

Soft Robotics

for Alpine Skiers

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**Design Studio IV
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Alpine Skiing Sport Overview

- For each discipline of the sport, a course is created using red and blue gates made of two poles connected by a banner stretched between them.
- The skier must ski around all the gates in the prescribed order to keep from being disqualified.
- Downhill speed events challenges the skiers skill in speed and requires the athlete to be as fast as possible.
- Technical slalom events challenges the skiers maneuverability.

Alpine Skiing Protective Equipment



Race Helmet

- Protects head, ears, and chin.



Goggles

- Protects eyes against weather, glare and the effects of speed on the eyes.



Downhill Speed Suit

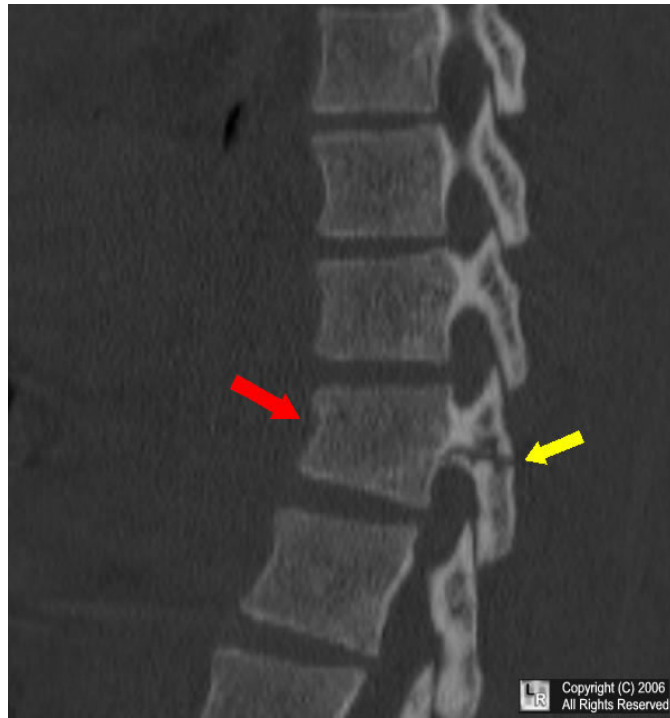
- Skin tight performance enhancer.
- Provides protection from elements.
- Designed for speed events.
- Not padded.
- Can be worn for Slalom events but requires skier to wear separate body armor.



Slalom Suit

- Designed for technical events.
- Padding is either sewn into suit or removable.

Common Spine Injuries Within Alpine Skiing



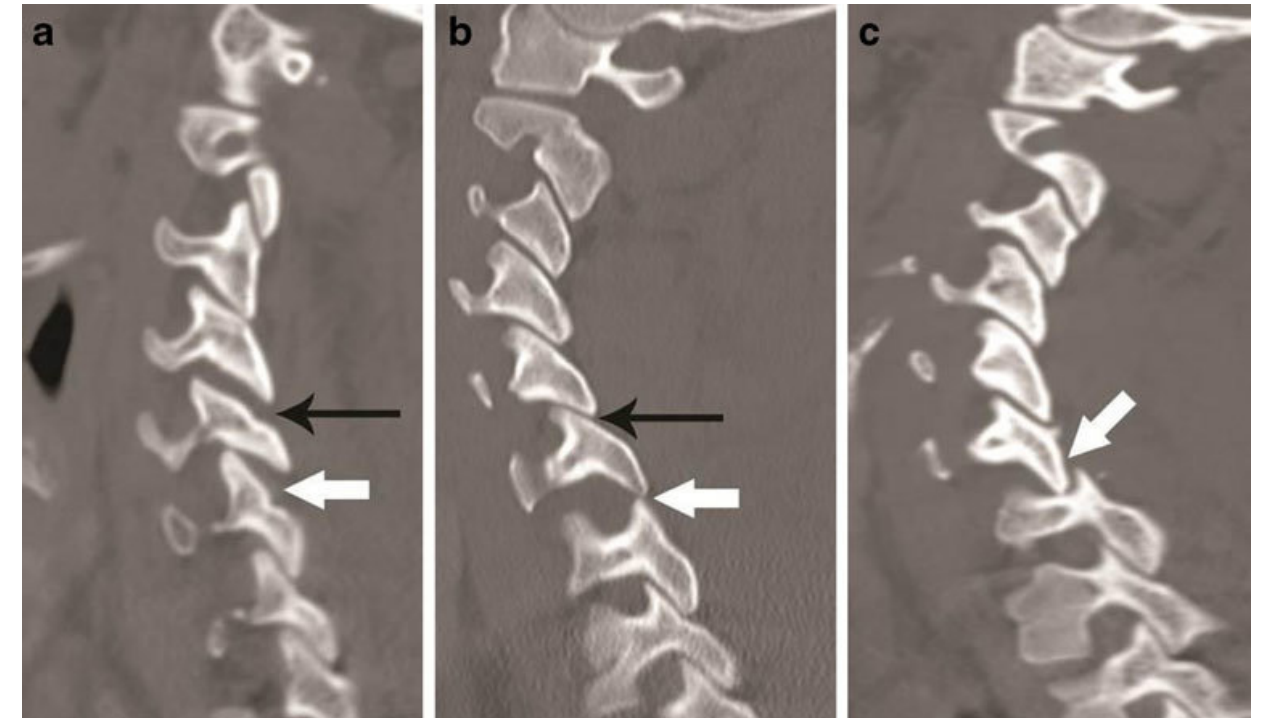
Thoracic Spine Injury, Chance Fracture

- Located in the upper and middle part of the spine.
- Occurs when the athlete hits a fixed object or makes a quick sudden movement.
- Possible related abdominal injuries.



Lumbar Spine Injury, Burst Fracture

- Located in the lower part of the spine.
- Occurs when the athlete lands hard on their feet or buttocks and the force is transmitted up their spine
- Can cause nerve damage and paralysis



Hyperflexion / Hyperextension Injury

- Occurs when spine is extended beyond its normal capacity

Market Analysis



Spine VPD Air Vest

- Vest Format.
- VPD (Visco-Elastic Polymer Dough).
- Malleable.
- When impacted the material stiffens and has extreme impact absorption properties.



POC VPD System Back

- Harness Format.
- VPD (Visco-Elastic Polymer Dough).
- Malleable.
- When impacted the material stiffens and has extreme impact absorption properties.



Ortovox Clasp Spine Protector

- SAS-TEC Foam.
- Remains soft in case of slowly increasing forces.
- Heavy impacts, the resistance of the foam grows with increasing speed.



Pro-Armor G2

- Expanded Nitrile Rubber.
- Breathable.
- Slides into jacket or backpack.



Klim D30 Viper T5

- D30 Material (Visco Elastic Polymer)
- Extremely Flexible
- Slides into jacket

Design Brief

Problem:

While professional and collegiate alpine skiers should wear sufficient spine protective equipment, often they do not. For skiers to effectively perform in downhill speed and technical disciplines they need to have full range of motion with their body. By not wearing proper protection they are sacrificing the safety of their body. Some protective equipment reduces their maneuverability due to the equipment's tight fitting and restrictive properties, this can be seen in some spine protection. The problem that will be addressed in this project is to effectively protect the skiers spine without decreasing their maneuverability.

Objective:

The objective is to develop a new piece of protective equipment for skiers that will prohibit injuring the spine from T1 to L5 (middle to lower back) by prohibiting the spine from hyperextension and hyperflexion as well as provide impact protection.

Hypothesis:

The use of this protective equipment would protect the athlete's spine from impacts at highspeeds, then this will prevent the spine from hyperextension, hyperflexion, and fracture while competing.

Research Precedent:

Downhill skiing is a very popular international sport. Alpine skiers are known to develop serious health issues to the knees and back.¹ Alpine skiers can develop lower back and spine issues related to blunt force trauma that occurs when training and racing. Thirty five percent of spinal injuries that occur in skiers are of the lumbar section of the spine.²

Currently to counteract these injuries from impacts, hyperextension and hyperflexion of the spine, skiers use foam padding around the back and make sure to properly condition and stretch before and after their events.³

Top Canadian ski coaches agree that the “...designs of commercially available spinal protection devices do not address the commonest biomechanical injury mechanisms (hyperflexion/hyperextension, rotational or axial compression)...spinal protection devices provide no cervical spine protection and provide little support in high energy trauma situations”.⁴

1 Davey, Annabelle et al. “Alpine Skiing Injuries.” Sports health vol. 11,1 (2019): 18-26. doi:10.1177/1941738118813051

2 Bigdon, S.F., Gewiess, J., Hoppe, S. et al. Spinal injury in alpine winter sports: a review. Scand J Trauma Resusc Emerg Med 27, 69 (2019). <https://doi.org/10.1186/s13049-019-0645-z>

3 Bigdon, S.F., Gewiess, J., Hoppe, S. et al. Spinal injury in alpine winter sports: a review.

4 Bigdon, S.F., Gewiess, J., Hoppe, S. et al.

Procedure:

I am going to study and research existing spine protection and materials, interview athletes about their experience with the equipment they use and the sport, as well as ideation and concept development. Next, physical prototyping and continued additional research to further aid the design process. User testing and feedback will provide possible opportunities and information not yet pursued in order to allow skiers to perform at their highest level.

Requirements:

- Comfortable (apparatus does not inhibit or create pain on the user).
- Simple to don and doff.
- Prevent hyperextension.
- Prevent hyperflexion.
- Provides impact protection.
- Provides full range of motion.

User Interview Responses

Do you wear padding? Specifically back protection? If not, why?

All three of my interviewee's wear a back protector almost always and arm and shoulder padding for GS.

How many different types of back protection products have you used? Which one?

Two interviewee's use POC air vest's and one uses a shred flexi back protector. "I have only used one specific type of back protector - POC, but it's pretty old. It's some sort of non newtonian foam".

What protective products do you like? What do you not like?

"I enjoy the foam/gel ones a lot better". More shell like (plating/hard plastic) they they are generally too stiff but don't absorb sweat and doesn't get sticky.

Have you injured yourself competing? How?

"I recently fell by hooking an edge and sliding back first into a tree, jammed my thumb pretty bad and had a contusion on my back that was pretty severe - couldn't walk without significant pain. I also fell a few years ago but slid chest first into a tree. Bruised a few ribs and couldn't breath deeply/ right without pain for about 3 months."

What discipline do you compete in? Do you compete in all of them?

GS/Slalom and Super G.

Which ones and what are the problems?

"It's a pain to wash products that allow you to take the foam padding out because you have to take the foam out and then put it back in". Hard plastic guards crack.

Have you ever injured yourself by hitting a gate?

GS gates can bend around and slap you in the rear of the shoulder where the back protector doesn't cover. Causes welts. "Occasionally you straddle one or two slalom or GS gates".

Does your equipment keep you warm? Too Warm?

"Yes, I usually drop a layer when I wear my GS pads, and the back protector definitely keeps me warm. Only when I over dress do they get uncomfortable".

Do you get bruises from equipment?

No.

How much time does it take to put on your protective equipment?

Fairly quick. Back protector less than 20 seconds, GS pads about 30 seconds.

When you wear padding how restrictive do they feel?

"For the motions of ski racing, I do not feel limited by any of my pads, Slalom hard guards are not restrictive. Back protector is not restrictive. Only the GS pads are somewhat re-

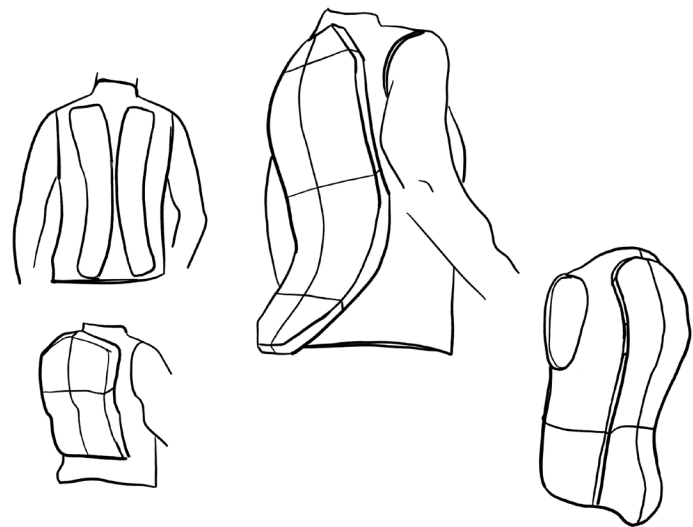
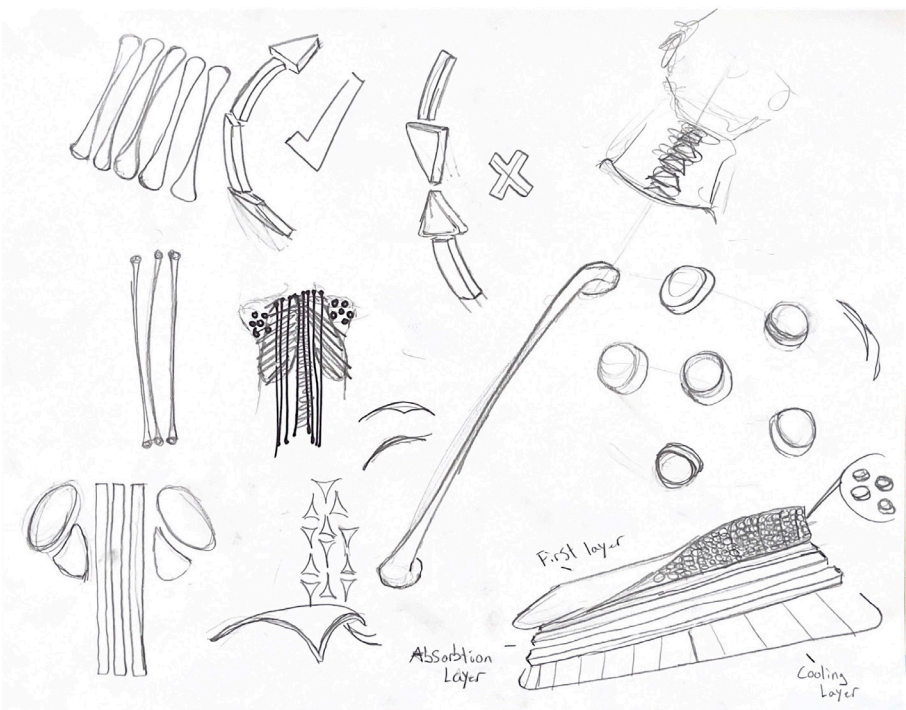
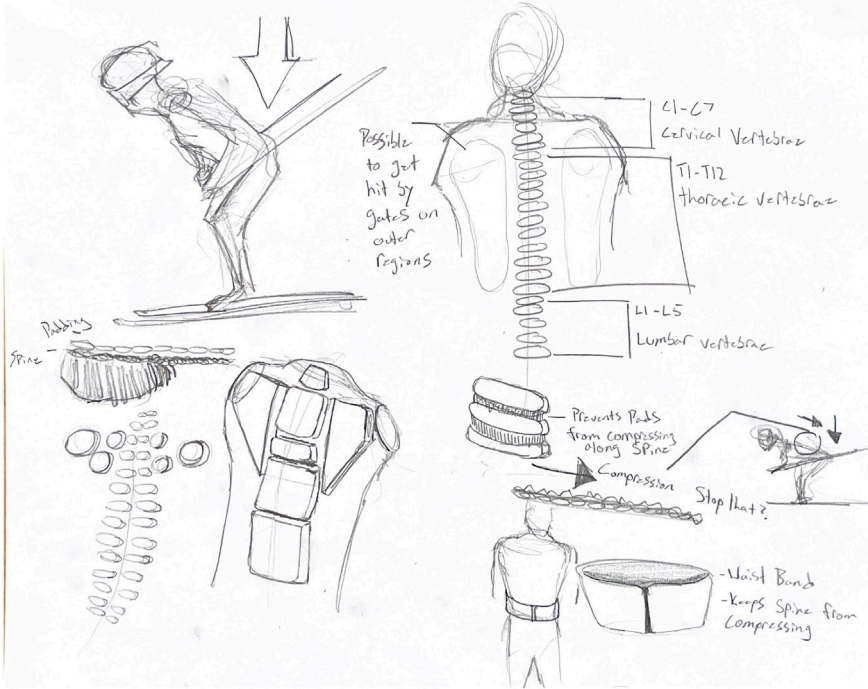
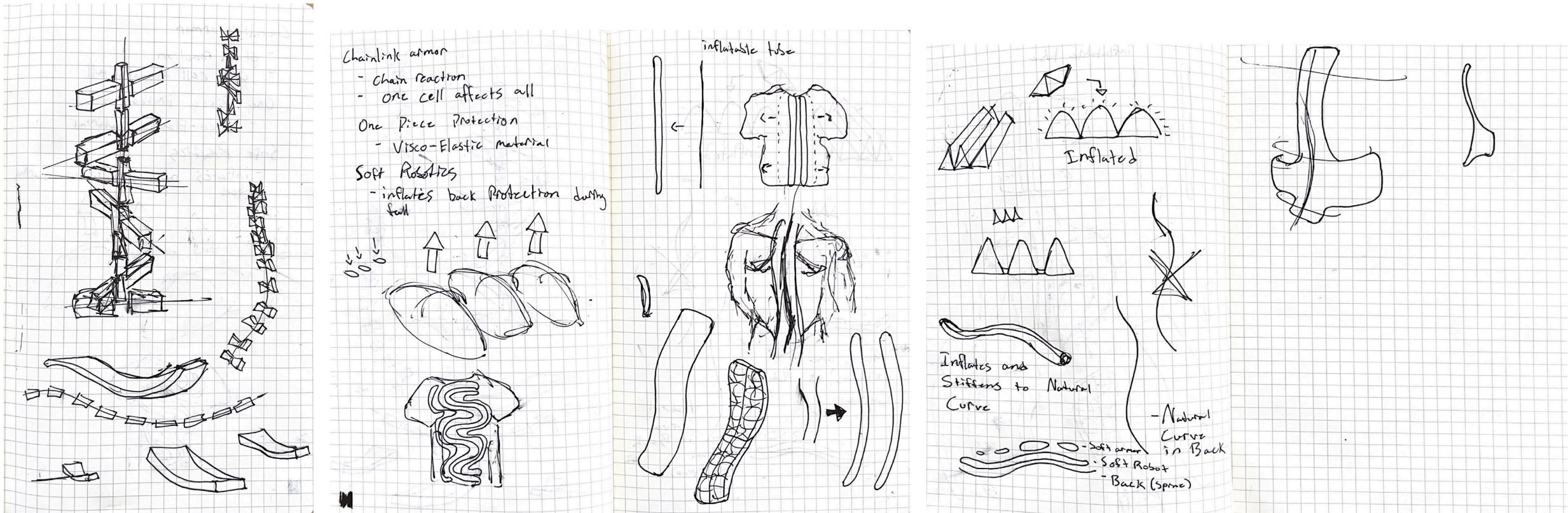
Spine Studies

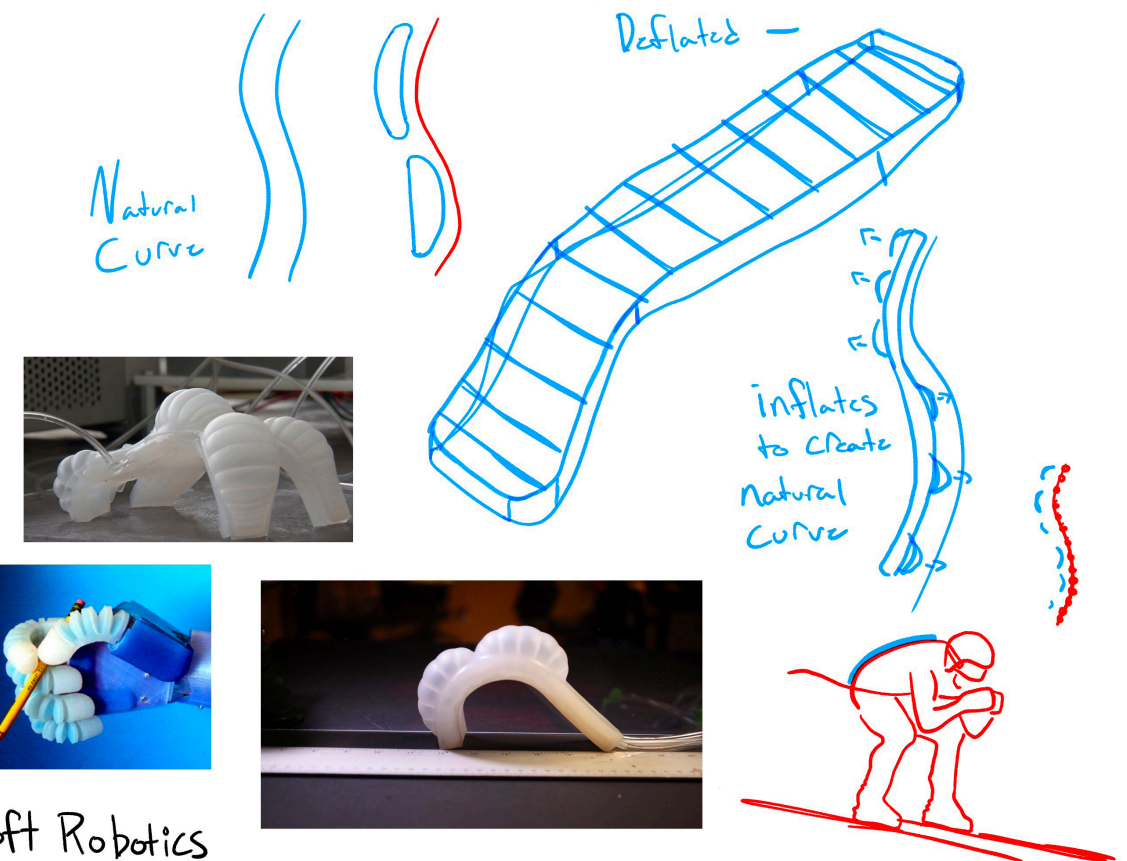




Ideation

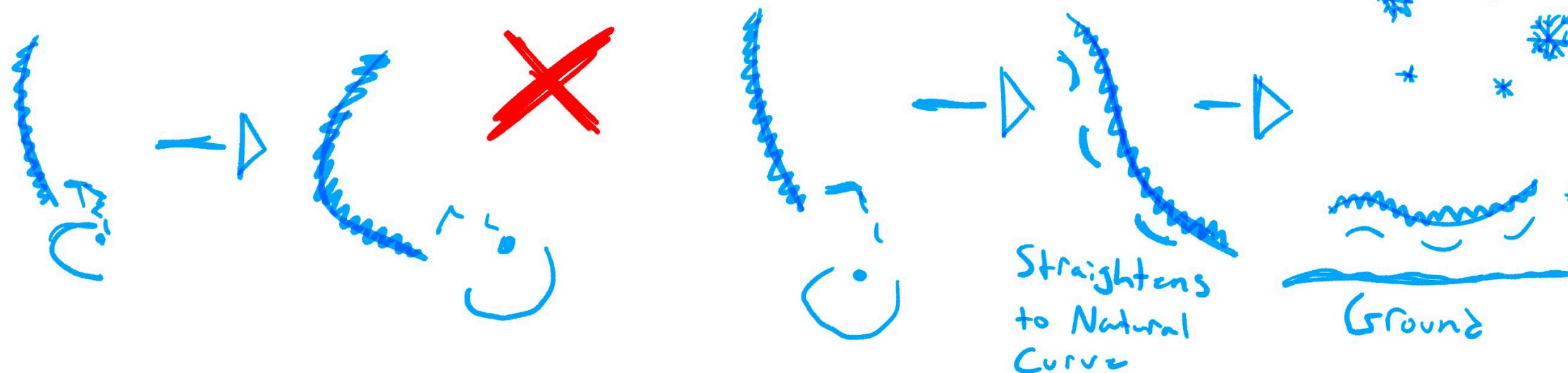
Phase One Exploration





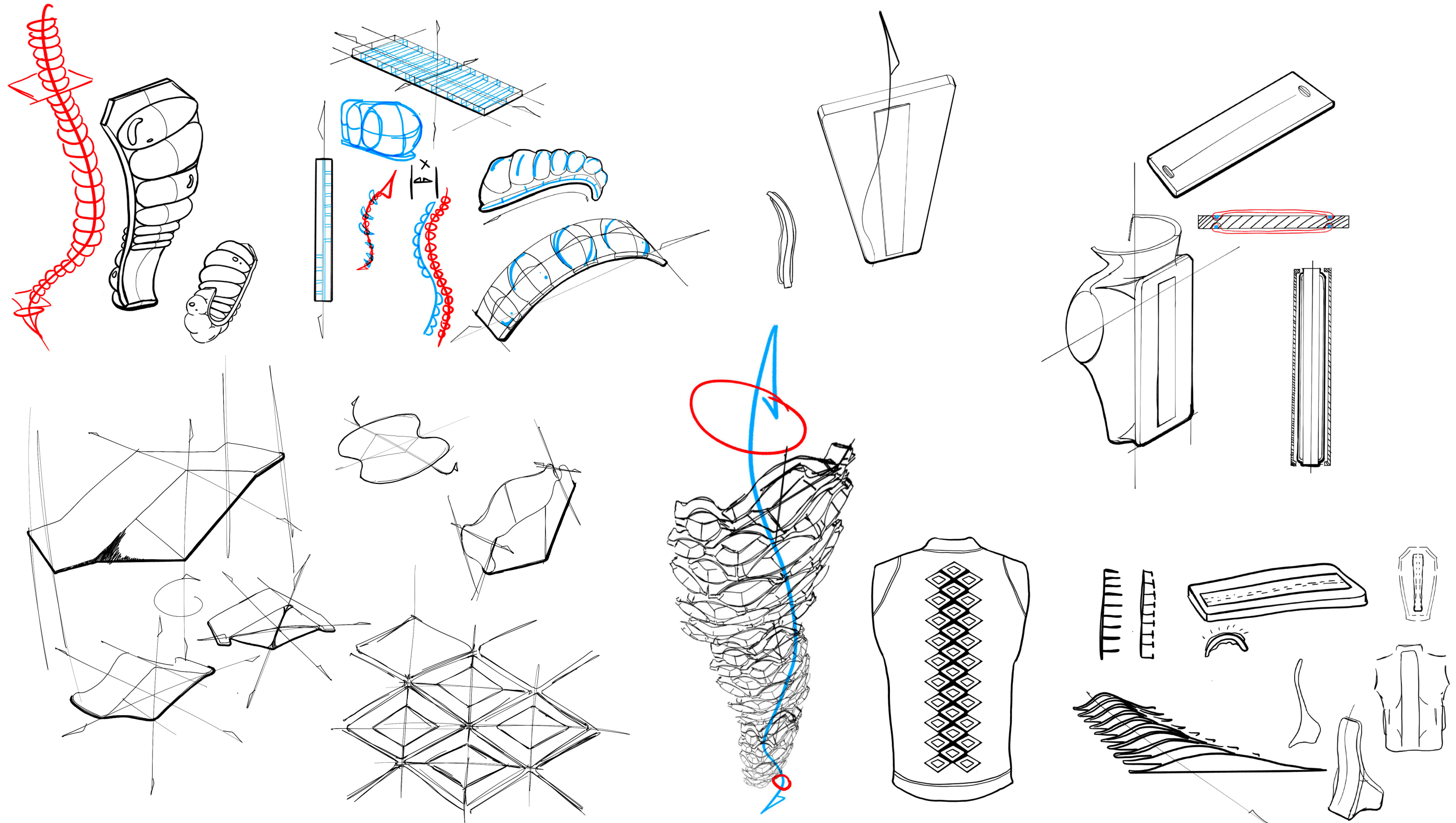
Soft Robotics

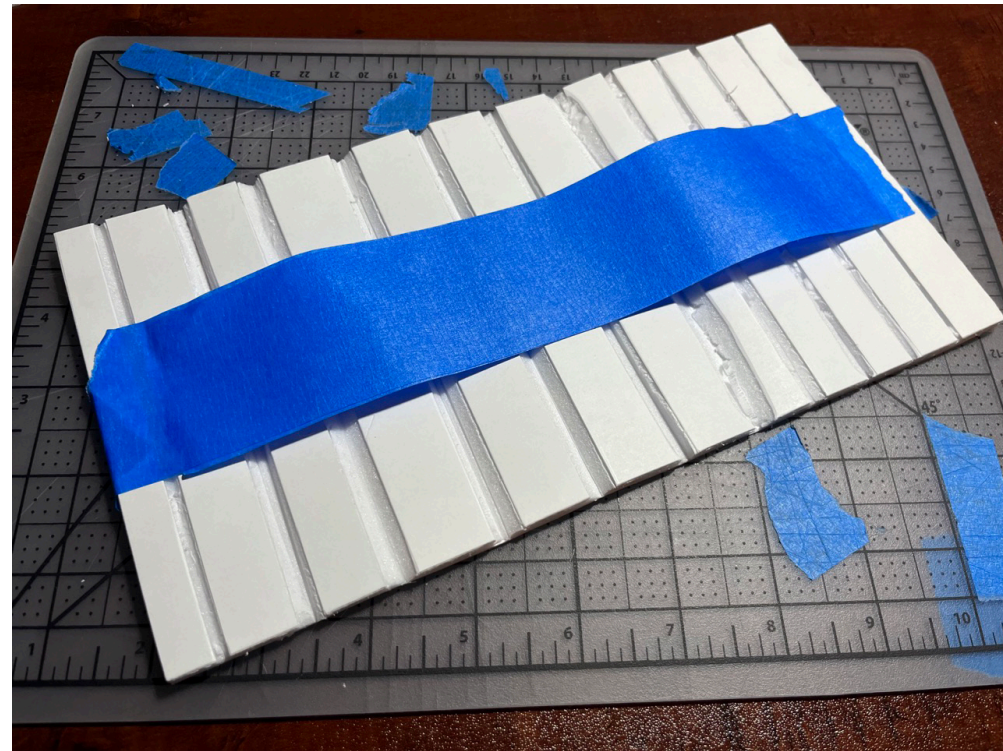
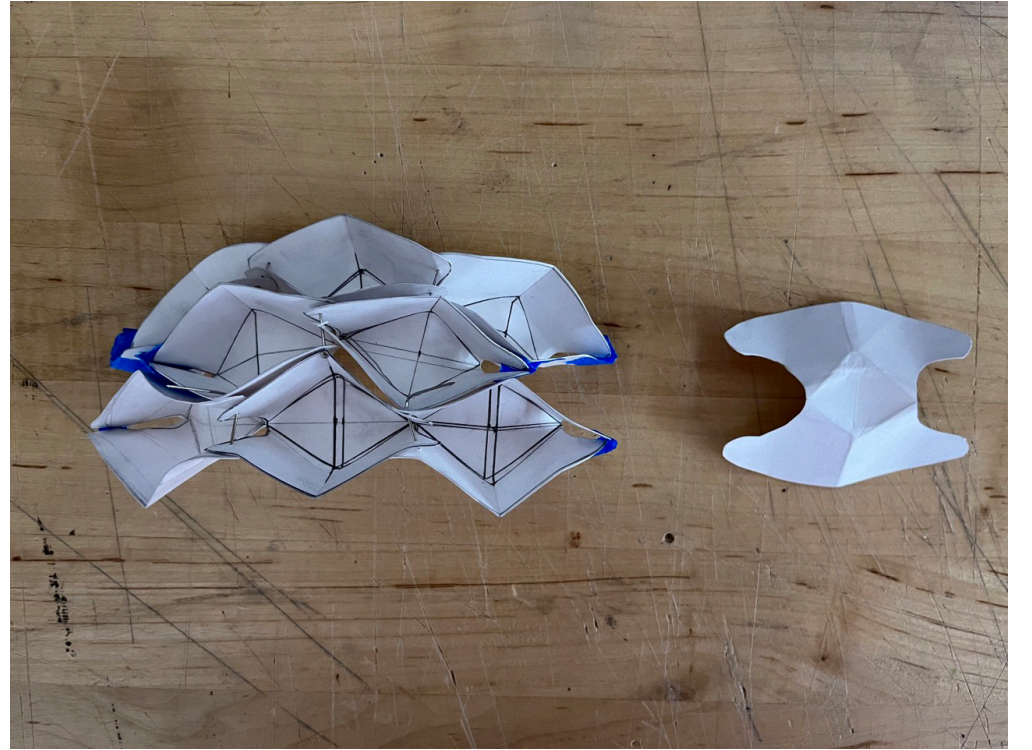
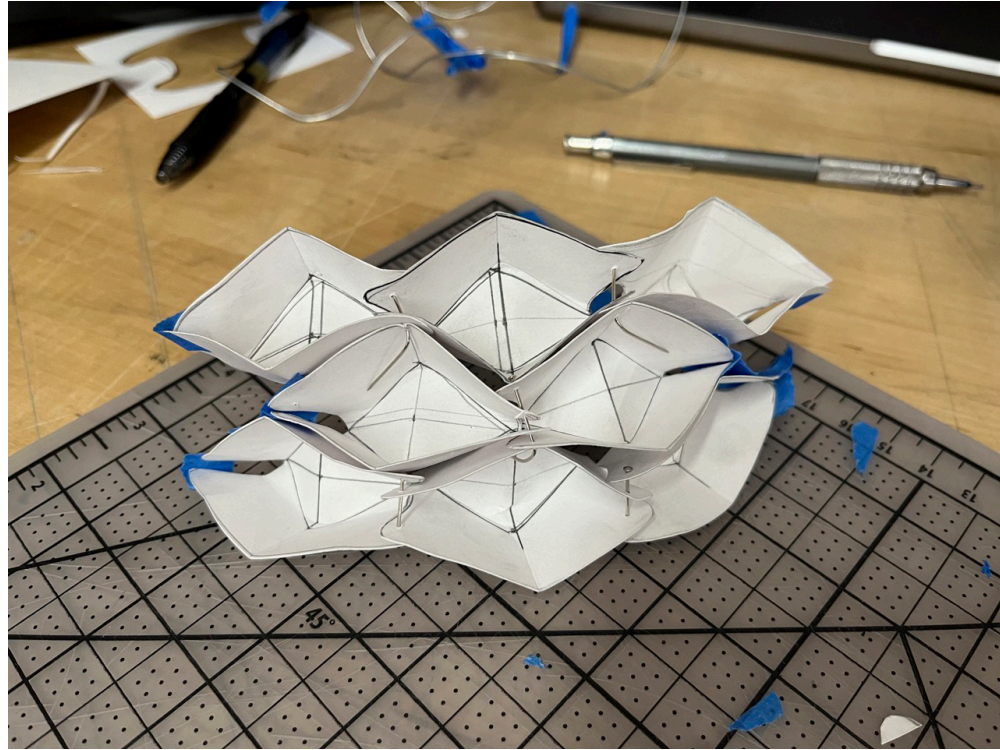
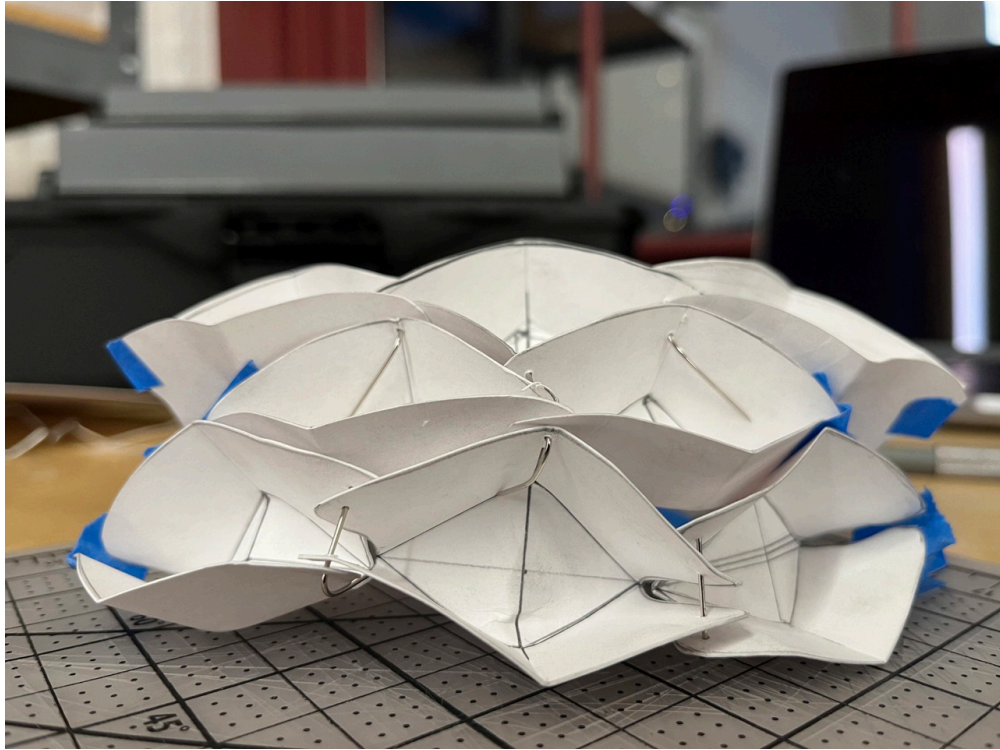
Protection Activates
During Fall



Ideation

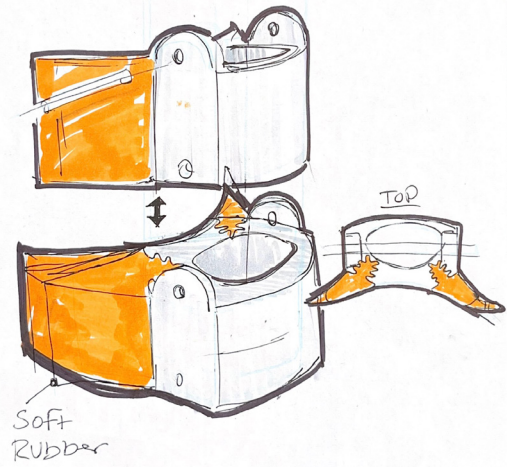
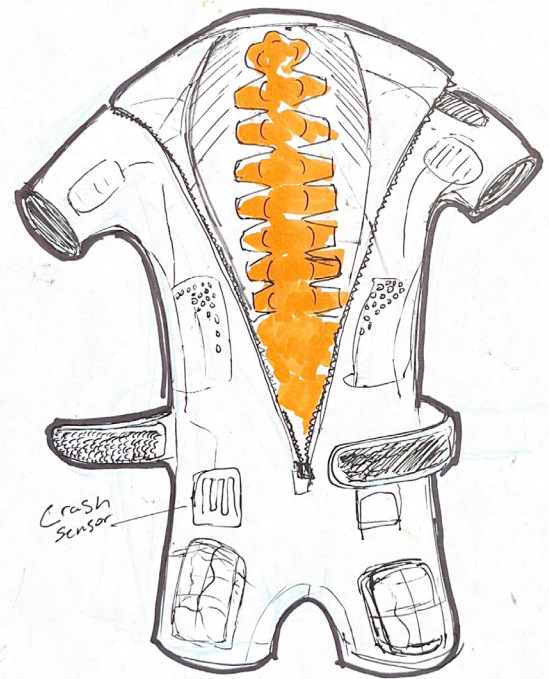
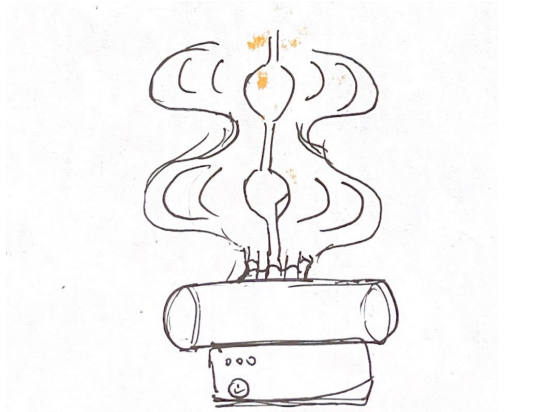
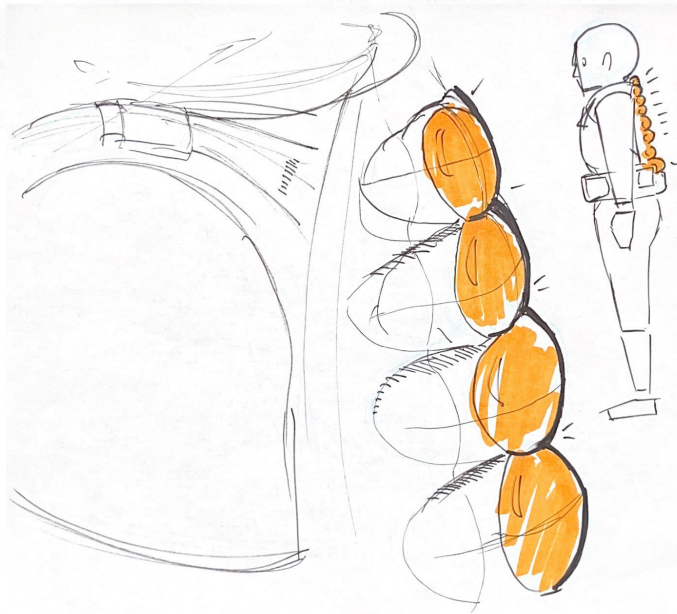
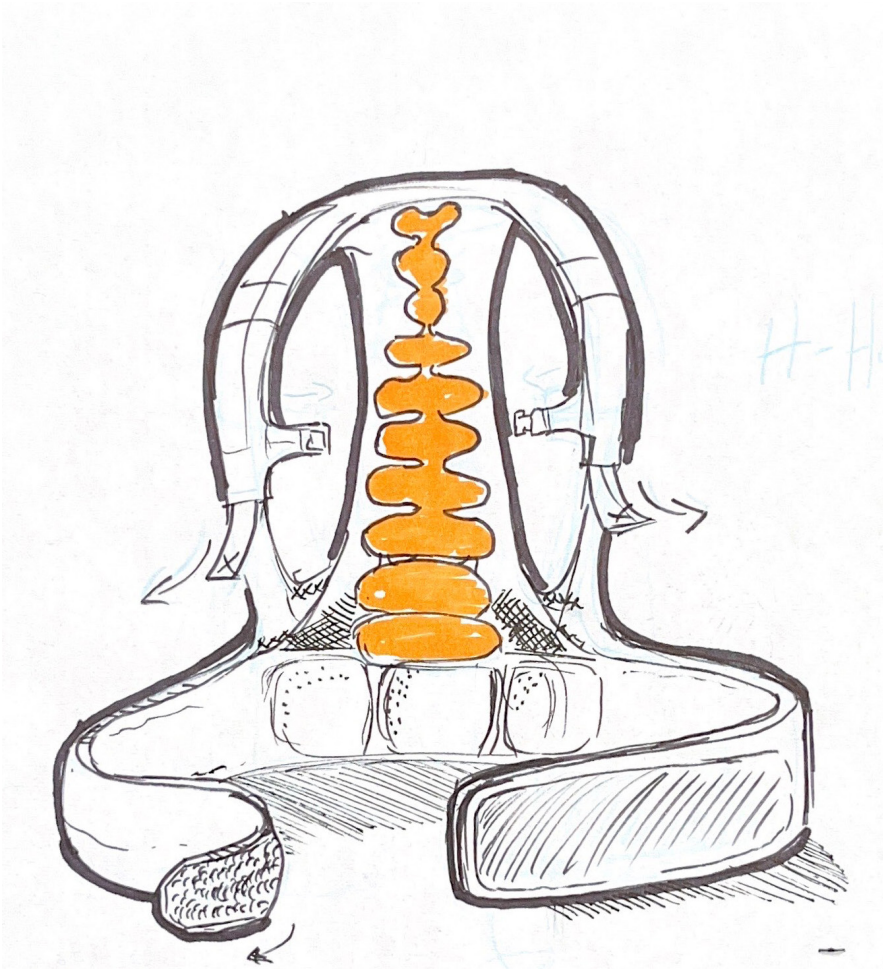
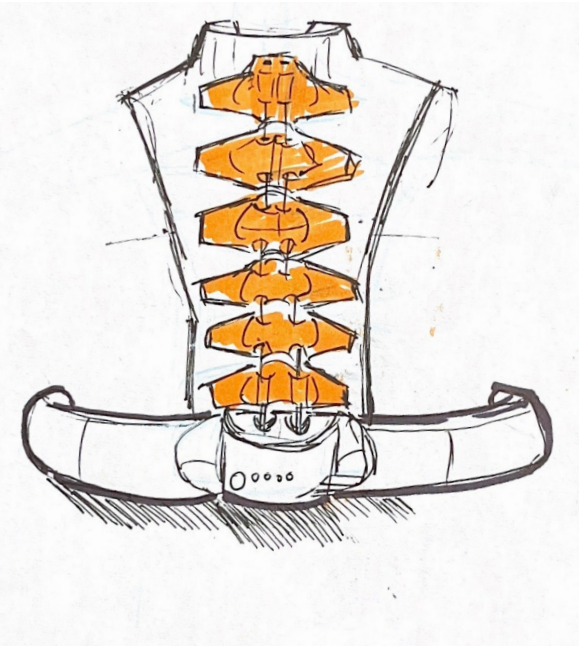
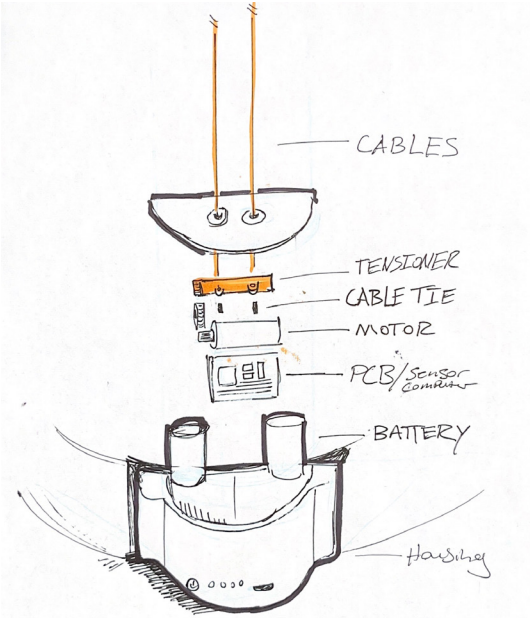
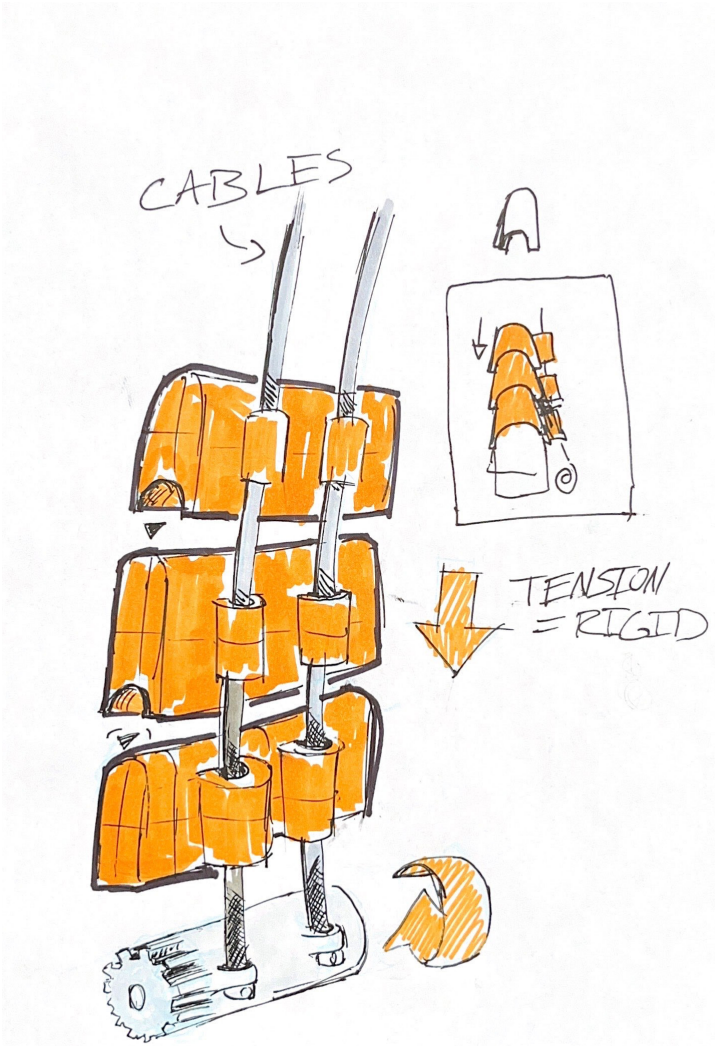
Phase Two Exploration

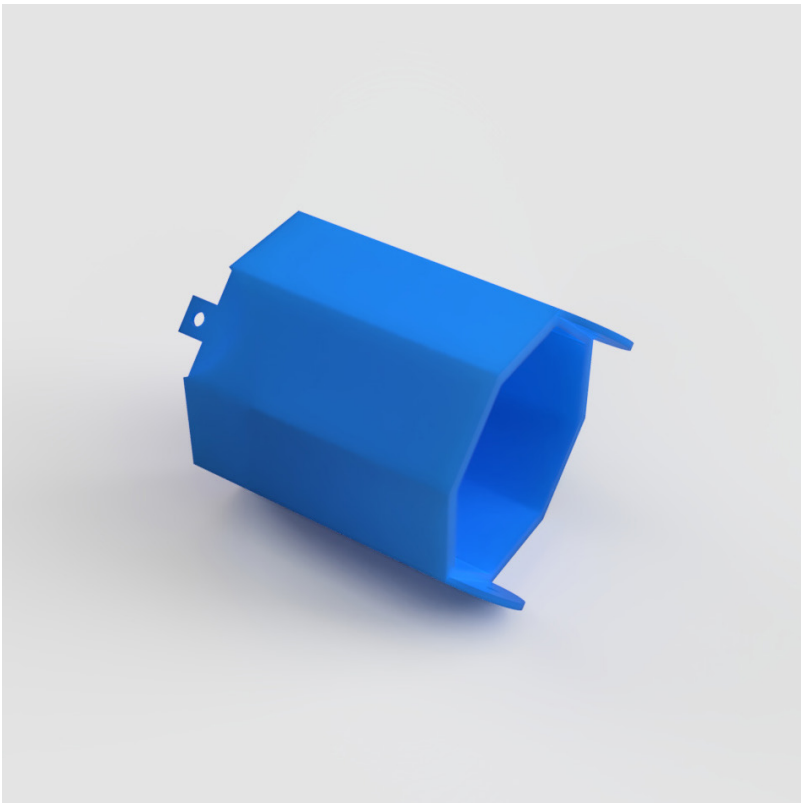
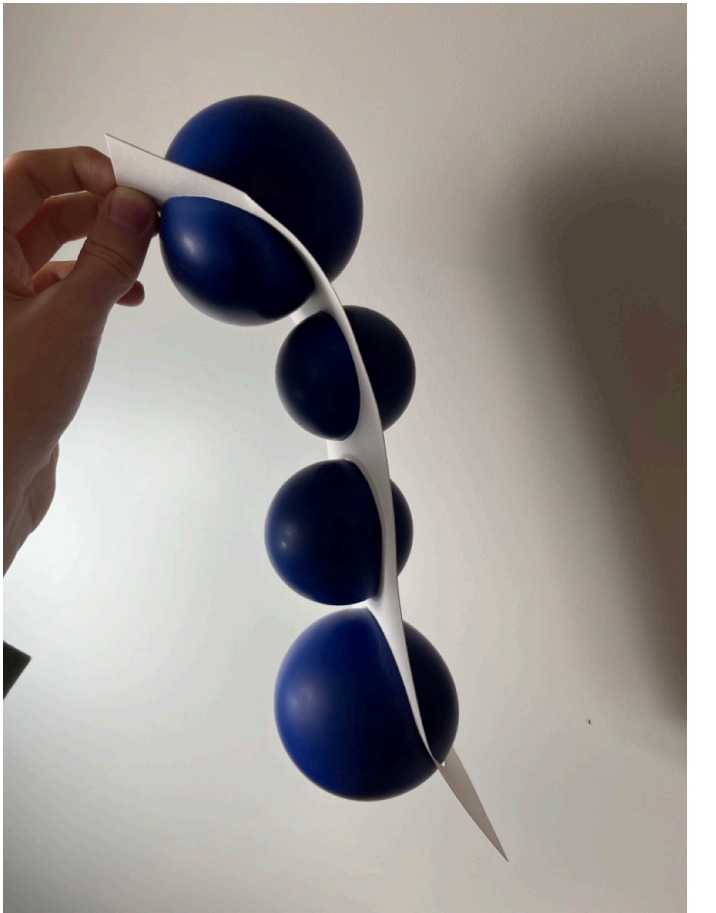
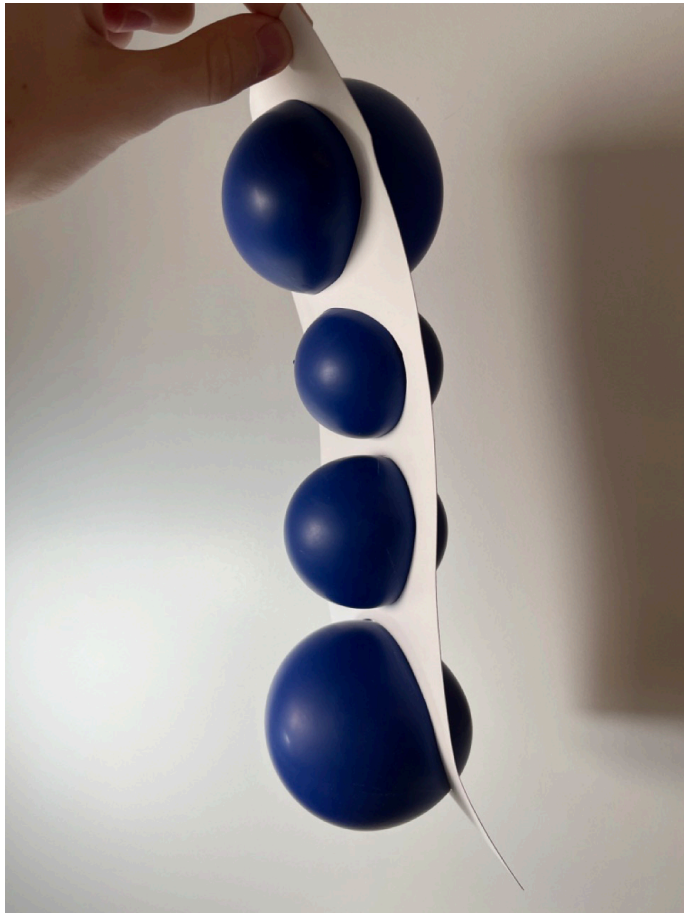
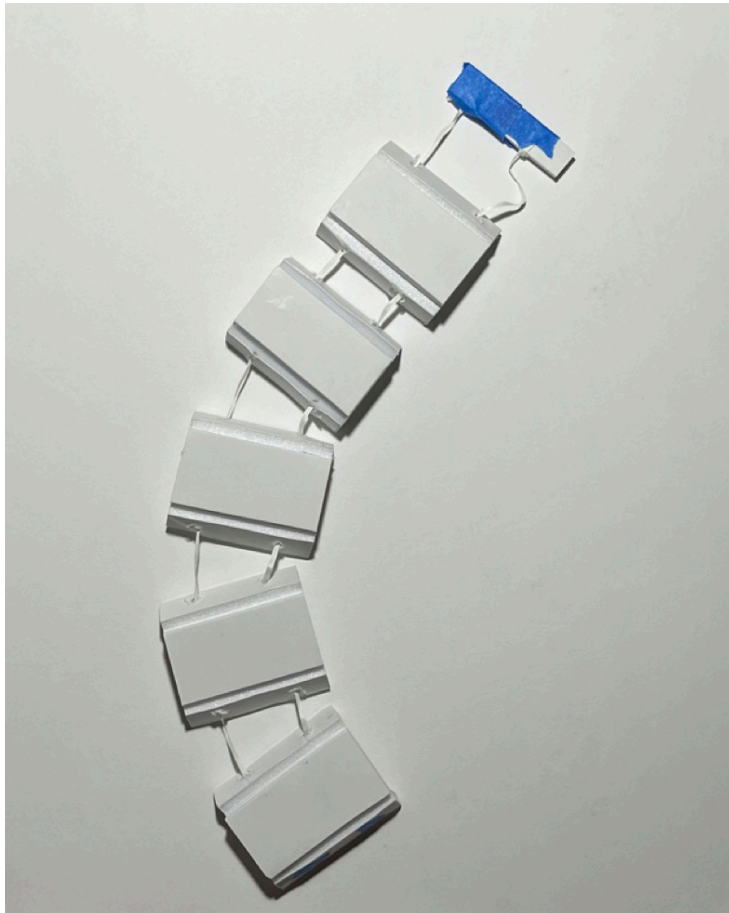
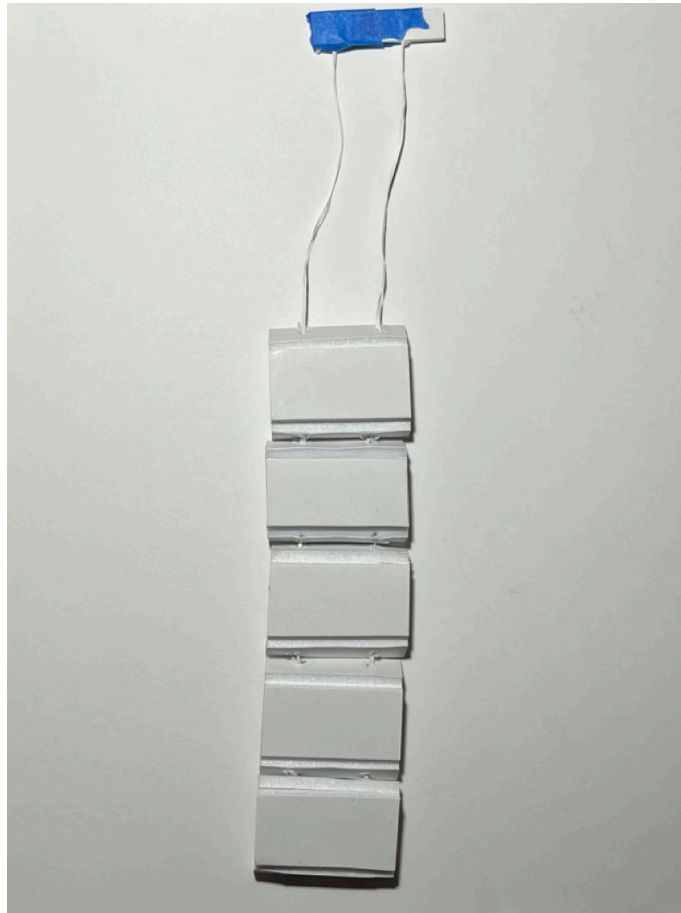




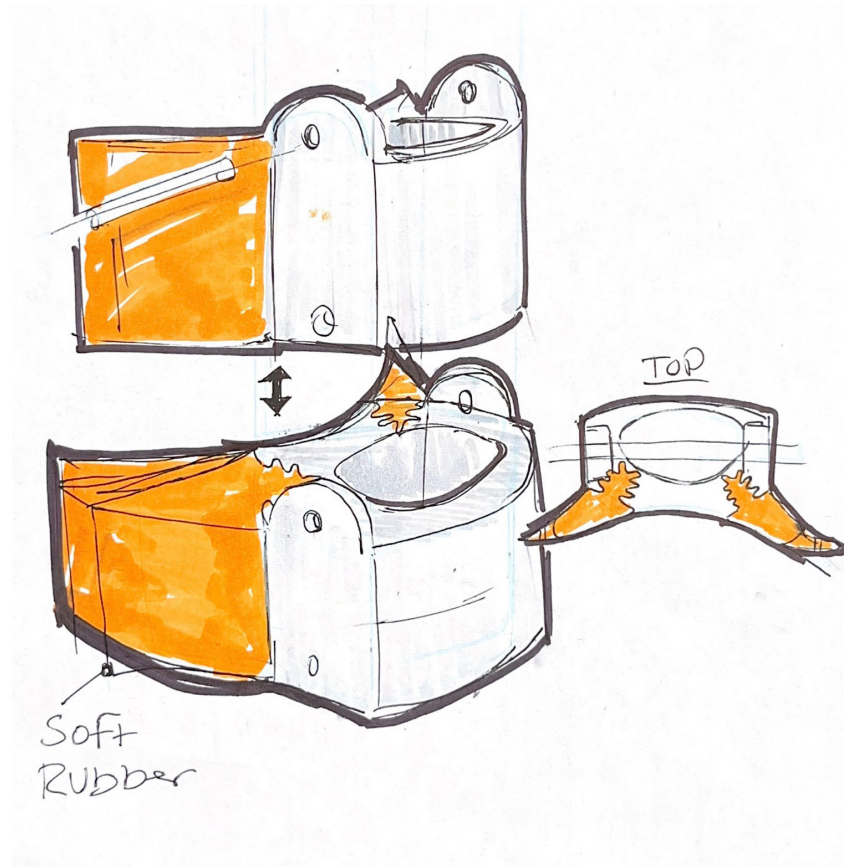
Ideation

Phase Three Exploration



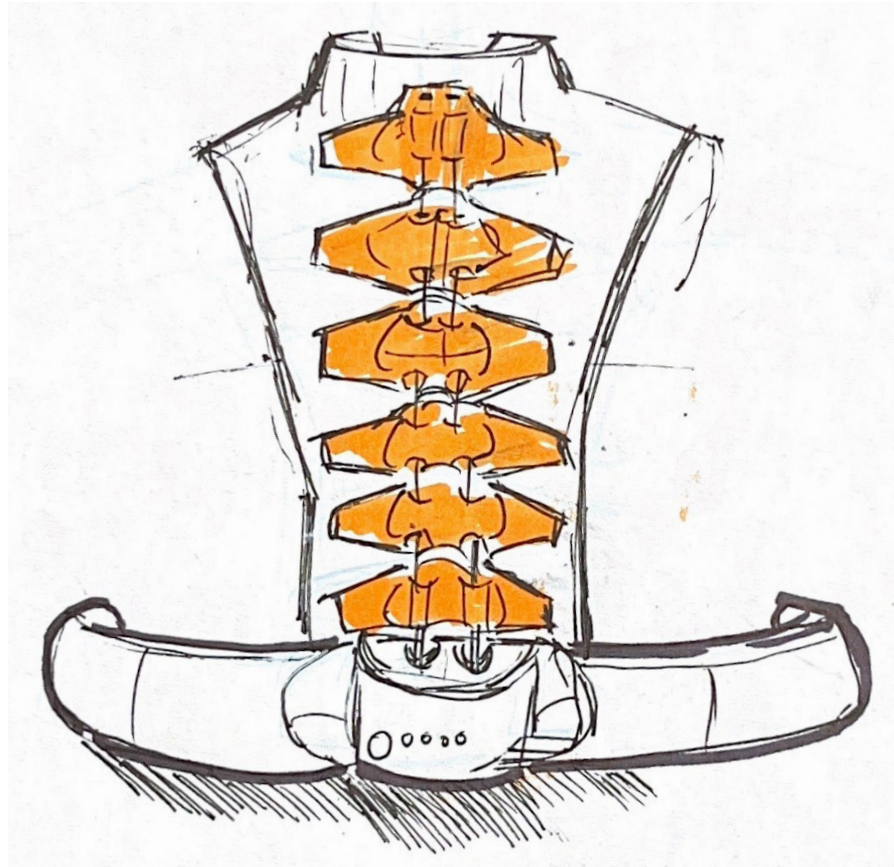


Project Proposals



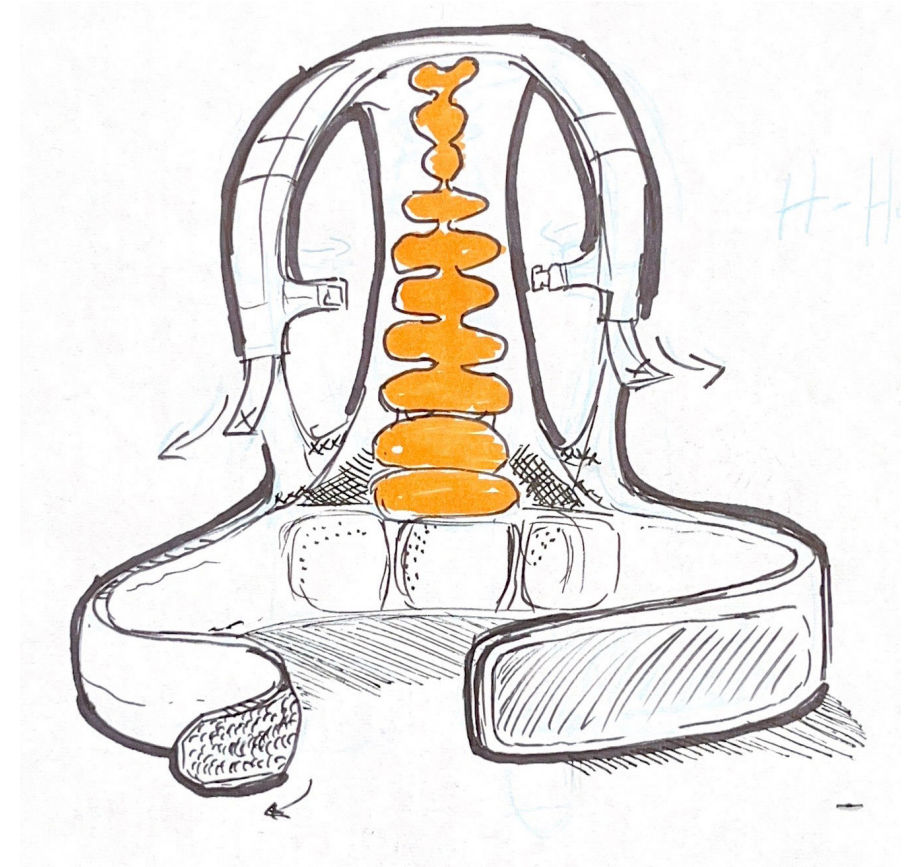
Concept 1: Semi-Rigid Back Brace

- Provides the Least Protection From Impacts
- Prevents Hyperflexion and Hyperextension of the Spine
- Flexible to a certain extent
- Does Not Require Electronics



Concept 2: Vertebrae Cable System

- Provides some Impact Protection
- Prevents Hyperflexion and Hyperextension of the Spine
- Flexible Until Impact



Concept 3: Soft Robotics

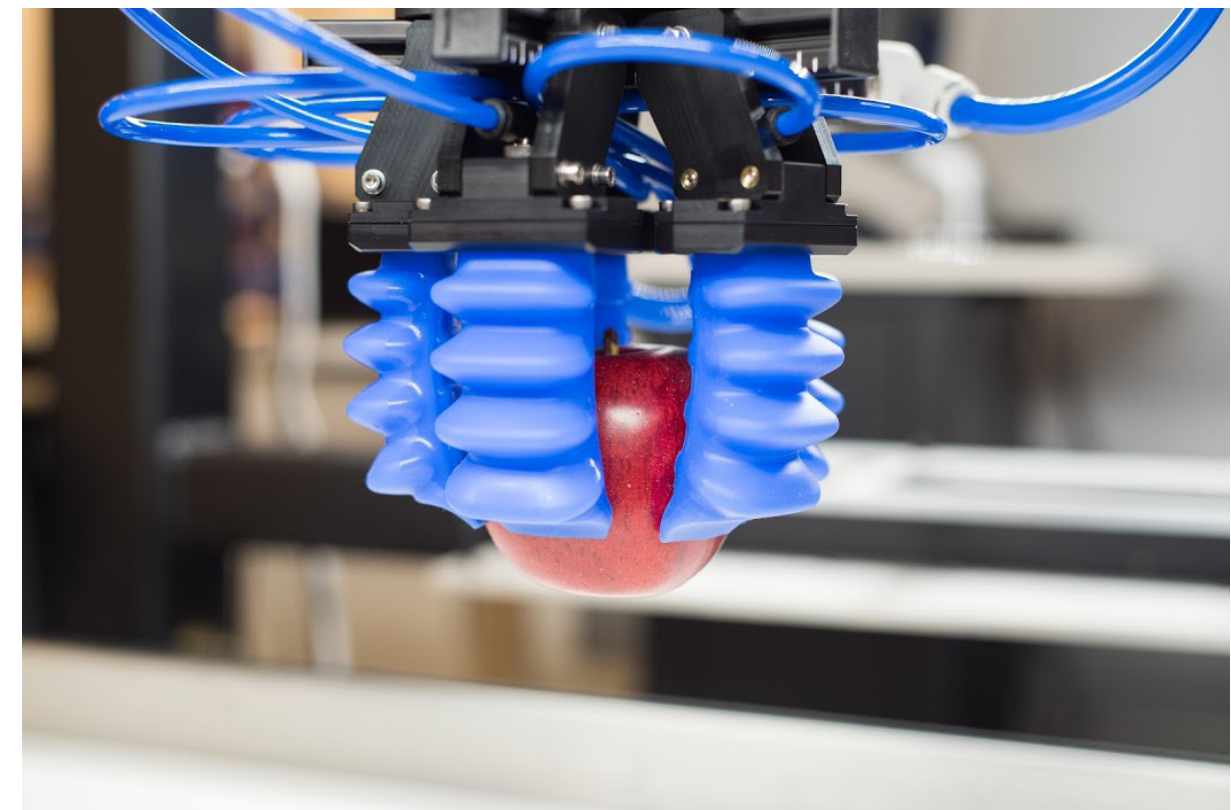
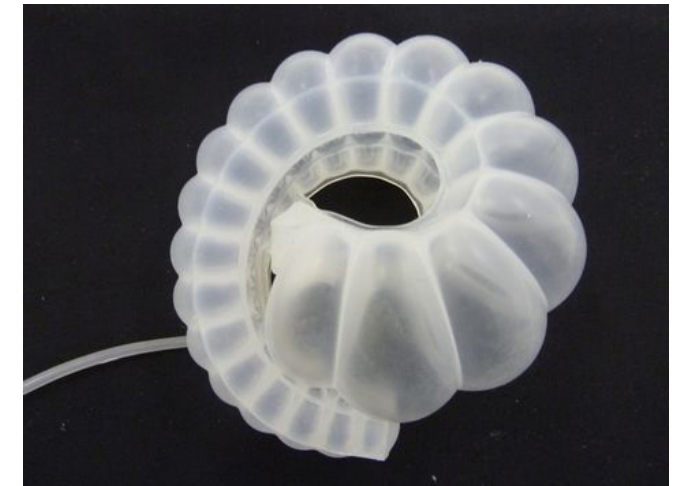
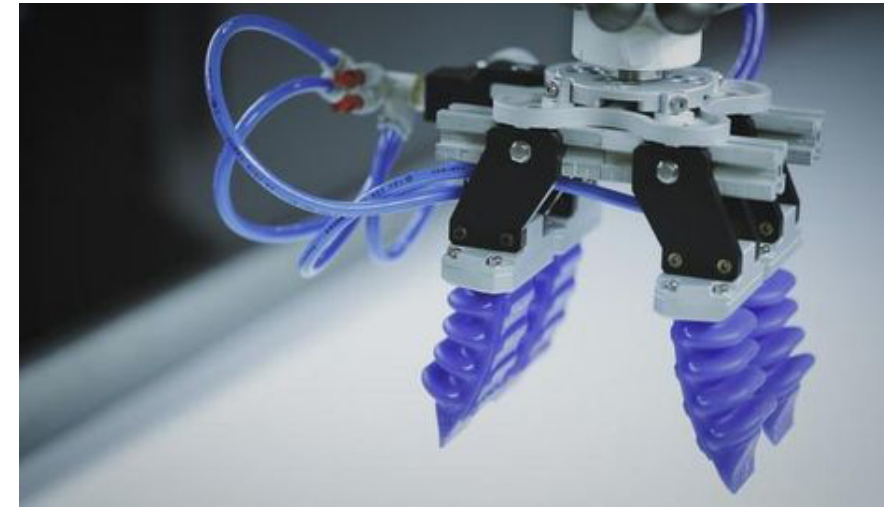
- Provides the Most Impact Protection
- Prevents Hyperflexion and Hyperextension of the Spine
- Flexible Until Impact

Soft Robotics Research

Soft robotics uses compressed air to expand rubber cavities to create a moving armature.

The shape and size of cavities determines how the armature will move as well as the direction it will move in.

Currently soft robotics are utilized in manufacturing and produce environments.



Integrating Soft Robotics to Spine Protection



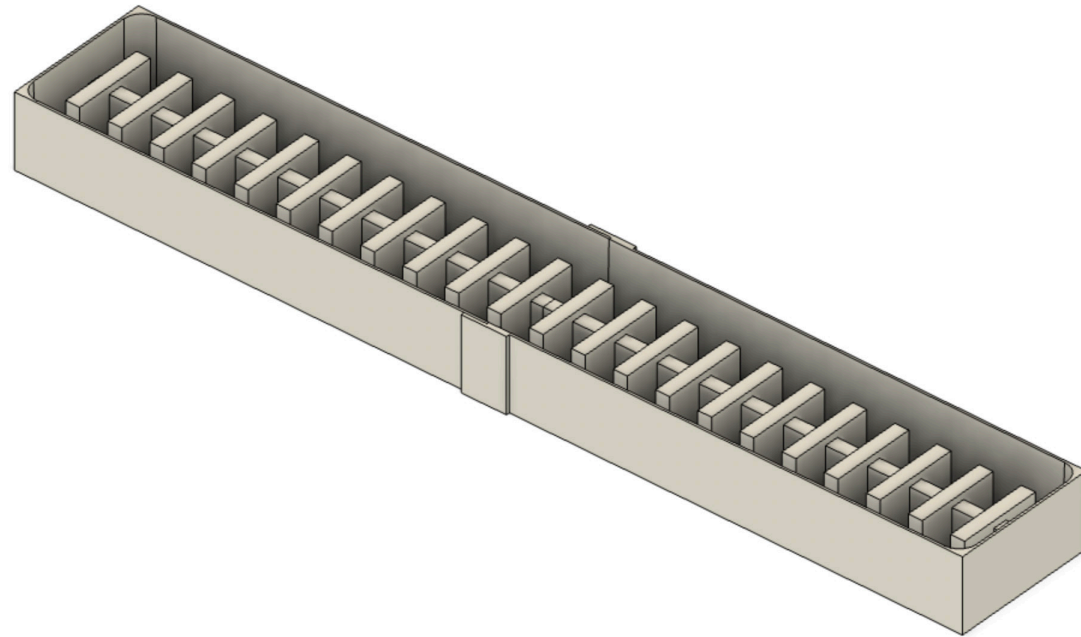
In an event of a fall that could lead to injury, the soft robotic spine protector will activate and prevent the spine from hyperflexion, hyperextension, and provide additional impact protection.



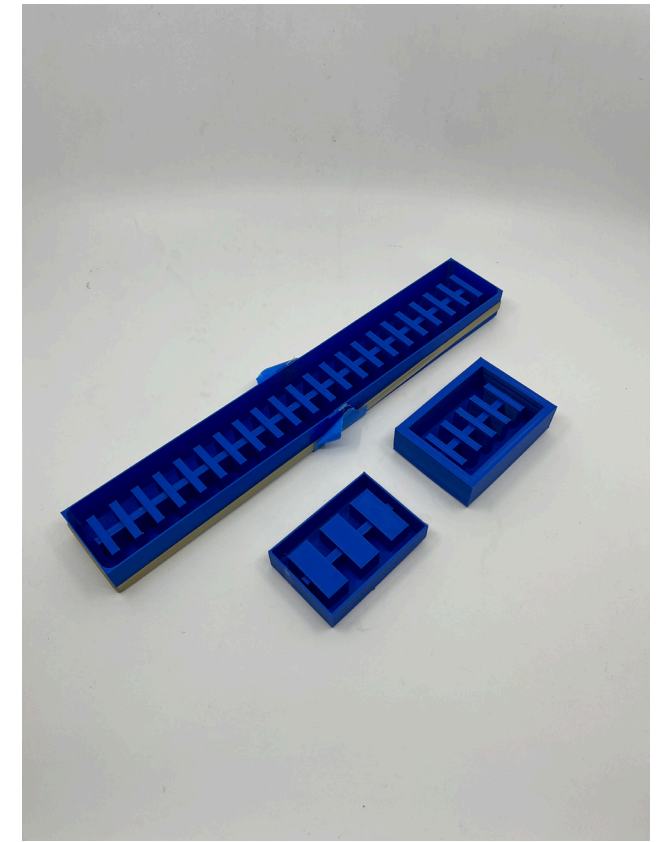
Soft Robotics Development

Mold Making

Mold Making in CAD



3D Printed Molds



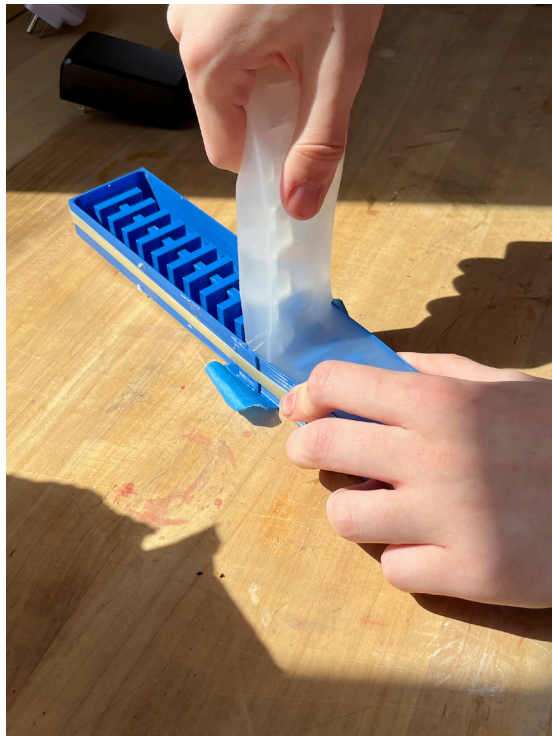
Soft Robotics Development

Mixing & Pouring Uncured Resin



Soft Robotics Development

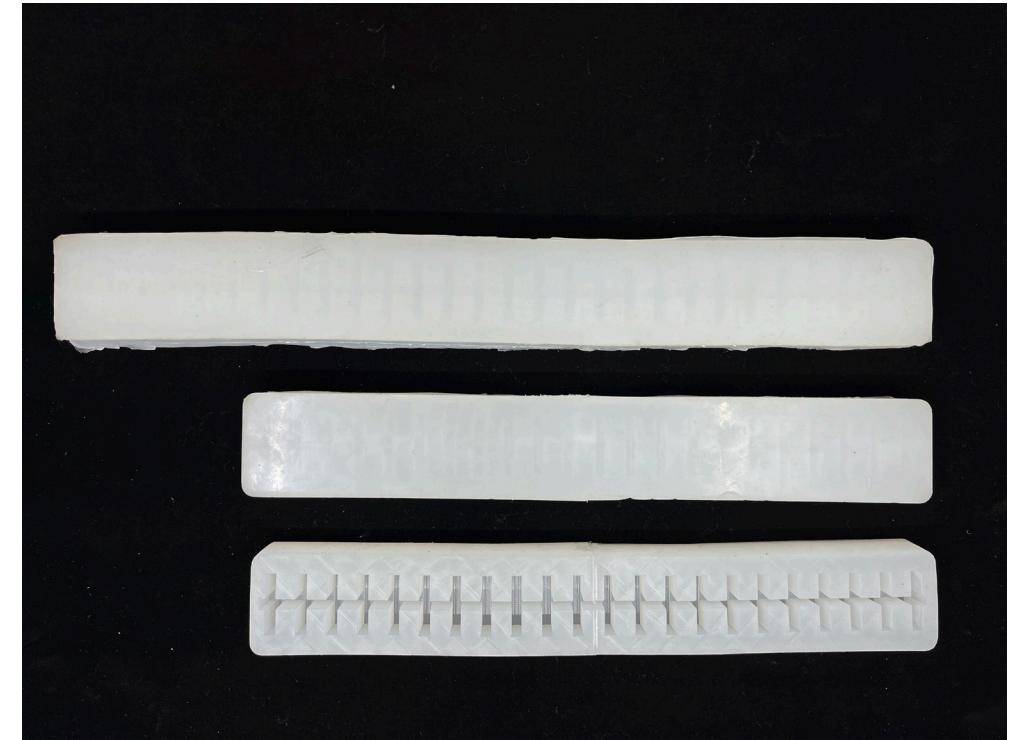
Cast & Cure Two Step Process



Removing Casted Part
From Mold

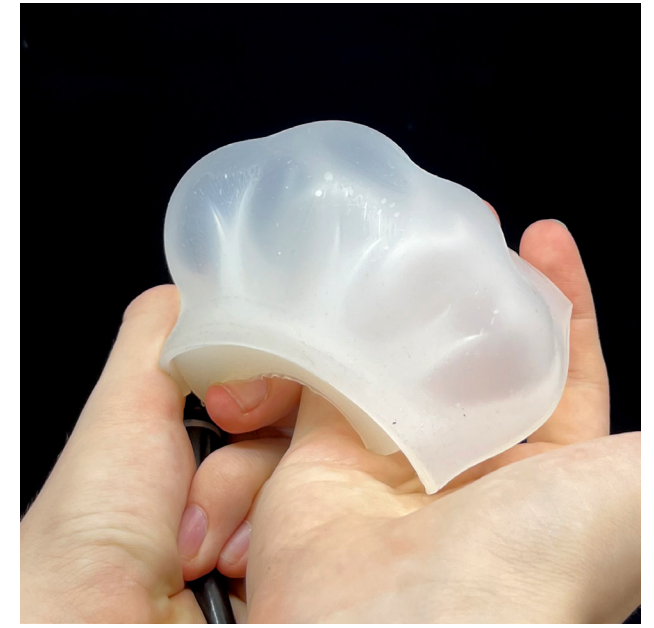


Dip Exposed Side of Part
in Uncured Resin To Seal
Armature



Soft Robotics Development

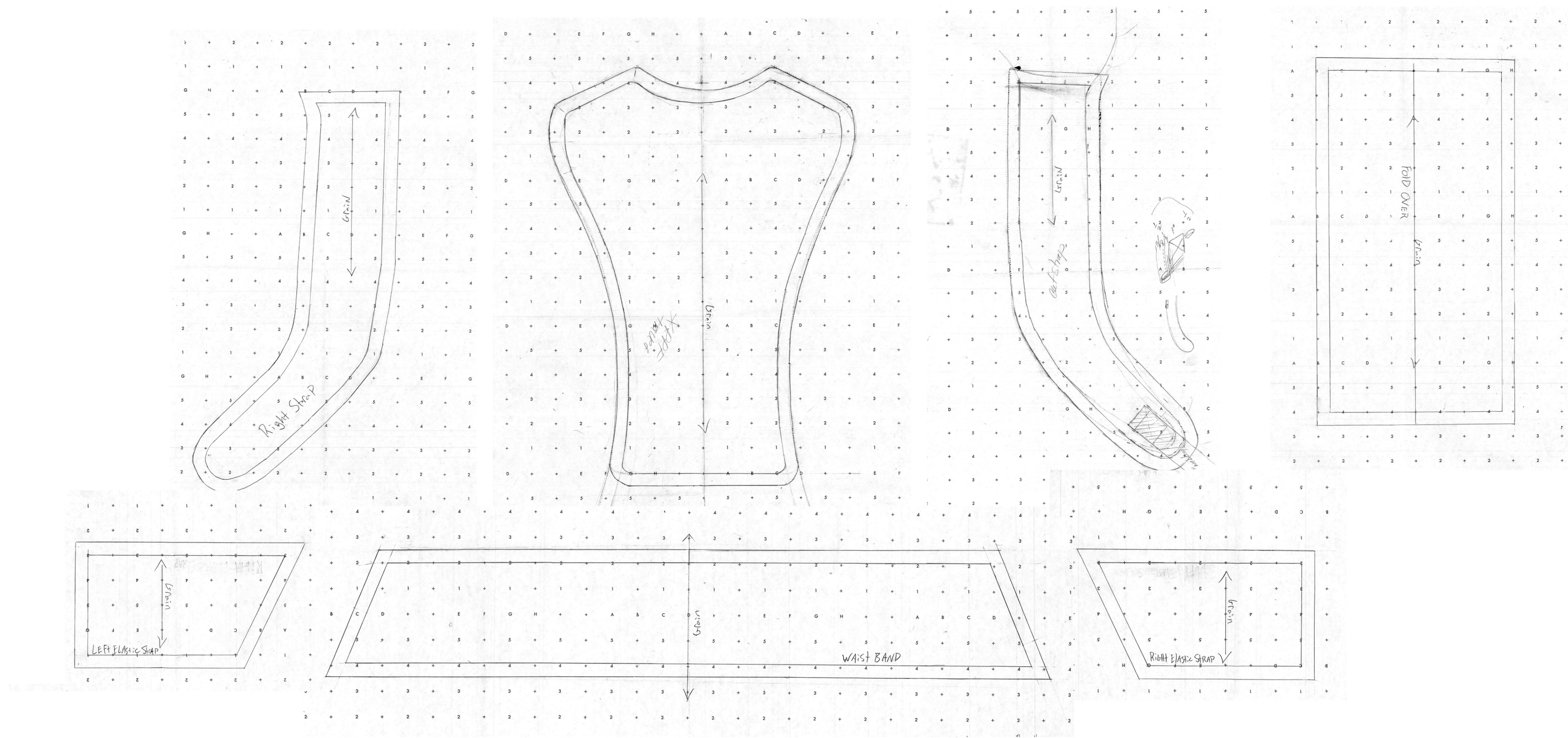
Testing





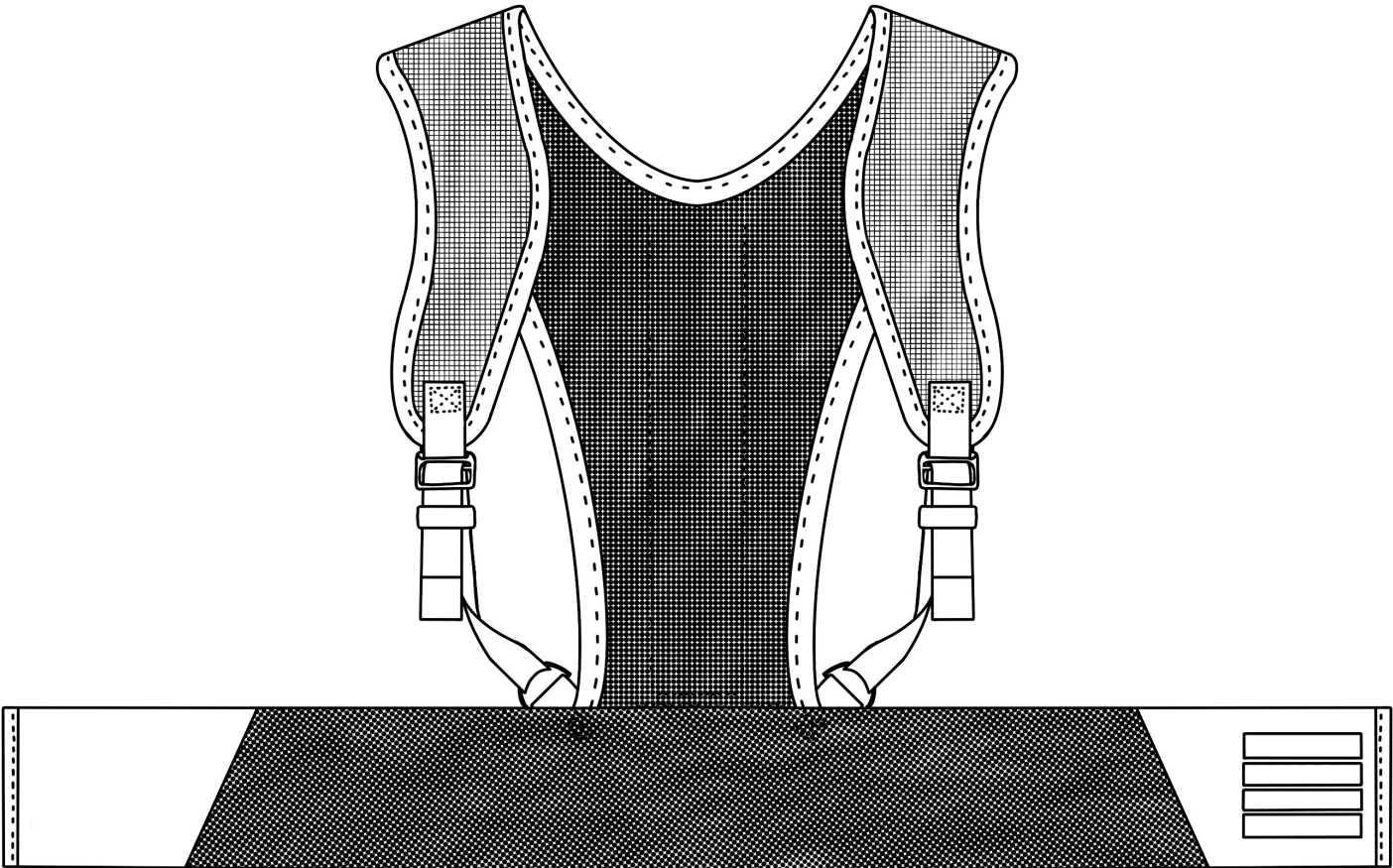
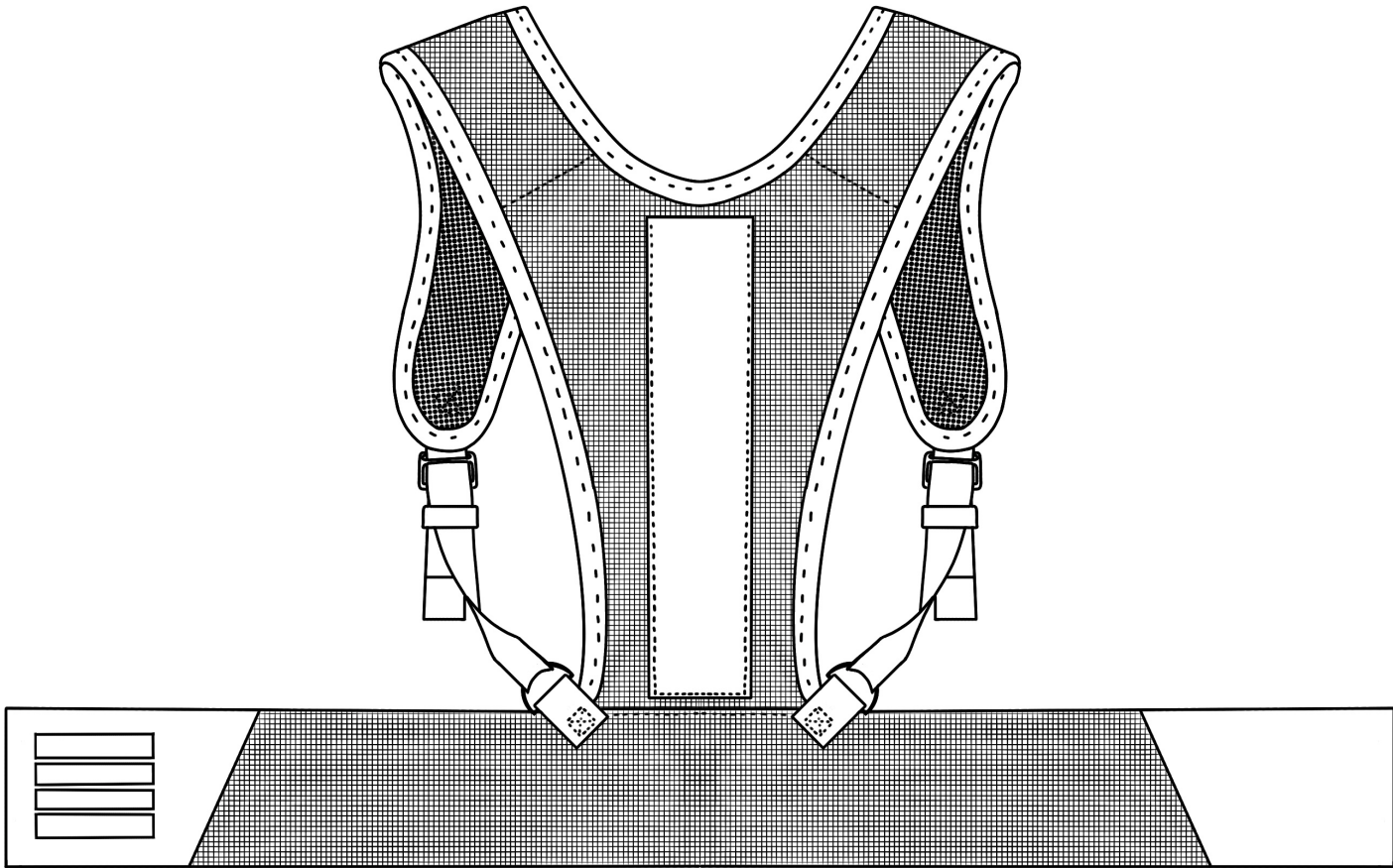
Harness Development

Pattern Pieces



Harness Development

Technical Drawings



Harness Development

First Iteration Muslin Prototype



Harness Development

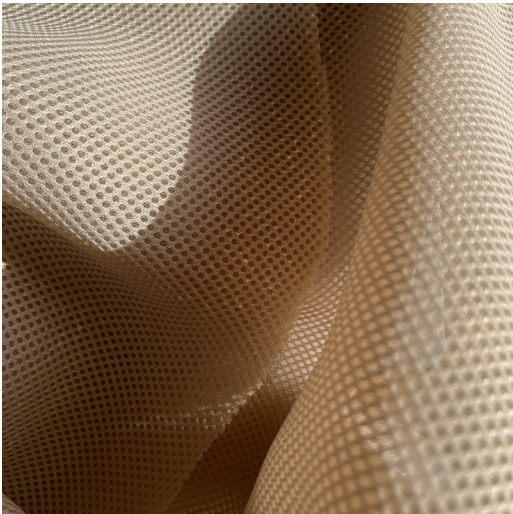
Second Iteration Muslin Prototype



Material Selection



1.
Spandex



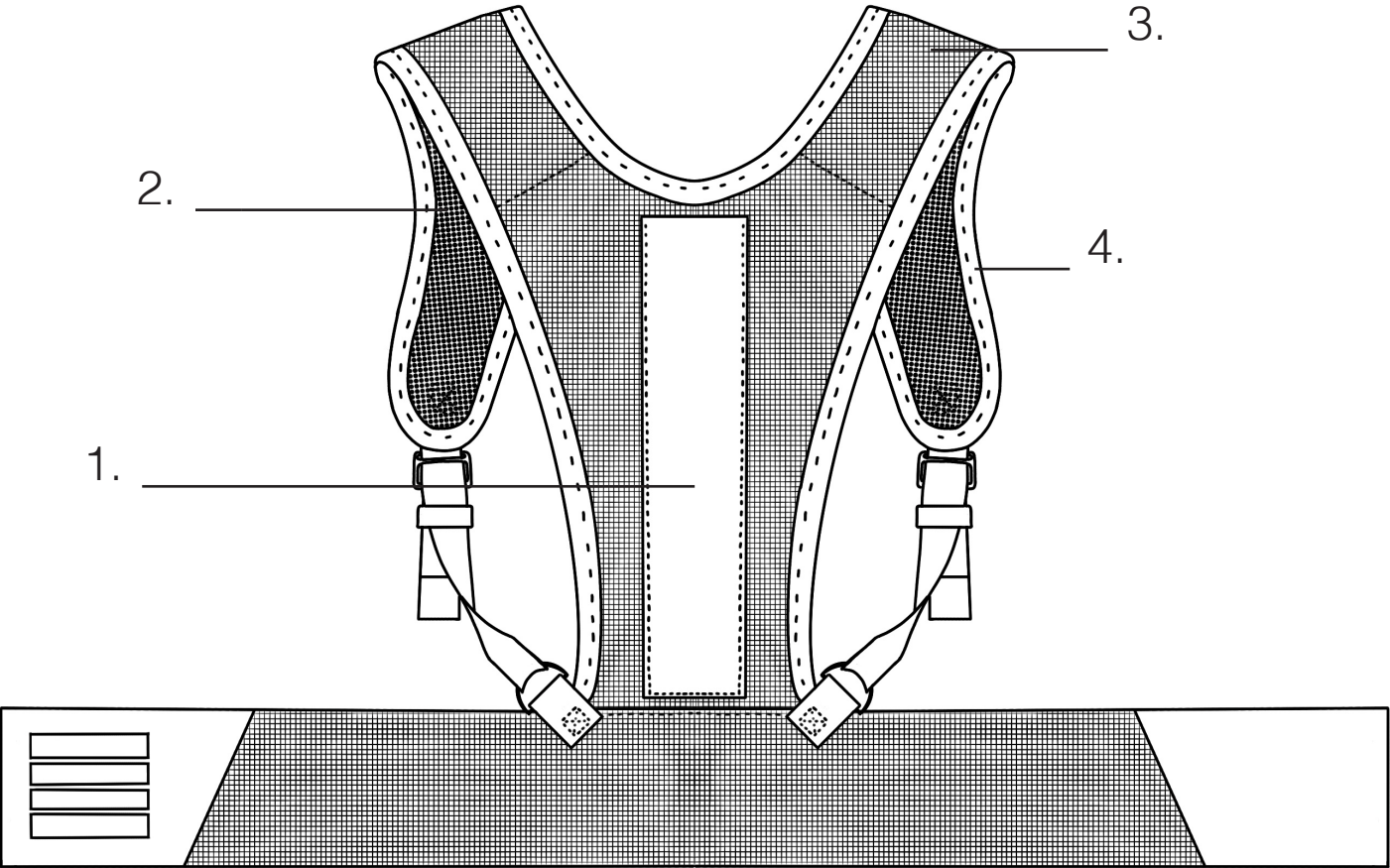
2.
Spacer Mesh



3.
Ripstop



4.
Nylon



Harness Development

Sewing Final Prototype



Final Prototype

Fitting





Final Prototype

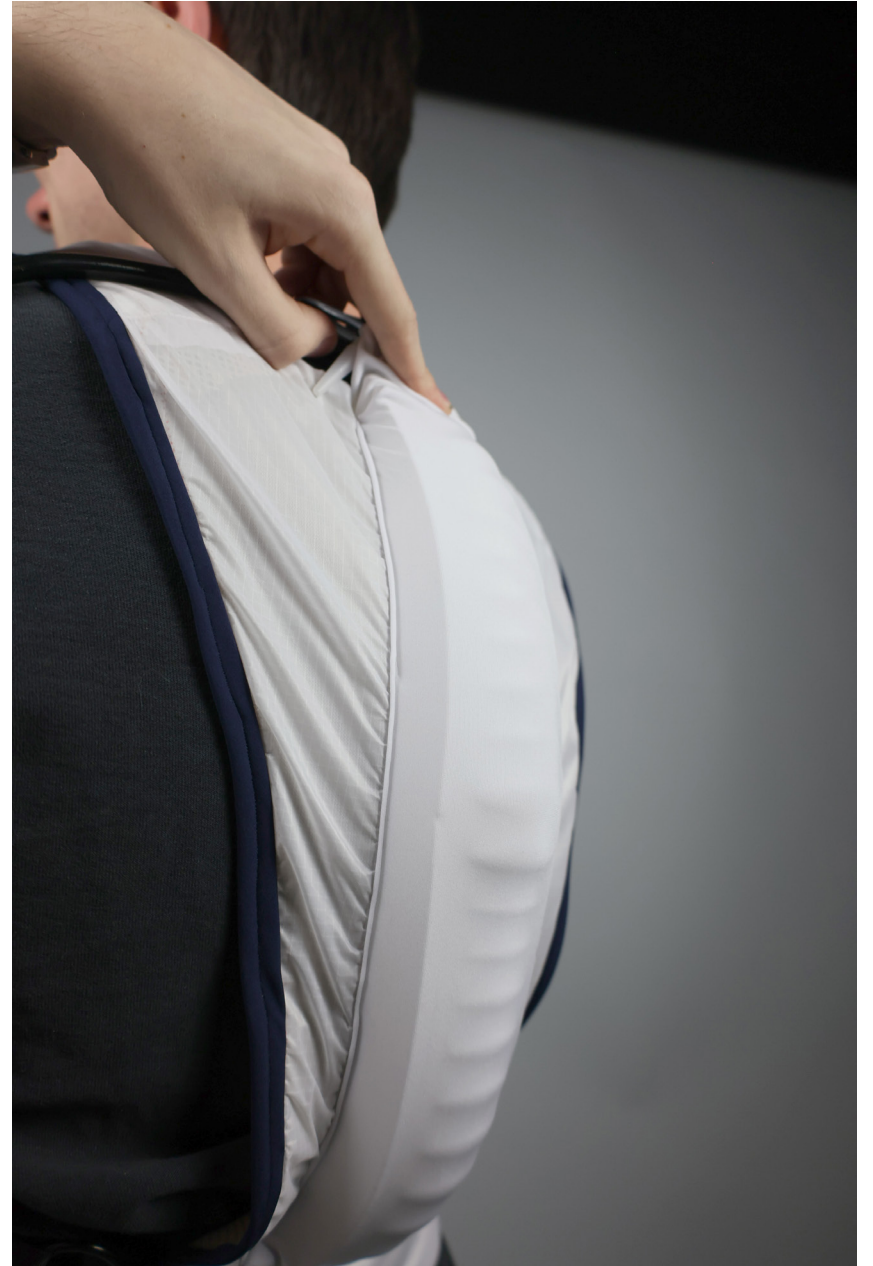
Maneuverability Test





Final Prototype

Inflation Test











Prototype Worn by Bruce Westgate

Bibliography

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