

# SPACE LAYER

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Capstone Project

A night landscape featuring a vibrant rainbow arching across a dark sky. The rainbow's colors transition from purple and blue on the left to red and orange on the right. Below the rainbow, a city skyline is visible, with numerous lights reflecting on a body of water. The overall scene is dark, with the rainbow providing the primary source of light and color.

The next frontier of living, working, and recreating.

Though NASA astronauts represent a small and elite consumer group for now, the future of the aerospace industry gives hints as to how large the sector could be and how many more people could be involved. The rise of private companies to the forefront of space exploration has shown that private exploration can move more nimbly and urgently than governments can in some cases. Competing against each other, and working hand-in-hand with governmental space agencies, the 'new space race' isn't driven by a desire to show dominance, as with the 1960's space race, but rather a drive to win customers—i.e., governments and the general public. With strong media presences, companies like SpaceX, Blue Origin, and Virgin Galactic have been focused on ways to reduce the cost of access to space through the reuse of launchers and spacecraft. Their goals are to make space more accessible to people who are not specially trained astronauts (Grady, 2017). As private space tourism and other exploration efforts grow, more products will be needed to equip and outfit these future explorers.

For many on earth, exercise is a choice activity to improve sport skills, stay fit, or improve appearance. For astronauts aboard the International Space Station (ISS), exercise isn't optional—but a requirement for maintaining physical and mental health in order to complete missions and conduct research while in an environment that leaves them vulnerable to bone and muscle loss. As government and corporate space missions run longer and go further, there will be a greater need for products and services that help limit this physical deconditioning during extended time in microgravity (Beringer, 2018). For apparel worn during this exercise and for the everyday (referred to as IVA clothing, or intravehicular activity clothing) new and continuing research is showing a need for specifically engineered garments and showing the ways performance can be impacted through materials and thoughtful design.



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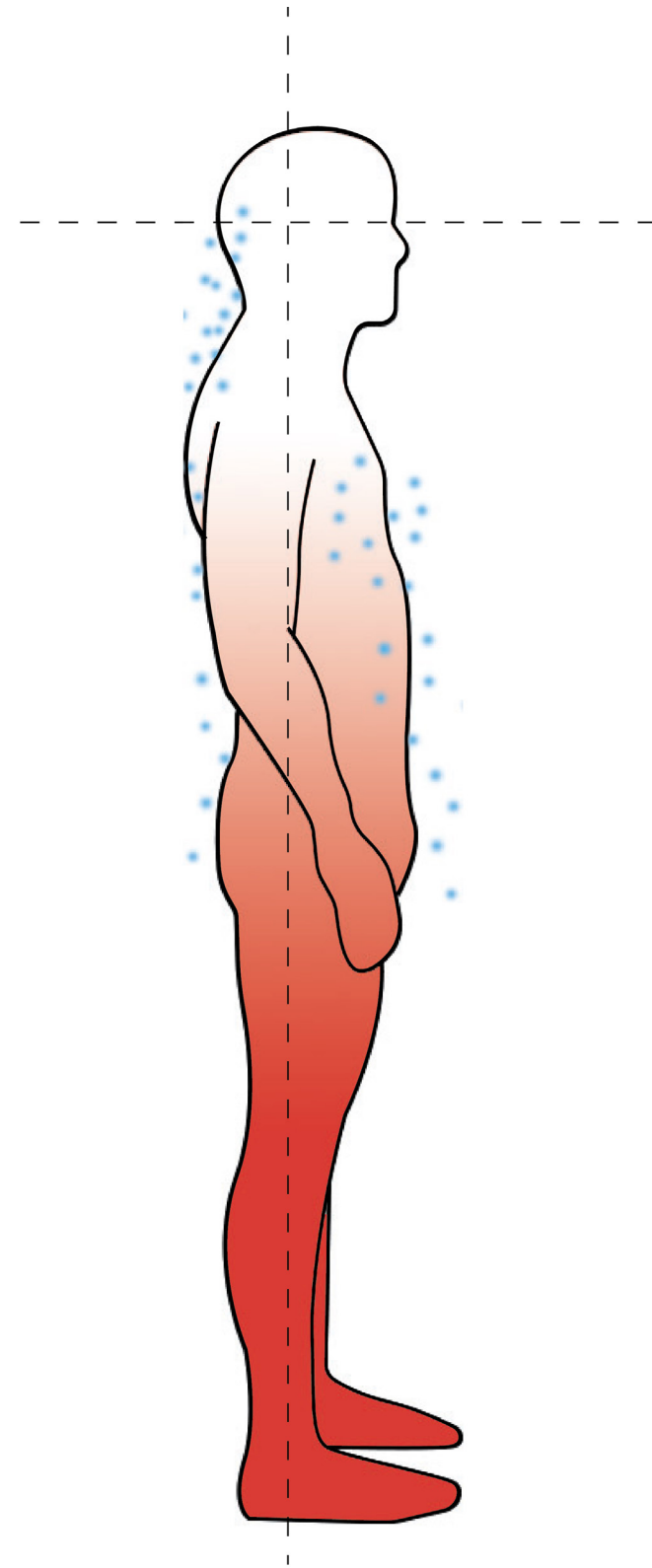
PHASE 1:  
**RESEARCH**



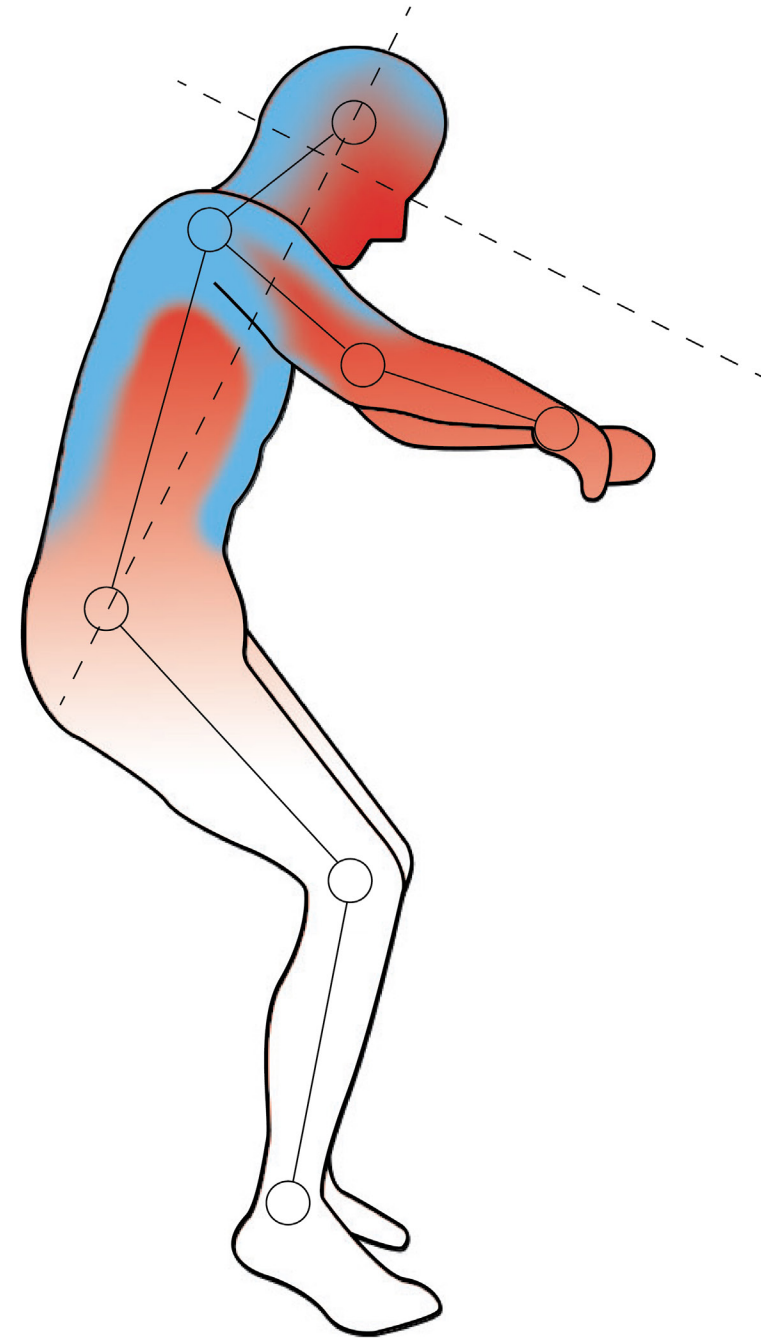
For clothing to be worn on the ISS or a longer-duration shuttle mission back to the Moon or to Mars, it is important to distinguish between IVA (Intravehicular activity apparel) suits, everyday and exercise apparel (also sometimes referred to as IVA), and EVA (Extravehicular activity apparel) suits. IVA suits are those worn during shuttle launch and re-entry to earth, in a pressurized aircraft to protect the astronaut in the event of an emergency. EVA suits are those used outside space craft, for space walks or planetary exploration such as walking on the Moon or Mars. These suits must protect against all conditions of space, but also provide mobility to enable walking and dexterity for experiments (Thomas & McMann, 2012).

The opportunity area (space)layer finds itself in, is the spot between IVA suits and EVA suits—clothing worn in microgravity, for rest, work, and exercise. Though SpaceX and Boeing have released their own IVA suit designs, everyday wear for astronauts remains a hodge-podge of clothing gathered across categories and brands. Armadillo has taken a stab at creating apparel in this space, though it is currently only focusing on tops and utilizing only merino wool.

# BODY IN SPACE



**ON EARTH**  
1g



**IN SPACE**  
microgravity

ADD MORE INFORMATION /  
CALLOUTS ON WHAT COLORS  
MEAN

# MARKET OPPORTUNITY

## HANES / JOCKEY

Undershirt, underwear & socks



## LAND'S END

Polos & long sleeve zip-ups



## CABELA'S

Pants & shorts



## UNDER ARMOUR

Workout tops & shorts



## HEAVY

Majority of kit is cotton, adding 75kg/person/year to payloads.

## SMELLY

Pieces are re-worn for long periods to reduce payloads

## FLAMMABLE

Technical apparel doesn't meet flammability requirements.

## BUILT FOR EARTH BODIES

Pieces don't take into account how the body changes in microgravity.



**W**ith limited cargo space and expensive rockets to get supplies off earth and into space, apparel worn on ISS is planned months in advance of a mission. Clothing is selected by the astronauts themselves, and often arrives to the station before they do, via resupply shuttles or Soyuz shuttles carrying additional astronauts (Petty, 2003). As they are in a controlled lab-conditioned environment, are able to shower everyday and after daily exercise, astronauts have less of a need to change their clothes daily, but rather change every ten days. This works out well considering space and shipping constraints. Exercise apparel is changed every 3 days, as astronauts are working out for 2 hours every day and build up a good amount of sweat (Petty, 2003). Because of limited water resources onboard, clothing is not washed or re-worn, once worn to the point of being soiled. Clothing is placed in a bag for disposal, along with other trash, which is then placed on a resupply shuttle headed back to earth, where the entire shuttle and it's contents are incinerated in the atmosphere (Petty, 2003).

Although astronauts may choose their own everyday and exercise clothing, there are some general guidelines on what should be worn based on previous mission experience. Everyday outfits usually consist of an undershirt, work shirt, cargo shorts/pants, underwear, socks and bra for women (Petty, 2003). Work shirts are generally long or short sleeve polo shirts, t-shirts, or rugby shirts. They are also allowed 2 sweaters, and Polartec socks to wear if their feet get cold (Petty, 2003). Clothing choice generally depends on what astronauts are doing aboard the station—work pants, for example, are covered with many pockets and Velcro to keep tools and equipment near them during instrument repair or lab work. Without these pockets and Velcro, anything they let go of will float away, and wind up on the filter screen of the station's air circulation system for later retrieval (Petty, 2003). Clothing for exercise is basic, generally a t-shirt and shorts for men, and a t-shirt or tank, shorts,

and sports bra for women. If not taking part in exercise clothing research initiatives, astronauts are also free to decide what they prefer to wear during exercise—some wearing armadillo merino wool shirts, and adidas running shorts, or standard cotton military-issue shirt and shorts.

While silhouette remains simple, fibers used for clothing must meet specific requirements to be worn in space, for flammability, toxicity, anti-microbial, and anti-static properties. Currently, cotton is mostly worn for while onboard but NASA is investigating if non-cotton apparel like polyester, wool, modacrylic, and other performance textiles can be suitable alternatives to reduce weight and extend the amount of time that a garment can be worn. Enough cotton clothing for a crew of six adds more than 900 pounds of freight weight to the Space Station, all of which must also go on a cargo launch, and eventually included in trash removal (Orndoff, 2019).

In exercise-specific textiles, SpaceTex is leading the way in research and creation of textiles engineered to perform in space. A collaborative effort between the Hohenstein Institute for Textile Innovation, the European Space Agency, and Schoeller Textiles, SpaceTex is currently testing materials aboard the ISS which provide a higher rate of sweat evaporation, as compared to the cotton mainly worn (Beringer, 2018).

At the heart of the SpaceTex textile investigation, is an intriguing aspect about exercise in a microgravity environment, which is the impact that a lack of gravity has on the body's methods of effectively creating heat loss. On earth, we rely on gravity to drive convective heat loss, and pull sweat down and off the body. SpaceTex has shown that with no to very little gravity, sweat stays collected in high-sweat zones like the chest and back, and heat created during exercise does not rise away from the body, but creates an "aura" of warm air around the body (Beringer, 2018).



## Underwear

North-Carolina based brand Hanes has long been a supplier for astronauts' undershirts, underwear and socks, which are worn daily. For undershirts, the main option is a shirt like the Hanes Beefy-T Crewneck Short-Sleeve T-Shirt, which retails for \$11. It's 100% ultra-soft premium cotton jersey fabric is comfortable against the skin, and fully cut for a roomy fit. Adding to comfort is a non-chafe fabric-tape reinforced neck and shoulders, with a lay-flat collar. It is traditionally made, with durable double-stitched sleeves and bottom hem ("Hanes Beefy-T Crewneck Short-Sleeve T-Shirt," 2019).

For underwear, much depends on personal preference, but in general traditional style boxers, like the Hanes Tagless Men's Full Cut Boxers, are worn. A 55% cotton / 45% Polyester blend, the woven material is breathable and comfortable next-to-skin. For additional comfort, a generous full cut allows for full range of motion, a tag-free label keeps them itch-free, and a 'comfort-flex' waistband is soft and stretchable. It also features a no-gap fly, and retails for \$18.18 for a pack of 4 pairs. They are manufactured via cut and sew, with a conventional lock-stitch ("Hanes TAGLESS Men's Full-Cut Boxers 4-Pack," 2019).

Socks are almost always worn on the ISS, to keep feet warm, to protect the top of the foot from calluses when holding rails for stability, and as a display of professionalism aboard the vessel. Again, from Hanes, is the Men's Cushion Crew Socks, retailing for \$15 for a pack of 13 pairs. They feature FreshIQ advanced odor protection technology, a grey sole for durability, and a cushioned foot bottom for comfort when walking. They are traditionally made, on a circular knit machine, with a comfort seam at the toe ("Hanes Men's Cushion Crew Socks 13-Pack," 2019).



## Workwear: Tops

Based in Wisconsin, Land's End is a key retailer providing the signature mission-embroidered polos frequently seen in the images and videos from the space station. Obtained through Land's End Business, the Men's Short Sleeve Banded Mesh Polo retails for \$35.95 and includes custom embroidery at the upper left chest. It features a five in one finish which resists stains, wrinkles, shrinking, fading, and pilling, and a no-curl collar that stays flat. Made from 100% cotton, it is constructed through conventional cut and sew methods, with a smooth neck cover seam and sturdy reinforced shoulders ("Men's Short Sleeve Banded Mesh Polo," 2019). Astronauts also have the option to get the same polo in a long-sleeve version (Anderson, 2017).

As a cover-up, Land's End Business also supplies the Men's Performance Half Zip Mock Sweater for \$70.95, which can also be custom-embroidered. It features a versatile half-zip style, and shape-keeping cuffs and bottom hem. A fully fashioned flat knit construction, it is made from an acrylic/nylon blend which resists pilling, holds color and retains its natural shape after long periods of wear ("Men's Performance Half Zip Mock Sweater," 2019).

Out of the UK and a newer option for astronauts is Armadillo, a brand built in 2011, based off the premise of providing merino wool base layers to military, first responders and others, to replace and prevent the skin damage which can occur when wearing polyester-based apparel, in the event of a fire. Armadillo's elite range is targeted towards the aerospace industry, astronauts in particular, and currently only features two styles. First, similar to Land's End, is the Polo, a short sleeve polo shirt. It has an athletic fit, 3 button placket front, and generous back length to consider the posture of the body when in microgravity. It is 100% merino jersey, light, and soft for maximum comfortable protection. It is cut and sewn, with single-needle stitching ("Armadillo Workbook 2018/19," 2018).

The second top is similar to the Hanes

Beefy-T offering, called the Cobra Short Sleeve Crewneck, it is a tee with an athletic fit. Armadillo offers it as a versatile piece which can be worn as a performance base layer or a Tee-shirt; it can be seen being worn both ways by astronauts aboard the ISS on their Instagram feed (armadillomerino, 2016). The Cobra is also a 100% merino jersey knit, constructed with single-needle stitching ("Armadillo Workbook 2018/19," 2018).



### Workwear: Bottoms

In terms of everyday work pants, the common choice is khaki cargos, with post-purchase Velcro applied by NASA to the front legs and pocket flaps, for added tool security (Anderson, 2017). Cabela's is the key retailer for this bottom, and the Men's Legendary Seven-Hiker Pants are the most common style, retailing for \$34.99. They feature seven pockets for gear storage, stone-washed 100% cotton canvas for comfortable durability, and a buttoned zipper fly (Cabela's Men's Legendary Seven-Pocket Hiker Pants," n.d.). Astronauts also have the option to wear a version of these pants in short length (Anderson, 2017).



### Exercise: Tops

Considering tops worn during exercise, it is interesting to note that while many astronauts request preferred brands and styles to wear, they will also wear their worn undershirts (such as the Hanes Beefy T or Armadillo Cobra Tee) as exercise shirts after a personally-decided length of wear- averaging around 2 weeks (Beringer, 2019). For those choosing tops other than a worn undershirt, brands such as Under Armour, adidas, and Nike feature basic shirts. For simplicity, only one of the major brands will be discussed in the scope of competitor products, as products from these three are fairly similar in price, features, and materials/construction.

Under Armour will be discussed as it was the preferred brand for German astronaut Alexander Gerst (Beringer, 2019). The Under Armour Tech 2.0 Short Sleeve Shirt retails for \$25, has a fuller cut for complete comfort, and is 100% polyester. The UA tech material has many key features, such as quick drying, an ultra-soft and more natural handfeel. In addition to being quick drying, the material also wicks sweat, and anti-odor technology prevents growth of odor-causing bacteria ("Men's UA Tech™ 2.0 Short Sleeve," n.d.).



## Exercise – Bottoms

Similar to exercise tops, the competitor range of shorts is a mix of basics (in this case, military issue), and offerings from the major activewear companies. Under Armour's UA MK-1 Short retails for \$35, and utilize heat-gear fabric, which is ultra-soft for extreme comfort with little weight. The 100% polyester material wicks sweat, dries quickly, and the incorporates a mesh side panel for added strategic ventilation. Lastly, it features anti-odor technology to prevent the growth of odor-causing microbes ("Men's UA MK-1 Shorts," n.d.).

In terms of military issue shorts, North-Carolina based Soffe is the key retailer. The first of two styles is the Soffe Adult Classic Cotton Pocket Short, retailing for \$14.99. It is made from a classic, heavy 100% cotton jersey, with side pockets and a covered elastic waistband with inside drawstring for adjustable fit. While being cotton, it also features a moisture management finish, to wick sweat and remain comfortable ("Soffe Adult Classic Cotton Pocket Short," n.d.). The second style is the Soffe Adult Dri Running Shorts, also retailing for \$14.99. They are made from 100% supplex nylon, with a 100% polyester brief liner. A covered elastic waistband and inside drawstring make for a comfortable fit ("Soffe Adult Dri Running Shorts," n.d.).



## Differentiation, Independent Designers, and Continuing Research:

For clothing to be worn on the ISS or a longer-duration shuttle mission back to the Moon or to Mars, it is important to distinguish between IVA (Intravehicular activity apparel) suits, everyday and exercise apparel (also sometimes referred to as IVA), and EVA (Extravehicular activity apparel) suits. IVA suits are those worn during shuttle launch and re-entry to earth, in a pressurized aircraft to protect the astronaut in the event of an emergency. EVA suits are those used outside space craft, for space walks or planetary exploration such as walking on the Moon or Mars. These suits must protect against all conditions of space, but also provide mobility to enable walking and dexterity for experiments (Thomas & McMann, 2012). The opportunity area (space)layer finds itself in, is the spot between IVA suits and EVA suits—clothing worn in microgravity, for rest, work, and exercise. Though SpaceX and Boeing have released their own IVA suit designs, everyday wear for astronauts remains a hodge-podge of clothing gathered across categories and brands. Armadillo has taken a stab at creating apparel in this space, though it is currently only focusing on tops and utilizing only merino wool.

Various student competitions sponsored by entities like NASA and SpaceTex have challenged students to envision what this everyday wear would look like, and some independent designers have received media attention for releasing their visions of what this apparel could look like. Most notably is Clément Balavoine, who created an "in-flight" suit for commercial SpaceX passengers to wear during the 9 month trip to Mars. Though not associated with SpaceX, the work caught the attention of many outlets, like HypeBeast (Menendez, 2017). The full-body suits are futuristic looking and skillfully rendered in 3D, but upon closer inspection and with knowledge as to how bodies venturing into space will need to stay healthy, these designs leave questions as to their feasibility and

how realistically the suit alone would keep one healthy. The key features are an electroactive fabric to stimulate muscles, and a structure throughout the suit to support weakened bones. Though potentially aiding health, these designs do not address the real need to exercise in space, or the other real problems around thermoregulation that accompany exercise (Balavoine, n.d.). As mentioned in part A of this case study, SpaceTex is an ongoing effort to understand the physiological effects of microgravity on astronauts during exercise. This will eventually lead to the development of space-specific activewear materials, as the second round of ISS testing was just completed in 2018. After speaking with chief researcher Jan Beringer, the main material currently under investigation is Coolcore, a patented chemical-free thermoregulation fabric (Beringer, 2019). Through a proprietary construction, the fabrics are engineered to distribute moisture quickly throughout the garment ("Chemical-Free Cooling Apparel and Cooling Accessories," n.d.). Although lab results are still pending, anecdotal remarks from test astronaut Gerst showed that there was a noticeable difference in comfort during exercise, as compared to his usual Under Armour gear (Beringer, 2019). Lab results pending, which will lead to innovations in materials—potentially to be applied in silhouette by brand like (space)layer.

PHASE 2:  
**MISSION + BRAND**

# MISSION

Revolutionize in-flight clothing to become iconic, functional garments that augment the body in microgravity.



Unisex



Reduce Mass



Smell Better



Design for Microgravity



Ensure Safety



A new company entering the mix, (space)layer serves global astro-athletes, across all genders and ages. At its core, (space)layer's strength is to look at product holistically—bringing together the latest research on fibers, textiles, garment functionality, and combine this knowledge to create new silhouettes for ultimate performance in microgravity. With a vision beyond apparel alone, (space)layer is also able to ideate on how to incorporate other equipment needed for space exercise, like the Glenn Harness for running or future harness concepts for lifting.

Because astronauts pick their own IVA apparel for everyday and working out individually, (space)layer will interact directly with mission-assigned astronauts, astronauts in training, astronaut candidates, and future lay-explorers in the general public. However, (space)layer will also connect and collaborate with global research agencies and government departments to show due diligence on creating relevant and tested product that fits within current mission requirements.

As a new brand, (space)layer's initial goal will be to establish a market presence, and brand itself as the tastemaker in space apparel. Though there have been developments in textile innovation from companies like Schoeller, and Spacetex-sponsored student design competitions for IVA clothing, few are creating apparel companies that are owning the space market ("Mission to Mars," 2015). Brands that are worn in space are through astronaut preference, versus being worn for microgravity-specific performance properties. Our current metric is basic and straightforward—getting an astronaut to try our product during a stay on the ISS. Because this metric is zero so far, (space)layer will make a push through industry collaborations and partnerships to grow brand awareness through social media impressions, to get more product in the hands of astronauts.

# SWOT

## Strengths

The key strength to (space) layer is its ability to take a holistic approach to space clothing and associated products. From looking at the competitor landscape, and all that goes into an astronaut's in-flight or in-station kit, there could be opportunity to combine, reduce, and figure out ways of reusing or washing clothing in novel ways. As a not yet established product or brand, (space) layer is flexible, and can still go towards the area with the biggest opportunity area for product innovation. With a background in sports apparel, (space) layer also brings knowledge of sport physiology and biomechanics, and how those theories may play out in space apparel. A strong maker and prototyping background also enables (space)layer to develop concepts quickly, and push beyond the traditional making methods of places like Land's End, Hanes, and even Under Armour.

## Weaknesses

The main weaknesses of (space)layer is a lack of knowledge in the aerospace industry, and a lack of connections to key experts in the field. Without thorough research, and effort to find these experts, (space)layer is at risk of creating concepts similar to Balavoine's— designs without the meaningful design solutions to answer the physiological problems beyond space. (space)layer must move beyond this and create product that is grounded in research, feasible today, and which has been reviewed by industry experts. (space)layer is also vulnerable if it ignores the opportunity to connect back product to earthly pursuits or consumers. The question will be, how can product solutions also excite, inspire, and improve the lives of people going to never going to space? What are the crossovers for other apparel brands to implement in their own product?



## Opportunities

There are many opportunities for (space) layer to capitalize on, in terms of marketing and potential eyes on the project, given the timing of the brand's launch in June 2019. 2019 is going to be an exciting year for a renewed excitement and focus on space exploration, as this year marks the 50th anniversary of the Apollo moon landing, the Commercial Crew Program is planning for its first crewed missions, with test launches from Boeing and SpaceX in early summer, and operational missions at the end of the year (Lewis, 2018). (space)layer can also potentially capitalize on political efforts to bring manufacturing back to the United States, as all brands used through government contracts must be made in the United States. In addition, focusing on the end of life for the apparel or novel ways of "washing" clothing may be an opportunity that other apparel brands are not currently considering.

## Threats

Threats to (space)layer include recent government shutdowns to public space entities like NASA, and a general smaller amount of funds to the government program—though this may be countered by private space exploration efforts. Breakthroughs in materials and physiological research may contradict or supersede a product released by (space)layer. Though 2019 will be an exciting time for space exploration, and all the attention put upon it, non-astronaut consumers or general followers may grow overstimulated by the topic and lose interest. Added attention to space exploration may also put astronauts, astronauts in training, and astronaut candidates under an additional spotlight—and more brands may be competing for their attention.



# CONSUMER

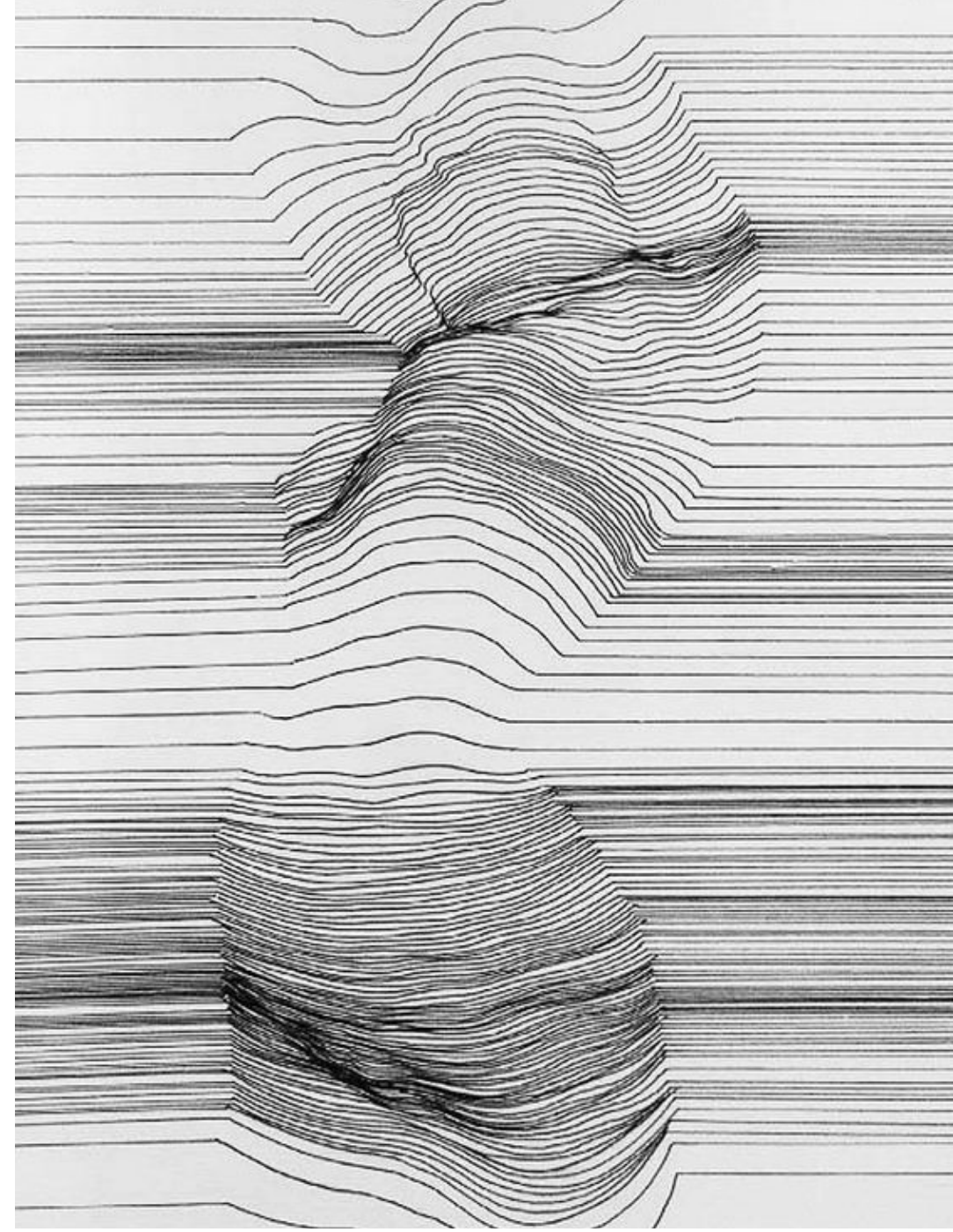
Since the beginning of space exploration, a total of 550 people have been to space, 220 of which have spent time aboard the ISS, living and exercising for an average of 6 months at a time (Brown, 2016). To make the market even smaller, there are fewer than 128 active astronauts (United States), cosmonauts (Russia), and taikonauts (China) worldwide (“List of Space Travelers by Name,” n.d.). It is no surprise this market is small—given the skill, training, and dedication it takes to become an astronaut. NASA’s requirements include:

- 1) American citizenship;
- 2) A bachelor’s degree in engineering, biological science, physical science, computer science, or mathematics;
- 3) At least three years of related professional experience after degree, or at least 1,000 hour pilot-in-command time on jet aircraft;
- 4) The ability to pass the NASA long-duration astronaut physical.” (Dunbar, 2015).

Of the qualified candidates who make it through screening and testing to become selected as astronauts, the majority by far are male, and come from a military background. Though they come from all over the United States, most come from the highly populated states of Texas, Pennsylvania, Ohio, New York, and California (“Astronaut Fact Book,” n.d.). NASA does not have any restrictions on age for those applying to the astronaut program, but past candidates have been between 26 and 46 years old, and the average age is 34 (“Astronaut Selection,” n.d.).



# MOOD



# BRANDING

BRAND PATCH, HANGTAG, PACKAGING



branded patch



Hangtag



packaging

PHASE 3:  
**FIELDWORK**



### **KIT COLLECTION**

Purchased clothing and analyzed them for construction & materials. All rely on conventional making like lockstitch construction. All were 100% cotton twill weaves or jersey knits.

### **EXPERT INTERVIEWS**

Met with Dr. Jan Beringer of SpaceTex, and Bill Dieter of Terrazign. Spacetex future direction will be odor solutions, and Terrazign stress the difficulty of NASA flammability standards.





### **NEUTRAL BUOYANCY DONNING & DOFFING**

Subject rated ease of donning & doffing of each piece from 1 to 5. Future pieces should consider not going over the head, and minimizing bending at the waist.



# FIELD TRIP - HOUSTON



## **SPACE CENTER UNIVERSITY**

Spent a week at Houston Space Center doing engineering & design challenges around rocketry, mars habitats, heat shields, robotics, and cryogenics. Historical IVA research.

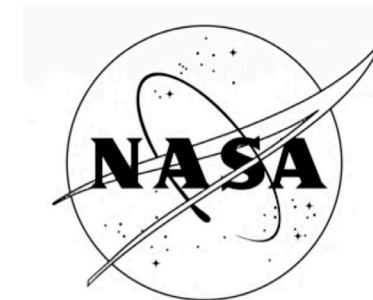
## **NEUTRAL BUOYANCY LAB**

Observed donning of spacesuit and getting suit ready for neutral buoyancy. Key takeaway was the massive team & work that goes into keeping astronauts alive.

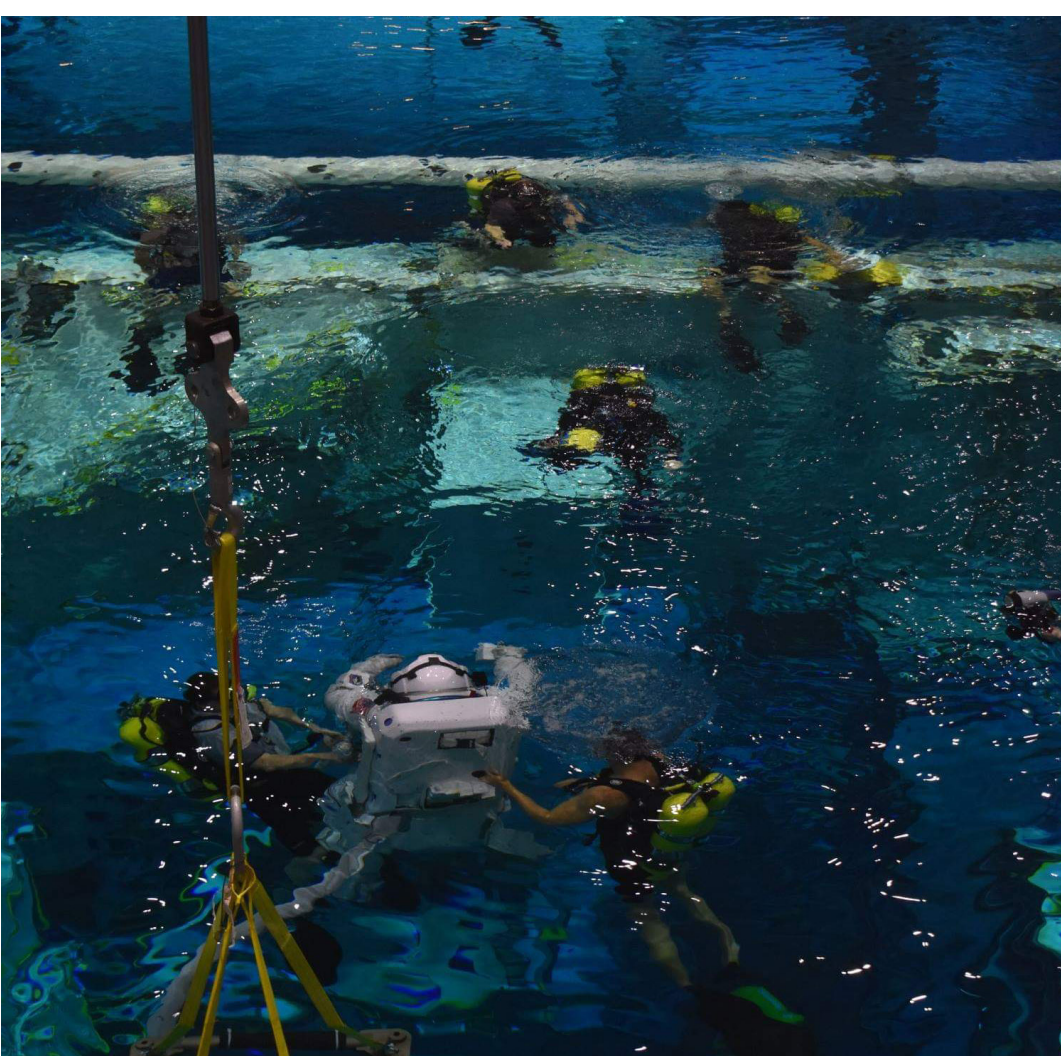
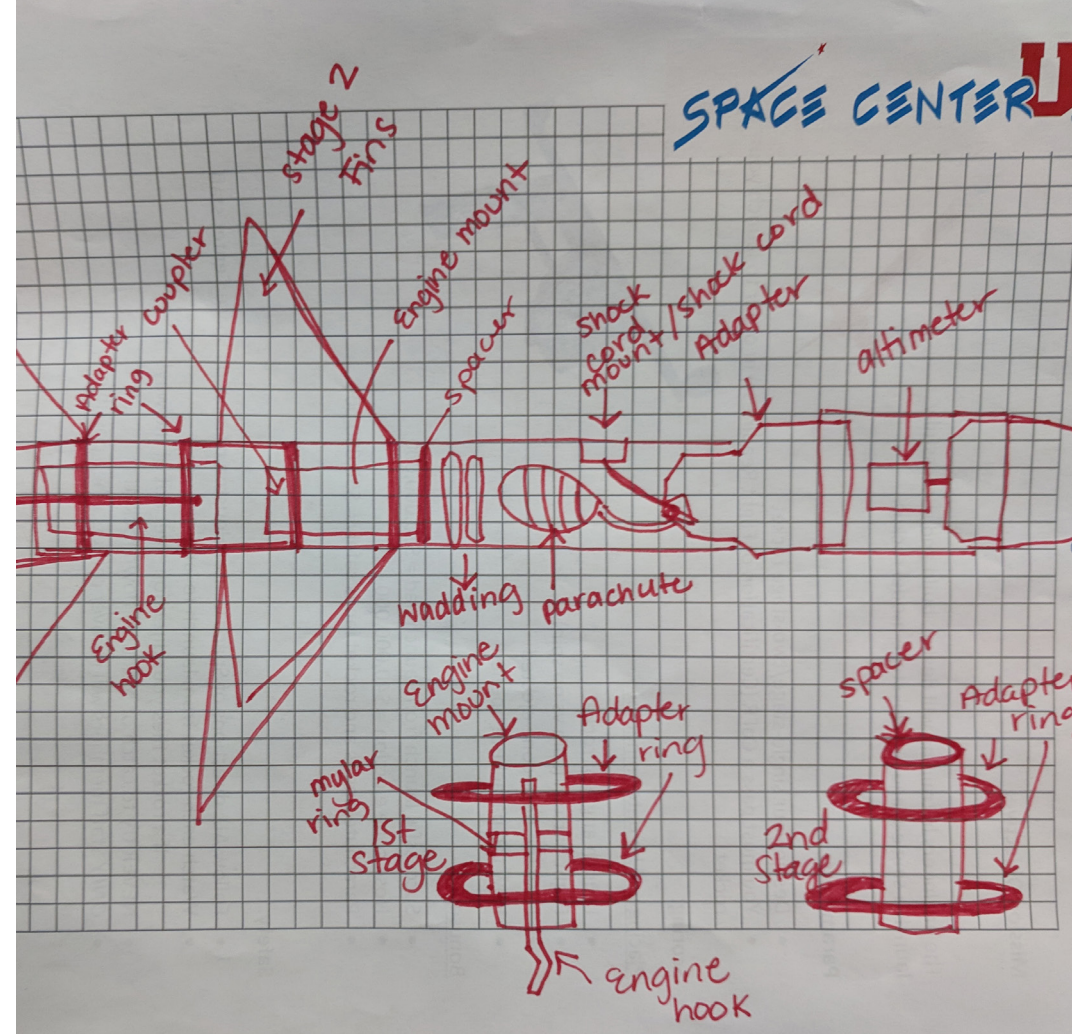
## **NASA MENTOR & TEAM**

Met mentor Evelyne Orndoff, lead for soft goods development and testing & her team at NASA. Shared initial concepts.

Takeaways: astronauts want to feel like they're going to work, love their flight suits & Under Armour.









## COMFORT

“Comfort was number one for us. We wore slacks and polos.”

## EXERCISE

“Because of the lack of gravity, respiration and body heat stays in a bubble around you during exercise...We had to have fans blowing on us constantly”

## ODOR

“Showers were a water bag into a washcloth. First thing after landing was a cold beer and a hot shower...not particularly in that order”

## KENNETH D. CAMERON

*Colonel, USMC, RET. and NASA Astronaut (Former)*

*561+ hours in space*

*Pilot on STS-37 Atlantis (1991)*

*Commander on STS-56 Discovery (1993) and STS-74 Atlantis (1995)*

# PHASE 4: EARLY IDEATION



Unisex



Reduce Mass



Smell Better



Design for Microgravity

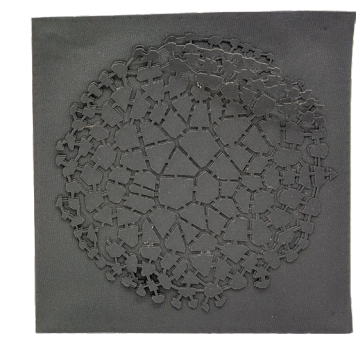
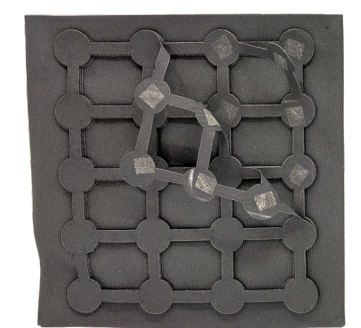
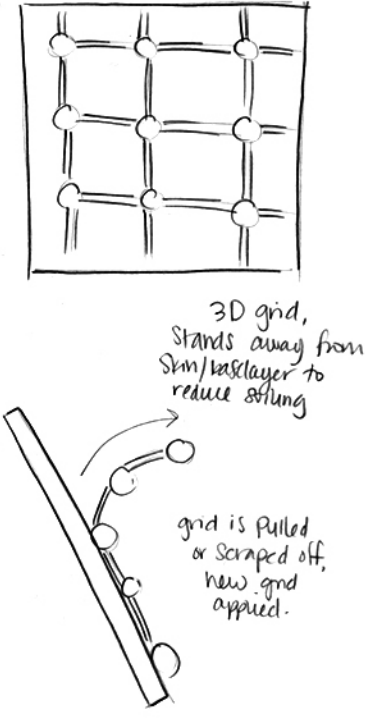
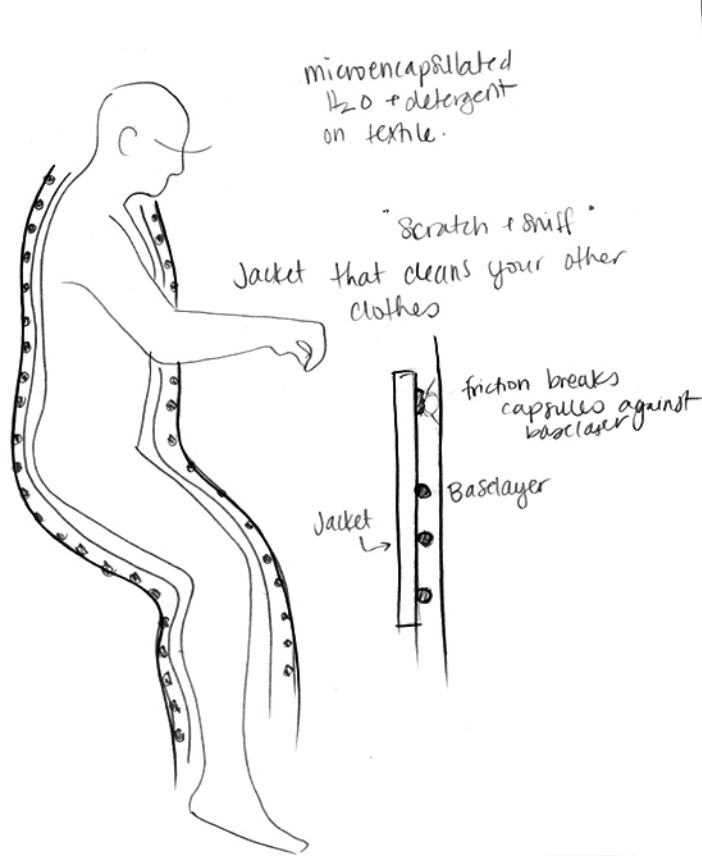
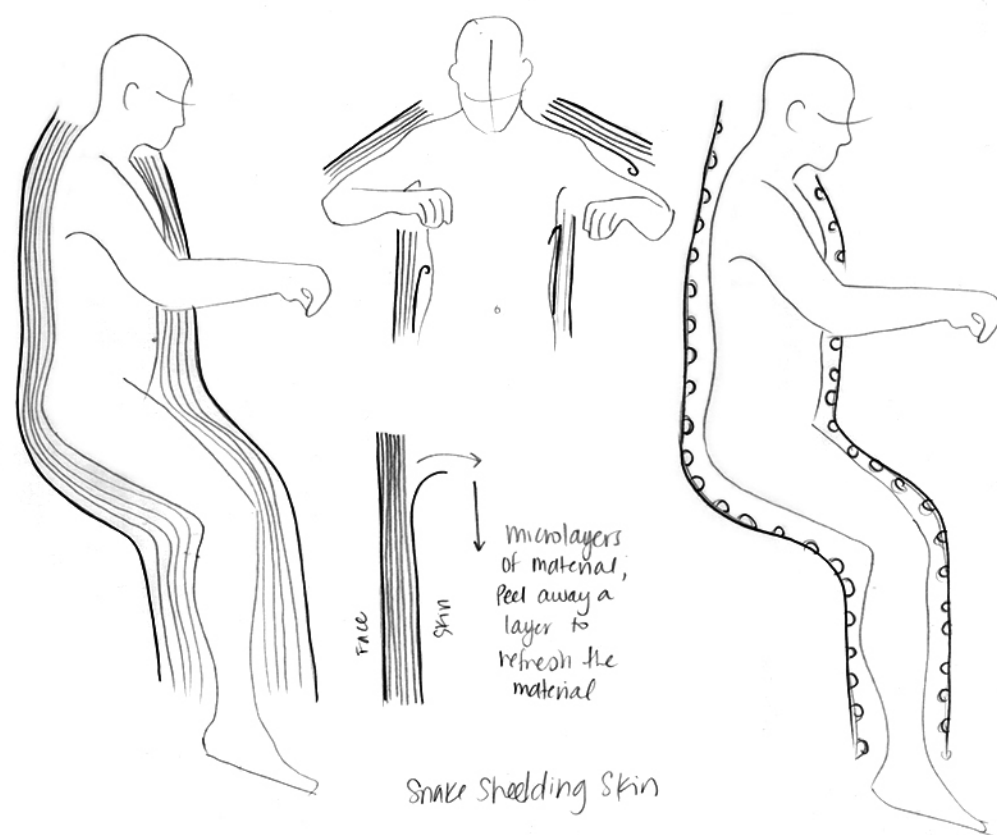
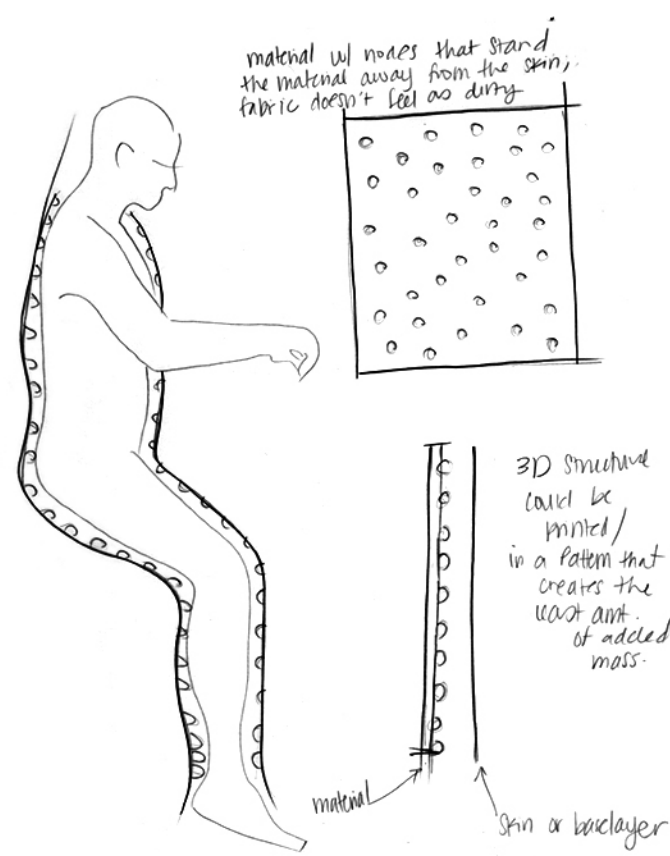
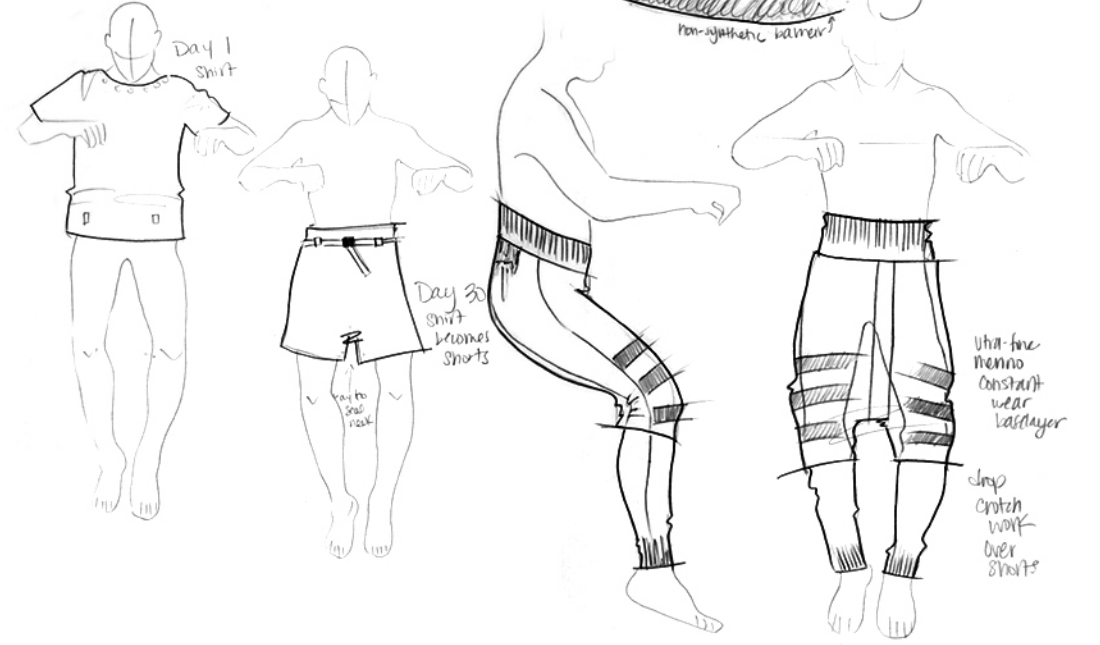
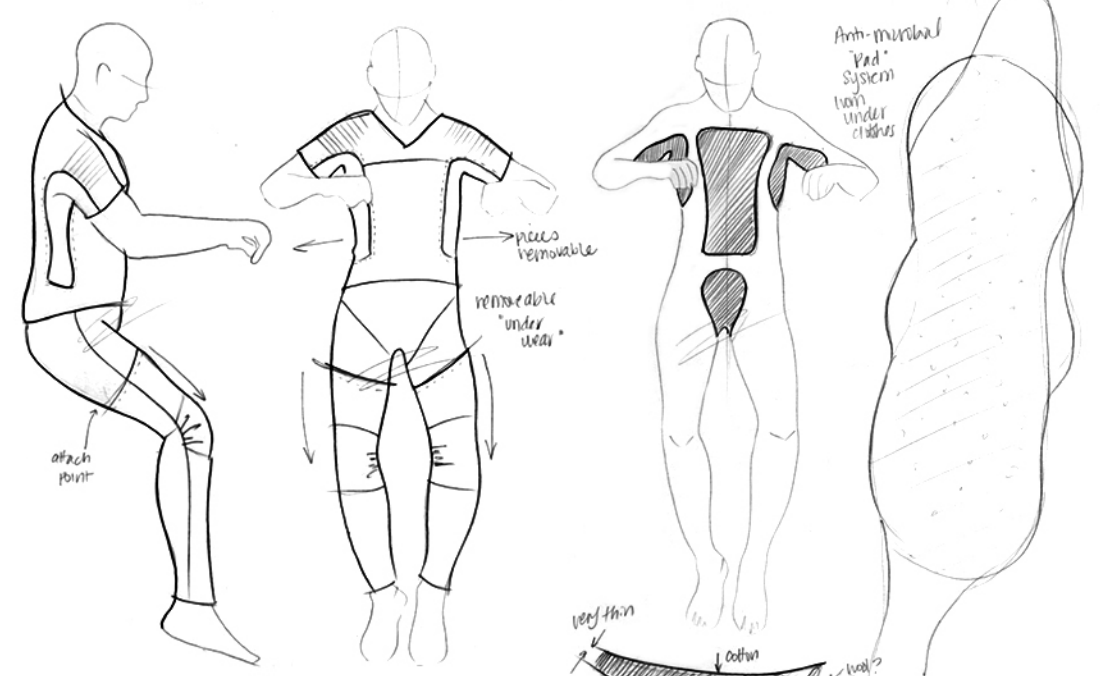
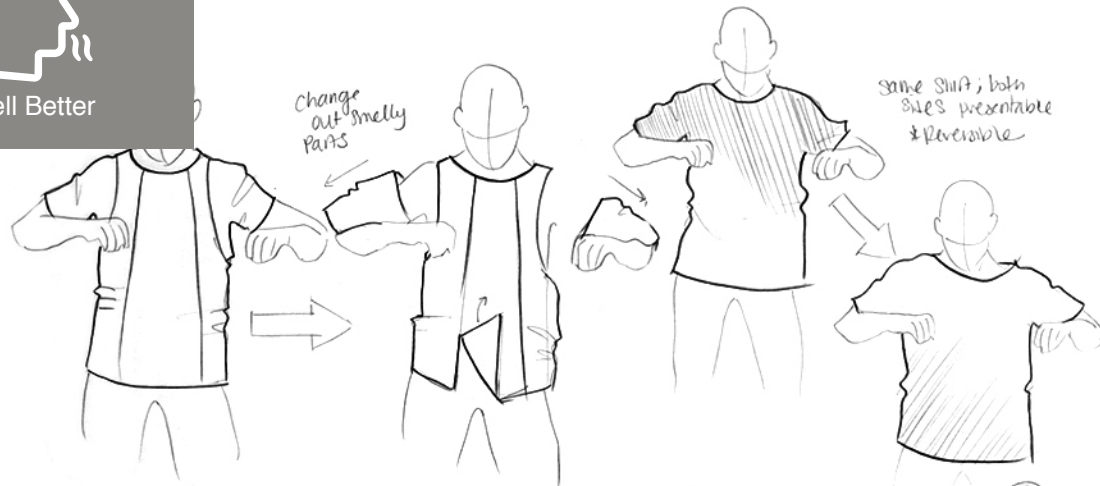


Ensure Safety





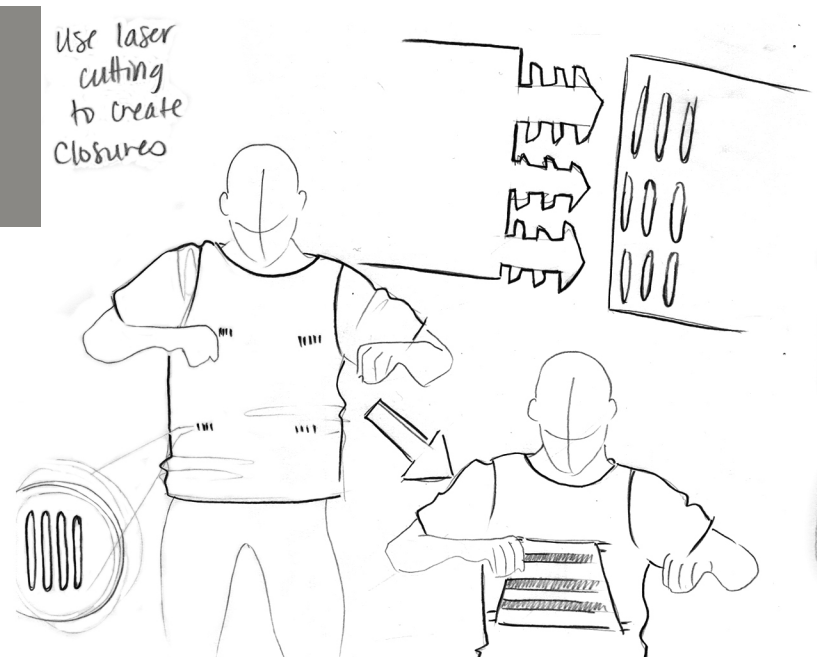
Smell Better



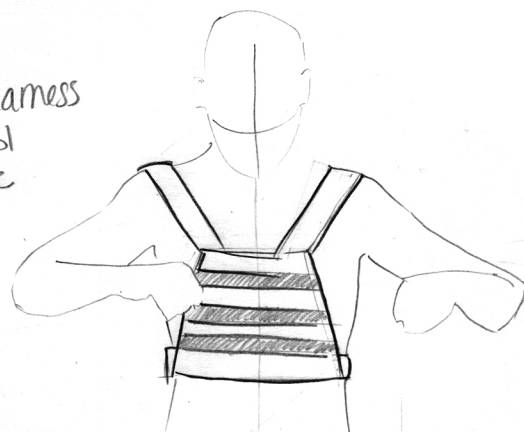


Reduce Mass

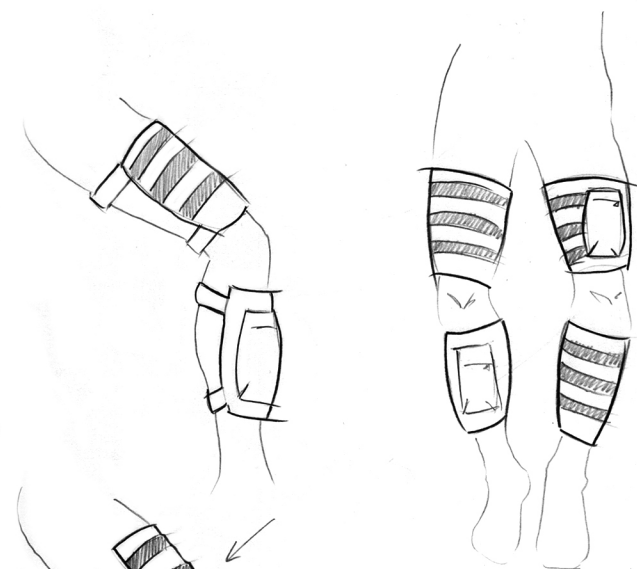
Use laser cutting to create closures



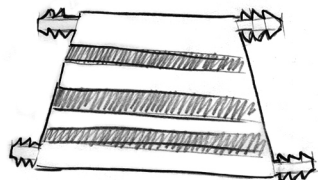
Chest harness for tool storage can be reused



no straps, attaches to chest



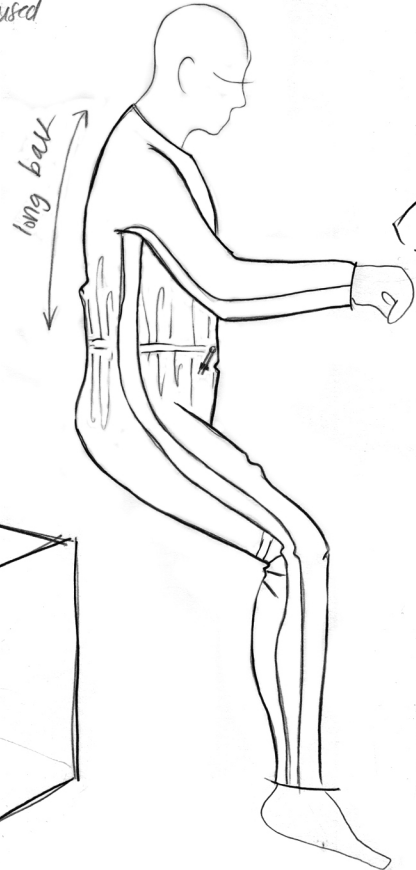
Stick on w/ no straps



functional pieces can be added in, reused to basic garments



interlocking segments backally grown kombucha leather alge



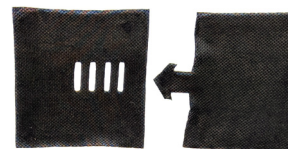
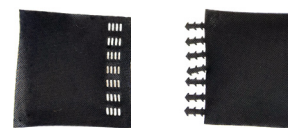
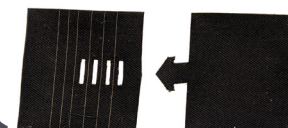
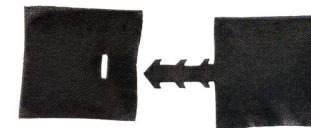
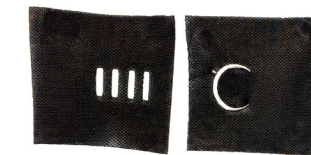
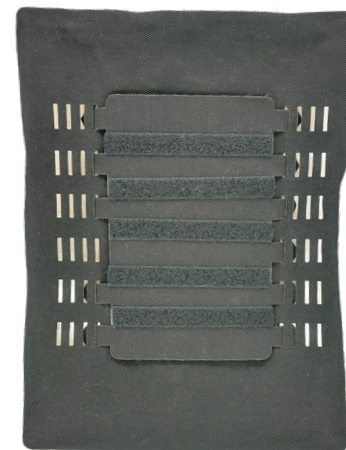
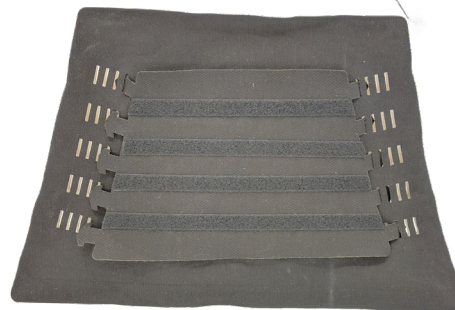
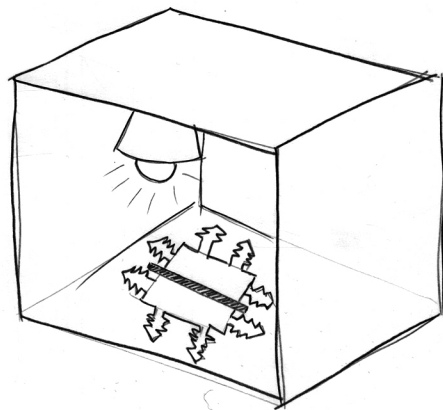
long back

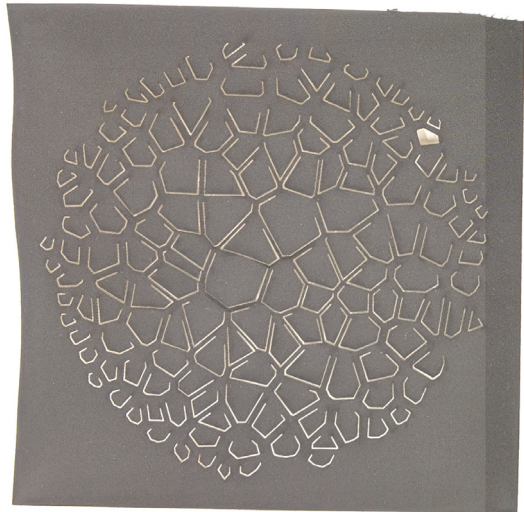
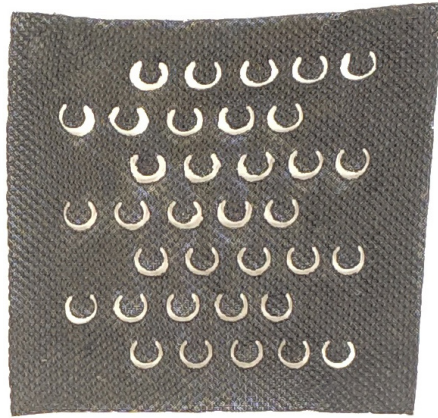
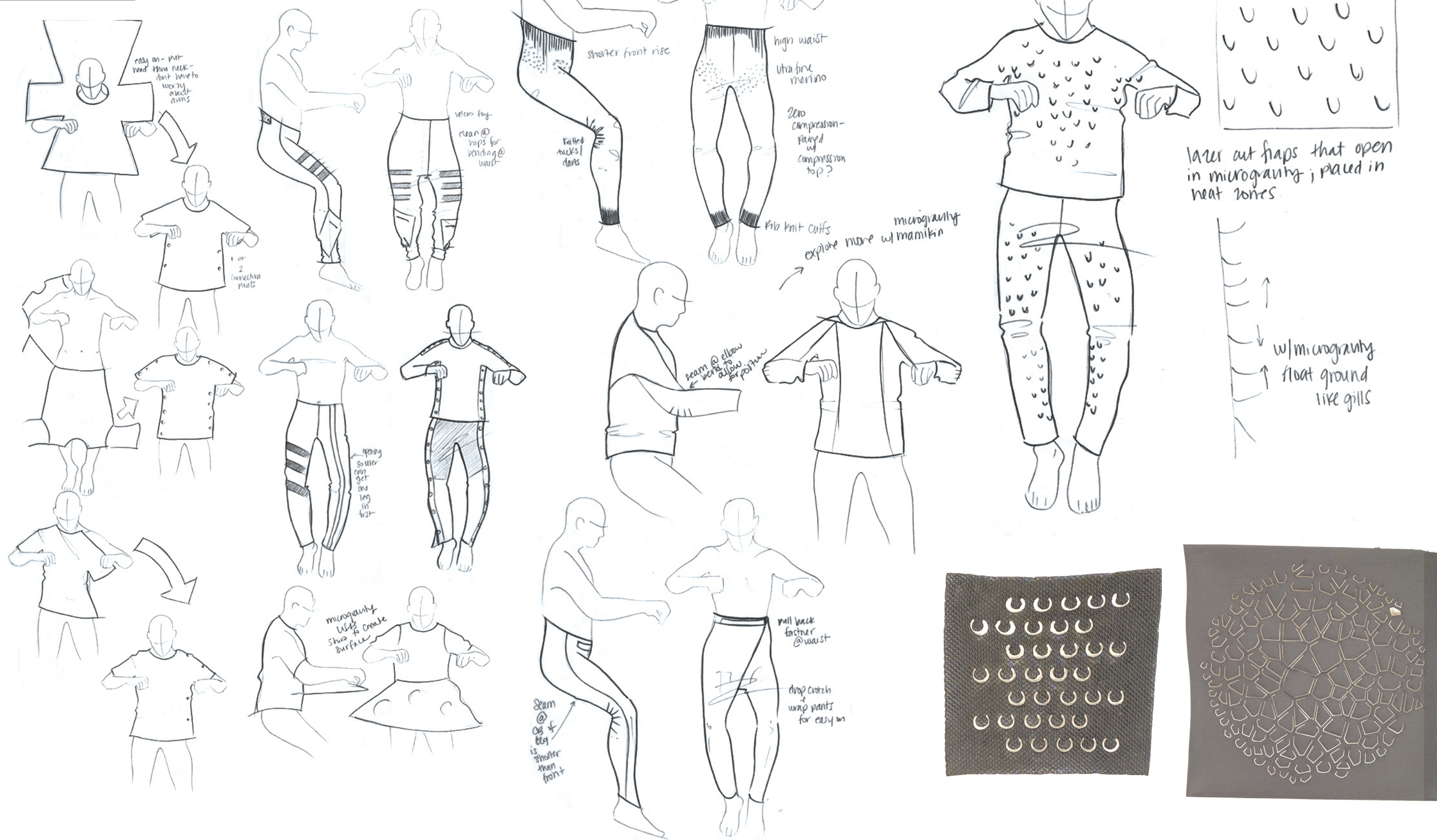


side opening

taped hems

constant wear baselayer jumpsuit

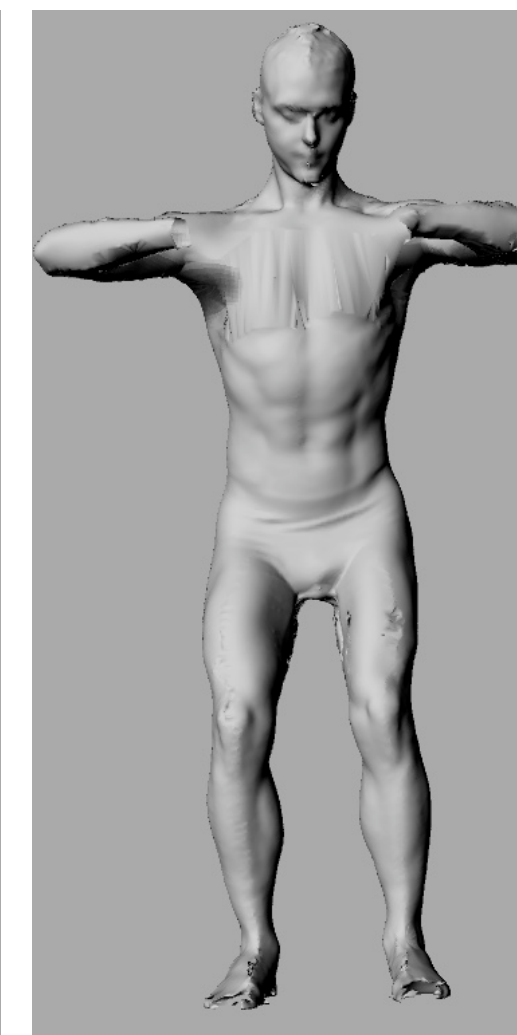
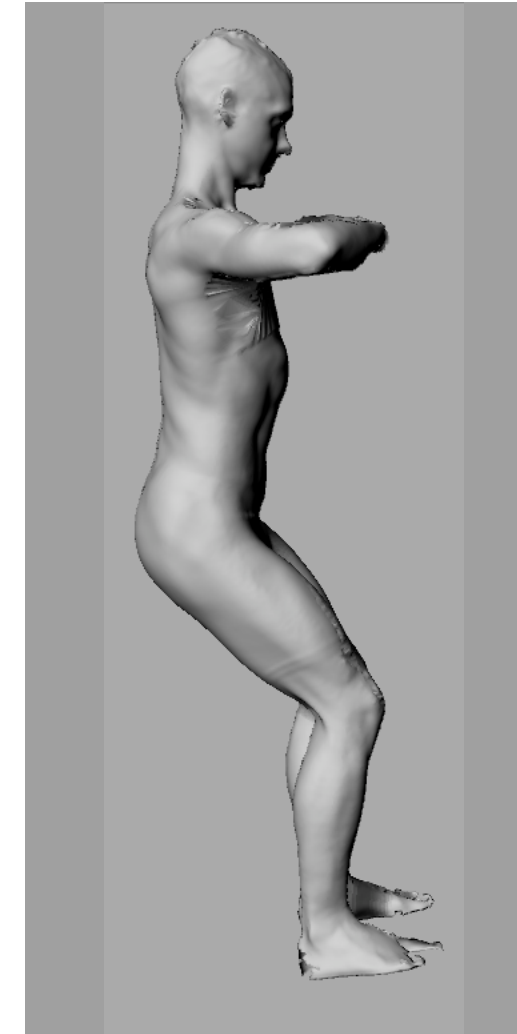
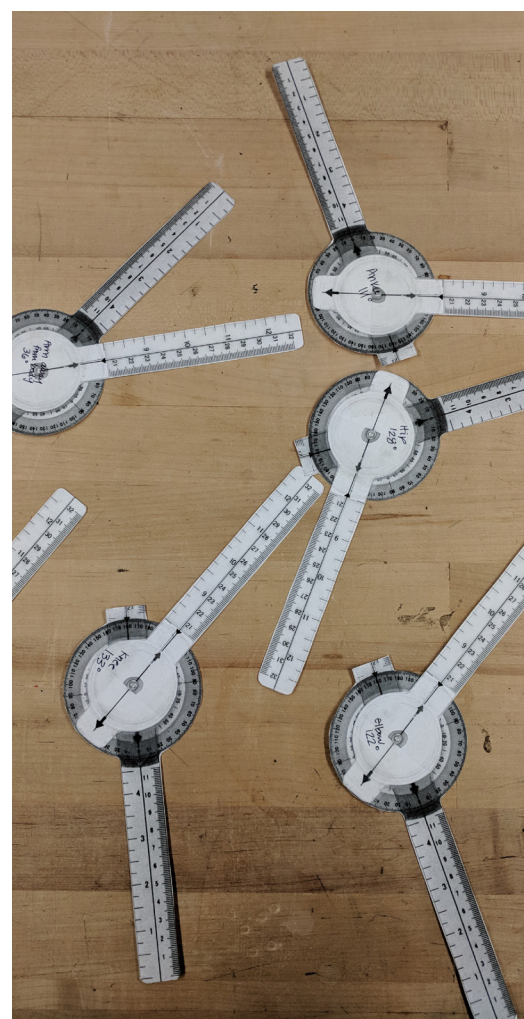
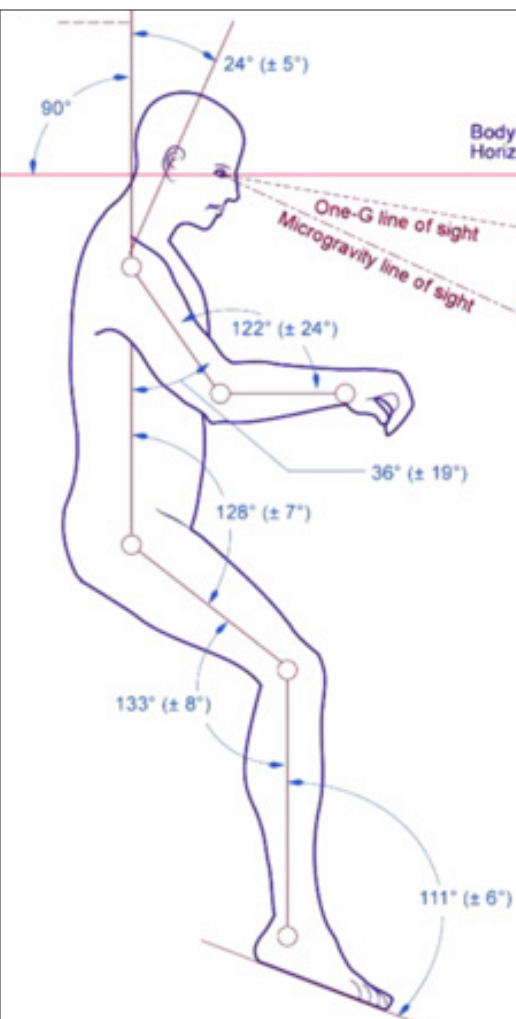






Design for Microgravity

Used body scanning to recreate the body's natural posture in microgravity—to inform a half scale mannequin for ideation.



The body's neutral posture & joint angles in microgravity.

Goniometers created to measure joint angles.

Initial body scan, then patched and cleaned in blender.



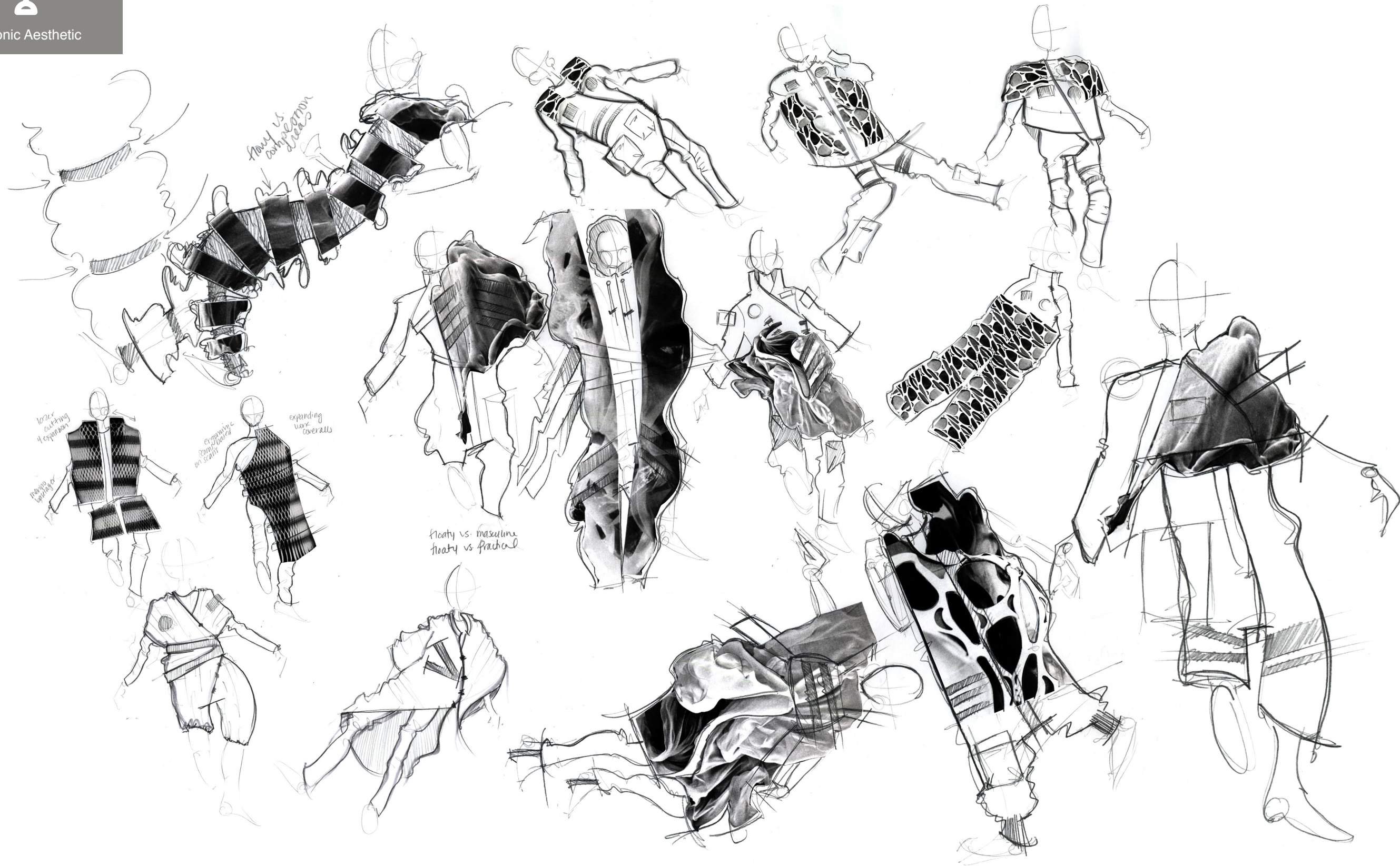
Unisex



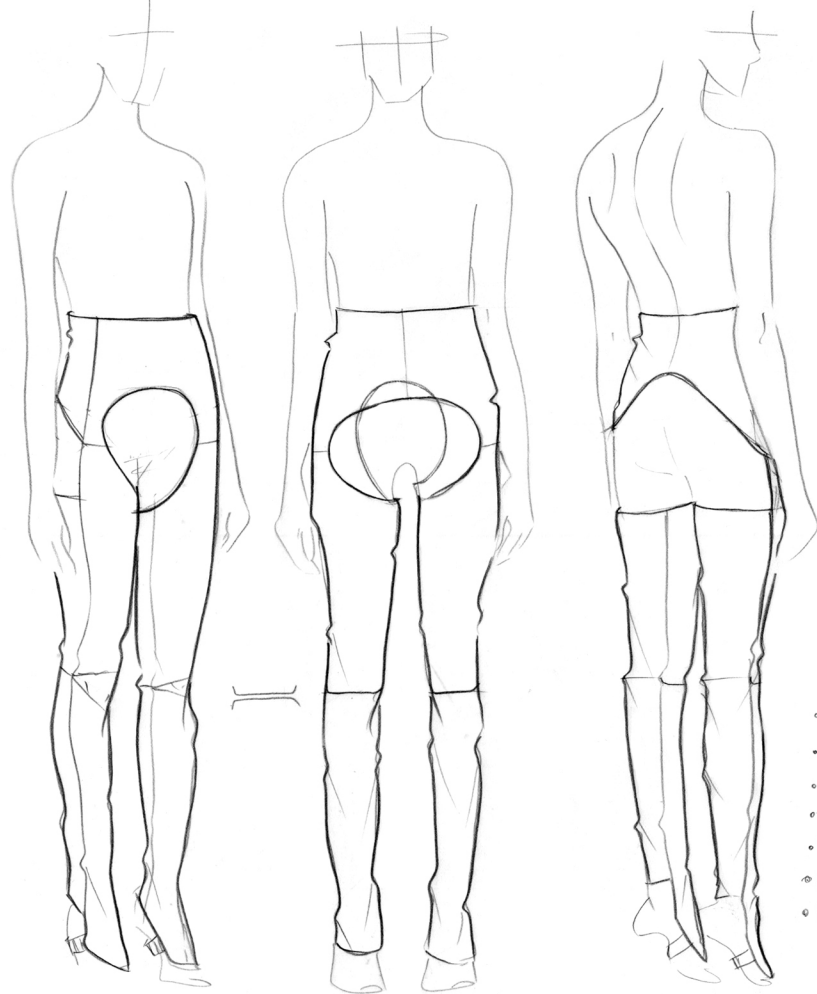




Iconic Aesthetic

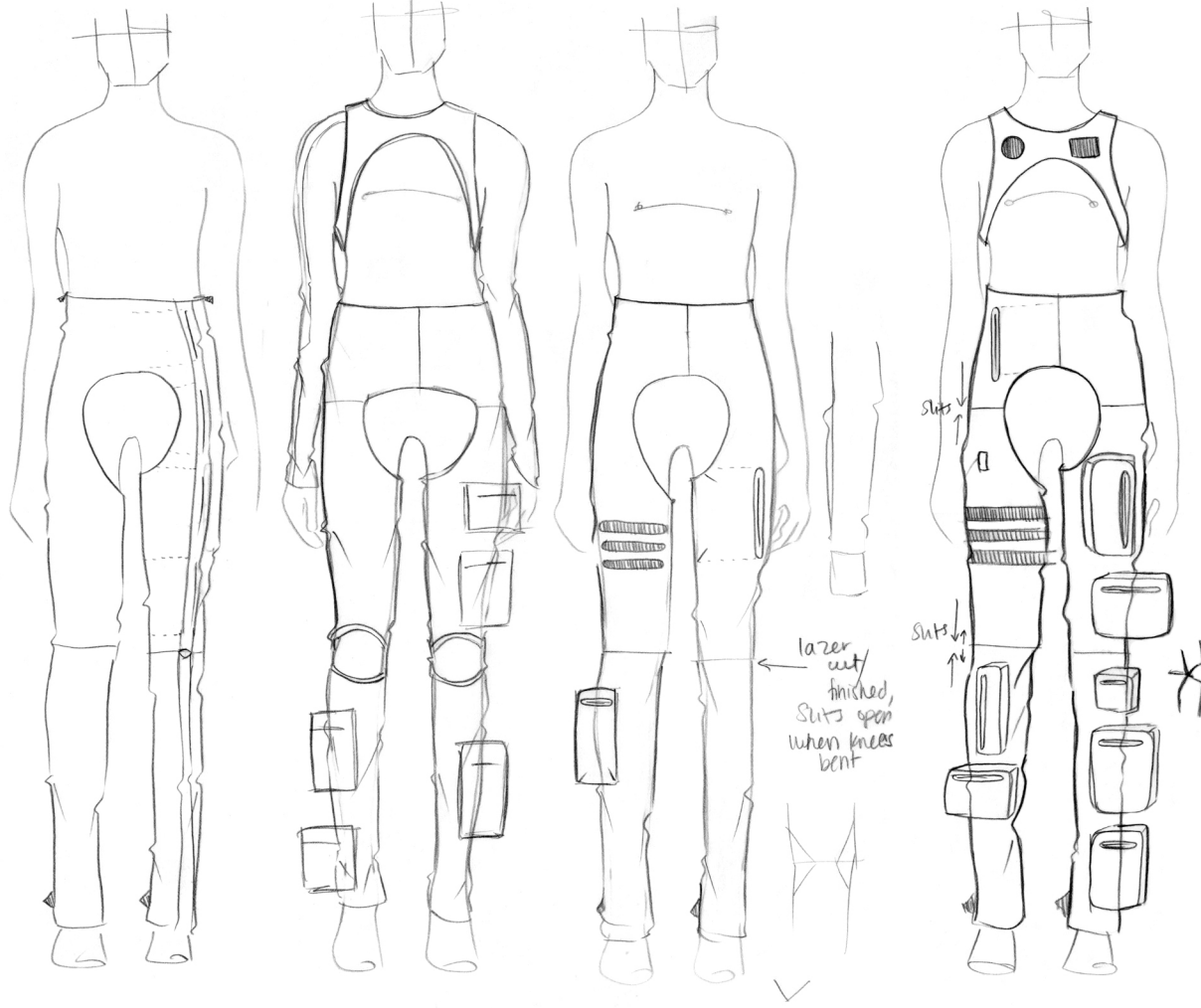


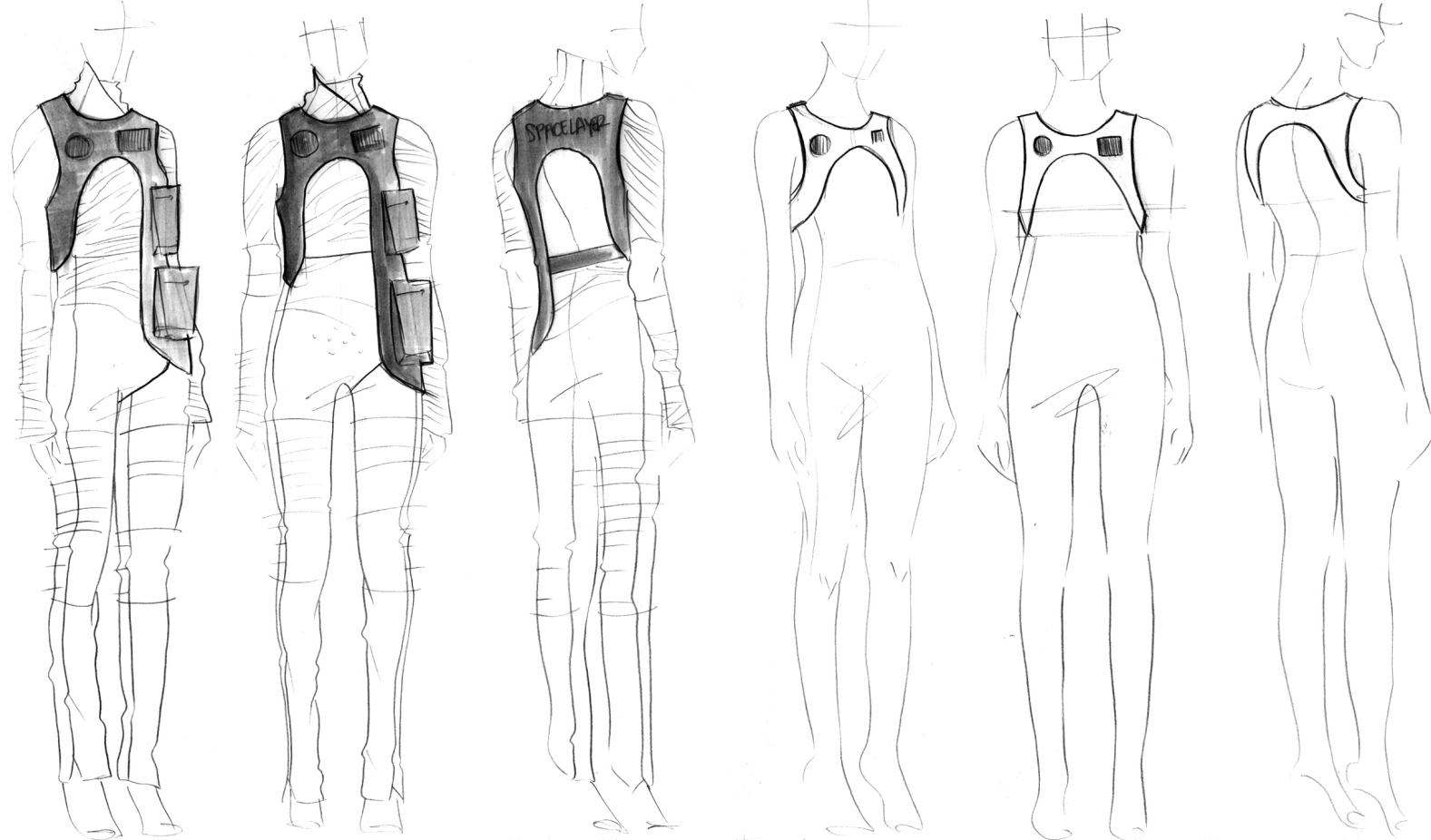
PHASE 5:  
**MAKE + REFINE**



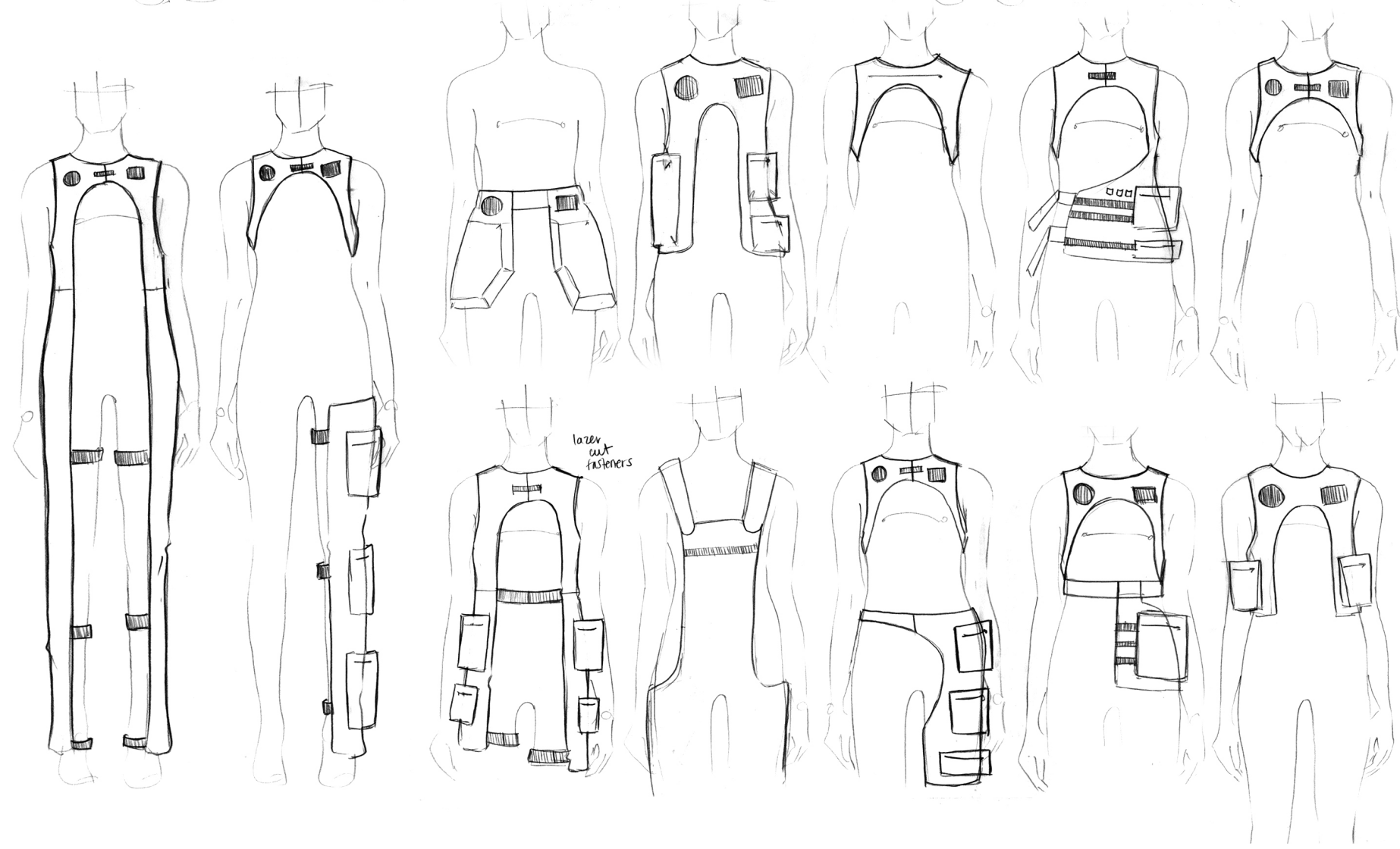
WORK Bottoms

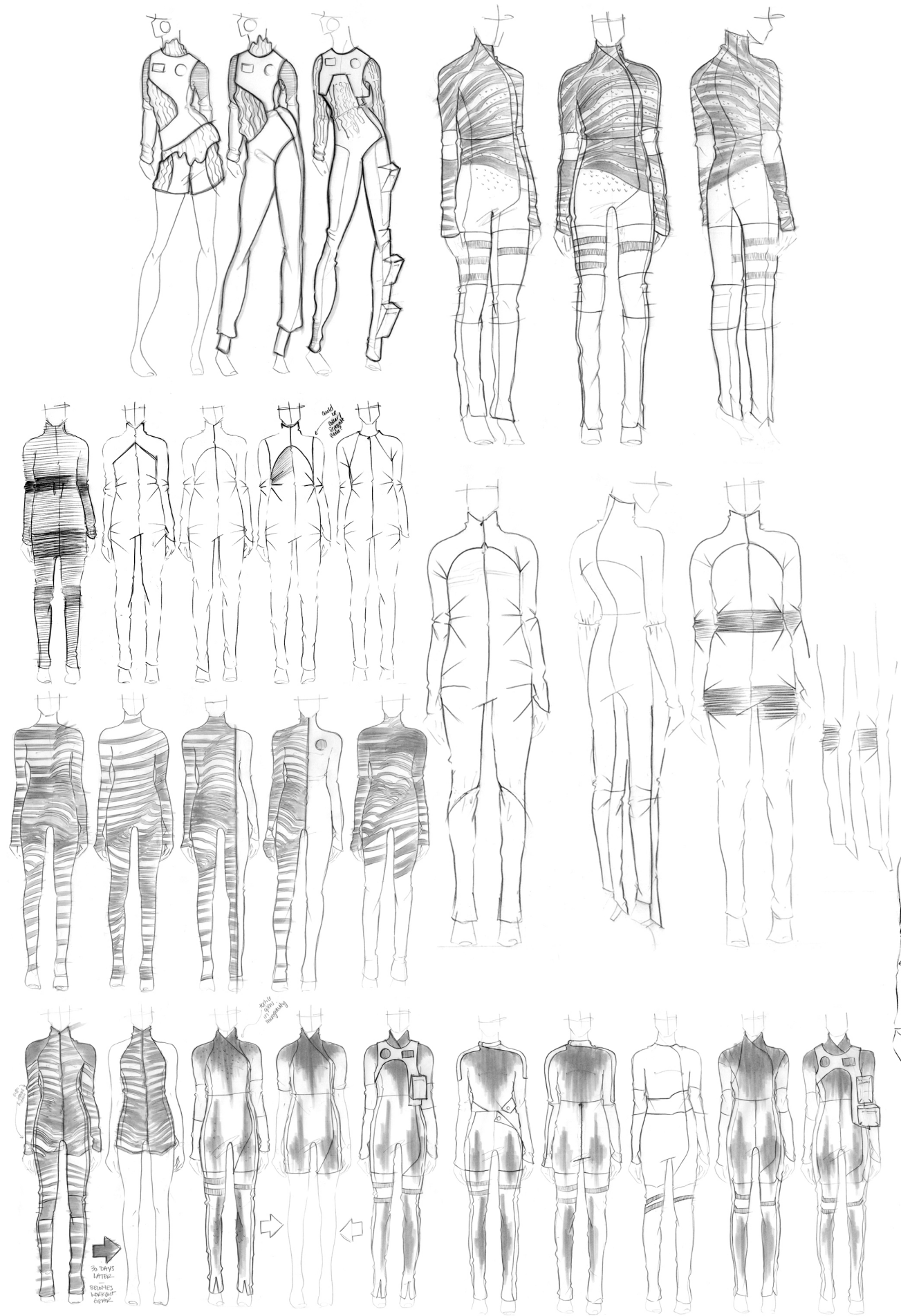
- psychological comfort - anti-6 suit
- pockets, velcro, hook loops (collage on)
- cover top of feet - protect
- suits @ knees & hips for body stance.
- side zip
- cotton P-ripstop
- 1 per mission





Public Relations, Harness  
- laser cut mission logo + flag  
- felt/waxed cotton  
- 1 per mission





LAUNCH:  
**SPACE LAYER 1.0**



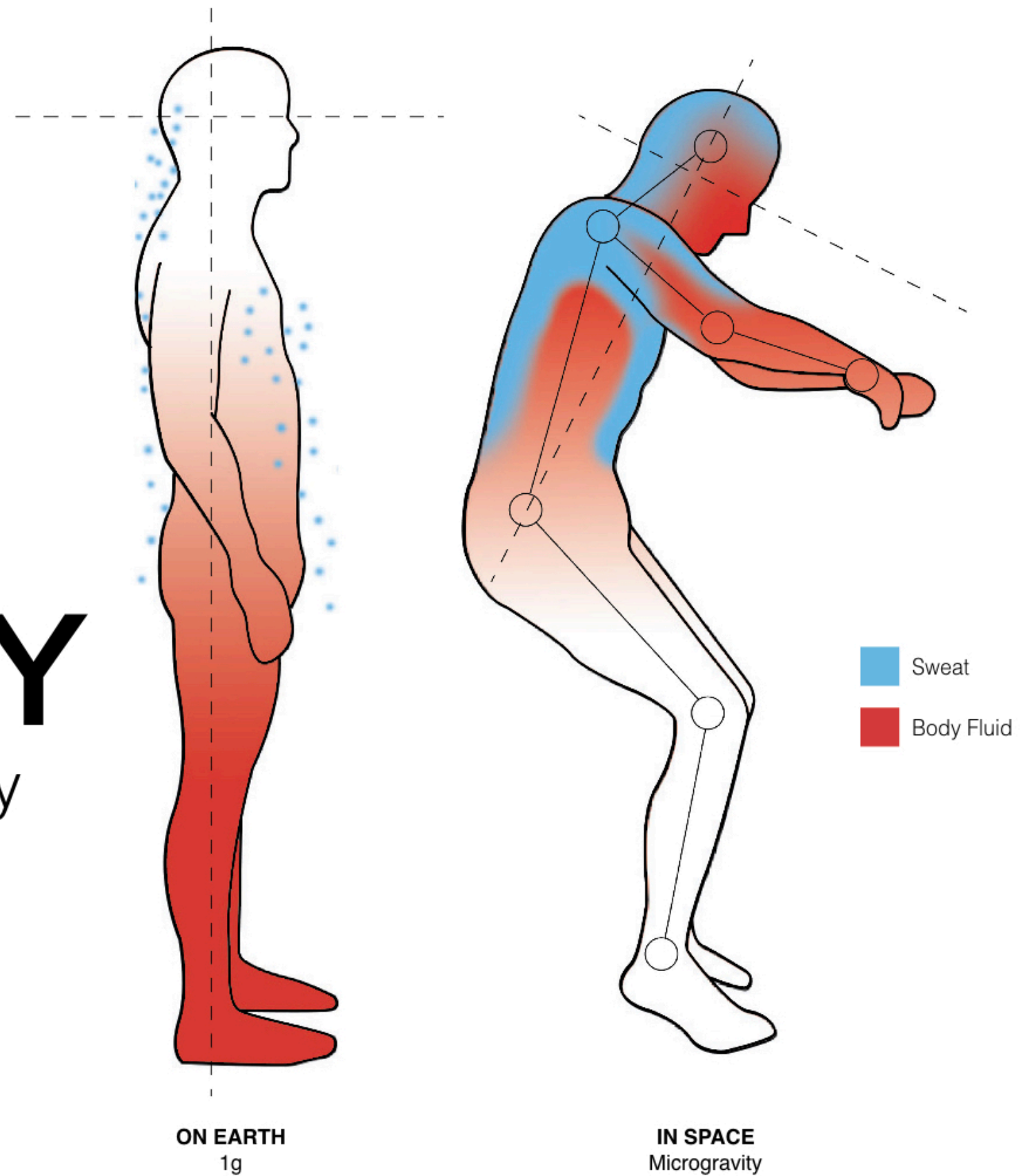
# OPPORTUNITY

Enable astronauts to perform their best mentally & physically with apparel that improves a mission's experience & logistical needs.

To NOD

# OPPORTUNITY

Create apparel that responds to the way human physiology and biomechanics changes in microgravity.







*“Safety is number one. As long as I work at NASA they won’t be wearing polyester!”*

**EVELYENE ORNDOFF**

*Soft Goods Testing & Development Lead  
NASA*



**HEAVY**

*Majority of kit is cotton, adding 75kg/person/year to payloads.*



**SMELLY**

*Pieces are re-worn for long periods to reduce payloads.*



**FLAMMABLE**

*Technical apparel doesn’t meet flammability requirements.*



**MISSING “LOOK”**

*IVA clothing currently has no distinct image or aesthetic.*

# INSIGHTS FROM THE EXPERT...

### COMFORT

*"Comfort was number one for us. We wore slacks and polos."*

### THERMOREGULATION

*"Because of the lack of gravity, respiration and body heat stays in a bubble around you during exercise...we had to have fans blowing on us constantly"*

### ODOR

*"Showers were a water bag into a washcloth. First thing after landing was a cold beer and A hot shower...not particularly in that order"*



# ...THE ASTRONAUT...

**KENNETH D. CAMERON**

*Colonel, USMC, RET. and NASA Astronaut (former)*

*561+ hours in space*

*Pilot on STS-37 Atlantis (1991)*

*Commander on STS-56 Discovery (1993) and STS-74 Atlantis (1995)*



...& THE FIELD



# HOW CAN WE?

Enable astronauts to perform their best mentally & physically through apparel? How can it also improve mission experience & logistical needs?



**Design for Microgravity**

*Circulation  
Thermoregulation  
Fit*



**Smell Better**



**Create Look**



**Unisex**



**Reduce Mass**



**Ensure Safety**

# IVEDAS

Intra Vehicular Extended Duration Apparel System



# IVEDAS

Intra Vehicular Extended Duration Apparel System



## **Built for Microgravity**

Articulated back knee to account for body's neutral posture in microgravity.



## **Odor Solution**

Fuze odor technology applied to the surface of the fabric—gold particles which kill odor causing bacteria.



## **Signature Crew Look**

Fusion of historic, nostalgic utilitarian pieces and sleek futuristic bodysuit.



## **Gender Neutral Style**

Jogger-style bottom for modesty & gender neutrality.



## **Reduced Mass**

864 grams in total kit weight



## **Augmented Natural Materials**

100% Merino wool and 100% cotton pieces for odor reduction & fire safety.

# ENGINEERED KNIT BODYSUIT

Graduated compression from the upper body downward, to combat the effects of the body's fluid shifts in microgravity by pushing fluid back down to the legs. Knit bands of compression used as alternative to Lycra Follow lines of non-extension and never lose compressive power as body moves.



## Helping Blood Flow

Compressive knit at upper body help push fluid back to legs, to counteract effects of microgravity.



## Articulated Joints

Articulated back knee and elbow joints keep material from bunching during movement.



## Kit Integration

D-rings at side waist, to secure work qaiters.



## Reduced Mass & Extended Wear

Jumpsuit weighs 482g, and can be worn for 30+ days



## Augmented Natural Materials

Fuze-treated 100% Merino wool warp knit for thermoregulation and fire safety.



# WORK GAITERS

Worn over the engineered knit bodysuit, the work gaiters provide durable storage for tools and equipment needed during a workday in space.



## Thigh Velcro

Soft-sided velcro at thighs for integration with current tool security methods.



## 3D Pockets

Space for things needed during the average workday—like gloves, notebook, first aid kit, and extra camera batteries.



## Articulated Joint

Articulated back knee from bunching during movement.



## Reduced Mass & Extended Wear

Pair of gaiters weighs 242g, and one pair is issued for duration of mission.



## Augmented Natural Materials

Fuze-treated 100% Cotton ripstop for durability and fire safety.





# HARNESSES

Meant to replace current mission polos—which are only worn during PR events and interviews, the harness has space for a logo badge and pocket, loop and d-ring for essentials.



## PR-Ready

Upper chest displays agency, mission, and name badges.



## 3D Pocket

Below chest for easy grab supplies—like notebook, or to hold microphone supplies during communication.



## Loop and D-ring

Clip radiation monitor to d-ring, and hook reading glasses or pen through loop.



## Adjustable Back D-Rings

Pull down for to secure harness and adjust fit.



## Reduced Mass & Extended Wear

Harness weighs 130g, and is worn for the duration of the mission.

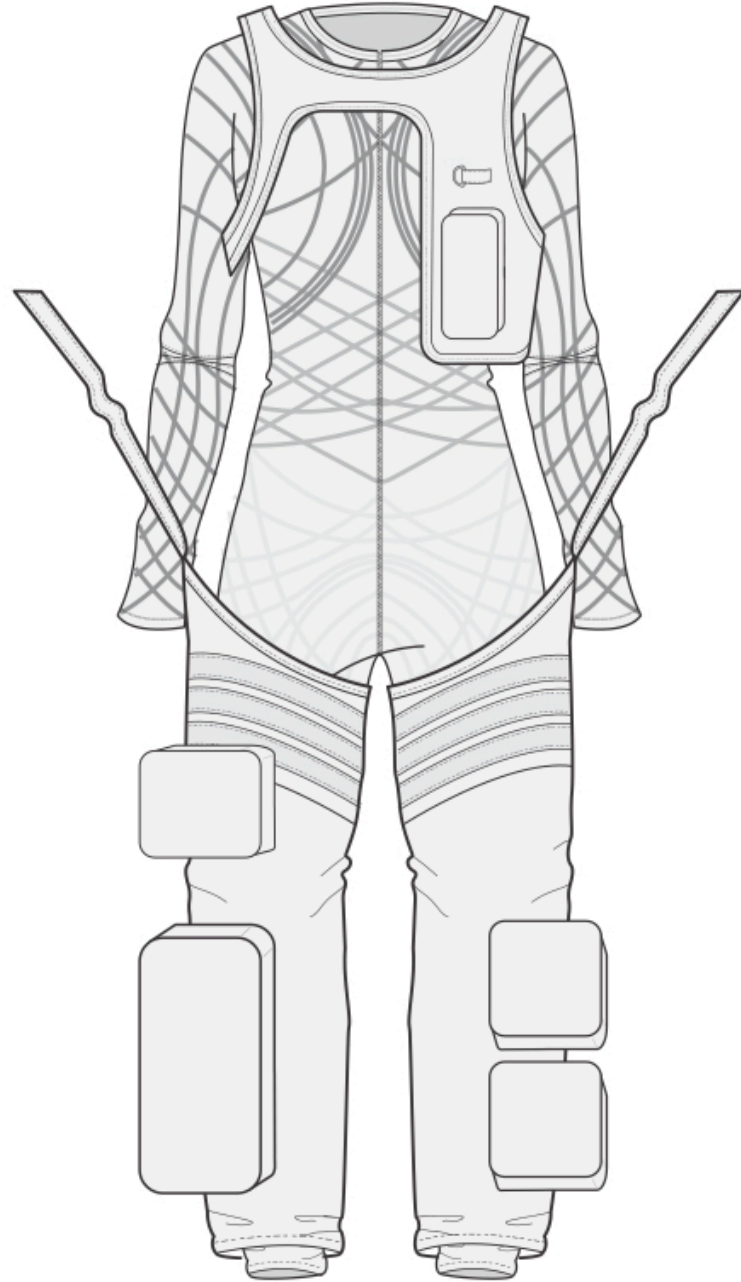


## Augmented Natural Materials

Fuze-treated 100% Cotton ripstop for durability and fire safety.

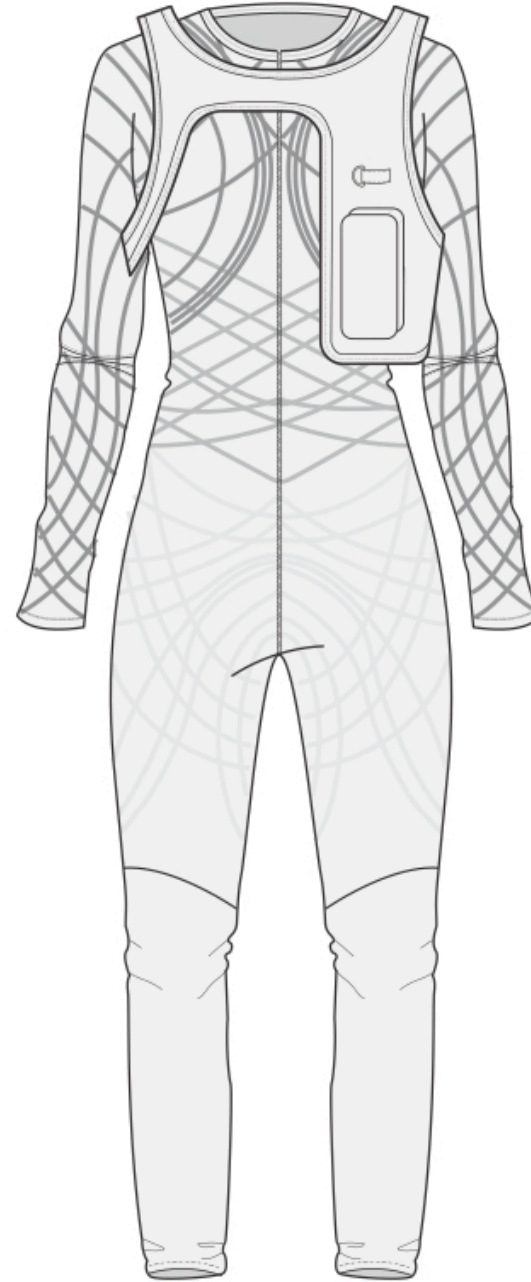


# USE MODES



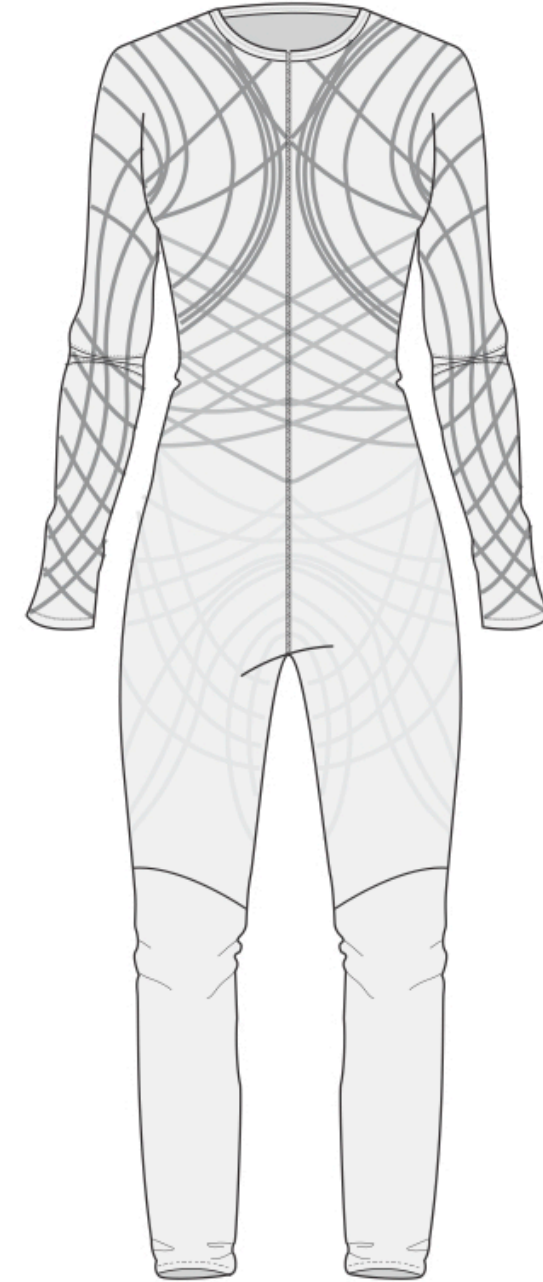
## Work

Gaiters create functionality & storage ability on top of engineered knit bodysuit. Harness gives added easy reach pocket & feeling of "going to work".



## Press Conferences

Worn for meetings & earth transmissions, the badge harness worn over the engineered knit body suit increases formality and displays nationality and mission badges.



## Relax + Recreation

As the basis of the IVEDAS kit, the engineered knit bodysuit is built for the body's unique posture in space and has graduated compression to aid in combating fluid shifts.

POST-LAUNCH  
**TEST + VALIDATE**

**100% Merino Wool Jersey**

**UNTREATED**



**100% Merino Wool Jersey**

**TREATED with Fuze  
technology**

# 18 DAY WEAR TEST



DAY 1



DAY 18

**Of five people surveyed, all five rated both sides of the shirt as “4-smells ok, I would probably wear”**

**WEAR LOG:**

May 15 - June 2: wore for approx 12 hours per day.

Shower before each wear

In between use let air dry hanging up

# WEAR TESTER #1

## WEAR LOG:

May 17-18, 18 hrs on flight to Florence, then 5 more hours in evening on 18th.

May 19, 20, 21, 22 - wore each day 30 minutes running

May 25 - 30 mins run

May 28, 29, 30 - 30 mins run

June 3 - 30 min stationary bike + weights

In between use let air dry hanging up



**Of five people surveyed, all five rated both sides of the shirt as “4-smells ok, I would probably wear”**

# WEAR TESTER #2

## WEAR LOG:

6 consecutive days - 2 outside runs, 4 yoga sessions

In between use let air dry hanging up



**Of five people surveyed, all five rated the UNTREATED SIDE of the shirt as “1 - yuck! would definitely not wear.”**

**five out of five rated the TREATED SIDE as “4-smells ok, I would probably wear”**

Conclusion: FUZE is a viable technology for increasing the long-wear properties of wool.

# MASS CALCULATIONS



126g  
+ 116g  
+ 130g  
+ 6396g  
**= 6804g**  
per year for one crew member

**6804g = 6.804kg / year**

**NASA's current kit is 75kg/ year**

**IVEDAS is less than current kit mass based on consumption.**

1. Right Gaiter mass: **126g**
2. Suggested lifespan of Right Gaiter: **mission duration**
3. Number of Right Gaiters required for 365 days: **1**
4. Total weight of Right Gaiters for 365 days: **126g**

1. Left Gaiter mass: **116g**
2. Suggested lifespan of Right Gaiter: **mission duration**
3. Number of Right Gaiters required for 365 days: **1**
4. Total weight of Right Gaiters for 365 days: **116g**

1. Harness mass: **130g**
2. Suggested lifespan of Harness: **mission duration**
3. Number of Harnesses required for 365 days: **1**
4. Total weight of Harness for 365 days: **130g**

1. Bodysuit mass: **492g**
2. Suggested lifespan of Bodysuit: **30 days**
3. Number of Bodysuits required for 365 days: **13**
4. Total weight of Bodysuit for 365 days: **6396g**





# THANK YOU

RYAN KNAUBER

CLAUDIA ECHOLS

SCOTT ECHOLS

EVELYENE ORNDOFF & SOFT GOODS TEAM AT NASA

SPACE CENTER UNIVERSITY

JOHN, EVERGREEN APPAREL MANUFACTURING

ANDREW & CO AT FUZE

SOUTHWEST COMMUNITY CENTER POOL + STAFF

RACHEL VORE & MEGAN COLLINS