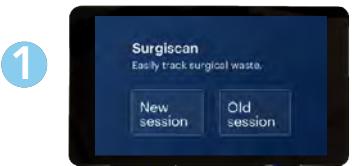






## How does it work?



After the surgery, collect supplies and bring them to the device. Turn device on and select surgery.



Start the scanning application and image items as they are thrown into the waste bin.

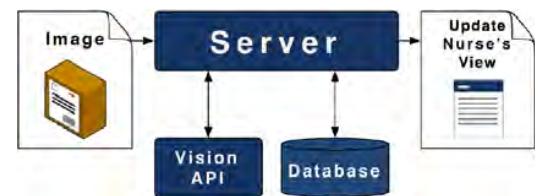


After scanning is complete, stop the session and review data collected.



- Easy-to-use interface
- Built into existing workflow of surgeons and nurses
- Immediate analytics on items wasted and total cost after operation
- Personalized for each surgeon and surgery

## Web Application



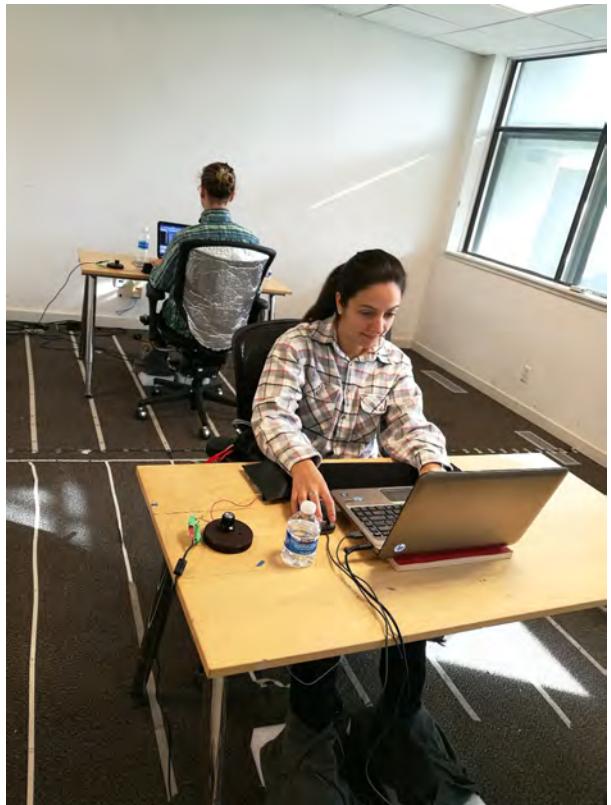
# SURGITRACK

Interactive Device Design, 2016

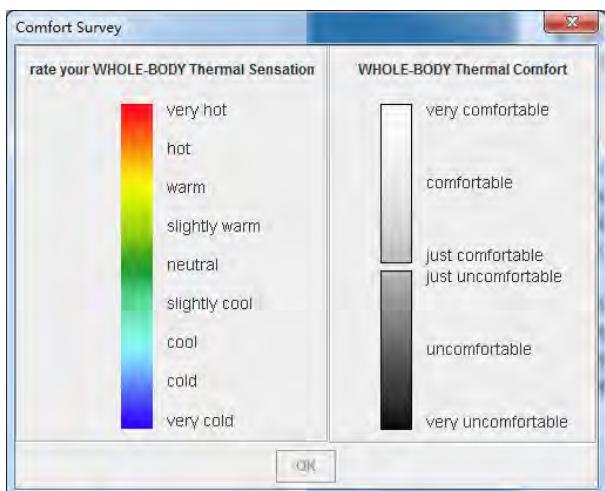
Surgittrack generates analytics for preventable surgical waste during surgeries, providing hospitals with valuable data to cut down unnecessary spending.

This device helps nurses and surgeons determine the proper amount of equipment needed for each surgery to reduce spending and waste during operations, which can add up to over \$650 per surgery.

Collaboration with UCSF Medical Center.



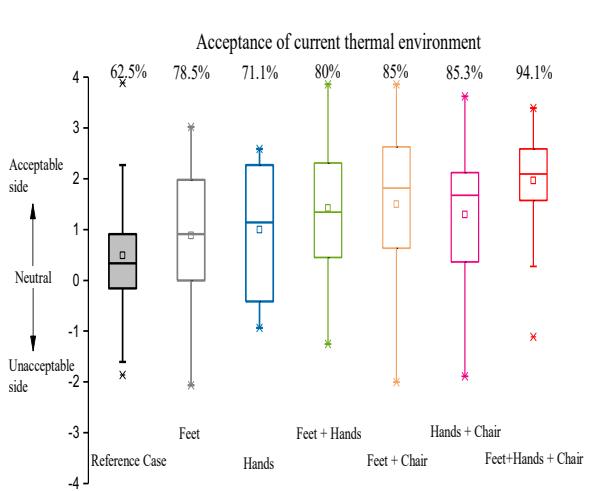
Users were tested in a controlled thermal environment



Users filled out a questionnaire to assess their thermal comfort



Different participants were given different thermal devices



Questionnaire responses were digitized and used to inform design



A temperature controlled thermal probe mapped sensitivity across the body

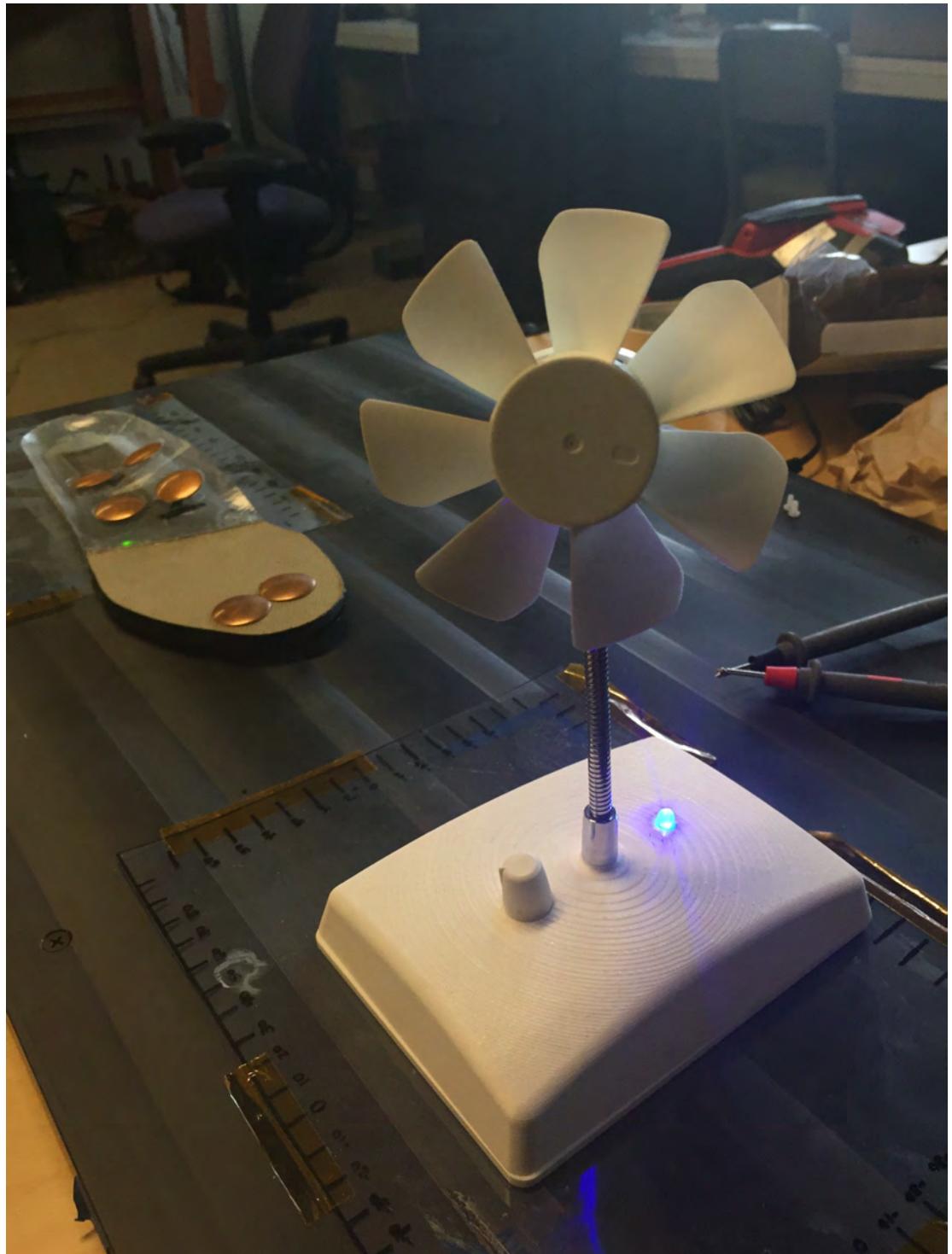
## DELTA

ARPA-E RESEARCH PROJECT, 2017 - 2018

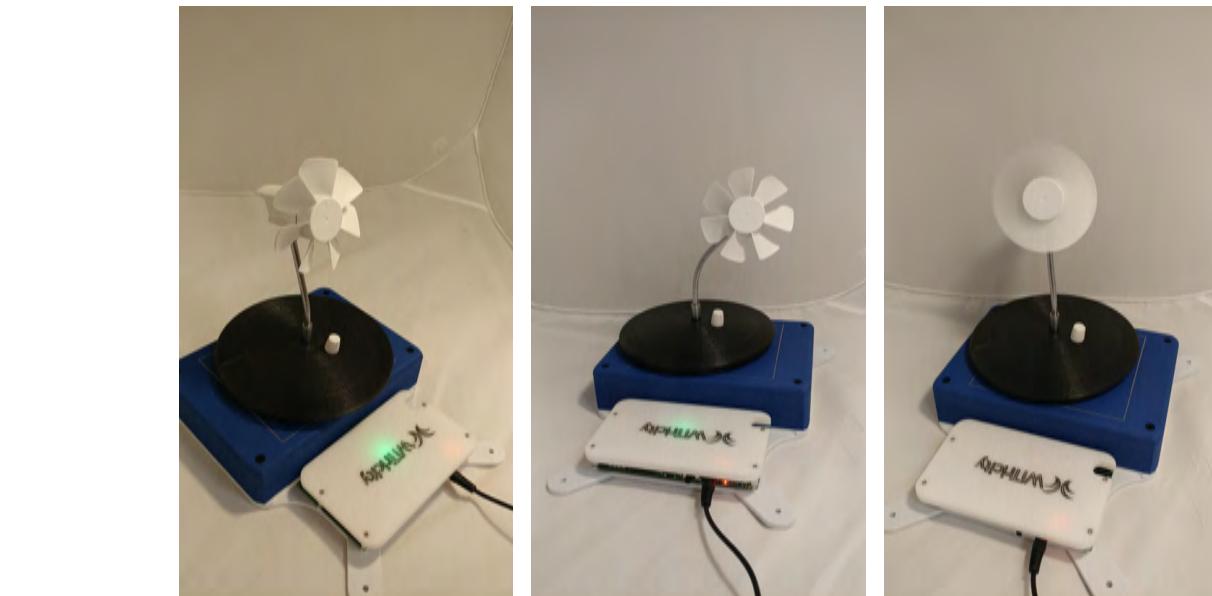
Every year, more than 12% of all domestic energy is used to condition spaces for occupant comfort. Yet, more office occupants are dissatisfied (42%) than satisfied (38%) with their thermal environment. Building-scale solutions fail to address the underlying issue with dissatisfaction: different people prefer different thermal conditions at any given time.

The DELTA project addressed this problem by building a suite of wirelessly-powered personal comfort devices. Designs were based on human-subject testing and FEA Simulations.

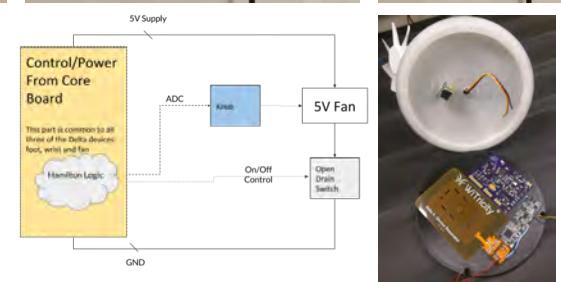
Collaboration with WiTricity.



*Demo of early prototype wireless charging and operation*



*Control and power schematic of fan operation*



## DELTA

ARPA-E RESEARCH PROJECT, 2017 - 2018

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Collaboration with WiTricity.



*Electronics are mounted in a hollow chamber under the arch and heel of the insole*



*Adjustable insoles for various foot sizes were developed for human-subject testing*



*Heating elements are positioned in locations that provide the highest perceived comfort*



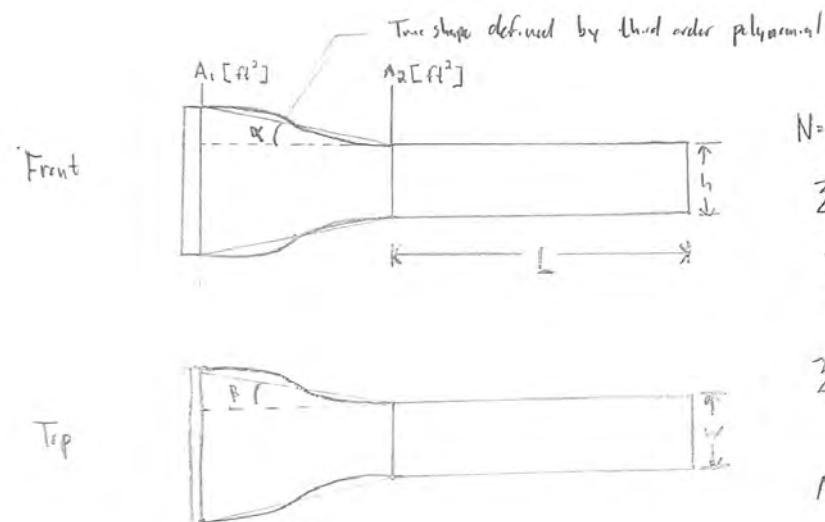
## DELTA

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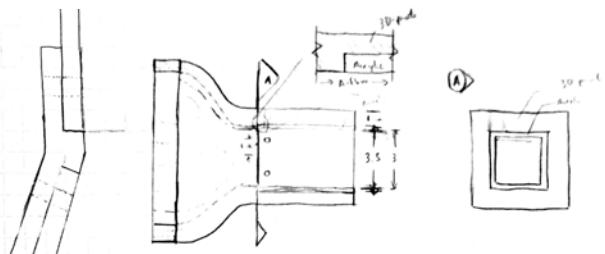
$$N = \frac{A_1}{A_2} = \text{contraction ratio}, \quad N = 8 \text{ or } 9$$

$\zeta$  = pressure loss

$$\zeta_{\text{restr. section}} = \frac{\lambda L}{h} \quad \lambda = \frac{1}{(1.8 \log Re - 1.64)^2}$$

$$\zeta_{\text{total}} = \left[ \left\{ \frac{\lambda}{16 \sin \frac{\alpha}{2}} \right\} + \left\{ \frac{\lambda}{16 \sin \frac{\beta}{2}} \right\} \right] \left( 1 - \frac{1}{N_2} \right)$$

Minimize  $\zeta$  with  $\alpha, \beta = 0: 90^\circ$  (GA)



## WIND TUNNEL

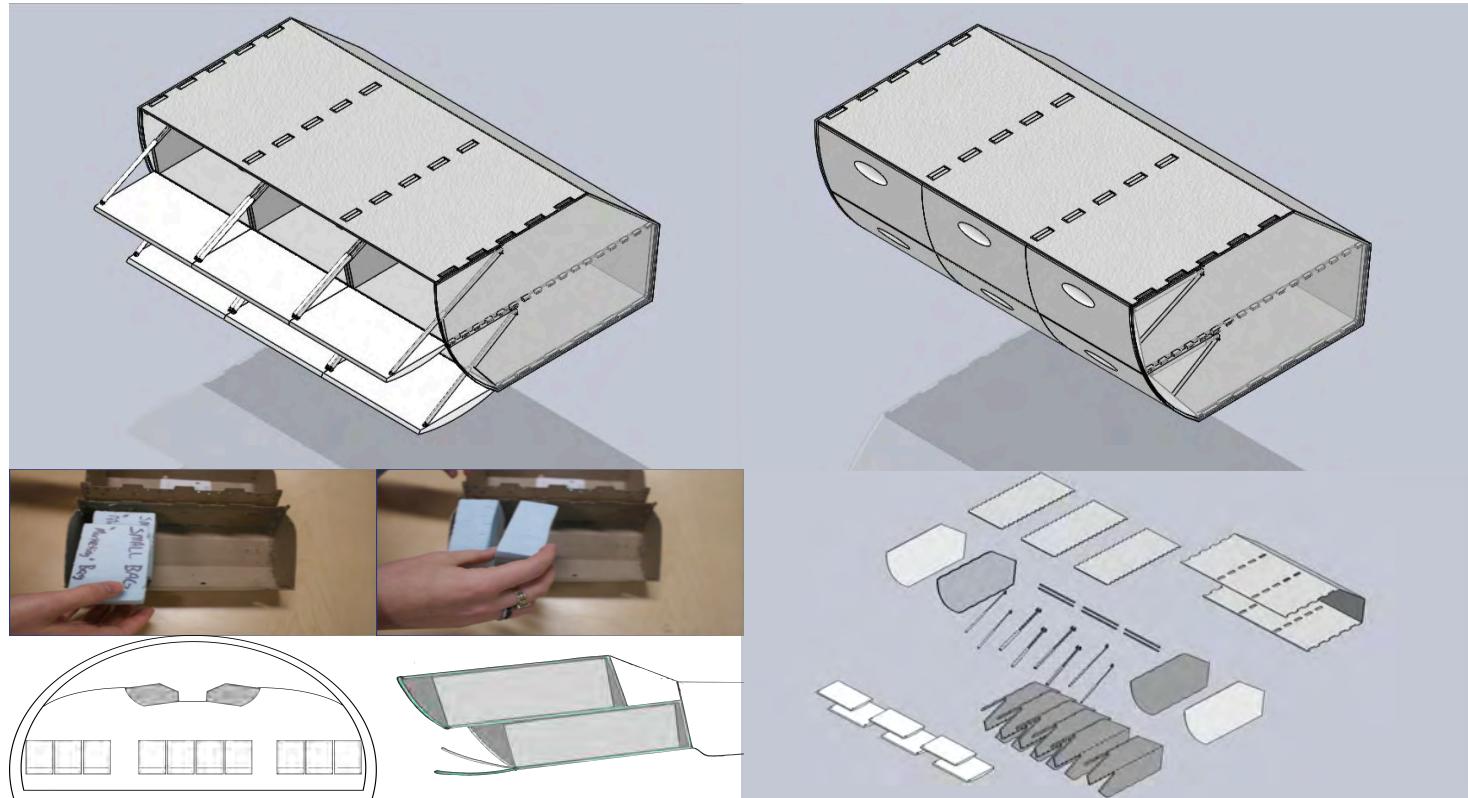
### INTEL MICROTURBINE PROJECT, 2017

In late 2017, an academic co-advisor mentioned the need for a wind tunnel to test a micro-wind turbine energy harvester we were developing for Intel.

With a relatively open schedule for the next week, I jumped on the opportunity to step out of the wet-lab and get my hands dirty with something mechanical.

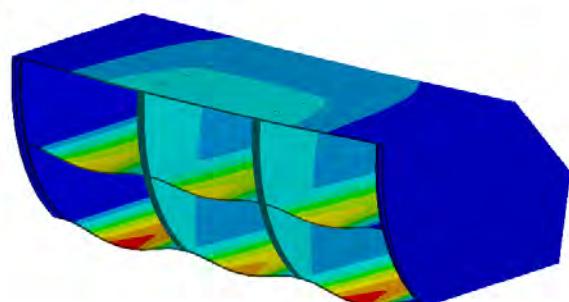
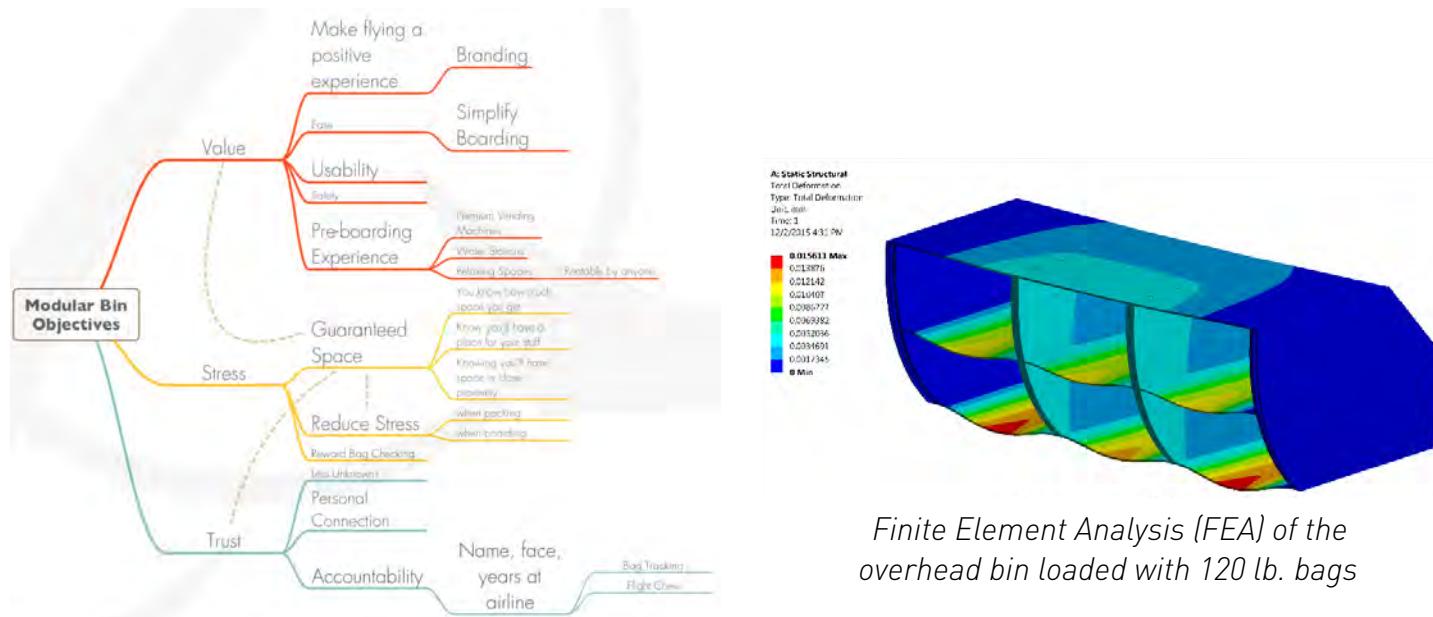
The resulting wind tunnel is the product of a forty-odd hour sprint of research, design, and debugged optimization algorithms.

Initial sketches and governing equations for the geometric optimization algorithms



#### Why Divide The Space?

1. Provide individual space
2. Guide people to bring just what they need on the airplane
3. Prompt people to check luggage that doesn't need to be used
4. Help enforce current carry-on size requirements
5. Shows the passenger the most effective use of the space



Finite Element Analysis (FEA) of the overhead bin loaded with 120 lb. bags

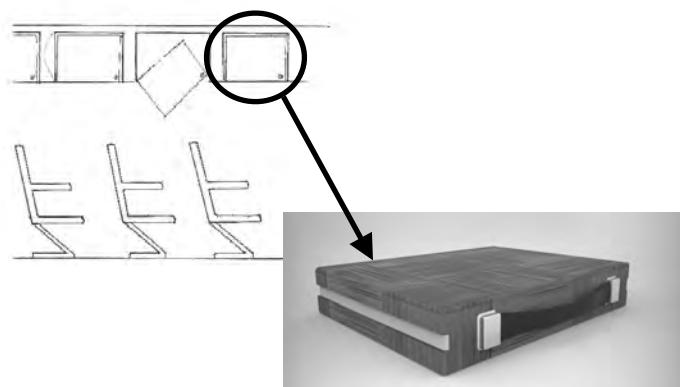
## BOEING 777X LUGGAGE Management

### INTERDISCIPLINARY DESIGN, 2015

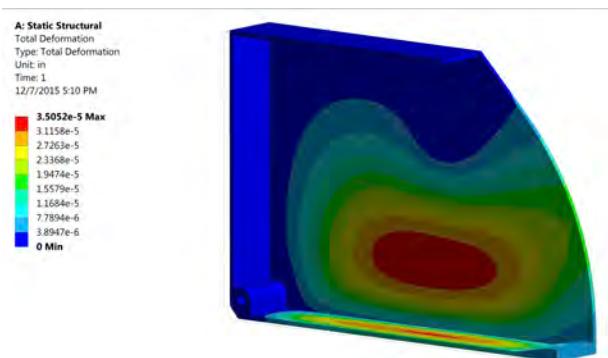
Ticketing, security, and arrive at your terminal. Check, check, and check. You've done the heavy lifting of traveling - all you have to do is get on your flight. So why do you still feel anxious? Why are all of these passengers forming lines before their seating zone has even been called?

A sense of nervous anxiety is a terrible start to any experience. That's why we set out to design a luggage management system to maximize available space in the cabin, provide guaranteed overhead storage to each and every passenger.

Collaboration with Boeing and TEAGUE.



*The hinge-bin reimagines the HVAC and lighting space as a space for briefcase-sized personal items*



*Finite Element Analysis (FEA) of the hinge-bin loaded with 40 lb. briefcase*



## BOEING 777X LUGGAGE Management

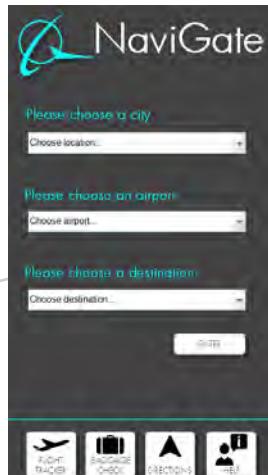
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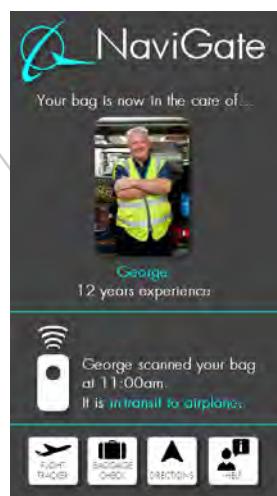
Collaboration with Boeing and TEAGUE.



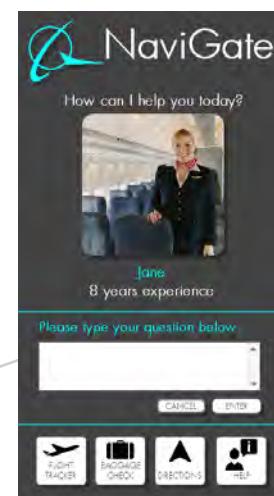
Airport Directions



Airport Navigation



Bag Tracking



Real-time help

## BOEING 777X LUGGAGE Management

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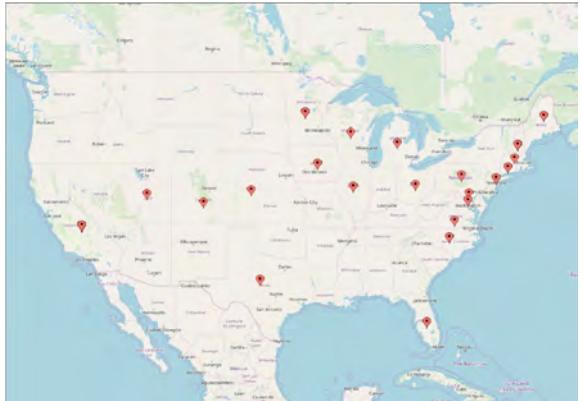
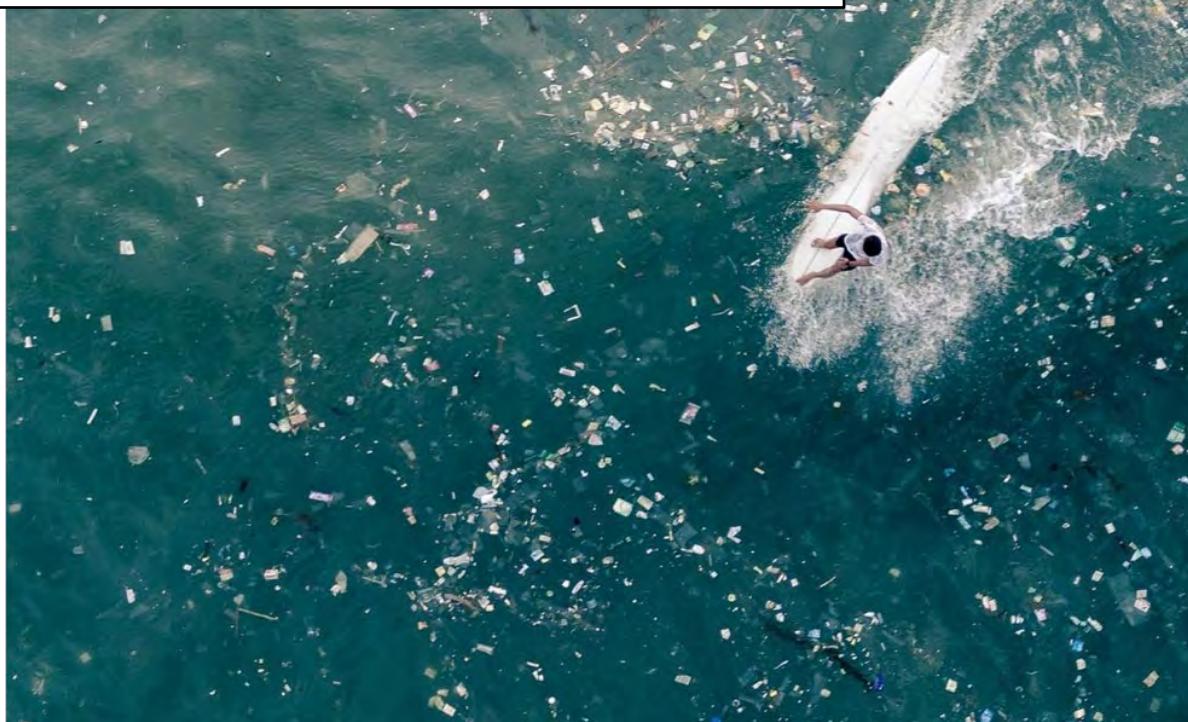
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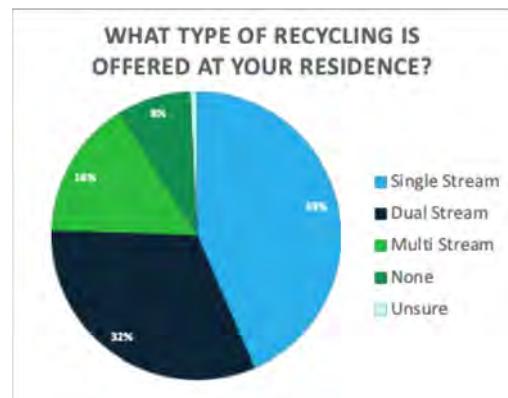
A sense of nervous anxiety is a terrible start to any experience. That's why we set out to design a luggage management system to maximize available space in the cabin, provide guaranteed overhead storage to each and every passenger.

Collaboration with Boeing and TEAGUE.

*91% of plastics are not recycled and have the potential to end up in the ocean: the final sink*



*We received feedback on our prototypes from 154 individuals across 22 states through an online survey and questionnaire*



*The wide-span of local recycling methods highlights the need for a solution that's customizable for all types*



*"When it comes to recycling plastic, I get confused all the time. Daily even."*



**CONSUMERS** desire a low-tech, cheap, non-time consuming solution.

**RECYCLING CENTERS** desire lower contamination and decreased sorting time and cost.

## CONSCIOUS RECYCLING

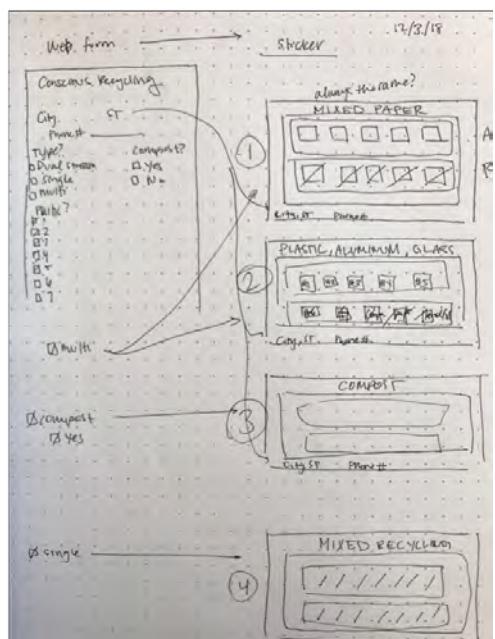
HUMAN-CENTERED DESIGN PROJECT, 2018

It started with a simple question with enormous implications - how can we reduce the amount of plastic waste that ends up in our landfills and the natural environment? After interviewing industry-leading product designers, plastics manufacturers, recycling plants, recycled plastic brokers, corporate brands, and the general public, we discovered that the front-end of user recycling had the most potential for a human-centered design solution. The result? A customizable recycling solution that increases recycling participation and reduces recycling mistakes.

# Minimum Viable Product

The form includes fields for facility type (Single Stream or Multistream), recycling acceptances (e.g., HDPE, PET, PVC, LDPE, PP), layout options (4x4, 6x4, 9x7, 10x8, 12x12, 16x16), and dimensions. It also has checkboxes for non-recyclables, recycling tips, and drag-and-drop customization.

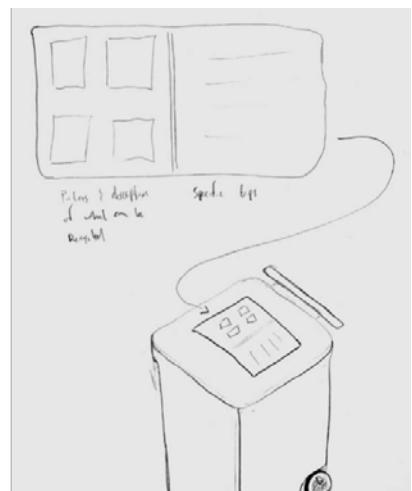
1. Local recycling utility fills out a simple webform for what they can and can't recycle



2. Responses generate which images go on the sticker and where they're placed

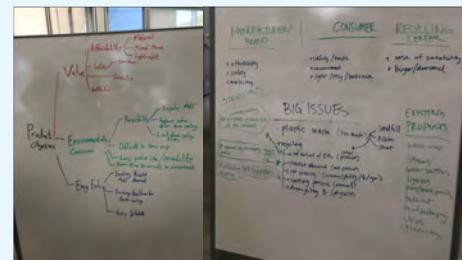


3. Stickers are printed by consumer or by the recycling utility and mailed to their locality



4. Stickers are placed on trash, recycling, and/or compost bins in homes and offices

## Problem Definition



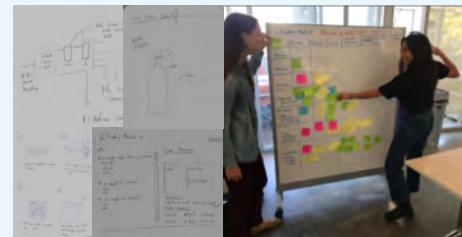
Mind-maps and framing the design outlined user-interview topics

## Research Analysis



Abstract customer requirements were converted to measurable specifications

## Concept Generation



Brainstorming, sketches, affinity diagrams, and feature matrices generated features and concepts

## Concept Selection

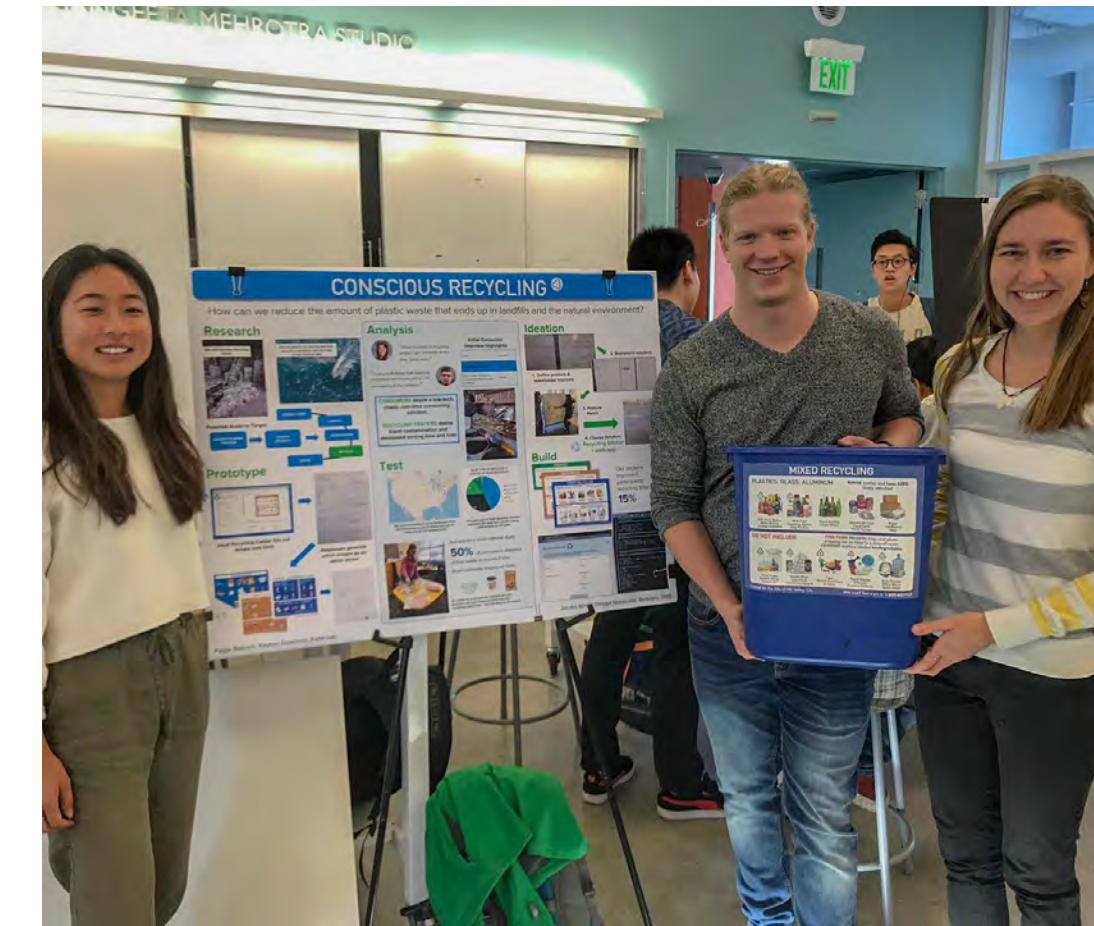


A QFD numerically scored the concepts to decide the best solution

# CONSCIOUS RECYCLING

HUMAN-CENTERED DESIGN PROJECT, 2018

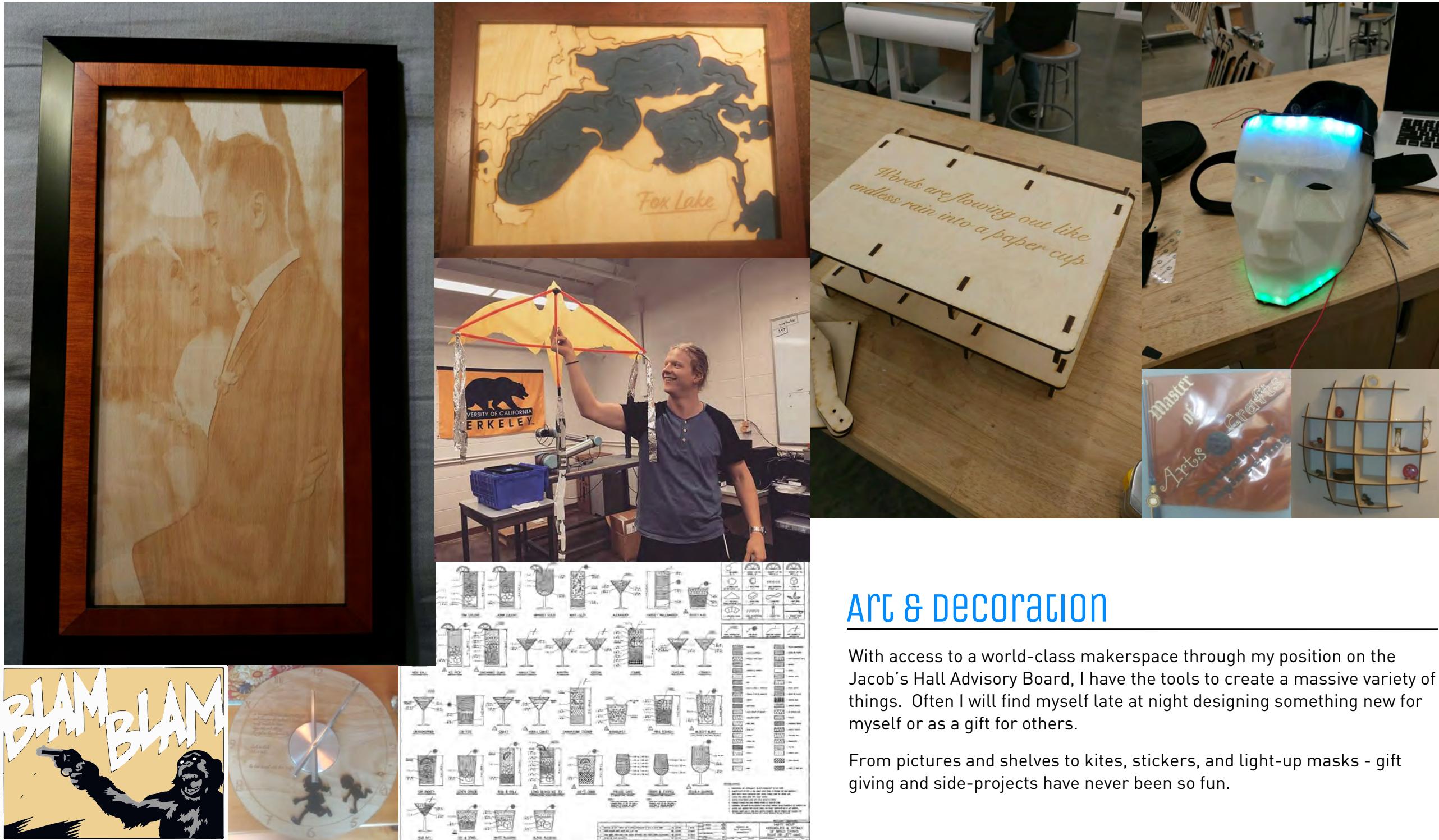
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# conscious RECYCLING

Human-centered Design Project, 2018

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## ART & DECORATION

With access to a world-class makerspace through my position on the Jacob's Hall Advisory Board, I have the tools to create a massive variety of things. Often I will find myself late at night designing something new for myself or as a gift for others.

From pictures and shelves to kites, stickers, and light-up masks - gift giving and side-projects have never been so fun.

## Desire Was Everywhere

I remember how it used to be  
late nights in the spring  
our bones were just loose from that winter's grasp  
which seemed to drag its fingertips across April  
Everyone desired everyone – or perhaps just the chance to be desired  
It's amazing how contained we are  
Searching for meaning in a meaningless pursuit  
I tried to find the answer that never existed anyway

Desire was everywhere  
So much, it couldn't be reduced  
I can't remember when it happened,  
I started to walk the streets, desireless  
Wantless; Needless  
The beautiful girls I met, the boundless personalities  
Looked like effort, pain maybe.  
I had clinical reasons for dissatisfaction-  
I avoided a world so pointlessly small

Today, walking across some park unknown to me  
I felt it coming back  
The curiosity, the various  
The imagined life pretended at a glance  
I've witnessed how a hollow heart heals.  
I've witnessed, finally, how it never learns.

## Everything Shimmers

Everything shimmers  
like diamonds in the morning sun.  
Glitter is on the grass  
and I smell the sweet smell of damp, growing things.  
The smell of mud and twigs and mushrooms and snails.  
Last fall's leaves squish beneath my feet  
awakening memories of pumpkins and bonfire smoke.

A train whistles in the distance  
and rattles over a bridge  
mimicked by a woodpecker somewhere east.

I wandered into a prairie by a stream.  
Feet wet and buried in sand  
I waded to the river mouth  
where seven mosquitos sunk in my skin  
and drank me like summer wine.  
They left me with the strawberry moon and singing crickets  
with the earth soft against my back.

## Untitled

I know you didn't believe me  
when I wiped my eyes clean from tears  
that October morning when I got off the phone  
it was a Thursday I think  
and you'd never worn yellow before

following plans has never come easy  
if they did I'd kiss you and tell you about Ripple, the horse I rode  
when I was seven and didn't know how to ride  
the horse behind me was stung by a wasp  
and Brit fell from her saddle when the mare bucked  
we rode in circles around a rotting log  
while the counselor rushed to teach us "Woah now, girl."

it's very hot here  
sometimes I think we should just run

sometimes I wish I was closer to a river  
so on rainy days I could throw out a raft  
and float till I find a fisherman

have I ever taken you to the bridge where I grew up?  
low by reeds by water  
the reeds are dandelion short in April  
but grow like a promise in June

I understand why you didn't take the bus.  
It would have taken you through another smoldering city  
and you're still coughing from the ashes of Memphis.

## Hindrance

Yesterday, the son couldn't commit himself  
he had wanted to write his beloved a poem  
but couldn't find the word to describe her hands

He would have written her a sonnet  
relating her hugging arms to the rain  
her calming whisper to the saturated breeze  
and her eyes to still pools of water on leaves

He would have written her a light limerick  
About the days they fell laughing on the couch  
the time he found her sister's ring  
the Wisconsin sun and lapping water

He would have written her a haiku  
of the times they made love  
and the taste of her berry lips  
which hang like an aroma on his tongue

Today, he has nothing to write her.  
Though he wishes to,  
everything he has is already hers

## Twenty Growing On Seventeen

At twenty years old,  
I miss myself at seventeen.  
A mop of blonde hair sheltered blue eyes from the wind  
while my bike groaned from fatigue in the summer.  
I had so many questions still to ask  
and in the days I dreamt of ice skating at night  
cold with my love under the January stars.

At eighteen my hair curled in on itself.  
I forgot to bring my bike with me to college  
where I found the answers to my questions  
like how butterflies get their colors  
and what chemical creates love.  
I would dream with her at night, sometimes  
when we found our way back to the same room.

Nineteen my hair untangled.  
I began to answer my own questions  
and learned to stop asking so many  
like, "where did you sleep last night?"  
That year, I wished I'd never shared a kiss with my love  
after she asked me to keep it from her boyfriend.

At twenty years old  
I miss myself at seventeen.  
I cut my hair to the roots.  
My bike sits unused with broken gears by the fence.  
Answers have discarded all my questions,  
and I've finally stopped regretting  
that I never rented those skates.

## American Dream

He imagines he's doing everything  
right as he sits straight  
up in his chair  
in front of her; in her coruscate dress  
laugh appropriately, look in her eyes  
almost

painfully

\$40 champagne fabricates confidence  
he draws close,  
reaches for her hand  
but her bracelet stabs him  
and he bleeds  
softly, even

# POETRY

Before I discovered physical arts as a means of creative outlet, the art of poetry sustained my need to express myself. In high school I would cram in personal lessons with the English department teachers to learn how to evoke emotions with writing, and a lifelong passion to freeze those feelings in time blossomed.

Heavily inspired by E.E. Cummings, Edgar Allan Poe, and T.S. Elliot, a selection of my published poems are offered here.



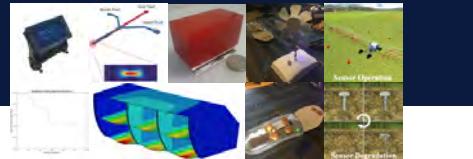
## OTHER Interests

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When I'm not in the office, the lab, or the workshop, I can most often be found at a comedy or music bar watching live performances or in a humid gym practicing combat sports like as jiu-jitsu, boxing, or wrestling. Most Fridays since 2011, I'll spend an hour of my day volunteering through an educational organization or cause - often by tutoring younger generations.

Once or twice a month, I unplug all electronics and spend the weekend backpacking through California's beautiful landscapes.

## Education



### **University of California Berkeley**

Ph.D. Mechanical Engineering, Design  
M.S. Mechanical Engineering, Design

**Iowa State University**  
B.S. Mechanical Engineering, Magna Cum Laude, Honors Program

expected May 2021  
May 2018

December 2015

## Research Experience

### **Flexible Electronics, Devices, and Systems Lab**

*NSF Graduate Fellow*

- Designed FPC printed interconnects and device architecture for a biodegradable wireless sensor node (modules in development)
- Developed a novel photothermal process to create conductive graphene/metal-ion hybrid structures within biodegradable substrates
- Co-wrote an accepted ARPA-E grant valued at \$1.69m

2017-current

### **Advanced Manufacturing for Energy Lab**

*Graduate Student Researcher*

Master's Thesis: Model-based design and fabrication of a flexible closed-loop heating element for wearable comfort applications

- Optimized low-power thermistor ink slurries for electrical conductivity, rheology, surface profile, and overall performance with a factorial design of experiments
- Designed plastic wireless sensor node (WSN) packaging that adhere to DFM and DFA theory
- Wrote a custom finite element (FEM) code to compute heat generation to explore the design space of parametric device designs
- Wrote a genetic algorithm to search through the FEM results and find the best design based on the weighted value of several device features (cost of fabrication, size, efficiency, operating temperature)
- Developed and demonstrated a multi-material additive process to create low-cost (<\$1) wearable heaters with optimized thermal feedback control for consumer electronics. These devices were 99.6% accurate to the predicted values of the self-written design algorithm and self-written FEM simulation
- Designed and built a wind tunnel to characterize a microturbine energy harvester's flow profile and power output for powering remote sensing of data centers
- Prototyped a thermal capacitor to harvest energy from ambient temperature changes of an aircraft in flight
- Prototyped a suite of wirelessly-powered personal thermal-comfort devices including a heated insole, desktop fan, and wrist pad

2016-2018

### **Bio- Microfluidics and Optofluidics Laboratory**

*Undergraduate Student Researcher*

- Designed, fabricated, and characterized microfluidic microbial fuel-cells ( $\mu$ MFC) and environmental sensors
- Programmed NI data acquisition devices in LabVIEW
- Developed the first multilayered microfluidic channel templates using layer-by-layer LaserJet printing on thermoplastic sheets
- Fabricated hollow polymer microfibers from a microfluidic device without chemical or UV light cross-linking for biological cell growth
- Created Mastercam and manually-written G-code toolpaths to carve microfluidic channel templates that match COMSOL Multiphysics simulation with a vertical 3-axis micro-mill

2012-2015

### **Center for Catalysis**

*Undergraduate Student Researcher*

2013

- Synthesized silicon-core/carbon-shell structured platinum nanocatalysts by performing colloidal lithography on silicon core-shell nanoparticles with three separate carbon sources
- Installed an electrochemical workstation and developed a comprehensive step-by-step operation procedure for battery, fuel cell, and catalyst characterization for oxygen reduction and methanol oxidation half-cell reactions

## Industry Experience

### **HGA Architects & Engineers**

*Mechanical Design Engineer*

2014-2016

- Generated macro-scale energy models to optimize performance of large scale (100,000+ ft<sup>2</sup>) hospitals
- Automated AIA/ASHRAE minimum design performance calculations in an Excel spreadsheet, now used as standard company-wide

## Publications

### **Journals (Refereed)**

- J.M. Lackore, N. Hashemi, F. Sharifi, **P.J. Goodrich**, M.L. Winchell, and N. Hashemi, "A Paper-Based Microbial Fuel Cell Operating under Continuous Flow Condition", *Technology*, 4, 98-103 (2016).  
**P.J. Goodrich**, F. Sharifi, and N. Hashemi, "Rapid Prototyping of Microchannels with Surface Patterns for Fabrication of Polymer Fibers", *RSC Advances*, 5, 71203-71209 (2015).  
J. Yang, S. Ghobadian, **P.J. Goodrich**, R. Montazami, and N. Hashemi, "Miniaturized Biological and Electrochemical Fuel Cells: Challenges and Applications", *Physical Chemistry Chemical Physics*, 15, 14147-14161 (2013). **Featured as Key Scientific Article on Renewable Energy Global Innovations.**

### **Conference Presentations**

- P.J. Goodrich**, A. Arias. "Model-based design and fabrication of micro- and milli- scale devices", Berkeley Wireless Research Center Summer 2018 Retreat, Sonoma, CA, May 24, 2018.  
**P.J. Goodrich**, G. Fierro, V. Luu, H. Zhang, E. Arens. "Heating and cooling the human body with wirelessly-powered devices", PowerMEMS 2017, Kanazawa, Japan, November 14-17, 2017.  
**P.J. Goodrich**, P. Wright. "Wireless Personal Comfort Devices", Berkeley Wireless Research Center Summer 2017 Retreat, Sonoma, CA, May 26, 2017.  
**P.J. Goodrich**, M. Kiziriglu, P. Wright. "Dynamic Thermoelectric Generators for Powering Wireless Sensor Nodes", Berkeley Wireless Research Center Winter 2016 Retreat, Berkeley, CA, November 1, 2016.  
**P.J. Goodrich**, F. Sharifi, and N. Hashemi. "Microfluidic channels for fabricating biocompatible polycaprolactone microfibers", Department of Energy Ames Laboratory Summer Science Intern Poster Presentation, Ames, IA, July 31, 2015.  
**P.J. Goodrich**, F. Sharifi, and N. Hashemi. "Fast and Affordable Fabrication of Microfluidic Mold Templates with Complex Multilayer Geometry", ASME 2015 4th Global Congress on NanoEngineering for Medicine and Biology, Minneapolis, MN, April 19-22, 2015.  
**P.J. Goodrich**, N. Hashemi, M. Winchell, J. Lackore, F. Sharifi, and N. Hashemi. "A Continuous Flow Paper-Based Microfluidic Microbial Fuel Cell", ASME 2015 4th Global Congress on NanoEngineering for Medicine and Biology, Minneapolis, MN, April 19-22, 2015.  
**P.J. Goodrich**, C. Xiao, Z. Qi, and W. Huang. "Synthesis of Carbon Coated Platinum Nanocatalysts for Methanol Oxidation and Oxygen Reduction Reactions", Department of Energy Ames Laboratory Summer Science Intern Poster Presentation, Ames, IA, August 2, 2013.

## Awards and Honors

### **Academic**

- National Science Foundation Graduate Research Fellowship  
Summer Grant Award and Block Grant Award  
Scholar of the Year  
Intro to Mechanical Design - Final Design Competition Award  
Inducted into the Golden Key International Honour Society  
Inducted into the Iowa State University Honors Program  
President's Award for Competitive Excellence  
Engineering Undergraduate Merit Award

- National Science Foundation, 2017  
University of California Berkeley, 2017  
Sigma Pi Fraternity, 2015  
Iowa State University, 2013  
Golden Key, 2013  
Iowa State University, 2013  
Iowa State University, 2011  
Iowa State University, 2011

### **Miscellaneous**

- Received blue belt in Brazilian jiu-jitsu  
Bring Back the Prairies Award  
OUSA Poetry Prize  
Richard Caplan Sketch Prize for Poetry

- Bay Jiu-Jitsu, 2017  
League of Minnesota Poets, 2015  
Otago University Student Association, 2014  
Iowa State University, 2013

### **Skills**

- DFA, DFE, DFM, HCD, LCA  
Solid modelling, FEM, simulation, and CAD  
Data processing and analysis  
Rapid prototyping  
Optimization of materials and processing  
Geometric dimensioning  
Mask design and lithography  
Failure and useful life analysis

### **Software**

- Matlab  
Autodesk Suite  
SolidWorks Suite and ANSYS  
LaTeX  
Microsoft Office  
Adobe Illustrator and Photoshop  
COMSOL Multiphysics  
LabVIEW

### **Equipment**

- 3d-printers (Carbon, Makerbot, Objet, Stratasys, TypeA, Ultimaker)  
ULS and Fortec laser cutters  
Automatic film applicator, inkjet printer, screen printer, spin coater, and spray coater  
Rheometer and profilometer  
Oscilloscope, LCR probe, and 4-point probe  
Cleanroom and glovebox equipment  
Machine shop tools and CNC

## Graduate Level Coursework

- Advanced system dynamics and controls  
Computer-aided design  
The finite element method  
Interdisciplinary design  
Modeling and simulation of advanced manufacturing processes

- Advanced technical communications  
Design of basic electromechanical devices  
Human-centered design  
Mechanics of engineering materials  
Piezoelectric MEMS

- Alternative energy  
Engineering economic analysis  
Interactive device design  
MEMS design (levels I and II)  
Principles of electrochemical processes

## Volunteerism & Social Design

### Laboratory research mentorship

*Research Mentor*

*2017-current*

- Managed and mentored five spectacular undergraduate students to date in mechanical engineering, material science, electrical engineering, computer science, and applied mathematics.
- Projects:
  - Printed complex electronics using laser-induced graphene and multi-material 3d-printing
  - Printed biodegradable humidity sensors
  - Magnetic field sensors by laser-induced graphene coils on polyimide
  - Product design of thermal comfort devices for the built environment
- Skills:
  - Laser-induced graphene synthesis and characterization
  - Electroactive ink and hydrogel synthesis
  - Doctor blade and stencil printing
  - Profilometry, optical microscopy, LCR probe, 4-point probe, clean room techniques and etiquette
  - CAD design and 3d-printing strategies for prototyping
  - Geometric tolerancing for 3d-printed and plastic injection molded snap-fit assemblies

### Jacob's Institute for Design Innovation Student Advisory Board

*Board Member*

*2017-current*

- Bi-annual review of 'spark' and 'ignite' grant proposals to finance student-led projects that align with the Jacob's Institute for Design Innovation mission statement (approximately 75 proposals reviewed to date).
- Participate in strategic planning and program development of the UC Berkeley's Jacob's Hall Maker Community, representing the opinions, needs, and interests of the student body

### Students for Environmental Energy Development (SEED)

*Tutor*

*2016-2017*

- Lead bi-weekly science experiments in an integrated high school physics class
- Planned curriculum and purchased supplies for a group science fair project

### Engineers for a Sustainable World

*President*

*2015*

- Led monthly all-hands meetings and bi-weekly meetings with six different project managers to ensure project success
- Initiated four new local development projects to grow unrepresented demographics and tripled club size

#### *Solar-powered light project manager*

- Led a team of multidisciplinary engineers to develop a low-cost solar/grid hybrid powered street light which was installed on campus and in rural Nicaragua

### Minds of Tomorrow

*Outreach Coordinator*

*2011-2013*

- Organized STEM outreach projects and demos to K-12 schools across Iowa
- Reviewed grant proposals to fund STEM projects





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