Feeling Climate Change:
Intersections of Climate Change and Everyday Cyclists

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Abstract

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This thesis deals with ways in which everyday cyclists will be uniquely impacted by climate change. While cyclists have a rich sensorial and embodied understanding of Seattle's weather and climate, when prompted, they cannot pinpoint symptoms of climate change in their commute over time—although transpired and transpiring, climate change is difficult to perceive due to its generational time scale. Therefore, this project sought to make speculative tools that 'bend time', by enabling future climate change projections to be experienced in the present.

The *High Water Pants* developed in this thesis raise up in geofenced areas where Seattle will be impacted by rising sea levels. The focus on sea level rise relates to Seattle's unique geography and hydrology and confronts the hard-to-imagine, longer-term nature of its impacts. Water levels in the Seattle area have already risen about 8 inches in the last century, and are projected to rise 10 more inches by 2050 and 28 inches by 2100 (by moderate estimates).Through the in-motion experience offered by the High Water Pants, a cyclist's history of practice can mesh with future data about sea level rise, creating spaces for speculation about the future impacts of sea level rise on everyday cycling practices.

The goal of this project is to create embodied tools for speculation that make climate change tangible and shift conversations around climate change from global, catastrophic narratives to more local, personal and nuanced narratives.

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1.Introduction

My interest in the intersection of cycling and climate is situated in my own commitment to everyday cycling—I've been riding bikes in Seattle for the past twelve years for a plethora of reasons including but not limited to racing, commuting, touring, delivering pizza, critical mass and socializing. Cycling is a practice I love—it has defined many aspects of my identity and community. However, spending the last few summers dubiously deciding to continue bike commuting in spite of forest-fire-ash-filled air, I began to wonder if these wildfires were related to climate change, and if so, what other strange or unexpected side effects of climate change would impact my cycling practices and health in the future. This made me realize that, due to their everyday exposure to the elements, cyclists would be uniquely impacted by climate change—it could pose threats to their mental and physical health, mobility and sense of freedom!

Yet climate change remains hard to feel: while cyclists I interviewed showed genuine distress over the concept of climate change, aside from the smoky summers and some conjectures about harder rain in winter and hotter summers, they were often tentative to offer evidence of climate change in their daily lives and bike commutes—this seems to reinforce climate change is hard to perceive at the scale of everyday life. Therefore, my thesis seeks to take climate change, a phenomenon somewhat beyond perception due to its global and generational scale and narrow it to its intersection with everyday cyclists, situating it and making it perceptible within their everyday practices. Ultimately, I my research attempts to make climate change tangible through creating speculative tools for everyday cyclists for them to notice, validate, envision and concretize their intersections with climate change.

While difficult to perceive, climate change is in progress and already impacting cyclists as they start donning particulate masks in smoky summers, and climate change will continue to transpire at an accelerating pace if we don't act radically to reduce CO2 emissions. According to *The Puget Sound State of Knowledge Report* (Mauger et al., 2015), a comprehensive outlook on climate change impacts expected for the Puget Sound, the first tangible signs of climate change are becoming noticeable and the acceleration of impact is projected to increase in the next 30-60 years. This report explains how average annual temperatures have warmed 1.3 degrees Fahrenheit in the last century, and summers are projected to warm by 4-6 degrees Fahrenheit by 2050 (relative to 1970-1999). It also reports on how precipitation will increase both in total annual rainfall and in the intensity of 24-hour heavy rain events. At the same time, less precipitation will fall as snow, resulting in reduced snow pack and increased winter flooding and summer droughts. Sea levels have already risen 8 inches in the past century, are projected to raise another 10 inches by 2050, and an additional 28 inches by 2100 by moderate estimates (Miller et al. 2018). The impacts of climate change on the Pacific Northwest aren't fully known, both due to the complexity of compounding factors leading to climate change impacts, and the unknown aspect of how much we will reduce CO2 emissions in the coming years, but we can expect continued smoke from large-scale forest fires, increased nuisance flooding and chronic inundation, increase in allergens and desynchronizing of annual biological events to name just a few expected outcomes (Mauger et al., 2015).

The complexity of feeling climate change is elucidated by Timothy Morton's description of climate change as a hyperobject, a term he coined in his book *Hyperobjects: Philosophy and Ecology after the End of the World.* According to Morton, hyperobjects are, "viscous, which means that they "stick" to beings that are involved with them. They are nonlocal; in other words, any "local manifestation" of a hyper object is not directly the hyperobject" and, in addition "they involve profoundly different temporalities than the human-scale ones we are used to" (Morton 2013, p.1). This acknowledgment of the profoundly different temporalities and nonlocal yet viscous nature of hyper object helps explain the difficulty in feeling climate change at the level of everyday life. It is at once ubiquitous and ineffable, present but never the totality of an occurrence, so the challenge remains of how to feel it or understand it tangibly or at a local and human scale of perception—the level in which cyclists understand climate through their daily practices. My primary research reflects the hyperobject nature of

climate change from the perspective of Seattle's everyday cyclists. Through semi-structured interviews, I noticed that while almost all of my participants felt a deep sadness about the concept of climate change, they were hard-pressed to point to specific evidence of it in their day-to-day-commute, citing temporal reasons for the difficulty in perception such as, "if I'm riding every day, it's like watching your nails grow or if I'm outside all the time then I'm just part of the slow change." Or saying more time might help: "give me five more years, ten more years."

The temporal scale of this challenge was especially well suited to be explored through speculative design which seeks to imagine alternative presents or probable or preferable futures, and in the case of my thesis, I sought to create a speculation through mediating perceptions of time using tangible, tactile interactions that dovetailed with cyclist's existing, embodied and sensorial understanding of Seattle's climate. Peter Paul Verbeek describes mediation theory in *What Things Do* (Verbeek 2005) as a furthering of the phenomenological analysis of artifacts through the synthesis theories by Heidegger and Merleau-Ponty. He claims together, their theories "can be described in terms of mediation" which is, "the intentional relation between human beings and the world is thus, as it were, extended or stretched out through artifacts" (p. 125). In this model, technology or artifacts intervene in how a person perceives and experiences the world. My goal is to create mediating technologies that help shift people's perception of climate change in ways that either help a user imagine and feel impacts of climate change in the future, or make climate change and its impacts more palpable now.

To do this, I created the High Water Pants, which are mechatronic pants created be worn while riding a bicycle. These pants dynamically shorten in areas that will be susceptible to sea level rise in Seattle in the future. The design of the pants uses tactile cues to layer future data over present-day scenarios, 'bending' time and making climate change more tangible at the scale of everyday life. In the following I describe my research process and its implications for design. My research happened in several phases: discovery, ideation, fabrication and testing. My discovery phase sought to learn about everyday cyclists' understanding of weather and climate and intersections with climate change. Through ideation I developed a concept for the High Water Pants and a framework for time bending speculative design. I then detail the process of fabricating the High Water Pants, including my consideration of cycling ergonomics, computational systems, and integration of mechanical systems into a pair of pants worn in motion. Finally, I discuss results of a pilot study run with the High Water Pants. The ultimate goals of this project are to discover how climate change narratives could become more personal and nuanced, as well as how to mediate perception of climate change so that people can tangibly experience it at a scale and setting that makes it meaningful. The High Water Pants are an artistic research object and a ground-up way of envisioning climate change impacts for and with the everyday cyclists population as well as a way to build embodied understanding of climate change.

2. Related works

The High Water Pants are speculative tools to make climate change tangible for everyday cyclists which intersect with traditions of tactile, non-screen-based, wearable technologies for cyclists, a history sustainable human computer interaction design, and speculative design research methods. Through combining and engaging in tangible technologies for cyclists and speculation, the High Water Pants enable local, personal narratives about climate change to emerge, offering cyclists a tactile interface through which they can notice and reflect on longer-term, future impacts of sea level rise.

Sustainable Human Computer Interaction

High Water Pants belong to a linage of focus on sustainability in HCI, the origin of which is often credited to Eli Blevis' seminal paper, *Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse*, written in 2007. This paper argues that sustainability should be the primary focus of interaction design and that designers should aim to create viable futures which, "include aspects of the environment, public health, social equality and

justice, as well as other conditions and choices about humanity and the biosphere" (Blevis 2007, 503). The terrain of Sustainable HCI (SHCI) became increasingly popular and was subsequently mapped into five genres by Disalvo et al. in 2010 in their paper, *Mapping the landscape of sustainable HCI*, which has served as a SHCI touchstone ever since. The categories Disalvo et al. created included tracking and sensing environmental data, ambient awareness, persuading users to change behavior, understanding users views of sustainability and critical design for SHCI.

Human and Non-Human Relations in the Anthropocene Era

In recent years, some focus on sustainable interaction design has shifted to be urgently aligned with climate change (Knowles, Bates, and Maria 2018) as well as seeking adaptive, post-capitalist, post-anthropocentric approaches to SHCI. SHCI researchers have begun to acknowledge the Anthropocene era and have sought to break down dichotomies between human and non-human actors through 'collaborative survival' (Liu, Byrne, and Devendorf 2018) and designing for interspecies interrelationships and a multi-species world view (Jönsson and Lenskjold 2015; Phillips and Kau 2019; Soden et al. 2017). The goal behind collaborative survival and design for multi-species interactions is to sensitize humans to their connections to ecology, acknowledge limitations in growth and production and seek harmonious relationships with the natural world.

In Liu et al.'s paper about collaborative survival, they claim to be designing for inter-species resilience between human and mushroom, borrowing a premise from Ann Tsing's book *Mushroom At The End of the World* (Tsing 2015). While their project is dubious in its ability to actually support human-mushroom collaborative survival, it does offer a new framework for thinking about ways of designing for sustainability which are adaptive and resigned to the fact that we are inescapably going to experience the impacts of climate change, citing technoscience scholar Donna Haraway's recent call to, "stay with the trouble" (Haraway 2016). They frame collaborative survival as, "a call to look at, notice, and respond to the destructive processes we may prefer to ignore" (Liu, Byrne, and Devendorf 2018, 2). Following this charge, the High Water Pants were built not only to stay with the trouble, but to bring to the 'trouble' of climate change and sea level rise that is beyond our perception into a scale that can be grappled with an speculated over within the context of everyday cycling. It is also pushing past 'living' creatures and moving into the terrain of non-living agents, seeking connection to bodies of water, parks, and geographic locations—expanding the terrain of non-humans to the non-living, which reflects arguments by Jane Bennet in *Vibrant Matter* (Bennet 2009) where she claims matter doesn't have to be living to be vibrant.

Environmental Sensors

A great deal of SHCI research, as demonstrated by the 'sensing' and ambient awareness categories in DiSalvo et al's 2010 paper, rely on sensing or sensors to acknowledge and understand environmental concerns. These projects which involve environmental sensing sensors can be divided into three trends: personal, ludic, and inter-environmental. A personal approach to environmental sensing is exemplified by *wearAir* (Kim, Paulos, and Gross 2010) which shows air quality through an LED display embedded in a t-shirt, or the *myPart* (Tian et al. 2016), a personal portable air quality sensor, worn on the wrist, which transforms data into a visualization in a smart phone app. These projects visualize air quality data for the use and interpretation of the user. In a ludic approach, Gaver et al. created the *Indoor Weather Stations*: three sensor-based devices to track temperature, light, and wind in the home. Data is displayed in an open-ended way, allowing "people to explore questions about their relationship with the environment but without imposing a pre-established sense of what the right and wrong answers are" (W. W. Gaver et al. 2013, 3452). Finally, the inter-environmental approach is exemplified by Liu et al., in their work to design for collective survival (Liu, Byrne, and Devendorf 2018). The sensor-based speculative prototypes Liu et al. create for mushroom hunting ask users to place their hands in soil, walk amongst trees and understand histories of mushroom growth and foraging. In this example, data supports a reflective, embodied experience with the goal of better experiencing tactile and embodied connections to mushrooms and their environments.

Through these three approaches, three different definitions of 'environment' emerge. While the Liu et al.'s tools for mushroom hunting defines an environment as a web-like-ecosystem, emphasizing human-non-human interactions, the two air-quality displays define an environment as a set of factors which impact people—their health and wellness—without much consideration to ecologies the person sits within. The ludic interactions created by Gaver et al. are ambiguous, and invite a user to participate in the definition of an environment, but they are critical of persuasive technologies and don't offer critique of human-centered world view or encourage the embodied exploration of human-non-human interactions that the mushroom hunting tools offer. The high water pants are situated within these ideological intersections: while they seek to acknowledge the web-like nature of environments, exploring human-non-human intersections at the level of geography, hydrology and ecology, they also offer opportunities for riders to make open ended speculations about the future of climate change, leaving some room for authorship like Gaver et al's. Indoor Weather Stations. In a way, the High Water Pants invert sensory models—they don't sense environmental data, they sense geographic boundaries which are based projection models of sea level rise. Their tactile cues let riders know when they enter a future sea level impact zone, heightening awareness in cyclists and leveraging their history of sensing and their current senses in that specific location to envision what a possible future will entail.

Speculation

The nature of the High Water Pants as way to stimulate scenarios about future of sea level rise make them a speculative tool, broadly defined as a way of envisioning possible futures or alternative presents (Auger 2013). Design is an act of bringing things—objects, strategies, services, products—into being, and as such has a natural inclination towards futuring, envisioning and fiction writing practices to create preferable outcomes. Often, these speculative designs in HCI are tied to futures in relation to new technologies, but the High Water Pants use technology (data, microcontrollers, GPS) to speculate about a future of climate change. The pants borrow from three subsections of speculative design: embodied speculation (Andersen 2013; Candy and Dunagan 2017; Elsden et al. 2017), material speculation (Pierce and Paulos 2014; R. Wakkary et al. 2015; R. L. Wakkary et al. 2017) and co-speculation (Desjardins, Viny, et al. 2019; DiSalvo, Jenkins, and Lodato 2016; R. Wakkary et al. 2018) to create speculative visions of sea level rise by being tactile/tangible, being a real physical object for inquiry, make room for embodied reflection and imagination, and requiring the participation and situated and specialized knowledge of the everyday cyclists to craft speculations.

Embodied speculation

Embodied speculation is an approach to speculative design which acknowledges a need for speculation to be grounded in experience. Candy and Dunagan champion this type of speculation, asserting there is a need to, "bridge the experiential gulf between inherently abstract notions of possible futures, and life as it is apprehended, felt, embedded and embodied in the present and on the ground." (2017, 137). While Candy and Dunagan use a guided activity to co-create an experiential scenario, Elsden et al. have used a slightly different technique to enact speculations. Speculative enactments are crafted to utilize and, "intervene in familiar routines and experiences" (2017, pg. 5393) in ways that open the door for participants to feel comfortable and meaningful connection to the content of the speculation. The High Water Pants follow suit of experiential speculation by creating an experience which relies on felt, embedded and embodied experiences to ground speculation, while placing the speculation within a history of practice and a community of cyclists for whom the speculation, and the consequent future scenario, has consequence and gravity.

Material Speculation

While aspects of material speculation related to embodied speculation practices due to the experiential nature of both, but material speculations rely on a physical object for

critical, speculative reflection. Material speculation, "utilizes physical design artifacts to generate possibilities to reason upon"—acknowledging how experiencing a physical object can embody and inform speculations. While some material speculations are designed to be counterfactual (Pierce and Paulos 2014), unaware (Odom and Wakkary 2015) and slow (Odom et al. 2012), the High Water Pants were designed to be time bending: taking computational systems and climate change models and overlaying them into the physical world through tangible, real-time feedback. It would be impossible to speculate in this way without the physical artifact as a point of experiential inquiry.

Co-speculation

The High Water Pants rely of the expert knowledge of everyday cyclists to ground the speculation, this is a practice known as co-speculation. Co-speculation arose as a way to utilize expert knowledge within the design process as well as distribute authorship of speculation between designers and research participants. Recent examples of co-speculation have included non-stereotypical home dwellers, political scientists, and philosophers as co-crafters of speculation (to name a few) (Desjardins, Viny, et al. 2019; DiSalvo, Jenkins, and Lodato 2016; R. Wakkary et al. 2018). In a recent paper detailing the methodology for crafting co-speculation with non-stereotypical home owners, Desjardins et al. also discuss the importance of situating speculation within each participant's unique home environment, creating bespoke speculations, in order to show a plurality of potential futures with domestic IoT devices (Desjardins et al., 2019). In my research with everyday cyclists, by situating my speculation within the context of their cycling practice and specific geography of Seattle which they have built unique histories of practice within, I seek pluralistic and situated speculations where the authorship of the imagined future belongs to the cyclist participant.

Tangible, Wearable HCI for Cyclists

While cycling is already a type of technology that offers latent experiences of larger ecosystems and there are many examples of tangible, embodied technologies for cyclists, no designs for cyclists explicitly focus on ecosystems or climate change, instead, most wearable and tactile designs for cyclists focus on safety and navigation. In the case of way-finding, the *Tacticycle* (Pielot et al. 2012) and the *Vibrobelt* both use vibration as a tool for navigation. Safety-oriented cycling designs include *beSeen* (Grosse-Puppendahl et al. 2015), a series of light-up wearable displays that communicate cyclist's intentions in conjunction with their gestures, Dancu et al. have explored ways that light-up displays can enhance clear communication between cyclists and cars in urban settings (2015) and *Rep(AIR)* uses smell as an interface for alerting a cyclist to bike maintenance issues on long, solo bike packing trips (Key and Desjardins 2019). While most of these projects support a human-centered approach to designing for cyclists, *Rep(AIR)* creates a relationship between cyclists and rider, increasing awareness and strengthening maintenance relationships through smell-based alerts. Many of these examples demonstrate a knowledge of a cyclist's need to navigate space safely, but without attention paid to how those spaces might change in the future in relation to climate change—they have an anthropocentric approach to designing tangible and wearable interfaces for cyclists. The High Water Pants seek to create a post-anthropocentric, tangible, wearable interface that uses the practice of cycling as a familiar and meaningful grounds to speculate about our enmeshments with larger ecosystems.

To summarize, the High Water Pants follow the recent focus in SHCI on adaptive approaches sustainability. The use embodied, material and collaborative, speculative methodologies while also aligning with a history of tactile, sensorial and wearable technologies for cyclists. Through these methods and ideological approaches to design, the High Water Pants are a material artifact which create an opportunity for everyday cyclists to experience sea level rise data and author personal speculation about climate change based on their history of practice in tangible and embodied ways.

3. Research Methods & Findings

To learn more about potential opportunities for speculative tools to make climate change tangible at its intersections with everyday cyclists, in addition to the a literature review (above) I conducted primary research using three different methods which influenced and built off of each other. I first did a round of autobiographical exploration, I then conducted an expert interview with a climate scientist and semi-structured interviews with a community of Seattle everyday cyclists, and finally, I created a descriptive and speculative probe study to inspire design directions which I also deployed with Seattle cyclists.

3.1 First Person Rapid Experience Prototypes

Part of my research was conducted through a first person approach before I committed to a more narrow research question and conducted qualitative research with a group of everyday cyclists. I conducted first person research through a series of rapid experience prototypes which produced valuable knowledge and insights that guided my further decision making and final design direction. This research was from my own point of view as an experienced cyclist and designer, and these rapid experience prototypes were a way to quickly survey my personal intersections as a cyclist with the elements, my environment and my gear intuitively while building new knowledge and narrowing my thesis focus. These experiments stemmed from my first thesis proposal which wondered what other technologies could be developed for cyclists besides cycling technologies which simply route mapping and performance statistics.

These first person experience prototypes follow a recent acknowledgment of the value of first-person perspectives of designers in conducting design research such as autobiographical design (Desjardins and Ball 2018; Neustaedter and Sengers 2012) auto-ethnography, or observations of designs in their natural settings (Cunningham and Jones 2005) and annotated portfolios which is a format for reflecting on a series of designs (B. Gaver and Bowers 2012) to name just a few. My first-person research prototypes served as a quick way to investigate design directions based on my own experiences as a long-term cyclist. These experience prototypes operated as a rapid prototyping form of material speculation, which, as was mentioned in the related works, is a material object that is useful for opening up questions and reflection. In addition, these were experience prototypes which helped me clarify my position and interests, according to *What do Prototypes Prototype* (Houde and Hill 1997), which argues prototypes can serve different audiences and goals, these prototypes could be seen as prototypes for me, the designer, used to clarify my position and ask questions through making and experiencing. The prototypes I developed are important to understand as theoretical through lines in my research and design direction, so I will explain them in some detail below.

Song hunter

Song Hunter was inspired by a symbiotic moment cyclists have with cars as they ride around cities (Fig. 2). The prototype was based on an experience that I have had many times as a cyclist, where I will pull up to a stop light or intersection or ride alongside slow-moving traffic and hear someone playing a great song with their windows down that makes me want to ride my bike to the beat. Naturally, they always pull away and the song goes with them. However, using Song Hunter, I sought to capture a car's song and continue to listen to it even after the car pulled away.

To prototype the Song Hunter experience, I purchased a Bluetooth speaker and a phone mount for my bicycle (Fig. 1). When I heard someone loudly playing a song out their window I would ride beside them and attempt to Shazam the song. If I could successfully find the song with Shazam, I would then attempt to get it to play from my small Bluetooth speaker.

This experience was interesting in that it experientially reinforced what I knew about traffic patterns in the city as well as how influential a game or challenge can be on my behavior. In

the beginning stages of this experiment, I tried to find songs during my morning commute. This failed, as apparently no one plays loud music at 8:30 am. In order to hunt songs, I had to change my behavior: I then tried riding my bike in rush hour traffic in the heat of summer. To successfully catch songs, I had to find slow moving, dense traffic, in temperatures conducive to having windows rolled down. I finally caught my first song breathing exhaust and swerving into tightly packed traffic in downtown Seattle—a situation I would normally avoid. It was also hard to catch songs, I would awkwardly fumble with my phone to get to Shazam, riding slowly next to cars, splitting/weaving through lanes in stop-and-go traffic, trying to pace with cars long enough to catch the song. I only successfully grabbed two songs, but I was very proud of myself when I did (see above playlist).

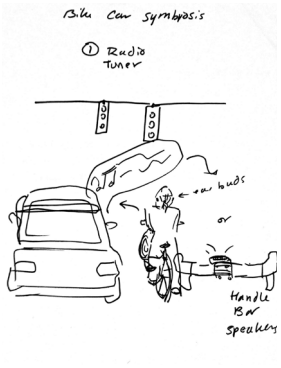

Figure 1. Song Hunter concept

Figure 2. Song Hunter cell phone mount and speaker

Figure 3. Clothing Cards

Clothing Cards

Something I think about all the time as a cyclist is what I'm going to wear. One aspect of being an everyday cyclist is the complexity of dressing for cycling and everyday life. If prompted, I could give a detailed inventory of how every piece of clothing in my closet intersects with cycling. Some clothes are for long rides, some only for short commutes, some coats are too long, while some are ugly but perfect for riding in a rainstorm, and some clothes I don't wear often because I love them, and I don't want to sweat in them. In order to identify and categorize my wardrobe, I created a set of cards that I could put alongside clothes, which I would then photograph that helped me create categories and draw out the complexities of dressing for everyday cycling.

I first created a digital mock-up of how clothes might be organized in a system of playing cards with labels denoting their place within a cycling lifestyle. I then created a hypothetical set of cards in illustrator that I thought I could print out and use as physical markers to inventory my clothes. I finally began to make paper prototypes of these 'clothing cards' on the fly as I went through my wardrobe. I noticed I was developing categories such as how much I liked the piece of clothing, how long I would be willing to ride in it, the fabric quality and durability (does it wrinkle easily?), and the weather the garment was best suited for (Fig. 3).

After re-drawing the clothing cards using a system of color-coding to represent larger themes, I took them to a friend's house and asked her to talk through some of her clothes with the cards. We ended up adding to the set and discussing the trade-offs between fashion and function in a cycling wardrobe as well as the complexities of sweat, rain, sun and packing for multiple activities throughout the day.

In the elements

In this exploration, I wanted to see if clothes for cycling could reflect the intersections of the cyclists with the elements and their cycling practice in playful ways. After sketching a lot of wacky ideas like chia-helmets and color-changing coats (fig. 4), I was inspired by the

phenomena of bike-tan-lines in combination with the tanning-bed practice of putting a sticker on your body somewhere while you were tanning (like a flower or shamrock) to show the difference between your tan and non-tan to keep track of your progress. Bike tan lines are also a pretty funny part of being a cyclist. A lot of cycling gear is made of spandex, so when one rides in the summer, the spandex creates these aggressive, perfect lines on a cyclist's legs and arms.

To riff on this idea of a cycling tan line, I cut the shape of a heart out of my cycling shorts and set off on a bike ride to see if I could give myself a heart-shaped tan (fig. 5). While this didn't happen in one ride, I found this low-fidelity experience profoundly impactful. The superfluous nature of this little heart added a layer of reflection to my cycling practice that highlighted the tension between the risk and joy involved in frequent, prolonged exposure to the sun.

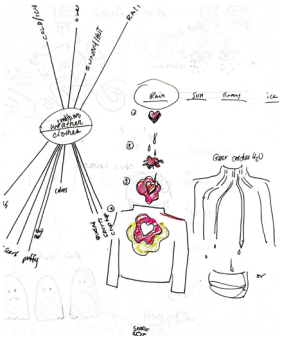

Figure 4. Gear & Elements sketches

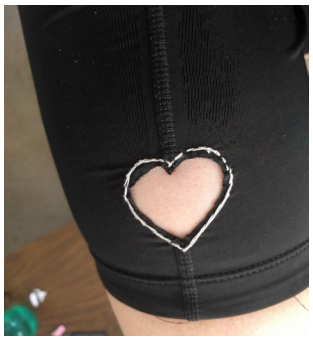

Figure 5. Heart-shaped tan lines

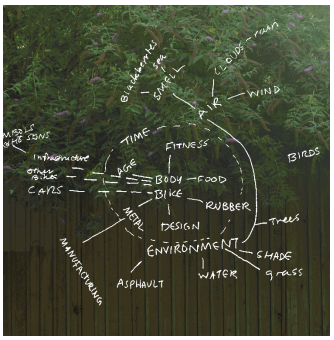

Figure 6. Assemblage GIF still-frame

Assemblage Reel

In this experiment, I was interested in exploring the concept of assemblages, which is a term used by Gilles Deleuze, and Jane Bennet (amongst many, many others) to make webs of actors more horizontal and challenge entrenched subject-object hierarchies (Bennet 2009; Deleuze and Guattari 1987). In the work of Jane Bennet Vibrant Matter: A Political Ecology of Things, assemblages are a way to reduce bias towards anthropocentrism by realizing the intertwined nature of human and non-human actors.

I wanted to explore the elements of an assemblage of riding a bike from two perspectives, one being the 'objective' lens of a camera and one being my own 'subjective' reflection after a bike ride. To accomplish this, I performed an extremely simple task—I went on a bike ride and took pictures with an old DSLR camera. I figured by reviewing the photographs later, I could create a more objective litany of the objects captured than the ones I normally pay attention to when I am riding. This obviously still had a curatorial element, as I was selecting when to take the photographs, but I figured they would still offer new information upon reflection. After completing the bike ride (and before looking at the photographs) I created a web of the parts of an assemblage of cycling from my own personal experiences. To represent the contrast between a digital, photographic record and my conceptual, mind map record, I created a GIF (fig. 6) of my mind map overlaying the photographs of my ride. I then sketched a further iteration of this where a 360 degree camera mounted to my bike would take random photographs, resulting in a less controlled record of a bike ride.

3.1.2 First person research findings:

These short-form experience prototypes had a profound impact on the rest of my research process and started through-lines of thinking that carried all the way through to my design artifact of the High Water Pants. The following were two major take-aways, but there were

undeniably more which I hope are seen as traces of thinking throughout the rest of the project such as assemblages, the importance of experiencing, and exploring geography to name a few.

Commitment to making a functioning artifact.
While it is perfectly acceptable to make a speculative design project which acts as a provocation or a diegetic prototype to stimulate reflection, based on my experience creating rapid, autobiographical design experience prototypes, I realized there was a unique type of knowledge generated through creating prototypes asked questions and were meant to be experienced. These prototypes function like the material speculations (R. Wakkary et al. 2015) or embodied speculations (Candy and Dunagan 2017; Elsden et al. 2017) mentioned in the related works, where the 'realness' of having an experience of using something designed to ask questions brings those questions to life in unexpected ways. For example, I wasn't expecting to have to ride through rush hour traffic jams in 85°F heat to catch songs with Song Catcher, nor was I expecting that cutting a small heart shape in my shorts would make me reflect on the dangers of sun exposure I also, simultaneously enjoy while riding a bicycle. Having the experience was a critical part of my reflection and learning and I wanted my final design to offer others experiences that left space for that same type of rich, personal, learning and reflection as well.

Cycling gear: practical connection to a cyclists and critical connection to climate change
My first-person explorations of cycling gear, specifically In the Elements which focused on gear that exposed the sun's impact on cyclists made me consider the potential of cycling gear, which is already in conversation and a mediator between cyclists and the elements, to be pushed into a critical engagement with climate change. In addition, I realized technology for a cyclist needed to be integrated into their gear as I fumbled with my phone during Song Hunter and stopped to take pictures during Assemblage Shooter, it became clear to me that any technology that wasn't integrated with the inertia of a moving cyclist would feel unnatural or slow the cyclists down. This made me aware of how the speculative tools I created needed to be fluidly integrated into the cyclists' bike ride.

3.2 Expert Interview

After the autobiographical exploration, and as a part of preparation for qualitative research with cyclists, I conducted an expert interview with Dr. Guillaume Mauger of the University of Washington's Climate Impact Group. Mauger helped me understand, from a climate scientist's point of view, some of the major challenges of communicating climate change impacts, one of which is the intangibility of climate change projections and the long time-scales these changes are operating at. One of the methods climate scientists use to understand what climate change might feel like, he mentioned, are comparisons. For example, the abnormally hot summer of 2015 in Seattle was comparable to climate change projections for about 50 years in the future. In addition, he mentioned climate change alters existing weather and seasonal systems, but that events like hurricanes aren't caused by climate change, but can be altered by climate change, climate change always has some effect on weather events, and that effect can be small in some cases and large in others.

3.3 Research with Seattle's Cycling Community

After conducting research from a first-person and expert perspective and having a general framework around climate change, cyclists and their gear and practices, I began research to better understand the intersections of Seattle's everyday cyclists and climate change.

3.3.1 Semi structured interviews

I conducted a semi-structured interview with six Seattle bike commuters. My semi-structured interviews sought to investigate cyclists' practices in relation to the weather and their attitudes about climate change. My interview participants rode their bike an average of 4-7

days a week year-round, ranged from age 29-63, had ridden between 2 and 20 years and had between 1.5 and 15 mile commutes one-way. I was seeking a diversity of ages and experience levels in my participants but required that they had an established practice of cycling so that they would be familiar with riding a bike in Seattle and its unique climate. The participant's professions were a school administrator, a building engineer, a bike shop owner, a user experience designer, a bike shop program manager and a nutritionist.

I used these interviews to ask cyclists about their cycling practices and how those practices relate to understanding Seattle's climate and weather. I also asked them the open ended question of 'how they felt about climate change' and if they had seen any trends in their cycling practices that they attributed to climate change. Finally, I asked them how they learned about climate change and how they would want to share information about climate change if they had new or novel information.

3.3.2 Probe Design and Deployment

Based on insights from my interview and through lines from my initial autobiographical experiments, I created a cultural probe kit (B. Gaver, Dunne, and Pacenti 1999) to question cyclist's relationship to their gear, routes and further investigate questions and concerns they have about climate change (Fig. 7). Cultural probes were originally created to, "[pursue] experimental design in a responsive way" (p. 22) by leaving behind activities that participants could fill out and letting fragmented information return to the designers over time to inspire design directions. I wanted to make a probe to both deepen my understanding of cyclist's practices while being imaginative, speculative and ambiguous enough to inspire reflection and imagination in my design process down the road. This probe isn't perfectly aligned to Gaver's vision of a cultural probe in that it still is seeking descriptive information, but it also has room for imagination, creativity and speculation.

For the probe, I recruited five different participants, two of whom had been a part of the semi-structured interview. These participants ranged from 23-45 in age, rode different types of bikes (one rode a fixed gear bike), rode for different reasons, most for commuting but two rode partly for work either leading group bike rides or as a bike delivery driver. Again, they were required to ride an average of 4+ days a week for at least the last 2 years. Their professions ranged from spin class instructor and bike shop owner, to data visualization designer, to a college student and bike courier, to a user experience designer, and an administrative assistant at a non-profit.

Figure 7. Each component of the probe kit: My Route by Season, Gabbing Gear, Strange Sensors

My Route By Season

The first activity in the probe was a map activity called My Route By Season. This activity was inspired by comments in the interviews that riders would ride different routes in different seasons. I was hoping to get a greater fidelity of information about where people rode and for what reasons in relationship to topography, geography and climate by asking people to map out their commute. For this activity, I created a large map of the Seattle area that I printed on architectural blueprint material. I guided the participants by asking them to draw their normal, every-day commute on the map as well as alternate routes they took for different seasons and conditions, and notable animals and plants they encounter. This

activity allowed relationships between geography, ecology, seasons and weather to emerge.

Gabbing Gear

The second part of the probe was a small workbook called Gabbing Gear, inspired by design workbooks which help imagine, organize and co-speculate design ideas in the generative stage of the design process (Bardzell et al. 2007; Desjardins, Key, et al. 2019; W. Gaver 2011). Gabbing Gear gave a first-person voice to bike-related clothing and gear. Giving the gear a voice related back to the idea of assemblages or agency of things in my *Assemblage Shooter* experience prototype which was curious about assemblages cyclists ride within seen from a different point of view, as well as tying into the strong through-line of gear-related inquiry heretofore. Perhaps cyclists know why they choose certain garments to ride in, but what do those garments think about the weather and impending climate change? To create the booklet, had participants pick out 5 pieces of their most cherished cycling gear. I then photographed their gear with my phone and printed 2"x3", sticker-photos of their chosen gear items and placed them in the workbooks next to a page filled with a series of speech bubbles. The bubbles were divided into columns where two of the bubbles asked what the gear would say about the weather now and two asked what the gear was thinking about climate change. This activity allowed relationships about weather and speculations about climate change to emerge while also giving a non-human actor a voice (albeit the human was imagining their voice), building empathy for more-than-human things in the cycling practice.

Strange Sensors

The third activity in the probe was called Strange Sensors where participants were given three 'magical' sensors with the ability to sense aspects of climate change previously unimaginable. This activity was designed to suspend disbelief and encourage imagination, similar to the speculative fiction 'magic machines' of Andersen et al, also used by Blythe et al, which use magic as a way to circumnavigate the necessity of technology to be able to work or sensors to be able to sense in actuality (Andersen 2013; Blythe et al. 2016). I created a set of 3 sensors for each participant by collaging together architectural and textile images, printing them out, and used a transfer pen to 'print' these images onto the craft foam. They were made of craft foam with the intention that participants could touch them and play with them to imagine their use to begin to imagine soft, wearable, tangible and novel sensors. I then placed each sensor in an envelope with an accompanying sheet of paper that had a few short questions as well as a representation of the sensor the person could sketch around. The envelope was encased with a short text that explained that these sensors had been found and were made of 'alien' technology and could sense anything about the present or future of climate change. This activity allowed participants to creatively express questions about climate change outside of the bounds of what existing sensors might limit them to knowing. I also hoped this stimulated placement of sensors, wearable sensors, and things cyclists would want to know about in regard to climate change and their cycling practices.

These methods were the building blocks of my research findings which I detail below. They focused on gaining knowledge through experience, play and making, wearable technologies for understanding intersections climate change and cycling, input about climate change from non-human actors, ways of knowing about climate and seasons that were embodied and sensorial, and tensions between present experiences of climate and future projections about climate change in the context of everyday cycling.

3.4 Semi-structured interview and probe findings

The results of my research with the Seattle cycling community show cyclists have a deep imbrication with and understanding of weather as well as genuine concerns about how it

will impact their cycling practices. In the following, I discuss the major intersections between cyclists and climate change that take into account their unique life-world and present-day ways of understanding climate and weather within Seattle's unique geography and topography. I move on to engage larger critical themes which emerged from my primary research which helped guide the speculative approach I took to my design direction. All names in the findings were changed to pseudonyms to protect participants identities.

Cyclists' have rich sensorial and embodied understanding of Seattle's climate:
Cyclists use trail conditions, smell and feeling/touch, to track the seasons. During different seasons, roads and trail conditions change—a trail might be sprinkled with in pollen or cherry blossoms in the spring, covered in black ice and fallen leaves in early winter and visited by rabbits in the summer. Cyclists also experience seasons through smells such as lilacs in spring, blackberries growing on the vine in the summer, or the "moldy fresh" (Darla) air of fall. Feeling also factors in to understanding the seasons, for example, Darla describes fall air as, "less humidified and more crisp," and Alton says he knows it's winter when his metal handle bars, "get [extremely] cold."

Cyclists have similar strategies for understanding daily fluctuations in weather. For example, participants noted looking at lights outside at night to assess the intensity of rain falling through the beam, or looking at the direction the wind is blowing by way of trees or flags—"there's a big flag on top of the Starbucks building and before I even come down the hill I'm looking to see which way the wind's blowing," explains Annie. Darla reported opening her window and sticking her hand outside to feel the temperature and precipitation before her house.

Feelings of being 'one with it all' and focus on non-human actors
While cycling is an every-day activity, at times mundane, participants reported occasionally being struck by moments of wonder and transcendence. Describing being caught in very heavy rain, participant Darla recounts feeling so drenched she felt, "one with it all". In another anecdote, Micha explains a surreal experience when a flying-v of ducks included him in their 'v' one morning on the Burke-Gillman trail. He comically recalled thinking, "Am I a duck!?" In addition, cyclists noted a great deal of plant and animal life they interact with on their rides like geese, rabbits, crows and gnats, as well as blooming flowers, leaves, and smells of lilac, jasmine and fennel, to name a few. Cyclists also care about the health of local ecologies, in his Strange Sensor response, Jack wanted to sense the health of nearby plants (fig. 8).

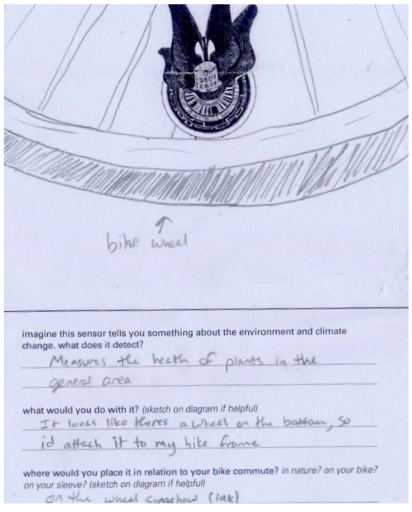

Figure 8. A Strange Sensor response "measures health of plants in the general area"

Interest in non-anthropocentric 'voices' and points of view that acknowledged assemblages and more-than-human actors stemmed from the Assemblage Shooter with looked for more objective ways to see cyclists engagements in larger systems, Gabbing Gear which gave gear a voice, My Route By Season, during which I asked specific questions about animals and plants on the ride to stimulate thinking about ecologies. In addition, there were responses to the Strange Sensor probe in which participants wondered about health of plants and sources of pollution.

Weather and seasons influence people's route and gear decisions.
The major outcome of understanding the seasons and weather is that it influences what cyclists wear and where they ride. Cyclist's adjust their gear seasonally as well as on a

daily scale. Participants explain how they have to pack more gear and packing gets more complicated in winter, and how they are excited in summer when they get to pack less and wear less gear but then they worry about having enough water, protection from the sun and avoiding sweat. In addition, as Annie mentioned in her interview, some cyclists are buying masks for summer smoke: “I bought a mask, like a nice mask that I’ll wear . . . It’s really hard to breathe in those things, but I feel a lot better.”

Routes change seasonally as well: during the My Route By Season activity, most cyclists mentioned having a wet weather route and a dry weather route, and some have routes for different seasons—riding closer to bus lines in winter and away from windy waterfronts in springtime. These routes use knowledge of the built and natural environment in conjunction with knowledge of how bikes perform to mitigate dangerous or challenging riding conditions. For example, Dan explains how, “I use this all the time, John [st] to Denny [st]. . . and it’s super, super steep. So sometimes I have to avoid that going down in bad weather.” Darla reports only riding out to Alki Beach in the summer stating, “Alki only exists in summer . . . it’s too cold and rainy in the winter.”

Bike gear is at an intersection point between cyclist and the elements, and cyclists fear climate change will add complexity to their gear rituals and routines.

As mentioned in the previous section, cyclists acknowledge changes in the seasons by changes in what they pack and what they wear. This activity is already complicated, especially in the winter. One rider when asked what is surprising about riding in Seattle, mentioned, “I just think it’s . . . it just takes planning and more gear than other places.” When confronted with impending climate change, I started to see anxiety in some of the cyclists’ attitudes towards gear. Especially in the Gabbing Gear probe, it became clear that cyclists were concerned with increased complexity of riding in weather that might become hotter or more extreme with harder precipitation. Micha’s Gabbing Gear demonstrates this. He took a picture of a collection of layers he uses to ride in variable weather—when the gear considers climate change, his pile of gear says back to him, “carrying more and more stuff may just make you quit altogether” (fig. 9) showing how frustrating and complex gear can already be and insinuating climate change will make it worse. Other participants mentioned their gear becoming obsolete, like when Dan discusses how a lot of his gear will be too warm for hotter summer days and not able to withstand harder rain, describing a jacket as, “too thin for increase/heavier rain” and shoes as, “too hot for warmer summers”.

Figure 9. Micha’s Gabbing Gear response to the thought of more gear complexity

Cyclists also expressed concern about their gear degrading in Gabbing Gear and interest in tracking what would degrade it in Strange Sensors. In his Gabbing Gear reflection, Jack worried if it got too hot, the plastic on his helmet might melt while Darla wondered if her favorite jacket could withstand harder rain. In Strange Sensors, one participant wanted to understand how increased acidity in rain might impact their bike components, while another was curious about tracking how acidity and salinity in rain and would degrade their outerwear.

Climate change is difficult to perceive at the scale of everyday life.
As mentioned in the introduction, climate change is happening at a scale beyond perception—and this was a realization that came up first in the semi-structured interviews with everyday cyclists. While most interviewed cyclists reported deep sadness about the concept of climate change, they had a hard time pinpointing tangible evidence of climate change in their everyday commute. For example, when asked how they feel about climate change, participants responded, "I believe in it . . . because science" (Brad) or, "It makes me extremely sad" (Annie). These responses were often followed by statements about the overwhelming nature of climate change such as: "people don't give a [darn] and huge corporations are dumping carbon in our atmosphere . . . and it just is so sad and infuriating" (Annie). These reactions to the concept of climate change seem to align with headlines and ways of disseminating information through news and media outlets, which publish articles about climate change with titles like, "Climate Change and the New Age of Extinction" published in the New Yorker in May of 2019 or "Major Climate Report Describes a Strong Risk of Crisis as Early as 2040" published in the New York Times in October of 2018.

However, when asked if they have noticed trends in local weather that they would attribute to climate change, people responded with uncertainty, often citing difficulty locating it spatially or temporally. Micha, who had been riding for the past 15 years was hesitant to point to trends related to climate change: "I'd like to say. I think so, yeah. Nothing so drastic that I can put my finger on it." Or, in another case, the same person who was so frustrated with climate change previously, Annie, when asked if she has noticed any symptoms of climate change in her daily commute admits, "I think that it will be one of those things that over . . . like give me 10 more years, give me five more years, but it's hard to think about it without a lot of time in the bank." And to add to the profound difficulty in feeling climate change in their cycling practice, this participant reported a near-daily commute for the past seven years.

Cyclists' hunches about climate change impacts are ambivalent
Interestingly, when prompted to speculate about their current and future intersections with climate change based on their experiences riding a bike locally, participants eventually admitted to having hunches about weather trends and climate change, but, while their feelings about climate change at a global/abstract scale often described catastrophe and despair, their local/personal reflections weren't necessarily negative! It was ambivalent whether hotter summers would be good or bad (some people reported disliking heat, others seemed to think they would ride more) and some thought more variable weather made for beautiful and interesting riding conditions like double rainbows (Darla). All of this is to say that local, personal narratives about experiences of climate change are more ambiguous and complex than 'global' or large-scale narratives passed through media.

Cyclists wanted to sense short term aspects of climate change.
Finally, in the Strange Sensors exercise specifically, it became clear that many cyclists wanted to sense information about climate change that was more about temperature and air quality, with five of the sketches dealing with air quality and three with temperature. Cyclists were also curious about wind and rain with three sketches devoted to each of these issues as well. There were a few examples of sensors sensing systemic and non-human intersections. One person wanted to track how shifting rain composition degraded their bike components, one was curious about health of nearby plants, and another wanted to know where air particulate matter came from globally. There were no real future-reaching sensors, most were situated in the present tense. For this reason, I decided to move my design into a realm of very future-leaning and harder to imagine impacts of sea level rise.

3.5 Design Principles

As I worked through general ideas and solutions, I also established with a set of design principles based on my research findings. This design direction needed to:

- Make climate change data tangible.
- Design to shift conversations around climate change—not does it exist, but what will it be like? What is it like already?
- Because of generational time scales, design to bend time, overlaying future data/ projections over in situ experiences.
- Leverage cyclists' innate knowledge of Seattle's weather, seasons and unique topography and geography.

And I had my own personal set of goals as well, I wanted my design to be:

- Something wearable (embodied technology, experiential): I was invested in creating something wearable because my initial proposal was a critique of technologies for cyclists, saying that while they were great for cycling due to their lack of screen and their tactile interfaces, they generally focused on the cyclists as an athlete, tracking routes at fitness statistics. I wondered what tactile/wearable technologies could be developed for cyclists that expanded the range of application.
- Fun: Fun-ness can take the edge and preachy-ness out of situations that seem dire, like climate change. I was hoping to walk the knife-edge of speculative design by creating something playful yet earnest, and not cynical so that people could engage with it fully and re-examine climate change from a new, softer perspective.
- Simple: I hoped the design direction would be simple enough to convey in a few short sentences but then quickly tumble out into complexity as well as being a design that could operate at multiple levels for different audiences at once.
- Weird / Colorful / Textural / Strange: I wanted to celebrate the culture of cycling by creating a kind of garb or regalia that draws attention to the practices, that aestheticize it, but without gendering it or being adherent to established aesthetic or material traditions in cycling (like the lycra of racing cyclists or cut-off jeans of messengers). I am also very inspired by upcycled, futuristic, androgynous, colorful and wacky designers such as Marine Serre and wanted to try to nod to the counter cultural aspects of cycling and celebrate the culture through colorful and delightful material and formal choices. The color and strangeness of the design might also spark conversations between cyclists at stop lights or trails, leading to in-action dissemination of information about the project.

Research Findings Summary:

- Cyclists' have rich sensorial and embodied understanding of Seattle's climate.
- Feelings of being 'one with it all' and focus on non-human actors
- Weather and seasons influence people's route and gear decisions.
- Bike gear is at an intersection point between cyclist and the elements, and cyclists fear climate change will add complexity to their gear rituals and routines.
- Climate change is difficult to perceive at the scale of everyday life.
- Cyclists' hunches about climate change impacts are ambivalent
- Cyclists wanted to sense short term aspects of climate change.

4. Ideation & High Water Pants Design Concept

4.1 Ideation

As a starting point for ideation, I did two rounds of low-fidelity, “one-liner + a sketch” sticky notes. This approach allowed me to see all of my ideas in one place and organize them into themes. During this process I started to group ideas via timeline and theme. I am not surprised a timeline emerged—as time is always a factor in speculative design—and the categories on my timeline were: history, present, present/future and future (fig. 10). To give examples for each category in the time line could present a way to create speculative technologies to tangibly understand climate change for everyday cyclists: historical solutions could have included ideas like, ‘a world where cars were never invented’, solutions based in the present were interested in identifying climate change as it exists now, present tense solutions would uncover symptoms of climate change already manifesting, present/future solutions sought to identify climate change trends of the future and creating a way to experience those things in the present, and future solutions were mainly diegetic—imagining future scenarios and designing artifacts to support those narratives.

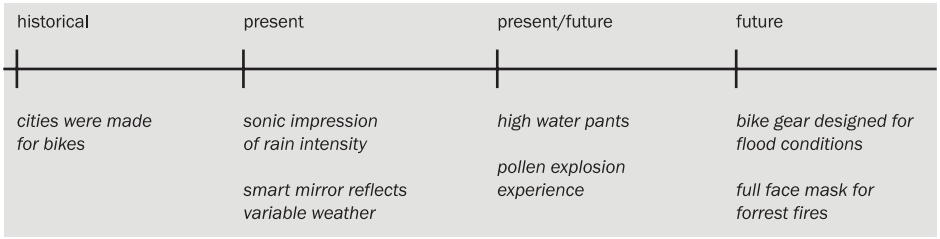

Figure 10. Timeline framework for speculative design

In addition to these time-based categories, my thematic groupings showed a range of possible focuses: the design could relate to the bike specifically, be wearable or interactive outerwear, utilize mapping, or be a diegetic prototype from some distant climate change impacted future.

I then created half-sheets with categorical sliders to help me gauge the range of ideas I was generating. I used the slides to help me gauge the diversity of my ideas I was generating and place them within ranges between the following: human-centered/post-anthropocentric, no-tech/tech, single body part/full body, current observations/future vision.

After creating a range of possible directions, I decided to create a type of mechatronic wearable that would help cyclists experience future climate change data in the present—utilizing the present/future category from my ideation timeline framework. I came up with two rough ideas: the High Water Pants, which would raise in areas impacted by sea level rise, and the Heat Shrink Jersey, which would constrict a riders ribcage slightly to represent the frequency that humidex values will be within a range shown to cause increased hospitalizations in a warmer climate (Isaksen et al. 2015). Due to time constraints, I only chose to fabricate and test the High Water Pants, however I came up with a detailed concept for the Heat Shrink Jersey as well. The Heat Shrink Jersey dealt with the more near-term climate change impact of increasing temperatures and associated health risks. Below is a description of the High Water Pants which served as a starting point for fabrication.

4.2 High Water Pants Concept

The High Water Pants are named after the colloquial term for pants that end above the ankle, jokingly associated with a coming flood—a play how the concept is tied to data about sea level rise in the Puget Sound (Miller et al. 2018). In the case of these High Water Pants, the pant legs dynamically shorten in correspondence with areas in Seattle that will be acutely impacted by sea level rise in the future to signal to the rider they are in a location

that will be affected by sea level rise in 30 to 80 years into the future.

The datasets that these pants respond to are sea level rise projections for the Puget Sound region and were chosen specifically for both their relation to climate change impacts, but also the type of movement and sensation they would elicit. The projections describe how sea levels in Seattle the area have already risen about 8 inches in the last century, and are projected to rise 10 inches by 2050 and 28 inches by 2100. If the sea level rises 28 inches, Seattle's current 100-year flood (in which sea level rises 38 inches above the current high tide line) will happen more than once a year. Sea level rise will also push the future 100-year event to a level that is 4 feet above today's high tide, by 2050.

Figure 11. Close up of a NOAA sea level rise viewer climate change map of south Seattle with 5-foot mean higher high waters (MHHW) projections in light blue and bright green..

Although Seattle is not at risk of completely and dramatically disappearing under water, we are projected to experience more flooding caused by storm surges and high tides due to higher water tables. According to mapping done by NOAA (https://coast.noaa.gov/slr/) and Seattle Public Utilities (http://www.seattle.gov/utilities/environment-and-conservation/climate-change-program/projected-changes/sea-level-rise-map), the areas most impacted will be the coasts that intersect with the Puget Sound and areas around the Duwamish River watershed. The High Water Pants use NOAA sea level viewer maps as a reference for creating geofences. The pants actuate within these geofenced impact areas through calculating location via a GPS module on the cyclist, and the latitude and longitude readings are passed through a polygon detection algorithm run through to a microcontroller. In order to give the cyclist wearing the High Water Pants opportunity for reflection and to account for the ambiguity of how climate change will impact coastal areas of Seattle, I padded the geofences slightly (fig. 12). However, the current areas I have geofenced for my pilot study are only around Golden Gardens and Elliot Bay Trail because these are familiar cycling destinations and my current code only detects one polygon and a time.

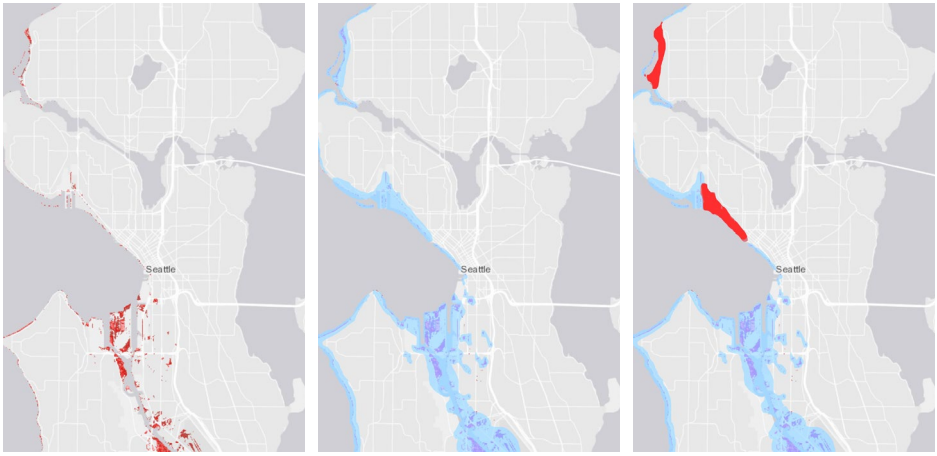

Figure 12. Left to right: Seattle Public Utilities map of sea level rise, my proposed geofences, the current geofences I have built.

I used the mapping of future sea level rise as a data set for the pants because it was binary, a cyclist would either be inside or outside an area of impact. The either/or nature of the data and created a simple ‘up’ or ‘down’ movement with the pants. This was important because a lower leg isn’t able to feel at a fine grain of detail so meaning had to be made through simple movements. In addition, the benefit of the tactile cue of a pant leg raising and lowering, in contrast to another type of sensation, is that there is immediate attention garnered by the raising pant leg that can then fade into a more peripheral awareness as a cyclist continues to ride. For example, a cyclist might ride along the Alaskan Way waterfront and continue onto the Elliot Bay trail (all areas that could be impacted by chronic flooding in the future), a route which could take upwards of 20 minutes to complete. If this is the case, a more acute sensation (vibration or knocking against the cyclist with the arm of a servo motor) might get annoying and hinder reflection or enjoyment of the bike ride. The raising and lowering pant leg is more innocuous and fades in and out of the cyclists’ direct attention, calling attention to borders or thresholds, while maintaining the ability into fade to a background sensation.

The subtlety of the feeling, its ability to not demand too much attention, was important so that cyclists would have space to mesh new data with their history of cycling to understand climate change. High Water Pants respond to the longer-term phenomenon of sea level rise, which, in my research, seemed more difficult for cyclists to conceptualize in terms of impacts. The garment, therefore, has the potential to fill a gap in cyclists understanding of intersections of sea level rise and cycling. In the probes and interviews, no cyclists imagined flooding as a potential impact of climate change, however, cyclists did mention a breadth and depth of experience riding in wet weather conditions as well as including areas of Seattle that are close to waterfronts like Elliott Bay trail, industrial areas of Seattle around the Duwamish river, and Golden Gardens Beach (areas that will be impacted) in their repertoire of routes. In my research probe’s mapping exercise, many cyclists mentioned having different routes for rainy weather which avoiding steep descents or brick surfaces because they are dangerous when wet. In addition, almost all cyclists interviewed noted that wetter riding makes riding more complicated: it requires more planning and gear, makes braking performance worse, and wears down components faster.

Hopefully, these pants will build new knowledge about climate change for cyclists by combining the in-ride experience of the pants overlaying their existing understanding of wet-weather cycling and Seattle’s unique topography and geography. The High Water Pants relate to my insights directly in the following ways:

Insights	***Design Decisions***
• Cyclists’ have rich sensorial and embodied understanding of Seattle’s climate.	• Data dovetails into this way to knowing by being embodied and in-ride.
• Feelings of being ‘one with it all’ and focus on non-human actors	• Feelings of being ‘one with it all’ and focus on non-human actors
• Bike gear is at an intersection point between cyclist and the elements, and cyclists fear climate change will add complexity to their gear rituals and routines.	• Create a garment that is playfully complex that speaks to future concerns about climate change.
• Climate change is difficult to perceive at the scale of everyday life.	• Bend time, overlaying future data over present experiences.
• Cyclists’ hunches about climate change impacts are ambivalent	• Create a platform for open ended reflection
• Cyclists wanted to sense short term aspects of climate change.	• Choose sea level rise, a longer term problem to focus on.

5. Design and Fabrication of the High Water Pants

5.1 Sketching & Early Prototypes

Creating a template for sketching

My designs for the High Water Pants and Heat Shrink Jersey started as a series of sketches. It seemed important to see the garment both on a cyclist on a bike on a person standing up straight so I created a template in Illustrator that had six different positions: a person on a bike from the front, side and back (which I traced from photographs) and images of a person standing front, side and back (which I borrowed from the internet). I then sketched and painted over the top of this template to create a range of ideas for both the jersey and the pants.

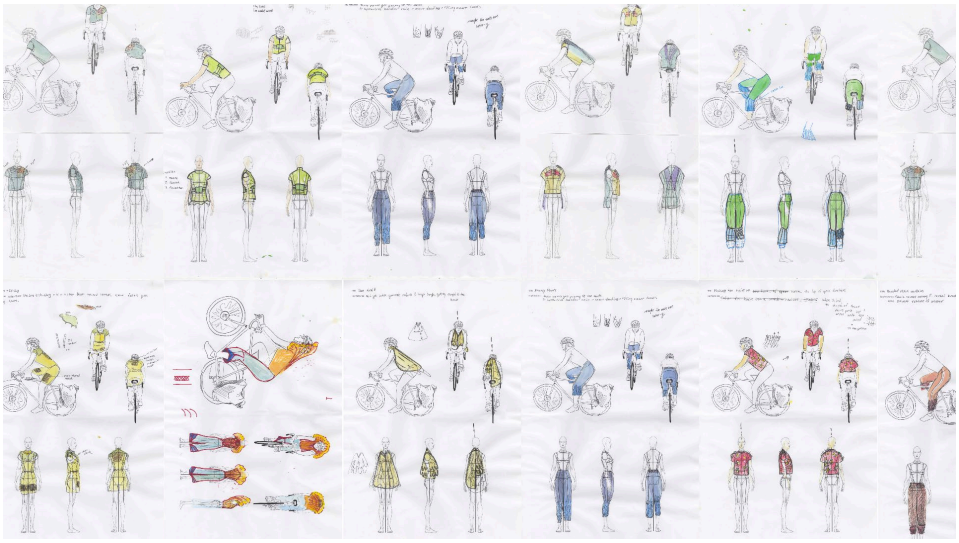

Figure 13. Sample of my sketches over the template.

I analyzed the different types of movement and sensations these sketches would create and the associated meanings they might impart and broke them into different mechanical and sensorial strategies for interaction with cyclists:

Garment Movement Classifications

- Pulling up / shortening
  Almost exclusively used with the pants, these designs focused on different strategies for pulling the garment up from a fixed point.
- Unfurling/expanding
  In these garments meaning would be made when something expanded (often a collar) or unfurled into the wind either shading the cyclist's neck or allowing additional air circulation around their torso as well as a fun enlargement of a shape or an expand/contract movement dichotomy.
- Tightening/contracting
  These garments were designed to tighten to make meaning. Perhaps to make a rider slightly uncomfortable and claustrophobic or to increase friction or cause slight discomfort.
- Texture, Sound and Form
  I also played with concepts that would create sound using pins shaken by the wind as they stood up on a cyclists' shoulders, change texture using beeswax or a jumpsuit with legs that have a striking formal relationships to the leg position of a cyclists while cycling.
- Venting
  These designs use the wind from a cyclists' momentum to create meaning. If a vent opens the cyclist is suddenly cooled off.

Through these explorations I began to see ways I could move forward in building without losing track of what a cyclists might experience while riding. These categories were ways of both envisioning possible technical approaches to building the garments, materials, colors, aesthetic choices, as well as classifying the broader types of feeling I could create for a cyclist as they moved through space.

Low-Fidelity Experience Prototypes

While creating these sketches, I also designed two different quick experiences to better understand what pulling up on a pant leg felt like while riding a bicycle (fig. 14) and, since one of my favorite ideas from my sketches had beads on it, how beads swung when attached to a cyclist's leg. The first prototype involved sewing a string into the inside of my pant leg.

I attached it to the outside-facing (three o'clock, if the front of my leg was noon) bottom seam of my right pant leg and sewed a loop halfway up the leg to thread the pull-string through to keep it in place.

I then wore those pants on a ride and tested manually pulling the string from out of the top of the waist band by hand. I discovered (and it is strange that I had never noticed this before) that my leg is always moving within my pants as I ride my bike. Pulling the pant leg up on one side created sensation by skewing the leg hole, pulling unevenly and therefore and making the opening slightly tighter as well as lifting the leg of the pant more on the outside than the inside of the leg. I realized that the extra tension created by pulling the outside of the pant leg could distress a motor if the leg opening of pants wasn't wide enough. I also learned that the leg is always moving within the pant-leg as a cyclist pedals and that legs don't have a fine-grain sense of feeling. These three things would prove to be constraints as the design process went on.

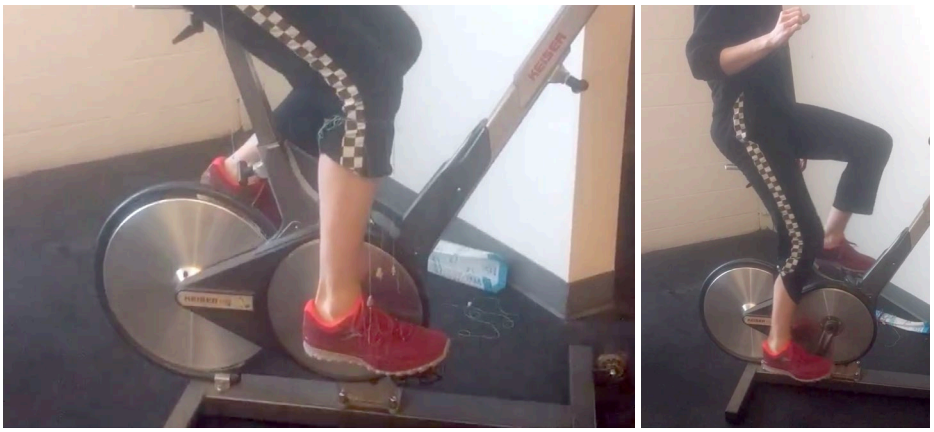

Figure 14. Stills from video of these two prototypes, left to right, beads attached right below my knee to explore bead swing, me pulling a string by hand to raise the bottom seam of my pants up.

GIFS

After creating the concepts I wanted to pursue moving forward, it was time to start building. In order to better understand movement of a cyclists and how their clothing might relate to that, I created a series of GIFs to illustrate the movement of the highwater pants on the cyclists as they rode. I did this by tracing four frames from a youtube video of a woman getting a bike fit. I then used concepts from my larger set of sketches which I was interested in pursuing and sketched them in various states on top of the cyclists moving with legs at 12, 3, 6, and 9 positions on the bike.

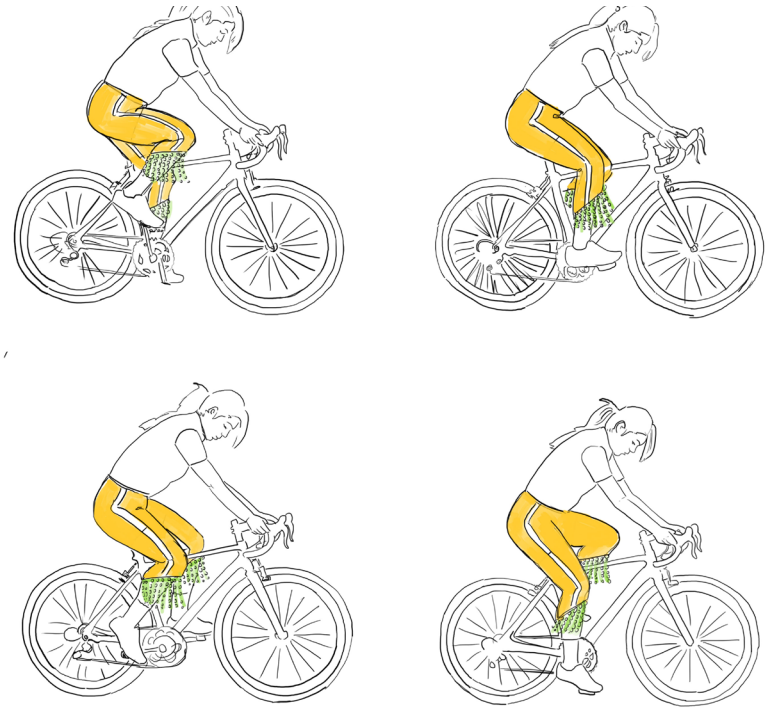

Figure 15. Stills from one gif I made of the High Water Pants with beads.

Again, to reiterate, even though the explorations above had sketches for the Heat Shrink Jersey as well as High Water Pants, as I began to fabricate the High Water Pants, I realized due to the steep learning curve of creating mechatronic garments, I would probably only have time to successfully tackle one design. For this reason, I decided to postpone creating the heat shrink jersey until a later time. From here on is an account of creating the High Water Pants.

5.2 First Pants Prototypes

Although I had several ideas explored by the GIFs and drawings, I needed to narrow to a design option to pursue. I had sketched a variety of technical ways to execute various feelings using both motors and nitinol wire. It was suggested that nitnol wire would require too much electricity and could burn through fabric, so I narrowed to sketches that used motors, which were largely designes that relied on the motor pulling up on the pant leg. While I had sketched pants that simply pulled up, I was more interested in a sketch that utilized the texture of beads as a part of the feeling on the lower leg, adding a tactile experience that was more meaningful because they are heavy, round, smooth and would be cold to the touch if they were glass, which would feel like and somewhat reflect water droplets, and they might also have a rhythmic auditory component as a cyclists pedaled and the swung back and forth.

I decided to move forward from the sketch of the bead fringe pants which used an inner sheath to raise and expose or lower and mute the feeling of beads against the cyclist's lower leg. To begin, I decided to create a very rough, but complete, analog physical prototype that closely followed my sketches and gifs which served as a proof of concept and afforded me and opportunity to dive back into sewing and pattern building, as well as do an initial audit of mechanical complexity.

Figure 16. Here's the first sketch I based these pants off of. I modified the pattern by chopping off the pant leg at a diagonal which from front to back, when the cyclist's leg was bent, would create a parallel line with the ground (as was modeled in my moving GIF). With the beads dangling down around the pant leg opening, I hoped this would visually represent a water-level line. I sewed beads only to the outside of the pant leg (away from the bike frame) so they wouldn't interfere with the chain or bang against the frame of the bike. I designed a fabric sheath that would fit inside of the leg of pants and attached two strings, one to each side of the sheath, that I ran up the inside of the pants and could pull manually from out of the top of the waistband to protect the leg from the swinging beads when down, or when pulled up, exposing the bare leg to the cold, swinging bead strands.

Through testing the design out at a slow speed by riding my bike and manually pulling the sheath up my leg I learned that I could feel a difference in texture when the sheath was pulled up, but the beads were chunky and the bead strands were too long so they eventually got disorganized and started to swing against the bike frame. The design of the sheath also seemed messy and complicated and would require many inches of pulling to be accomplished by whatever mechanism I found to pull the pant leg.

First Pants Prototype Findings:

- Beads were too long and heavy and became disorganized quickly, hitting the frame.
- However, beads did feel interesting on the lower leg
- The inner sheath might be complicated to pull up over the knee joint and to raise equally from multiple points with one motor.

5.3 Mechanical Development of the High Water Pants

While creating a the analog prototype and exploring materials, I also started learning about servo motors and how they would work attached to pants and in relation to the movements of cycling. I created some test code and started applying them to a pair of pants I already owned to see what type of pulling systems I could accomplish mechanically on a fabric surface. I worked on the mechanical and code parts of this project separately and combined them towards the end so I will discuss their development separately as well.

5.3.1 Rough Explorations on Existing Pants

I first began to test servo motors with a pair of pants I already owned but wore infrequently.

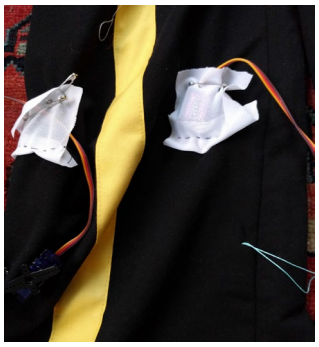

Figure 17a. Basting stitches and power mesh to secure servos.

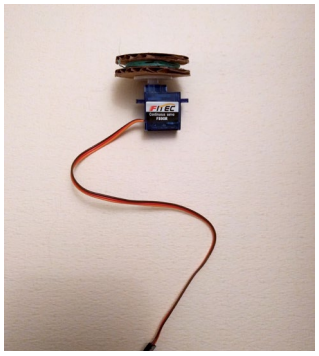

Figure 17b. 360 degree servo with a very dubious cardboard spool.

Figure 17. I started by sewing servos on with large basting stitches and using stretchy fabric and power mesh to strap the motors place. I attached a cuff of smocked fabric to the bottom of one pant leg and an inner sheath, much like the one I had used on my analog pants mockup to the other leg. On the leg with the smocked cuff, I used a 180 degree servo motor to pull straight up on the smocking. On the leg that had the inner sheath I wanted to pull up on, I attempted to use a 360 degree, continuous servo motor with a cardboard spool mounted on it to evenly pull up on strings attached to the inner sheath.

Findings about servo motors through this prototype

Servos offered the following constraints in relation to precision, and their interaction with fabric and pulling potential.

- I discovered the 360 degree servo was difficult to code with the type of refinement that would be required to pull fabric to a specific height.
- Spools need to be designed with more precision and it was easy for the string to fall off and wrap around the shaft of the servo motor where it attached to the spool.
- Servo motors can't pull very far. While I could create a longer arm or spool with a larger radius I still needed to adjust the design to work with a slightly smaller pulling distance than I initially imagined.
- The shape of the servo itself offered some better and worse design choices. Servos are rectangular so there are smaller sides and wider sides to attach to the fabric. To attach the servo to a pair of pants on its narrower or, upright-seeming end, would necessitate creating a support structure. The narrowness of the base, attached to fabric, would cause the motor to fall in on itself as it pulled the weight of the fabric. The nice thing about the servo attaching on its narrow end would be the ease of attaching a spool, as would rotate parallel to the pant leg and therefore spool could pull directly up on the bottom of the fabric. (this is where a stepper motor could have simplified things).

- I could have then switched to a DC motor or stepper motor and designed a mount with a hoop to guide the threads into the spool attached to the motor, *however* servos have the benefit of being lightweight, requiring few pins on a microcontroller and less power than some other types of motors so it seemed worth continuing to try with these motors.

Findings about servo placement through this prototype:
I also realized that choosing a place to put the motor would be complicated due to the rider being on a bike and pedaling.

- The only places you can really mount a servo on a cyclist's leg are the front, top and outside of the leg. The inside of the knee or leg isn't a good place for the motor because they might hit the top tube of the bike. The backside of the leg is either parallel to the ground or the pants are being creased dramatically in the knee joint as the cyclist pedals so the structure would require cabling, support structures or for the mount to be below the knee.
- Placing the servo higher than the knee joint adds complexity. Directly to the outside of the knee, any motor mount would change angles often as the leg goes through different angles as it passes through a complete pedal stroke, which also causes the fabric around the knee to crease. Pulling from the hip would cause drag since the distance of pull is greater and still has to go through the variable angles of the knee joint. Finally, pulling from the top of the knee created great variability in tension on the motor and string as the leg passed through various angles.

Deciding to build below the knee joint:
Due to difficulty of placing the servo above the knee joint and the lop-sided nature of only being able to really place the servo to the outside and front of the leg as a cyclists rides, I decided to create more detailed motor experiements that would work below the knee joint. The following detailes my methods for creating these experiments.

5.3.2 Fake leg to prototype below the knee

After deciding to try to find a mechanical solution that lived below the knee joint on the cyclists, I quickly realized that it would be helpful to use a faster way to prototype and test out ideas than sewing things onto already made pants which I had to reach inside of to blindly sew onto and also required that I take them on and off to see the design take shape and test mechanisms.

To explore mechanical solutions without having to try pants on, I made a model of a lower leg to craft prototypes on. I tried out four different mechanical experiments using the constructed leg model which I detail below.

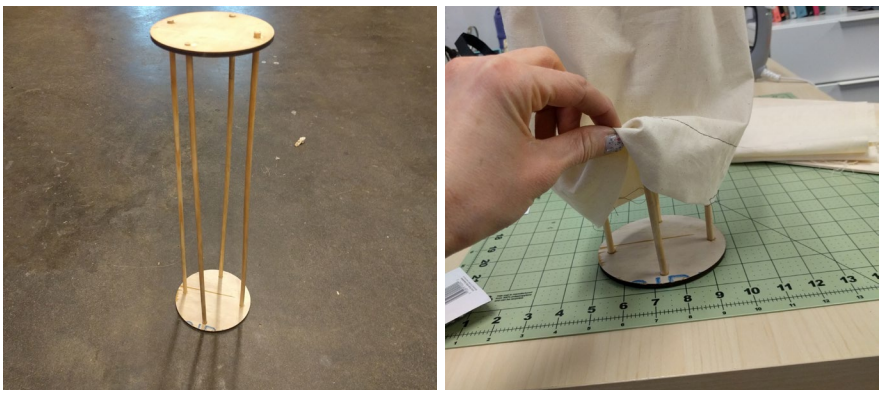

Figure 18 The 'fake leg', the base for several prototypes. I created this model by measuring my own leg and then laser cutting two circles that represented a rough circumference of my lower leg with holes for ¼" dowels. I then cut dowels at the length of my leg by and inserted them into the circles. I also created another frame to drape designs on. I then created tubes of muslin that were slightly larger than the circumference of the frames I would drape them on to attach motors and pulling systems to.

Spool pull prototype

In this prototype, I made a pulling system that pulled straight up on the hem of the pants. I made two different sized spools out of cast acrylic which I glued together which had different radii to test with. I also tried the spools with both a micro and large-sized servo motor.

Figure 19. The motor was placed at the very top of the model leg since I visualized it being right below a cyclist's knee joint. I attached the servo motor at the narrower part of the base, which is a weaker way to attach it so I strapped it on with nylon webbing and attempted to make a small x-shaped support structure. I also used the nylon webbing to strap the servo to the pants and add structure to the top and bottom of the pants. I sewed on a series of laser cut loops to guide string being pulled and later modified the string with butterfly clips to investigate how adding 'stopping' mechanisms could make the pull of the spool bunch up the pants in a more evenly distributed way.

Insights from spool prototype:

- The servo will sag in on itself when standing on its more narrow base. I tried to solve for this with structural support from nylon webbing and a supportive 'x' structure, but it still kind of fell in on itself no matter what.
- The fabric would get pulled not just up, but out and up, from a mechanism that protruded from the pant leg. This might impact the feeling of the pants on the cyclists' leg and would probably pull against the leg on the opposite side of the motor/pull system.
- Spools are relatively unstable, require guides to keep string on. It would have required a lot more refinement to be stable enough to hand off to the public in user testing.

Hoop Guided Pull

I also tried designing a hoop that could guide pulling from 4 places simultaneously and then, theoretically, gather all of the strings to one spool on a stepper or DC motor.

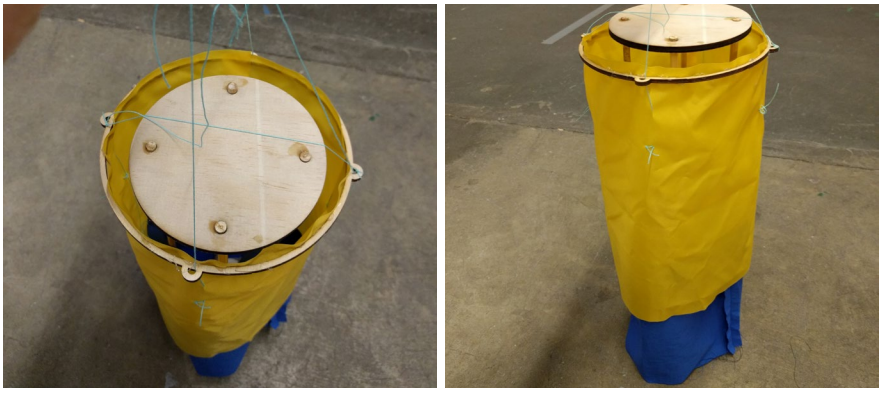

Figure 20. I laser cut a larger hoop that could fit over my leg with 4 smaller hoops along the edges of wood for string to pull through. I then sewed a pant leg and an internal sheath that could be pulled up from the inside of a pant leg using four strings (similar to my first, analog design).

Insights from hoop guided pull prototype:
Even though the design would have allowed me to pull evenly around the leg, I decided this approach wasn't ideal because the hoop would most likely bump against the frame of my bike as I rode and collecting four strings onto a spool could be difficult if they tangled or fell off.

Texture Flip Prototype:
I also designed a flap of fabric that a 180-degree servo motor could turn over which would have one side with a plain texture and one side with bead strings. The thought was that depending on which way the servo was turned, a different texture would be exposed to the leg.

Figure 21. The following are still sfrom a video showing the fabric flap flipping over. On one side I attached strands of beads, and I left the other side blank so texture would change if the fabric flipped.

Insights from texture flip:
While easier to build, this design seemed to have a small impact, would require multiple servos to create an effect that wrapped around the leg and also didn't raise up the pants, only changed texture against the leg. I considered it a plan B because of the mechanical simplicity, but I thought it might have electrical complexity and maybe be too clunky for cycling if I added more than one or two motors at the bottom of the High Water Pants.

Platform Pull Prototype
In order to keep the servo from falling in on itself as it pulled, I invented a platform that the servo could be attached to that was as long as the pulling arm so the arm would have something to pull against that it was also attached to and was solid. My original thought was that these simple platforms could be combined together with a short pull arm to create repeatable and additive pulling system. However, I eventually just settled on making the platform slightly longer and creating a longer pulling arm. This was the design I eventually went with, probably due to its simplicity and the fact that it really worked with fabric. It was low-profile and afforded quite a bit of stability.

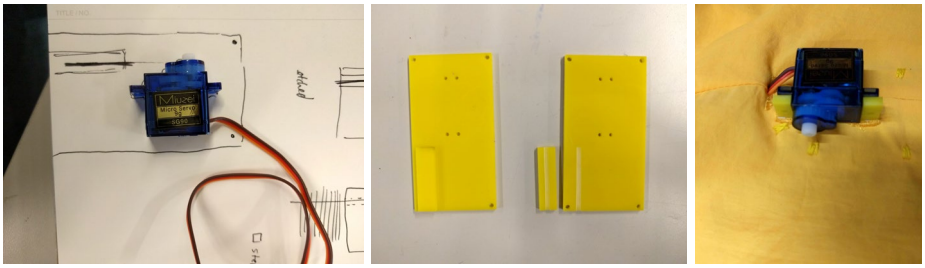

Figure 22. Iterative development of the platform pull, left to right, first sketch, first prototype, discovering how to pass the arms through pant leg with button holes.

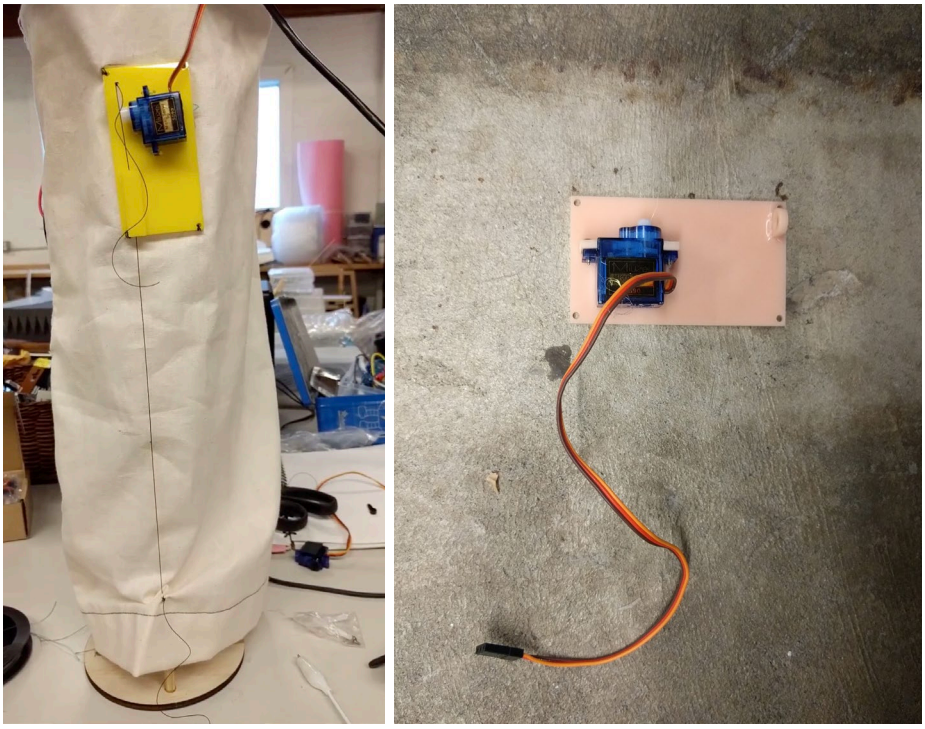

Figure 23. First exploration and first more complicated, interlocking model.

Insights from Platform Pull Prototype:
Simple design (although I refined it many times over the course of development) that had a way to pull against itself (stable) worked pretty well!

5.3.3 Other Mechanical Experiments

Beyond the model leg, I also investigated to other possibilities for construction, soft/sewn on electromagnets and a kind of spring-loaded beat-tautening system.

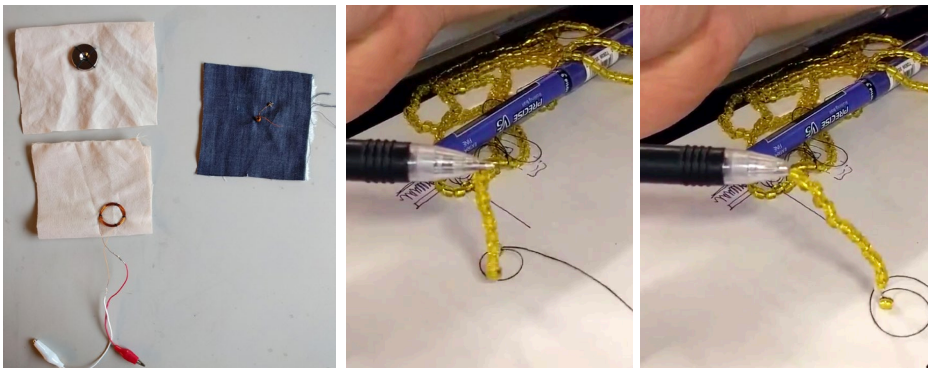

Figure 24. Left to Right, other experiments like electro magnets (big and small) and click pen bead tautening experiment (loose and tight)

Electromagents
As seen in Koba Kant website, there is a potential to use soft, hand-crafted electromagnets to pull fabric together. I made coils of copper wire, sewn them on some test fabric that I then applied an electrical current (fig. 24). I thought if the magnets were strong enough, it might be possible to use several of them in conjunction to pull the pant leg up. The magnets didn't prove strong enough, however and would have required more electricity than I was interested in asking a cyclists to cary around with them in terms of batteries.

Bead Tightening With Spring

I also briefly explored a mechanical solution that would tighten and loosen strings of beads instead of raising and lower fabric. This would create different textures (loose and flowing bead strings or taught and rigid bead strings) on the leg instead of raising or lower the pant leg. The rough prototype I created (alongside a mechanical engineering student) used the mechanism of a click pen (fig. 24). We attached a strand of beads to the pen ink shaft with glue so that when the pen tip was out, the beads were slack and when the pen retracted, the string wrapped around the ink well went farther back in the pen and pulled the beads against the end of the pen and they went taught.

Eventually this idea was abandoned because it came too late in the project and I alread hathe platform which seemed to work fairly well.

5.5 First Entire High Water Pants

In order to uncover complexity in creating a set of pants, I built pair of pants in their entirety to test not only the mechanism, but the code as well. I decided to try the platform side-pull method first and see how it went. I started with a pair of pants I found at Goodwill which had the basic shape I wanted to use, being wide legged but cropped. This was the first time I really tested the full, mechanized pants while riding as well.

Figure 25. In order to connect the servos to the microcontroller, I first created traces using conductive thread but discovered the thread wouldn't deliver power efficiently enough to the servos, so I switched to wire traces. I placed the microcontroller on the back of the pants around the waistband, which was really difficult to see and reach, so I moved it in later iterations.

Findings from the first whole pants:

- The platform pull method when on the side of the leg was a great way to pull up on the bottom of the pants. I tested the platform on the front of the leg and the side of the leg with a magnetically sealed opening on the opposite side of the motor. The motor seemed to encounter less dramatic pulling resistance when it was on the side of the pant, which I also felt was a successful test.
- Conductive thread wasn't conductive enough to deliver power evenly to my servo motors so I used wire in my design instead.
- The GPS geofence worked, but I needed to solve for computational interference between the running the servo and reading the GPS. By using a conditional statement that brackets the possible GPS coordinates to those above 47 degrees latitude, I solved this glitch.

- The feeling was not yet clear enough. I had a hunch this might be resolved with a higher fidelity version of the pants with more precise components builds, but I did create a version of the pulling system on each side of the pants and I tried to be more clean and precise on the second side, and even then, the feeling was not very clear when I tested it by riding my bike.
- To try to make the feeling clearer, I added beads to the inside of the pant leg which made the feeling of the pants on the leg stronger but not clearer and also made the pants uncomfortably heavy. I added beads to try to pay homage to my original design and to try to create a more coherent, cold, 'watery' feeling on the leg, but ultimately it added to confusion.

All in all, I felt that the feeling on the leg still remained difficult to fully comprehend. Feeling was also hard because, as mentioned before, as the pedals turn, the pant leg already subtly moves up and down the leg, adding a mere few inches of fabric movement to this experience on a shin bone is almost imperceptible if the state change isn't precise.

5.6 Creating a more integrated pulling mechanism

After completing the first full pair of pants, I received critique that the pulling system (motor/string/accordion/grommets etc.) needed to be more integrated into the material and fabric choices of the pants and that beads might not be unisex enough (a goal of my project was to create unisex garments). I went to a hardware store and an outdoor fabric store and began to experiment with new, more technical materials to try to bring the pants to life.

I did a series of material sketches with new materials which I photographed (fig. 26) I then translated these analog material constructions into a design that would integrate with the servo motor and platform pull mechanism. I chose three concepts to build out (fig. 27) and test.

Figure 26. I gathered technical, sporty and mechanical materials like a variety of chain, d-rings, sport and power mesh, technical fabrics which were water resistant, reflective ribbing, and nylon webbing. Then, I created compositions from these materials which I photographed to document a variety of ideas and work relatively quickly [photos of this].

Figure 27. Examples of one of the physical pull prototypes i built based on the material sketches above.

In the final iteration of this pulling mechanism, I integrated the mechanical and material findings from the previous experiments into the servo arm to also make that part of the design seem like a part of the pants and not a mechanical addition. I shortened the servo arm and added cross-beam supports. I then sandwiched the servo between two pieces of nylon webbing and added a d-ring at the end which was the point where the pulling mechanism attached to the bottom of the pant leg in order to pull it up. I started with an exposed servo arm and then moved to an arm that used nylon webbing as part of the length of the arm. In addition, I created a kind of scaffolding of webbing to pull evenly on the bottom of the pants (fig. 28).

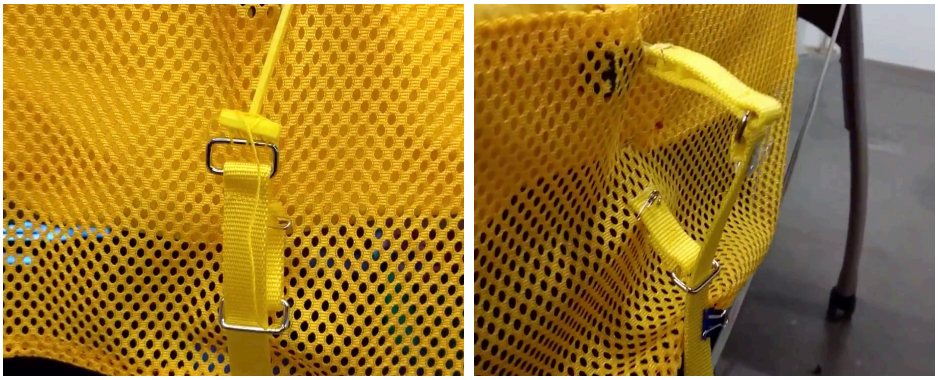

Figure 28. Iterations on the pulling mechanism on the actual pants and arm moving from exposed arm, to integrated arm.

5.7 Construction / Pattern Making / Final Pants

I then began construction of the actual pants I would use. I started by making a muslin mockup, developing pocket pattern pieces and then moving to the yellow/mesh fabric.

Figure 29. To test the initial pants concept, shape, look and feel, I created a muslin mockup of these pants and designed the pattern piece for the external pocket which, at first, was just a simple square pocket, but which I extended to run across the entire front of the leg to give the pants a more technical look and feel, like a utility pant or a Carhartt pant with external reinforcing. After I had made sure the muslin pants fit, I began cutting the higher fidelity fabric for the fully functioning pants prototype.

I chose a pattern that was simple with an elastic waistband and loose, wide leg (fig 30. 1&4) which could easily fit a variety of body shapes. The wide legs as also made sufficient room for a side-pull mechanism which avoided the pants getting stuck on the leg as they were pulled up. I also made sure the leg was cropped to avoid the pants getting stuck in a bike chain. In order to have a space to carry the microcontroller and GPS circuit, I modified the pants to have external pockets across the front of the leg to hold my electronics and created a pattern to repeat these pockets uniformly across all pants I constructed (fig. 30). I sewed a buttonhole to the outside of one of the pockets to pass wires from the inside to the outside of the pants through and I also added a Velcro closure to the pocket so the circuit wouldn't fall out while the cyclist was riding. The wires for the servo were couch stitched up the outside seam inside the pants and connected with the microcontroller through another buttonhole at the edge of the pocket where the microcontroller was kept (fig 30. 1&2)

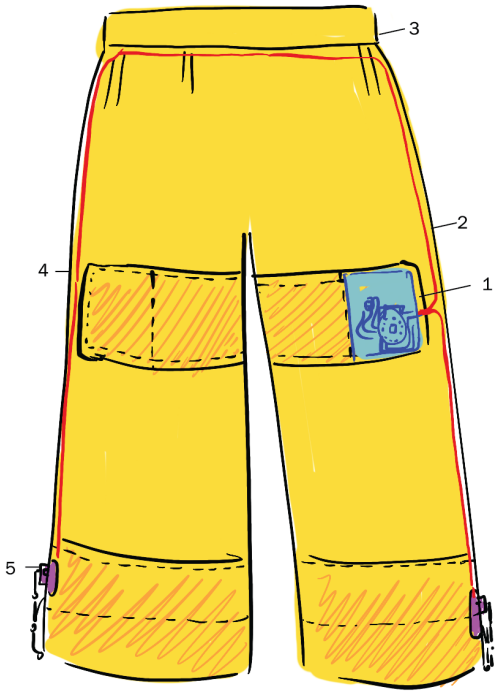

Figure 30. Sketch of some elements of the pants: (1) pocket and soft circuit, (2) red shows wire path couch stitched into seam of pants, (3) elastic waist for many sized riders (4) wide leg for many sized riders (5) servo attachment.

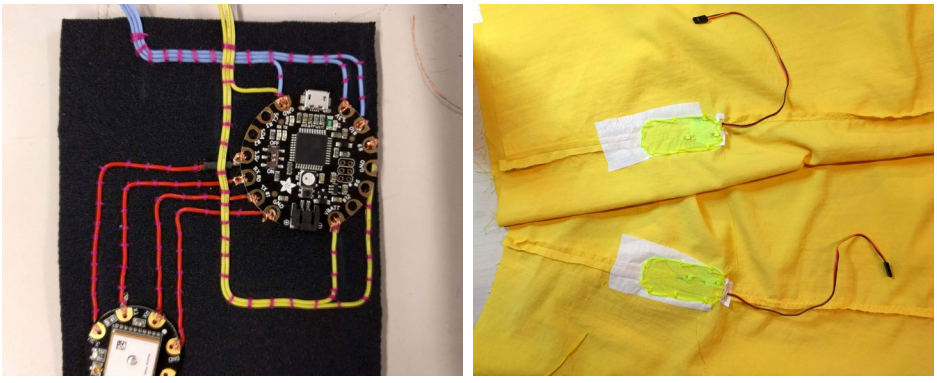

Figure 31. Left to right: soft circuit couch stitched with silicon wire, inside of pants showing the back of the servo with the servo wire passing from front to back of the patns through a button hole.

Figure 32, 33, 34. Final High Water Pants show in stills from their product video.

5.7 Computational System

While I was working iteratively on the mechanism parts of the pants, I was also working on the computational aspects of the pants. There were considerations and iterations in both the hardware and code I used to run the High Water Pants.

One of the main requirements of the High Water Pants was that they understood where they were geographically in order to raise and lower within certain zones. To accomplish this, I used a Flora Wearable Ultimate GPS Module in combination with a Flora microcontroller to create a GPS geofencing system. The GPS module could track where a rider is at all times. That location is then sent through an algorithm in the microcontroller that can detect whether or not the rider is inside or outside of a polygon which it builds through a collection of latitude and longitude points held in arrays. This can all happen as a cyclists rides, negating the need for a Bluetooth connection to android maps.

To create the geofences, I used the My Maps feature of google maps to create a set of points that would create a rough geofence that matched NOAA maps for sea level rise in the same area. [image] From these points, I would collect the latitude and longitude in a google docs spreadsheet and then manually load them into arrays in a program based in C that I could run on my computer. I had help writing since I have no experience writing in C. The C program was the polygon detection algorithm with a few lines that would print in the terminal for testing which would tell me whether or not a fixed point I would input manually was inside or outside of the polygon. So this is the sandbox where I tested my geofences to make sure they were functioning properly before I loaded them into the microcontroller and tested them in physical space.

There was an intermediary stage between this code being totally functional and integrated which I mentioned briefly in my account of creating the first totally integrated pair of pants in section 5.5. I started be inputting a polygon around my own home and attaching it to an Adafruit NeoPixel and writing code that would turn the NeoPixel red if I was outside of the polygon and green if I was inside of the polygon as a loose foil for actuating the servos with this code in the future. I then walked around my house, with the serial monitor open to double check that the code was working (if the serial monitor printed a 1 I was inside of the polygon and if it printed a 0 I was outside, it would also print the latitude and longitude, so I could reverse test my code to see where the GPS thought I was). This was the first way I tested the polygon detection algorithm in the physical world.

As I refined my code for testing with users wearing the High Water Pants, the code had to be refactored and refined to manage servos and boundaries. In the first stages of my code, I was just writing something along the lines of, “if the cyclists is inside of the polygon, make the servos rotate to 180 degrees, and if not, make them rotate to 0 degrees.” However, due to the way I constructed the pants, the servos were actually mirroring each other, so if a rider was inside of the polygon, one servo would need to think it was at 180 degrees and one servo would need to think it was at 0 degrees. For this reason, I had to create a for loop to equally step the servos through their oppositional trajectories at boundaries of the geofence and therefore I had to refine the code to only happen when the GPS noticed that it was changing states from inside, to outside of the polygon. This worked! But the fast rate at which the microcontroller was taking GPS readings meant that as a cyclist approached a boundary, the servo motors could jitter and go up and down in a strange and excited way. This, to me, actually seemed fairly interesting, but in order to calm down the impact a bit, I (again with help because I’m not that fast at coding) wrote a counter to track if a boundary had been ‘noticed’ by the polygon detection three or more times. After three times of recognizing either being in or out of the boundary, the pants would raise or drop accordingly. This still left room for the servo arm to oscillate at boundaries, but at a slightly slower pace.

In order to create a more robust system, I will soon be creating code that accepts multiple polygons, so I can have more areas in Seattle connected to my pants. The areas I currently have geofenced are Golden Gardens and Elliot Bay Trail and the Olympic Sculpture Park. In future iterations, I would like to use real NOAA sea level rise map files (available to

download) to create complex polygons for this project. The goal of having more geofences and multiple polygons would be to run a different type of testing with the High Water Pants. Currently, since I only have one area geofenced at a time, I have to tell the cyclist participants where to ride and then they know what to expect, in a way. If the test was more open ended with more geographic locations and they could explore over multiple days, their exploration would be more self-guided and full of surprise and discovery.

5.8 Material Choices

I made a lot of decisions about materials, some on purpose, and some more intuitively and organically. For example, the color yellow became a theme in an organic way. The first cast acrylic I used for laser cutting was acrylic I found in the discard bin and it was yellow. I also had a thick band of yellow nylon webbing I used for that project and all of the sudden, yellow was a theme in my first refined prototype. I followed through with yellow on my final pants because one of my personal design principles had been to create a project that was colorful and weird, and monochromatic yellow was joyful and playful. On the other hand, it is pragmatic! It is the color of a warning, a caution, and draws attention to an issue, or a rider, as they ride. It is the color of raincoats, so it deals with gear traditionally worn in wet conditions.

I was hoping to continue using found fabric for my designs, inspired by contemporary designers like Marine Serre who uses upcycled fabric in their colorful, unisex, futuristic clothing. However, in the interest of time I used fabric purchased from a retailer for my final design. Hopefully in the future, I find ways to incorporate or deconstruct other garments or material for use in my designs. It was also part of an aesthetic turning point to buy fabrics that were technical and ‘sporty’ and helped me refine my direction and integrate materials into the structural mechanics of the garment, so it helped me to step away from ‘found’ materials to clarify my vision and taste while I was in a learning and development phase.

Major Insights from Fabrication

- Creating a clear feeling requires clarity of craft I didn’t achieve a clear feeling until the craft of my pants was clarified and refined as well. Feeling differences on different parts of the body requires different design techniques, the leg requires a pretty obvious change. As do parts of the body while in motion.
- Depending on what part of the body you want to experience change, different design considerations would have to come into play. While the neck could detect a feather, the shin (in motion on a bike) needs more gross-motor movements.
- The feeling needed to be able to blend in and out of consciousness—I needed to craft the right level of ‘feeling’If a cyclist is riding along the water front and it takes like 20 minutes, I don’t want to hit them with a servo for 20 minutes.

6. High Water Pants Pilot

The final phase of research in my thesis was a user testing pilot for the High Water Pants. I wanted to do user testing to to learn how the High Water Pants would influence riders' ability to imagine possible futures in a Seattle when sea level had risen over two feet and Seattle faces chronic flooding and inundation. I also wanted feedback about the experience of using the High Water Pants in order to refine future testing. Through these tests, I saw anecdotal speculation of possible futures, responses to the experience of finding boundaries and the feeling of the pants, and the type of new awareness the pants gave the participants.

I tested with three people age 29, 35 and 38 who have ridden three or more times a week for between five and eleven years. In the future I plan to test with a diverse range of ages and genders, while still maintaining that participants should ride on an almost daily basis for two or more years. The participants were two designer friends and one bike shop owner who had been a part of every phase of my research thus far. This made the participants familiar either with the methods of my project or the trajectory so perhaps they were less surprised by the project that other people with less exposure might be.

My protocol for these first interviews was relatively simple, I met with a participant and made sure the pants fit them. In two cases I modified the bottom of the pant legs with safety pins to make them slightly shorter. I then explained to them the basic principles of the pants and what to expect and told them roughly where to ride. As mentioned before, my code currently only supports one geofence at a time so I gave them the general area to ride within and let them explore the experiment within that area. I then told the cyclists to ride around for as long as they found the experiment interesting. When they returned from their ride I conducted a brief exit interview where I asked for their general impressions, how the garment felt, any ideas they had about what that area might be like when sea levels are higher, and how their history of cycling practice helped them formulate those speculations

One of the first things I noticed was the anecdotal reflection cyclists had on impacts of sea level rise which related to memories they had as a cyclists in that area or the specific ecology of the space they were riding in. In one example, Patricia told a story about how during first few months of living in Seattle, she was having a bad day and decided to go on a bike ride to Elliot Bay. There was an event being hosted by the Seattle Art Museum and the park was so beautiful that the ride turned her feelings about Seattle into excitement and positivity. However, in our interview, she noted that sea level rise might erase public parks, "it's such a nice open space and there's so many people utilizing it . . . but then it goes straight from park to just straight up buildings . . . I think it'd be a totally different experiences living here without that access [to the waterfront] because otherwise it's like buildings [and then] water." She realized the placement of this park by Puget Sound and the immediate rise of land/buildings directly to the east might cause the park to become less useable, reducing public/shared land. In another example, Mort reflected on how if there was chronic flooding and inundation, salt water plants might become more common, imagining the following future ecology: "all of a sudden you get these different like kind of yellowy grasses that you usually see in estuaries . . . maybe you see like the cattails poking up different birds and that you know, suddenly the soundscape is all different."

In addition, both participants of my pilot study remarked on the feeling of the pants, stating it was subtle, and unlike anything they had felt before. Both mentioned how it was unlike typical, tech-type haptic feedback. Patricia remarked, "My phone vibrates, my watch vibrates. Um, but that was different. It was like something moving . . . I can't think of anything else that moves like that. It's very unique feeling." Similarly Mort mentioned, "it wasn't, you know, a device beeping at me and saying like, you know, 'this is the area.' I was just feeling it, sensing it" The feeling of the pants was not like a feeling traditionally associated with technology and was related to the garment and the concept. The feeling was easier to feel in the 'up' position: Mort mentioned when the pants were in the up position he could feel more wind on his legs and pressure from the mechanism of the outside of his calf. Patricia and Darla also mentioned feeling the mechanism against her leg while riding. However, the

pants ‘down’ movement feeling might be too subtle yet. All three participants mentioned having a hard time noticing when the pants went down right away.

All three participants mentioned the feeling of discovering boundaries. Patricia mentioned it was fun and she searched for the boundaries on purpose. Darla was curious when the pants would raise based on her history of riding through Elliot Bay Park—she wondered where they would raise around the park due to recent detours created for cyclists due to construction. Mort also mentioned riding specifically to find the boundaries and experience them. Finally, Patricia mentioned she noticed the pants oscillating at geofence boundaries.

The participants also both mentioned an increased awareness of the issue and an obvious focus on climate change impacts they would have never had been exposed to without the pants and the experience. Mort mentioned, sea level rise “became slightly more real,” and the High Water Pants offered a way to notice and be more aware. Patricia mentioned she was much more aware of the issue wearing the pants. Interestingly, when I asked Darla (who has done every phase of research in my project) if this experience gave her new knowledge, she said, “in general it does” When I asked why just in general, she responded, “since you asked me the first set of questions long time ago it’s been, more real . . .” This response made me wonder if a simple provocation for reflection is enough to stimulate awareness.

I look forward to testing these pants with more people, hopefully over longer periods of time and with a multiple geofenced areas readable by the High Water Pants so cyclists can explore Seattle without as many hints about where to ride. I think having the opportunity to take the pants and explore the city with them, seeking out boundaries in many different geographic locations will engage people’s curiousity and critical reasoning skills as they imagine geographic locations to search that will be impacted in the future. This might tie into their history of practice and give them more self-guided, surprising and impactful experiences.

7. Discussion

Through the act of making a speculative tool for everyday cyclists to tangibly understand climate change, I engaged with climate change and cyclists on multiple levels. Making this artifact opened up ways of addressing the temporality of climate change by creating speculative frameworks and the ensuing fabrication of ways to feel data models of the future impacts in the present. It also explored ways research methods can embrace non-human actors and how technology can mediate empathy not only for future selves but future selves-in-ecology. Finally, it is an example of situating research within the phenomenological lifeworld of a cyclist, showing the unique impacts of climate change on cyclists and exposing the worlds within worlds of climate change impacts. Below, I go into more detail and describe the four themes just mentioned.

7.1 Speculation in the Local, Present/Future: Crafting ‘time bending’ wearables situated in locatable histories of practice.

A major through-line in this thesis is the acknowledgment of how difficult it is to perceive climate change at the scale of everyday life. To revisit concepts from the introduction, climate change is what Timothy Morton calls a hyperobject, which is a phenomenon that operates at radically different temporalities than human scale ones we are used to. For this reason, my thesis argued that climate change will remain intangible unless its generational scale is ‘bent’ to a scale that humans can feel, or at least, imagine feeling. I discovered the present/future speculative paradigm through a timeline framework I created to organize ideas during ideation (pg#). Although I charted present/future on the timeline, it isn’t really a place in time, but rather the bending of two places on a timeline to touch. The present/future echoed how climate scientists use comparison to imagine climate change—for example, the summer of 2015 in Seattle, which maps to the expected temperatures of climate change some tens of years in the future, is often cited by climate scientists as a ‘dress rehearsal’ for what the future will feel like as global temperatures increase. Bending

is a way of comparing. In order to feel climate change, one must have something to compare against so that change isn't lost in the natural oscillation of weather patterns and the slow, incremental rate of change which makes the new seem normal.

Although the present/future lay at the heart of this speculative approach, it relied on a history of practice to function. The nature of the way cyclists understood climate, which was sensorial, embodied and gradually accrued knowledge built through trial and error and daily exposure to the elements, was the reason I believed they would be able to speculate about the future through experiencing it in the present. As cyclists use the High Water Pants, I anticipated that their memories and history of cycling would inform—or fill out—their speculations about the future of climate change. The knowledge built through a history of cycling presented itself as an opportunity, an embodied framework, from which to scaffold speculative tools to make climate change tangible. In addition, the unique speed of riding a bike allows someone to convert a considerable distance and possibly explore the majority of a city in a day or an afternoon, making them capable of drawing conclusions about both granular details about sea level rise in certain locations, as well as larger-scale impacts. While, as Timothy Morton acknowledges, no local instance a hyperobject is the entirety of the hyperobject it seems possible to use hyperlocal points of reference to speculate about pieces of the hyperobject of climate change. The present/future approach speculatively grounds climate change in everyday phenomenology, taking climate change from abstraction to something more concrete.

The tactility of the in-ride experience was also important to crafting the present/future speculation. Although the feeling developed through the highwater pants isn't an exact replication of what the future will feel like, it is a feeling nonetheless, and the feeling is a subtle cue that is meant to be layered into the present, an intimation of what is to come, formless, waiting to be given form by the imagination of an everyday cyclist, one with a history of practice, riding through specific, familiar geographic spaces. Maxine Sheets Johnston argues in The Primacy of Movement, a book dedicated to examining the underpinnings of meaning-making built through movement, that movement forms the basis of language (2011), this type of knowing which is embodied, personal, and somatic offers potential for creating new, memorable, nodes of insight about climate change which function differently than reading about it or looking at models or graphs. This embodied knowledge creates a body-mind memory node, which can serve as a catalyst for new vocabulary for and understanding of climate change. But ultimately, the importance of tactility of the present/future paradigm is that instead of a creative action, it offers a creative moment. While other speculative methods ask one to imagine abstractly, or enact or build potential futures, the High Water Pants ask one to be with a possible future in real time, and leaves the speculation open ended to be authored and evolve over time.

7.2 Crafting subtle tactile cues

Part of creating a present/future experience was crafting the tactile experience which signaled future sea level rise impact zones. The feeling was based on a play on words—high water pants, which colloquially are pants that are cropped 'to not get wet in a coming flood'—so I wanted the pants to move up and down the leg if possible to keep the language that inspired the concept alive. In addition to the concept of having pants that got shorter in areas that would one day be flooded, through my fabrication of the pants I discovered the feeling created by the pants was also was born of interweaving of many technical factors such as climate change data available and the type of movement that data would support (how does data move?) as well as the materials used to build the pants and their mechanics, the movement of a cyclist while riding and their position on the bike, the sensitivity of the lower leg (or lack thereof) and the duration and quality of feeling combined with considerations for how long feelings would last and how they should draw or recede from attention.

In order to craft the High Water Pants' subtle tactile cues, I found that having a thesis for the movement quality was important. The thesis ended up being something like: how can I create a feeling which signals future impacts of climate change in a way that dovetailed with cyclists' experiences riding a bike and their embodied understanding of climate and weather. These goals helped shape many of the decisions I made within the web of influences I encountered. Much of my research of making was uncovering constraints and finding ways to work within them to still create this main thesis or goal. This ended up having me craft a feeling that was somewhat 'analog'—a piece of fabric brushing against a leg and the incorporation of wind against the leg—instead of something that buzzed or beeped (canonical digital/technological haptic/audio cues) while still using data and a microcontroller to generate the feeling.

Another surprising aspect of crafting the subtle tactile cue was, as I mentioned at the end of section 5, the clarity of my craft impacted the clarity of the sensation I was able to create, and the tactile clarity developed slowly through iterations. In addition, the sensation is subtle and does relate to the pants, but it is different than I expected it to be or could have anticipated initially, it relies on the weight of the motor against the cyclists leg as the pants are pulled up and the wind against a cyclists' leg. While much of my explorations sought to have beads of chain dangle against a cyclists leg to signify the coldness of water, in the end I left the design more simple to keep clarity of craft. I discovered through my pilot that parts of the tactile cue could still be refined: those interviewed all mentioned that the 'up' feeling of the pants was easier to perceive than the 'down', I wonder about the potential of these pants to become more nuanced and readable as participants spend more time riding with them.

7.3 Mediating human and non-human intersections and including non-human voices

I was admittedly influenced by post-anthropocentric and new materialist writing while researching my thesis such as Ann Tsing's Mushroom at the end of the World (2015), Donna Haraway's Cthulucene (2016), Jane Bennet's Vibrant Matter (2009) and Liu et al.'s paper on collaborative survival (2018). The intent to have a more-than-human focus in this project permeated my research methods, starting with first-person exploration through Assemblage Shooter where I observed the intersection of my cycling practices with large collections of objects and actors ranging from the asphalt of roads to the calories I put in my body in the form of Cheetos and In the Elements where I explored my skin's relationship to the sun.

In my semi-structured interviews, I was pleasantly surprised to find an unprovoked language emerge around being 'one with it all' emerge. Some of my participants described themselves having transcendent experiences where their human boundaries were permeated or transformed by experiences they had while riding bikes. As mentioned in my research findings, Micha reported being surrounded by a low-flying group of ducks flying in a 'v' on the Burke Gillman Trail. Micha jokingly said he was thinking, "am I a duck?!" And while their reflection is funny, Micha described the experience as surreal, and a unique moment where boundaries blurred between them and another species, if only for a moment. A different example was given by Darla, who described hard rain as permeating or dissolving human/non-human boundaries, explaining how being caught in a torrential downpour, 'you just feel a part of it all'.

In my probe, I sought to give cyclists' gear a voice through the exercise of gabbing gear, which ultimately inspired the direction the High Water Pants. High Water Pants, in a way, have a voice of their own through their movements which communicate climate change projections. The fact that the High Water Pants actuate based on data that they embody independent of being 'useful' to or serving the riders needs put them in dialogue with the rider. This dialogue model contrasts other more hierarchical models for human-technology interactions, such as those found in the wearables for tracking environmental data which bring attention to immediate health concerns or technologies for cyclists which help them with navigation or safety mentioned in the related works section (with the exception of Rep(AIR)(Key et al. 2019)). In this way, the High Water Pants are in a more horizontal

relationship with the cyclists who wear them by having their own ‘language’ or way of communicating that speaks geographically and temporally. It could be argued that their voice isn’t their own: the data they use is was modeled by climate scientists, the geofences were drawn by me, the designer, and the rider has the ability to seek out the boundaries the pants embody giving them some agency over the movement of the pants. However, but the pants operate on their own inherent terms and I would argue that in use, they take on a life of their own. There is a duality to the voice of the pants as well, for if they are speaking literally and speculatively. Part of their voice is that of an oracle, or translator, speaking for/from an ecology-to-be, which will be impacted by sea level rise. While existing post-anthropocentric focus in design seeks to bridge gaps between humans and other species or adapt to survival, the High Water Pants seek to speak within present assemblages of cyclist-Seattle-ecologies from the vantage point of future assemblages of cyclists-Seatle-ecologies to build empathy and author first person climate change narratives which imagine nuanced impacts.

7.4 Cyclists as a unique actor in climate change

Part of the goal of this research was an attempt to celebrate and validate the unique and beautiful experience of being an everyday cyclist while touching on the irony of how this everyday exposure to the elements leaves cyclists uniquely vulnerable to climate change. My goal was to express simultaneously the unique lifeworld and unique impacts that climate change will have on cyclists. I hoped to bring awareness to these impacts and the larger theme of how there are microcosms within climate change where different subgroups of people, even within the same geographic location, will experience climate change differently. In this way, my thesis sought to conduct a subtle, energy humanities analysis of the slow violence that will occur within the practices of cyclists as climate change intensifies. Slow violence is a term defined by Rob Nixon, professor environmental humanities, as the slow, hard to document, impacts to health and wellness implicit in many environmental crises (Nixon 2013) and the energy humanities are the study of, at least in part, how, “the use and abuse of energy have had a significant impact—perhaps the most significant impact—on the shape in which we find the planet today” (Szeman and Boyer 2017, 1) This project reflects on the way those who use less energy are ironically more impacted by the abuse of energy which has been a major contributor to climate change. The way climate change will impact cyclists could be expanded to reflect how it will affect the poor and/or the global south, who will feel climate change through extreme heat and drought in some cases compounded by lack of infrastructure etc. though they use dramatically less energy than first world countries, or (for example) people who fly in private jets.

The narrow focus on cyclists forced attention on how cyclists’ health and practices are already being impacted by climate change and to speculate about how they will be impacted in the future as well, while people who choose more mainstream (in America) modes of transport like cars will perhaps feel climate change less initially. During an interview, a participant brought up an example that demonstrates this quite well—they remarked on how when it is raining and cold and a cyclist pulls up next to a car there is an, “extreme dissonance between you being five feet away from the person that you're experiencing.” This is how it is with climate change as well, there will be dissonance in experience between someone who drives in an air-conditioned car and someone riding a bike while exposed to smoke or hotter summer temperatures in the exact same geographic area. This worlds-within-worlds type of analysis reminds me of the premise of The City & The City by China Miéville where there are two cities within the same geographic area but the citizens don’t ‘see’ or interact with each other even as they walk right next to or by each other down the street. It is possible to live in the same geographic area and have a different lifeworld. I wanted to expose how there are diverging worlds of climate change impacts within the small geographic space of Seattle.

8. Conclusion

To conclude, perhaps it is helpful to frame the scope of this thesis as both a long and cyclical research project that explores the intersections of cycling and climate change and also the process of learning how to conduct research through design. While this project's central artifact appears to be the High Water Pants, these pants are the result of several lines of inquiry, which I was curious about due to twelve years of personal practice as an everyday cyclist. In addition, the High Water Pants are, at their core, an object of inquiry (or the opportunity to continue this line of questioning) so their fabrication created an opening for continued research. The point of these pants isn't to solve the problem of climate change or persuade people to change their behavior, but to explore how climate change can be brought to the tangible scale of everyday life through the specific instance of climate change's intersection with everyday cyclists. The pants extend a cyclist's ability to notice and be aware of those intersections through 'bending time', overlaying future data over present experiences while also emphasizing cyclists' connections to larger assemblages which they are a part of.

I conducted research in phases which built on and influenced each other, starting with mapping the terrain of my intersections with bike gear, the elements and the environment through first-person experience prototypes. This initial first person exploration led me to be curious about intersections of everyday cyclists and climate change. I then conducted qualitative research with Seattle's everyday cycling community through a semi-structured interview and probe kit. This research helped me understand cyclist's relationships to weather, seasons and climate change in Seattle. My research with Seattle's cyclists brought to my attention the difficulty of perceiving climate change, and my research question became focused on how to create speculative tools to make climate change tangible for everyday cyclists. To attempt to answer that question, I built the High Water Pants. The construction of these pants was a form of research-through-making which required topical research and material synthesis to bridge the practice of cycling, the crafting of soft wearable technologies and the impacts of climate change into one, coherent artifact. Finally, to gain insight into what impact that pants would have on people using them, I conducted a pilot study with the finished artifact and I intend to continue with more user testing.

Through this process certain tenets and design outcomes became important. First, I sought to resist stereotypes about ways to 'solve' climate change and resist design directions that sought to persuade or change the behavior of my research participants. I wanted to give participants agency and freedom to think, feel, discover, and encounter, without pressure to change or feel any way I prescribed or constructed for them. Second, I wanted to validate and give shape to the lifeworld of cyclists and their unique understanding of climate and weather. This line of inquiry became the bridge to creating the High Water Pants which leveraged cyclist's embodied experience of weather and seasons into a way to support embodied speculation about sea level rise. Finally, over time I realized I wanted to design for noticing and awareness as a way to allow nuanced, open ended narratives about intersections of cycling and sea level rise to form from participant's histories of situated practice as Seattle cyclists. The High Water Pants embody these tenets and I look forward to further testing their potential and success as 'time bending' bike gear, as well as hearing the speculative futures that everyday cyclists author as they ride with them.

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