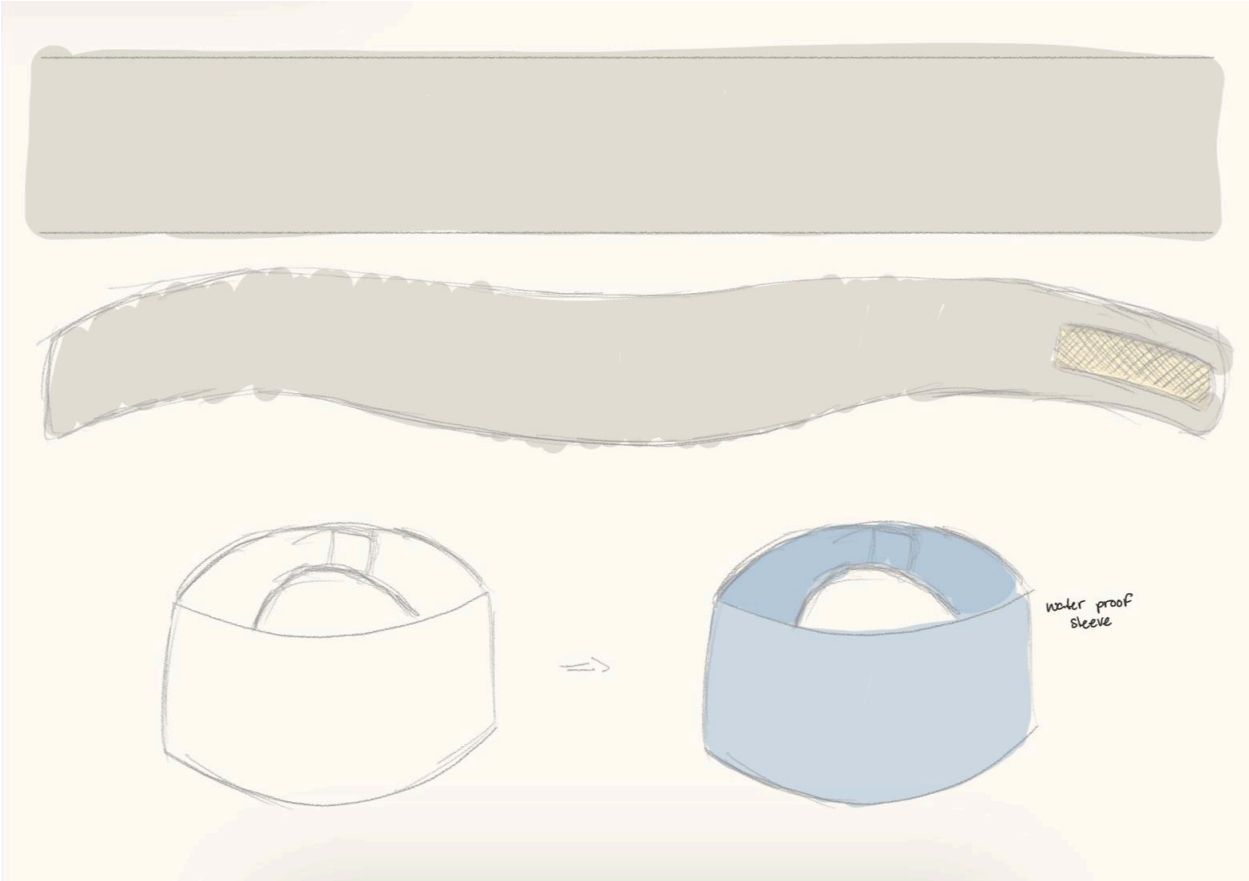
Assumption: The collar does not fade, shrink, or tear when exposed to sweat, chlorine, and physical stress from swimming and dancing among other events.

DFX Relation: This assumption is fundamental to Design for Durability since water, salt, and chlorine might affect the material negatively over a period.

Testing Needed: Future prototypes should be tested using sweat and chlorine conditions to determine whether the material used will likely break after exposure to these chemicals, and make sure it can stay maintained

Our second prototype includes a change in direction, being the use of already-made systems to improve efficiency. We have ultimately decided to buy the base of the neck collar from Velpeau which is already very similar to our early concepts, and first prototype. Next, we will use Neoprene to create the sleeve that goes over it, which will be waterproof and chemically resistant. Neoprene is the material used in competitive swimming suits, and is leak resistant, as well as comfy, so it can be worn for extended periods of time while the client is swimming.





Since our concept underwent a significant change, we made modifications to the detailed design and tested different subunits of the final product. It was decided that holes for ventilation were not needed as the collar will be used for aquatic purposes only. This also solves the previous issue of support when the holes were present.

Testing

Test	Method	Duration	Result
velcro durability in water	submerge a piece of velcro underwater and put together and pull apart 25 times	25 actions of putting together the velcro and pulling it apart	The velcro was durable enough to stick in water

Analytical stress test	update the CAD model and use solid works to simulate stress	n/a	without holes, the collar is able properly support the weight of a human head

Because of the design change, the budget is going to be spent on the following materials: This will be presented to the client at the next possible chance.

Neck Collar Base

https://www.amazon.ca/VELPEAU-Neck-Brace-Stabilizes-Stabilized/dp/B08R51YF85?ref_=ast_sto_dp&th=1

Neck Collar Sleeve Waterproof Material

https://www.amazon.ca/Homend-Neoprene-Adhesive-multiple-dimensions/dp/B0811TNP6V

3.3 Project plan update

Roles	Assigned To	Start Date	End Date	Due Date
Plan prototype 2	All Group Members	October 28	November 5	November 10 11:59PM
Design constraints	Olivia	October 28	November 5	November 10 11:59PM
Critical Assumptions	Kevin, Olivia	October 28	November 5	November 10 11:59PM
Client feedback overview	Kevin	October 28	November 9	November 10 11:59PM
Project Plan Update	Daniel	October 28	November 5	November 10 11:59PM

~ Daniel: Laptop is damaged this week so I was instructed by TA to complete milestones/tasks in a table.

4 Economic and IP Considerations

This section will analyse the economics of the soft cervical collar in the situation where full production and product sales have started. A table of costs is presented based on the manufacturing and sales of our product. In addition to this, a 3 year income statement will be created, and an NPV analysis to determine the break-even point. For this section, assumptions will be made in order to perform the necessary calculations and analysis.

4.1 Economics report

Table 1. Lists of Costs for Soft Cervical Collar

Reason for cost	Cost	Variable or Fixed	Direct or Indirect	Type of cost (material, labour, overhead)
Foam Base	24.99 $/unit	variable	direct	material
Velcro	5.99 $/unit	variable	direct	material
Neoprene Fabric	14.72 $/unit	variable	direct	material
Sewing Materials	3.50 $/unit	variable	direct	material
Rent	5233 $/month	fixed	indirect	overhead
Employee Pay	17.20 $/hour	fixed	indirect	labour
Marketing	29.99 $/month	fixed	indirect	overhead
Electricity/Hydro	0.13 $/kWh	fixed	indirect	overhead

Assumption:

#	Assumption	Justification	Reference/resource
1	Rent Cost	this assumption was made based on the average price/unit area of industrial buildings in Ontario, and an estimation of the building size (area) needed	https://www.spacelist.ca/listings/on/industrial#895536
2	Employee Wage	this assumption was made based on the minimum wages in Ontario	https://news.ontario.ca/en/release/1004366/ontario-raising-minimum-wage-to-support-workers
3	Marketing Cost	this assumption was made based on selling on Amazon Professional plan:29.99 a month Referral fees: 8% of the total transaction	https://sell.amazon.ca/start?ld=SECASOAGOOG-AD-SELL-D-202333
4	Electricity/Hydro Cost	This assumption was made based off of a statistic reported by Statista, on the average electricity cost, as well as average kWh used by a small business	https://www.circuitenergy.ca/blog/post/how-much-does-electricity-cost-for-industries-in-canada https://www.resolveenergy.co.uk/blog/article/what-is-the-average-business-energy-consumption
5	Number of Units Sold	Based on the average revenue of a small business in Canada, we can get the number of units sold. Since this is an average and our business is new our number will be much lower than the 700 units. Roughly around 300 units and increases by 200 each year.	https://www.fundera.com/resources/small-business-revenue-statistics#:~:text=Small%20businesses%20with%20no%20employees,%24100%2C000%20a%20year%20in%20income.
6	cost of a single unit	estimated value based on existing prices for similar products - 49.2	Added all of the costs from our BOM.

7	sell price for each (65CAD $)	Our sell price for each unit is determined off of two factors, being Amazon's Cut of the sell price, as well as our own profit margins. The source linked states that an average profit margin of an amazon product is around 15-25%, and excellent above that. This cost ($65) gives us a 30% which will help ensure we can pay off other costs	https://www.zonguru.com/blog/what-is-a-good-net-profit-margin-for-amazon

Income statement (3 years)

Income Statement	**Year 1**	**Year 2**	**Year 3**
Sales Revenue	300*65 = 19500	500*65 = 32500	700*65 = 45500
Cost of units sold	300*49.2 = 14760	500*49.2 = 24600	700*49.2 = 34440
Gross profit	4740	7900	11060
Operating Expenses	103,200 + 62,796 + 1950 + 29.99 = 167975.99	103,200 + 62,796 + 1950 + 29.99 = 167975.99	103,200 + 62,796 + 1950 + 29.99 = 167975.99
Operating Income	4740 - 167975.99 = $-163235.99	7900 - 167975.99 = $ -160075.99	11060- 167975.99 = $ -156915.99

-

Using a NPV analysis, determine the break-even point (i.e. number of units that must be sold for your business to become profitable). Note: It is highly unlikely that your operating income will be positive in the first year because of fixed costs.

Fixed Costs

- Electricity/Hydro cost: 15000 kWh * $0.13 CAD/kWh = $1950
- Salaries: (3 Workers * (8 hours * 250 days) * minimum wage) = $103,200
- Rent :$5233 * 12 = $62,796
- Marketing: 29.99

Variable Costs

- Foam Base: $24.99 /unit
- Velcro: $5.99 /unit
- Neoprene Fabric: $14.72 /unit
- Sewing Materials: $3.50 /unit

Break-Even Quantity = Fixed Costs / (Selling Price - Variable Cost per Unit)

Break-Even Quantity = (1950 + 103200 + 62796 + 29.99) / (49.20- 24.99 + 5.99 + 14.72 + 3.50)

Break-Even Quantity = 3470

Therefore, you must use an NPV analysis to compare costs and profits over multiple years based on present value. Draw two cash flow diagrams of the expenses and incomes for the next three years. Calculate the NPV value of each expense/income and determine the differences and then the break-event point

PV of Income in First Three Years of Operation

PV of Expenses in First Three Years of Operation

Year 1

NPV Income = 19500/(1+0.04) = 18750

NPV Expense = (167975.99+14760)/(1+0.04) =175707.70

Total = $-156957.682692

Year 2

NPV Income = 32500/(1+0.04)^2 = 30048.08

NPV Expense = (167975.99+24600)/(1+0.04)^2 = 178047.33

Total = $-147999.25

Year 3

NPV Income = 45000/(1+0.04)^3 = 40004.84

NPV Expense = (167975.99+34440)/(1+0.04)^3 = 179947.08

Total =-$-139942.24

At this rate of selling an increase of 200 collars each year it will take roughly 20 years to break even. In the 20th year the number of collars that will be sold is 4000.

https://www.businessresearchinsights.com/market-reports/emergency-cervical-collars-market-112000

4.2 Intellectual property report

Intellectual Property 1-Utility Patent

link: https://www.freepatentsonline.com/9289320.pdf

US patent number 9289320. It is similar to an early cervical collar concept the group came up with and to put it into simple terms, is an inflatable cervical collar. This patent is for the design of the collar, including the different attachment mechanisms and support components. The patent claims ownership and exclusive use of an inflatable design which uses a gas and liquid to fill an inflatable pocket, pushing against the user's neck to offer support.

Importance and legal constraints of the patent:

Claims:

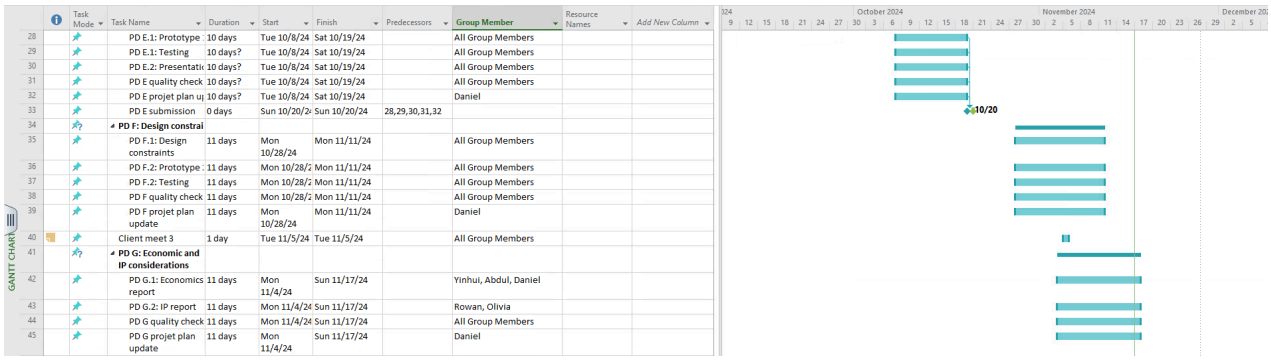
A cervical collar comprised of.

1. A body comprising of a front, back, and sides. with an upper and lower portion that all wraps around the wearer's neck.
2. A connector to attach the front and back.
3. A chin support at the upper portion on the front end.
4. A viscoelastic polyurethane foam lining the chin support.
5. An inflatable pocket on the body of the collar.

From the claims above, the soft cervical collar designed by our group cannot contain any components that are listed under the patent (if the patent is still valid). The current design of the soft cervical collar created by our group does not contain any of the listed aspects, and thus our design is legally viable without worry for copyright.

If we had continued with our earlier design of an inflatable soft cervical collar, our group would have had a legal constraint as inflation for neck support is one of the claimed design components in the patent.

4.3 Project plan update



	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Group Member	Resource Names	Add New Column
28		PD E.1: Prototype	10 days	Tue 10/8/24	Sat 10/19/24		All Group Members		
29		PD E.1: Testing	10 days?	Tue 10/8/24	Sat 10/19/24		All Group Members		
30		PD E.2: Presentati	10 days?	Tue 10/8/24	Sat 10/19/24		All Group Members		
31		PD E quality check	10 days?	Tue 10/8/24	Sat 10/19/24		All Group Members		
32		PD E projet plan u	10 days?	Tue 10/8/24	Sat 10/19/24		Daniel		
33		PD E submission	0 days	Sun 10/20/24	Sun 10/20/24	28,29,30,31,32			
34		PD F: Design constrai							
35		PD F.1: Design constraints	11 days	Mon 10/28/24	Mon 11/11/24		All Group Members		
36		PD F.2: Prototype	11 days	Mon 10/28/2	Mon 11/11/24		All Group Members		
37		PD F.2: Testing	11 days	Mon 10/28/2	Mon 11/11/24		All Group Members		
38		PD F quality check	11 days	Mon 10/28/2	Mon 11/11/24		All Group Members		
39		PD F projet plan update	11 days	Mon 10/28/24	Mon 11/11/24		Daniel		
40		Client meet 3	1 day	Tue 11/5/24	Tue 11/5/24		All Group Members		
41		PD G: Economic and IP considerations							
42		PD G.1: Economics report	11 days	Mon 11/4/24	Sun 11/17/24		Yinhui, Abdul, Daniel		
43		PD G.2: IP report	11 days	Mon 11/4/24	Sun 11/17/24		Rowan, Olivia		
44		PD G quality check	11 days	Mon 11/4/24	Sun 11/17/24		All Group Members		
45		PD G projet plan update	11 days	Mon 11/4/24	Sun 11/17/24		Daniel		

5 Design Day Pitch and Final Prototype Evaluation

PITCH SCRIPT

Thank you for joining us this morning, we are KODAR, and today we are going to be presenting our waterproof and chemically resistant soft cervical collar. You may be wondering, what exactly is a soft cervical collar? It is a medical device worn on the neck after surgery, neck injury, or for a disability. Its main goal is to give the neck support by keeping it held up and stable, all while providing our desired DFX, design for comfort and accessibility.

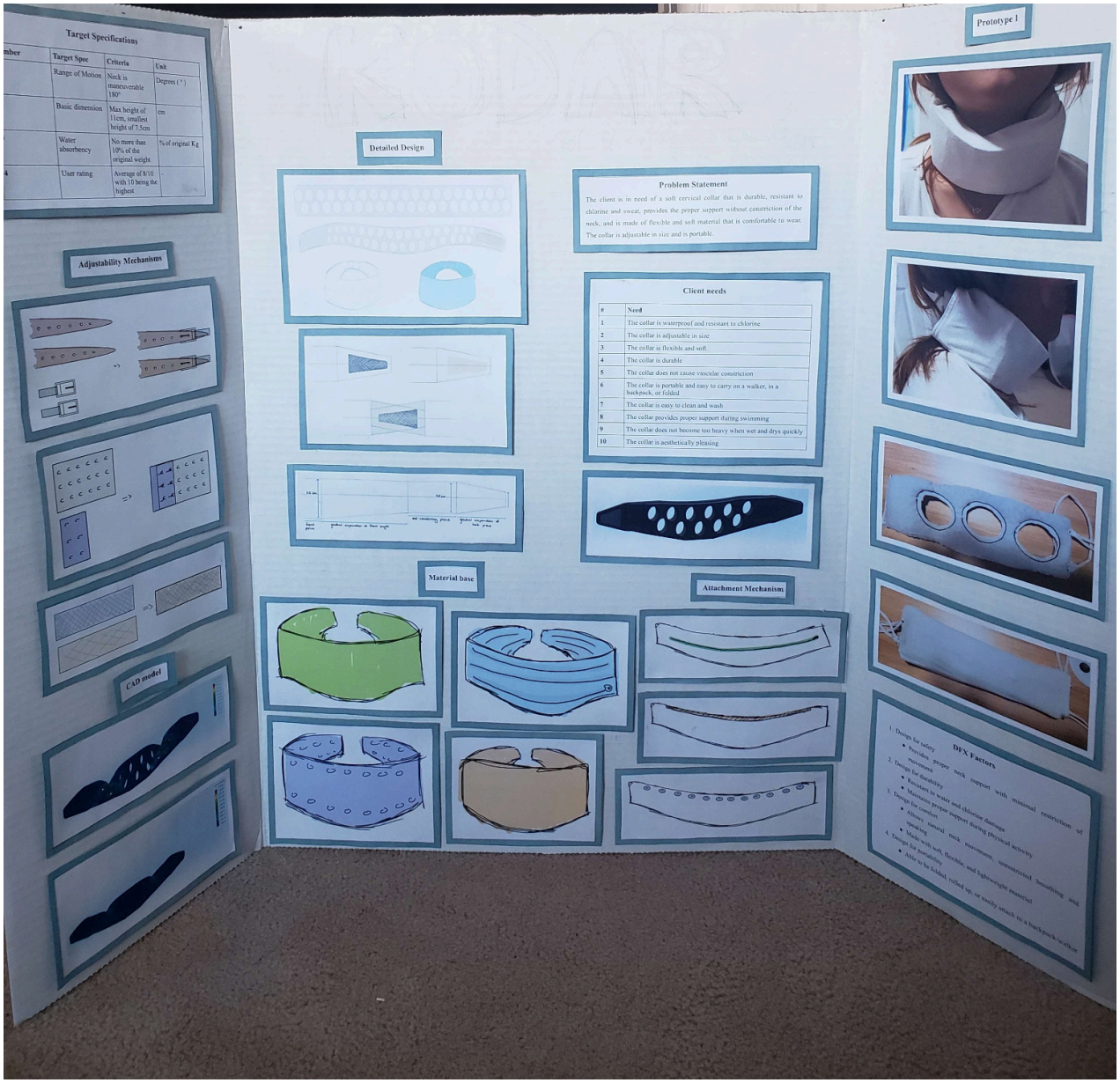
The main requirement that the client asked the collar to meet is water resistance. When it is exposed to water, it should not gain mass via water entering the collar, which will ensure maneuverability for disabled users. Protection against exposure of sweat and chlorine is also to be

included, which will allow it to be washed, as well as swam with while on. Finally, a we set a goal of 180 degrees range of motion which will make daily activities much easier to do.

So, why do we care about this issue? Currently, research and first-hand experience from our client has shown us that soft cervical collars on the market are lacking in durability, as well as usability in water. This problem is really important to solve for us, as it will not only make our client's lives much easier but all of those who are looking for a similar product as well. Our client's story touched us, so it's been our goal since, to develop a durable, functioning solution to bring an end to this problem.

In terms of our actual prototype, this is implemented using a foam base and a synthetic leather cover that was sewn on. This material allows the collar to not absorb too much water and remain close to its initial weight. The adjustability mechanism used was a velcro as its easy to use for people with limited dexterity. As you can see multiple adjustability mechanisms were considered such as a belt buck style and buttons but the client expressed their difficulty using these. Initially we had planned to use silicone as our base and have holes in the collar for breathability but after running a few tests we realized this would deform the structural integrity. Removing the holes wasn't a problem though since we opted out of using silicone due to it being rigid and difficult to work with. Using foam allowed the collar to be breathable and soft while the cover acts as the water resistance.

Thank you for listening to our presentation. Do we have any questions?



2 Sentence Summary:

Summary: Water and chemically resistant soft cervical collar made to withstand physical activity while competing with existing solutions in comfort. Intended for users with a neck disability.

Questions most likely to be asked

- What material is this - Leatherette, faux leather (can be described as similar material to school bus seat)

As a group, you will prepare a 3-minute pitch which you will deliver to judges, fellow students, professors, potential users/customers, and anyone else who may stop by on Design Day to check out your work. **You should also be prepared to answer questions related to your final prototype**. Your project and final prototype will be judged (based on the provided judging form) by a group of users/clients/professionals who will provide you with 3 minutes to pitch your final prototype and 5 minutes to answer questions. Specifically, you should be prepared to:

1. Explain why the problem is important ("*So What?*"). This will require some **research** and **rehearsal**. You need to be very crisp and clear about what problem you have solved and what work you have done.
2. Explain the basic user requirements and why solving the problem is important ("*Who Cares?*"), as well as **current solutions and alternatives**.
3. Explain the differentiation in your design or the key aspects that make your final prototype better than other solutions on the market ("*Why you?*").
4. Provide a demonstration of your functional final prototype **in action**.

6 Video and User Manual

6.1 Video pitch

Add link to video.

6.2 User manual

See separate template for the user manual. Do not write the content here.

7 Conclusions

Summarize your lessons learned and your work related to your project. Discuss any outstanding issues or implications for the project.

8 Bibliography

Insert your list of references here.