NSF Workshop on Additive Manufacturing for Civil Infrastructure Design and Construction

Performative 3D Printed Building Skins: Towards an Adaptable Built Environment

Arlington, VA
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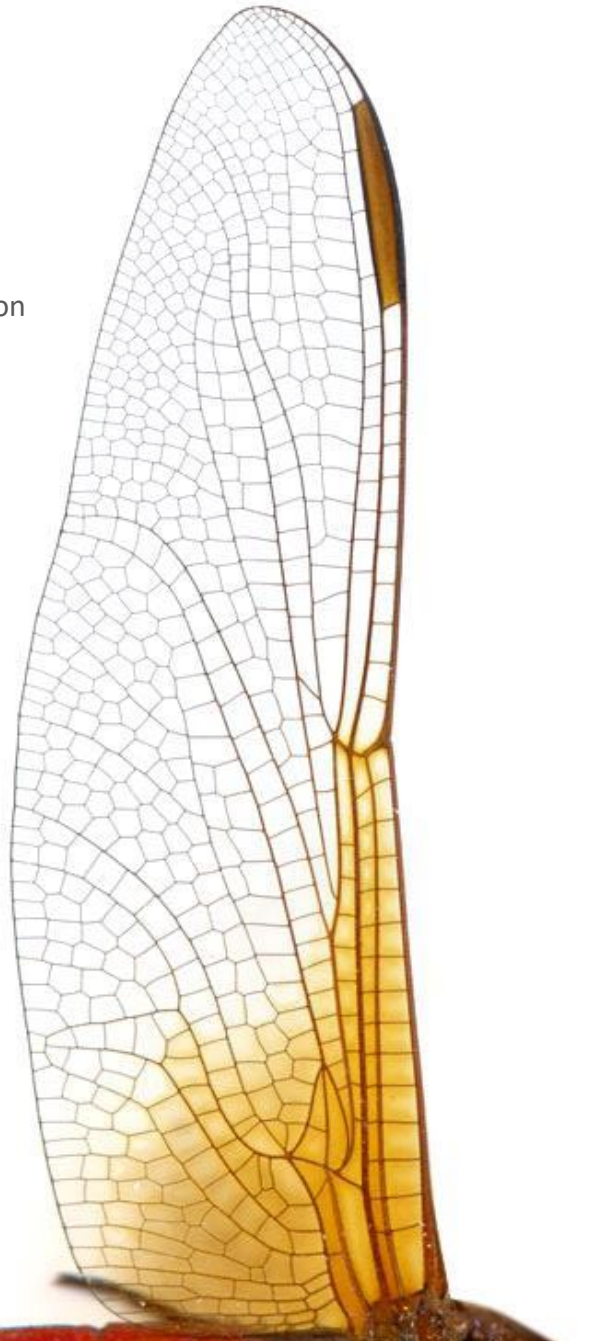
Zofia Rybkowski, PhD
zrybkowski@tamu.edu
Negar Kalantar, PhD
kalantar@tamu.edu

Texas A&M University
College of Architecture



Acknowledgements:

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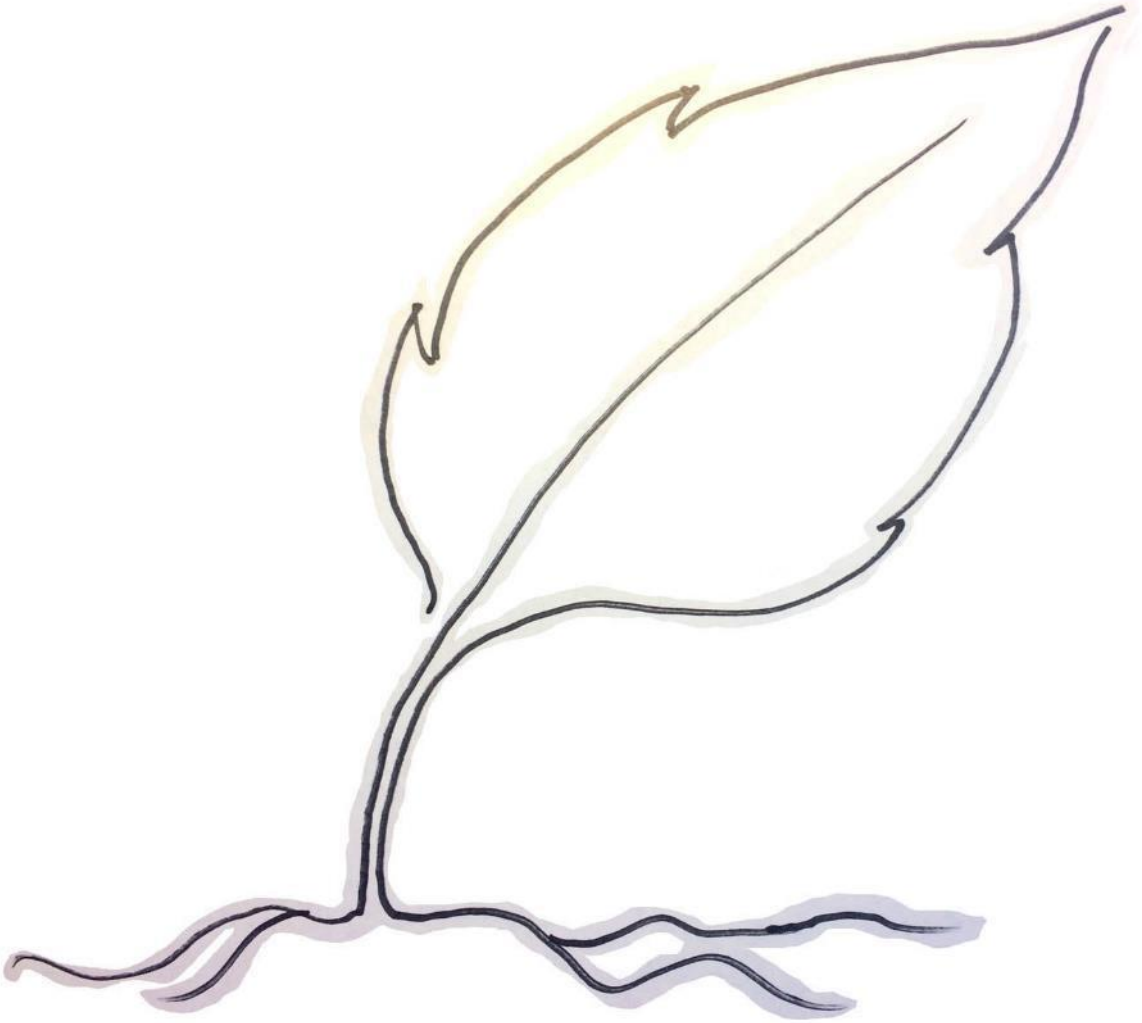
Research team:

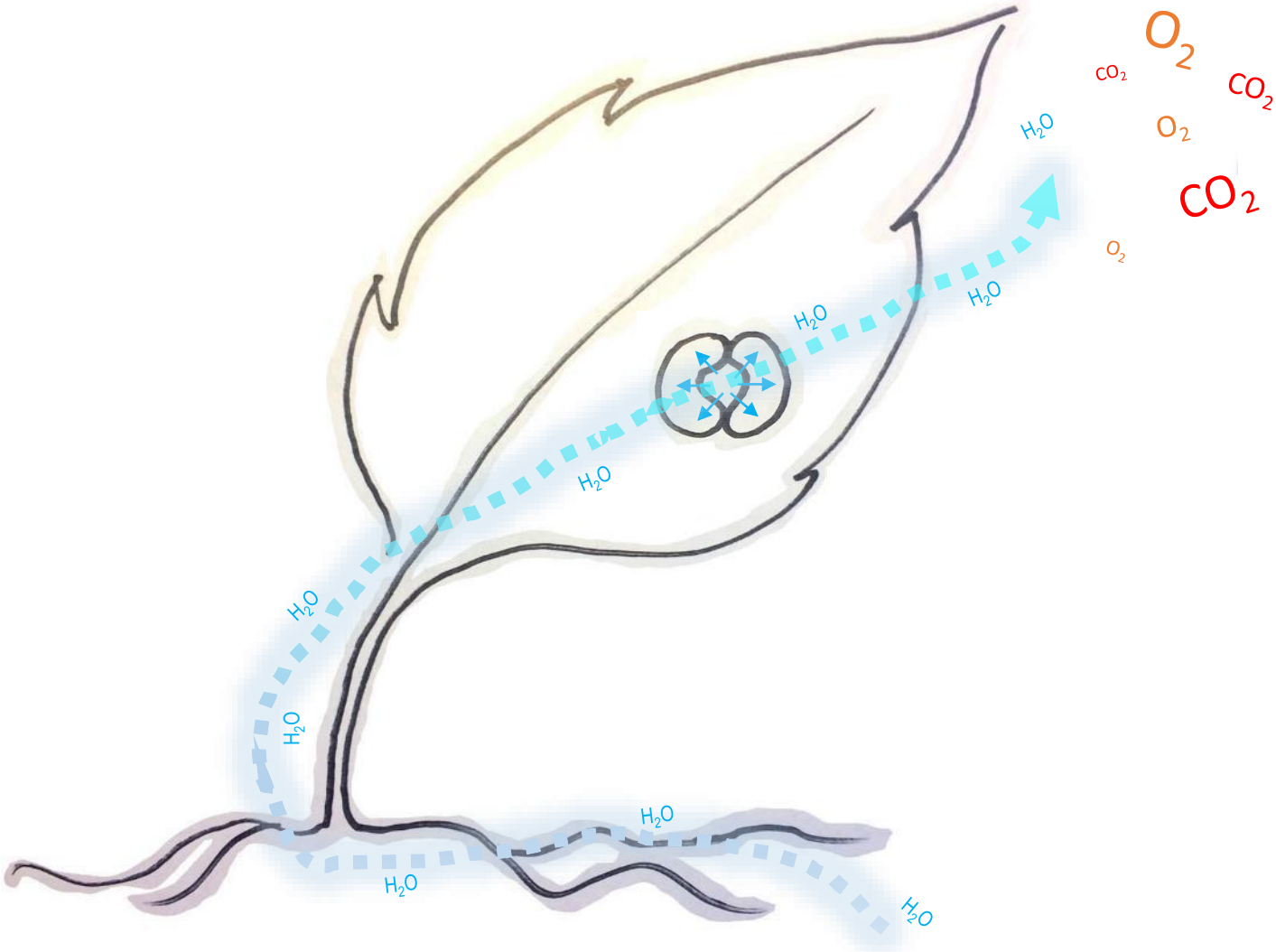
Zofia Rybkowski, PhD (PI)
Negar Kalantar, PhD (co-PI)
Ergun Akleman, PhD (co-PI)
Tahir Cagin, PhD (co-PI)
Terry Creasy, PhD (co-PI)

Teaching collaborators:

Alireza Borhani, MArch
Dylan Shell, PhD

+ 66 *student collaborators*

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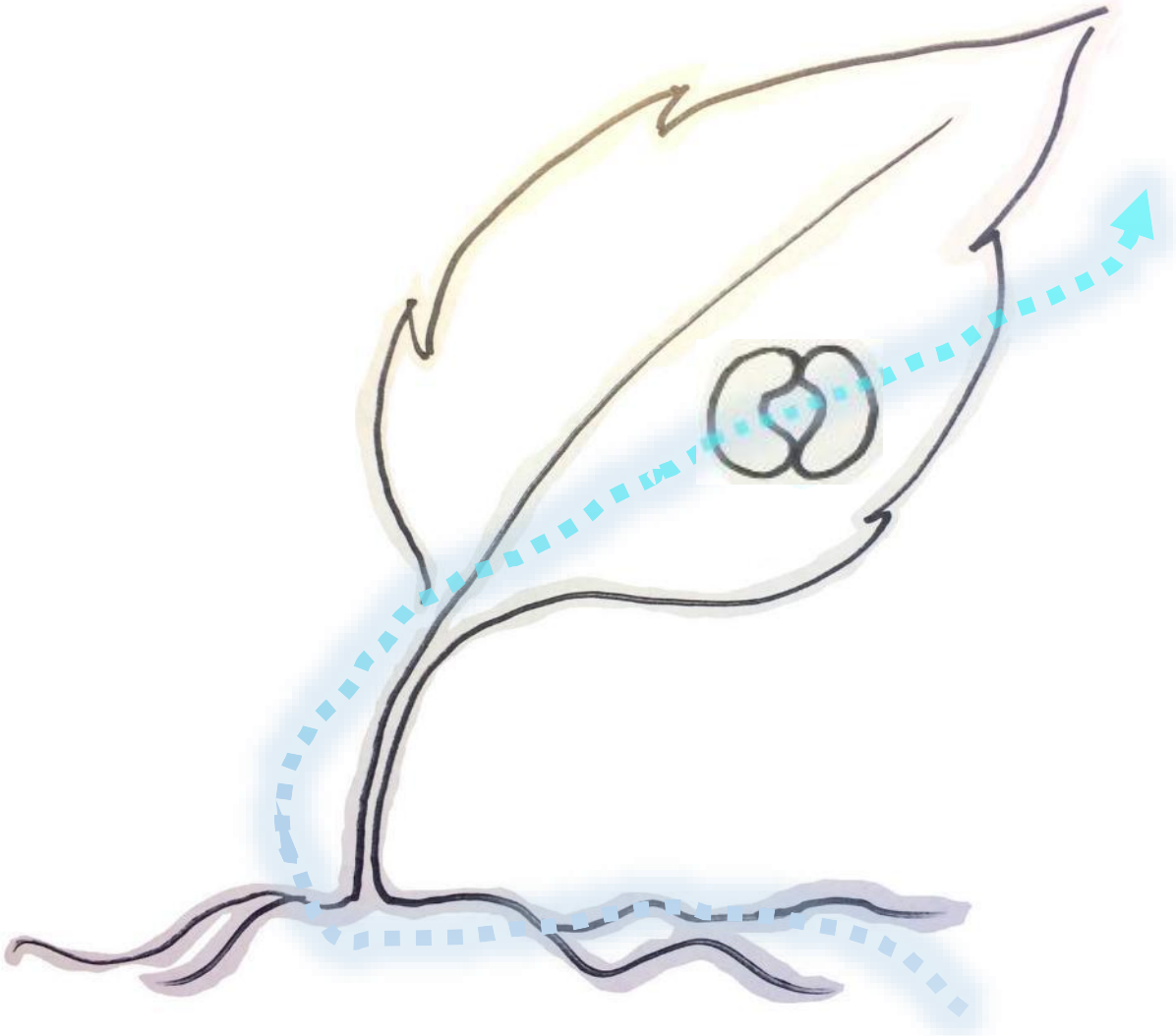


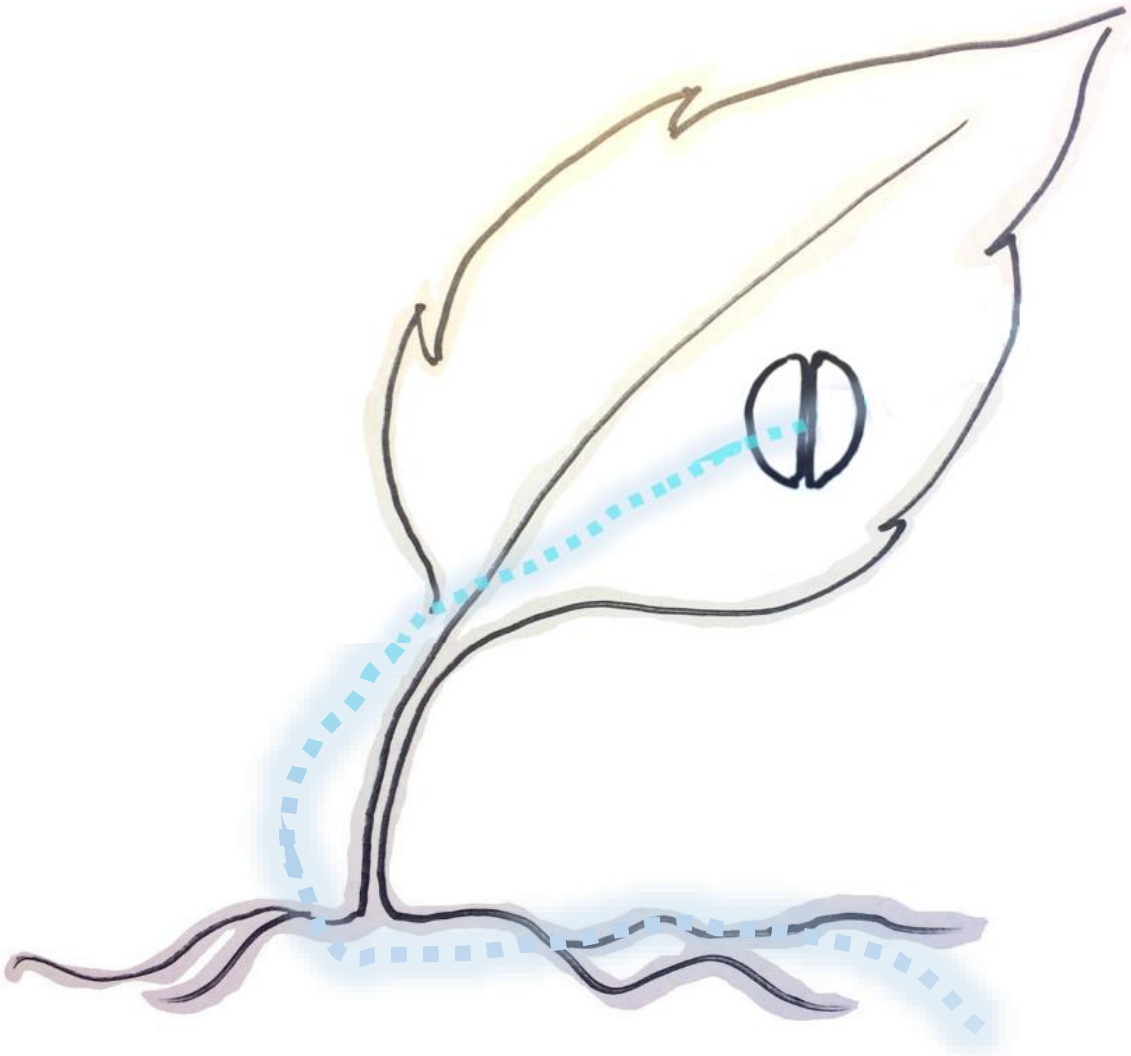
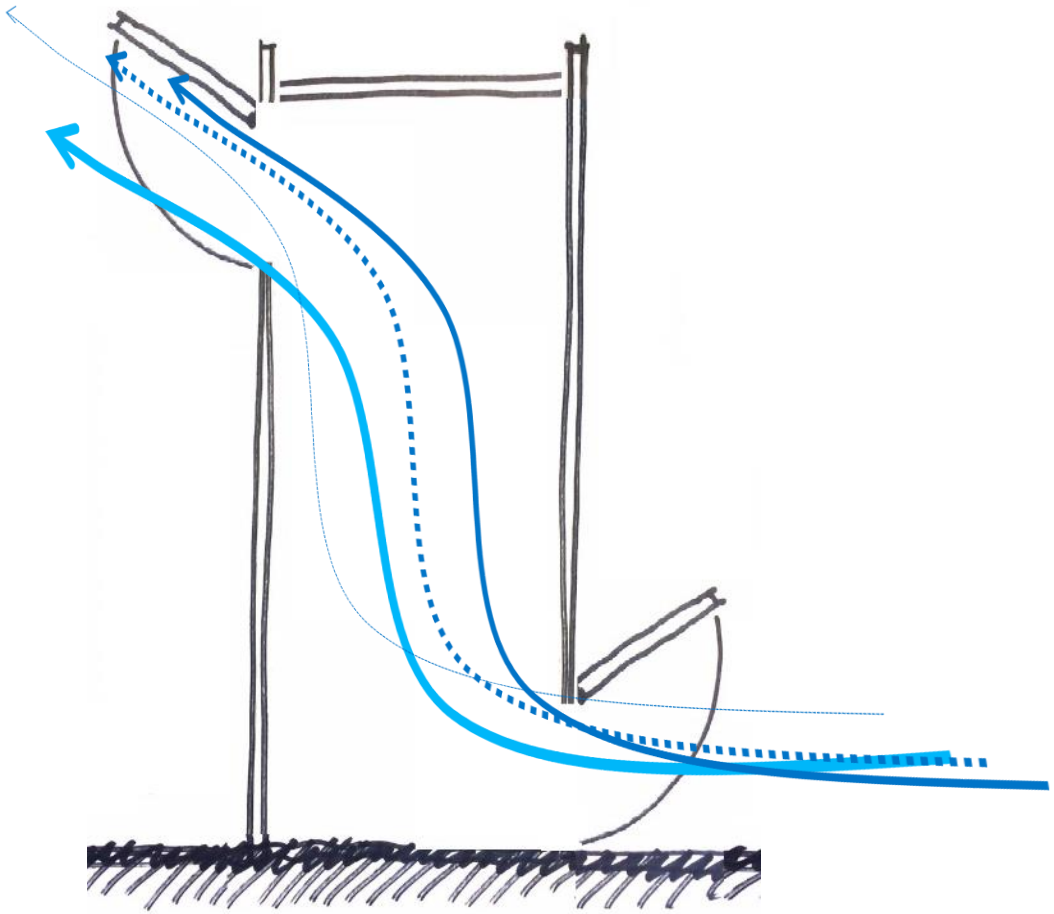
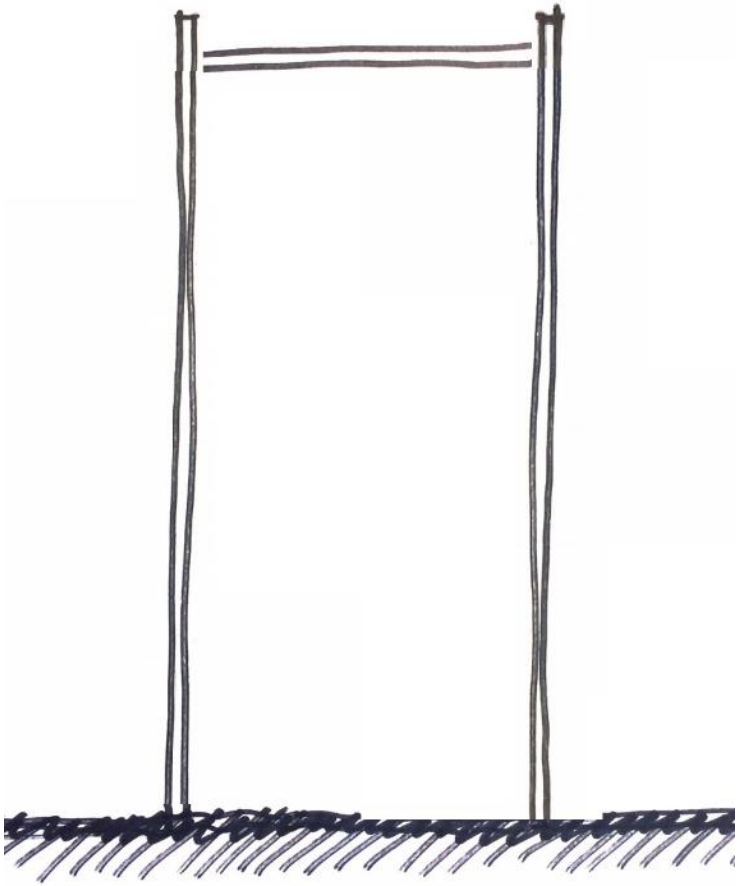
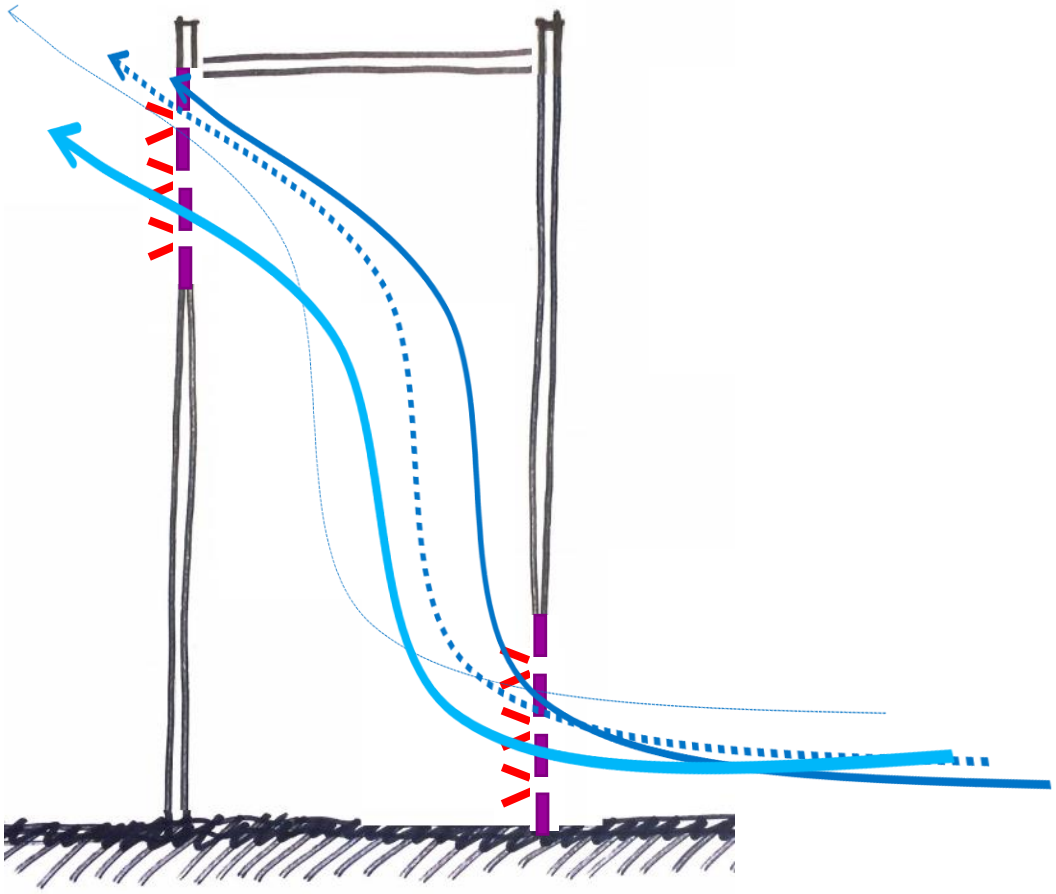
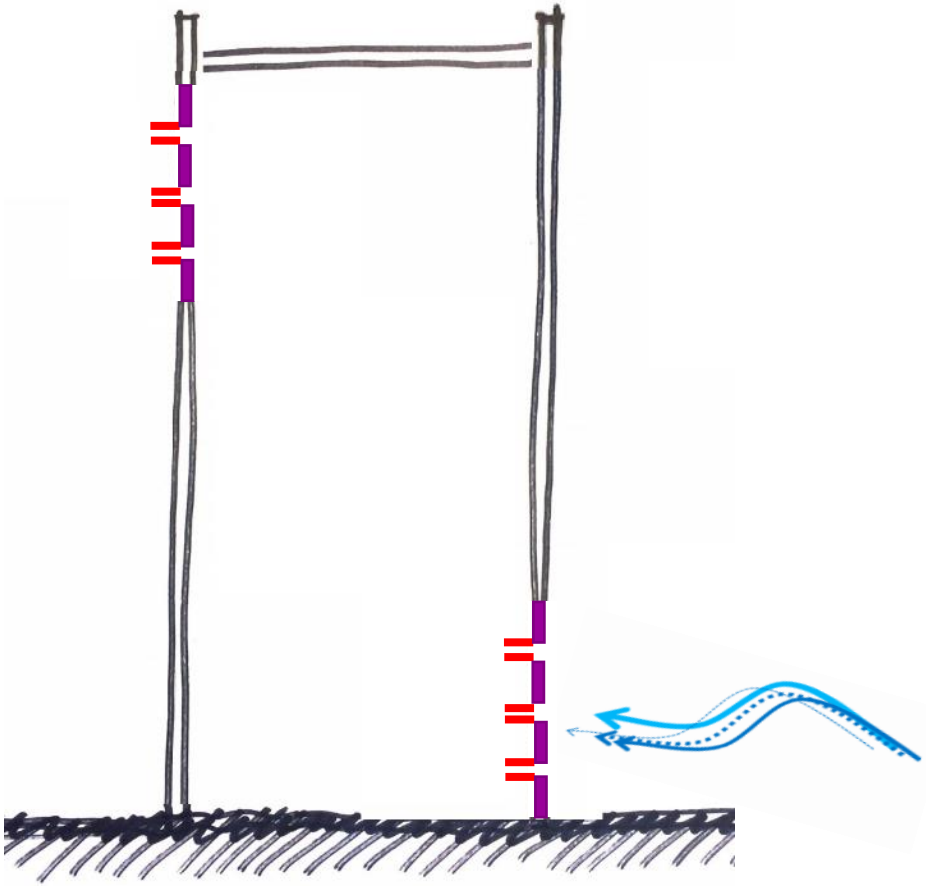


Image source: https://fineartamerica.com/featured/stomata-of-lavendula-dentata-sem-power-and-syred.html









General Strategy

Image source: http://uk.prweb.com/releases/2013/3/prweb10481856.htm

A B C D

A

B

C

D

Negar Kalantar Introduction

Diameter: 22 Ft (open position) and 3.3 Ft (closed position)

Based on Hoberman's Geodesic Dome

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Texas A&M University, College of Architecture

Research Collaborators: Kalantar, Borhani

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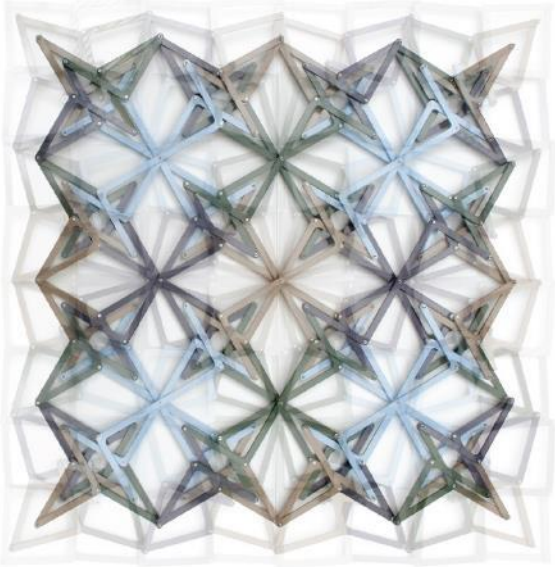
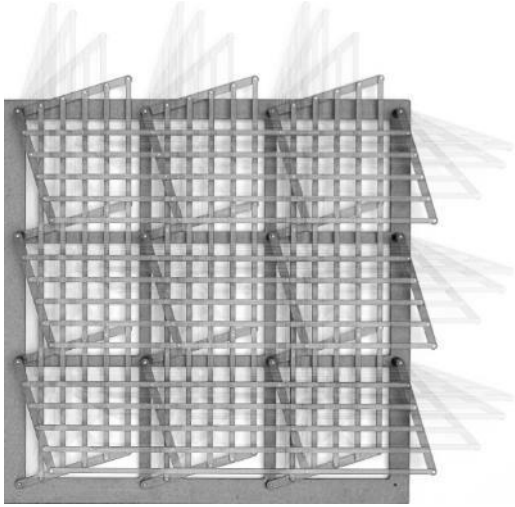
Expandable Spherical Cup II
Dimension: 10 Ft side (open position) and 2 Ft (closed position)
Material: Wood + Aluminum

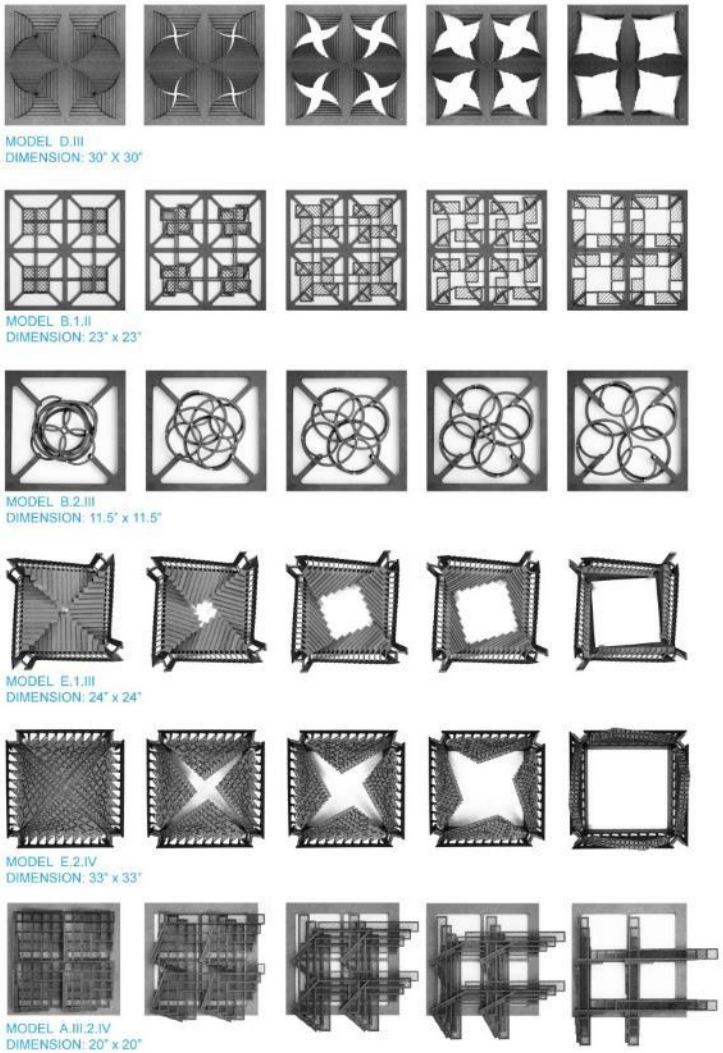
Expandable Spherical Cup I
Dimension: 9 Ft side (open position) and 1 Ft (closed position)
Material: Wood + Aluminum

http://vimeo.com/negarkalantar/spherical-domes

Negar Kalantar Introduction







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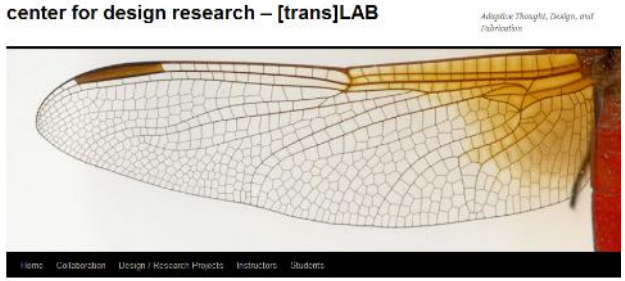

CDR – [trans]LAB

Posted on January 7, 2014 by nnaji

CDR – [trans]LAB engages emerging digital tools with respect to Architecture and Design. A conversation between computer controlled tools and design assumptions which are based on these tools comprises the umbrella for this lab. Experiment, invention and physical material are directed towards the development of architecturally relevant contributions. The focus is to interrogate digital platforms within the context of innovative building envelopes that are transformable and demonstrate real-time morphological changes into architecture. Clark and Kalantar are offering the CDR – [trans]LAB in the School of Architecture + Design at Virginia Tech through the Center for Design Research.

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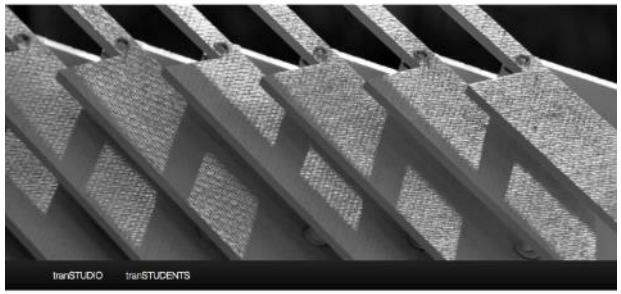
Adaptive Thought, Design and Fabrication



Posted on April 22, 2015 by jennyzh93

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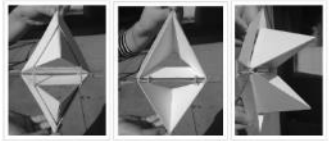
Edit

PRISM [Design Development 04]

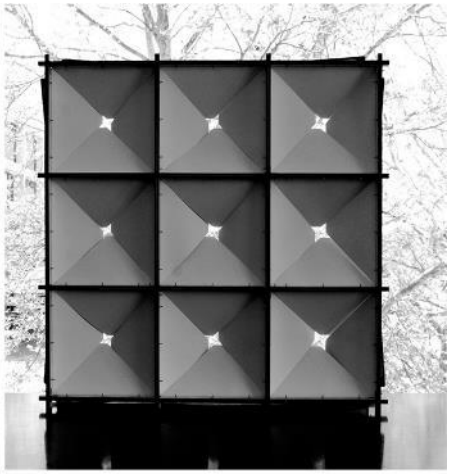
Matt Michalak/Jenny Zhou

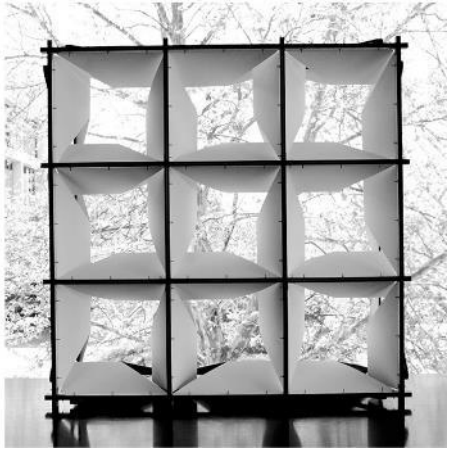
With a design iteration chosen, we moved forward towards physically realizing our rendition of the shading system.

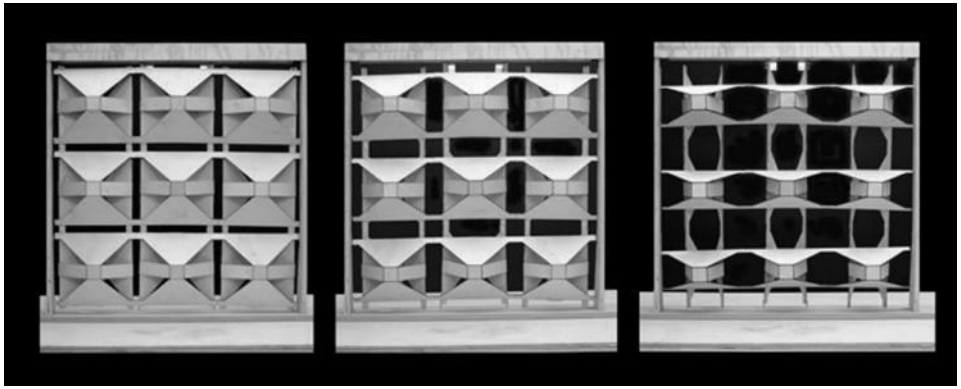
In our first attempt, we've noticed a few technical issues…



The fins were not catching onto the rod. In order for this system to work properly, the fins must be completely fixed to the rod. Also, building the frame was not as simple as we had thought. Because only the edges of the frames are touching, there is not much structural stability.







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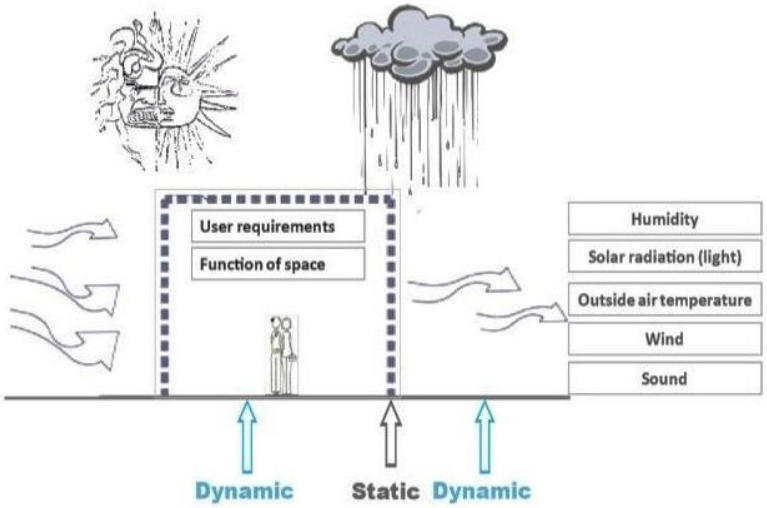
Research Collaborators: Kalantar, Clark, Kato, Hawkins, Miller& Nnaji


First Skin


Second Skin


Third Skin



Mediator between ***Inside*** & ***Outside***

Reaction to ***Environmental*** Changes

Responsive to the ***Occupant*** Needs

Could our third skin be adaptive similar to our first skin?

NOT REALLY!

The Difference between Natural & Man-made Constructions

Nature

Material is expensive BUT **complexity** is free

↓

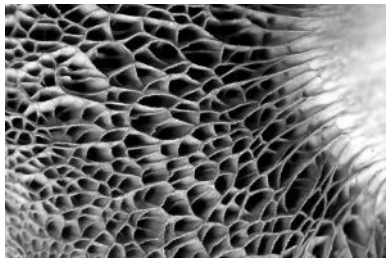
Less material + More complex forms

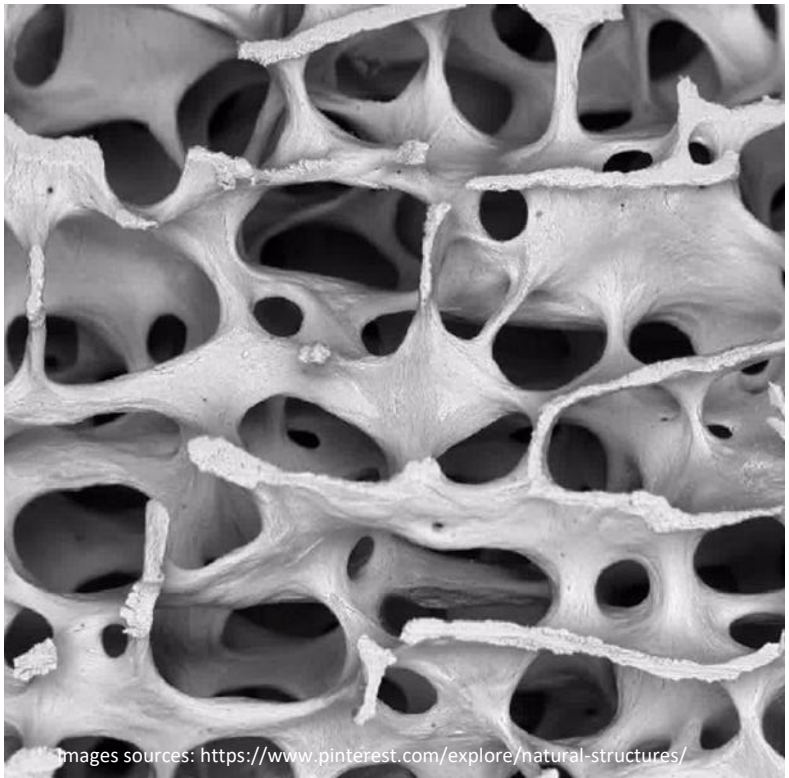
Man-made

Complexity is expensive while **material** is not

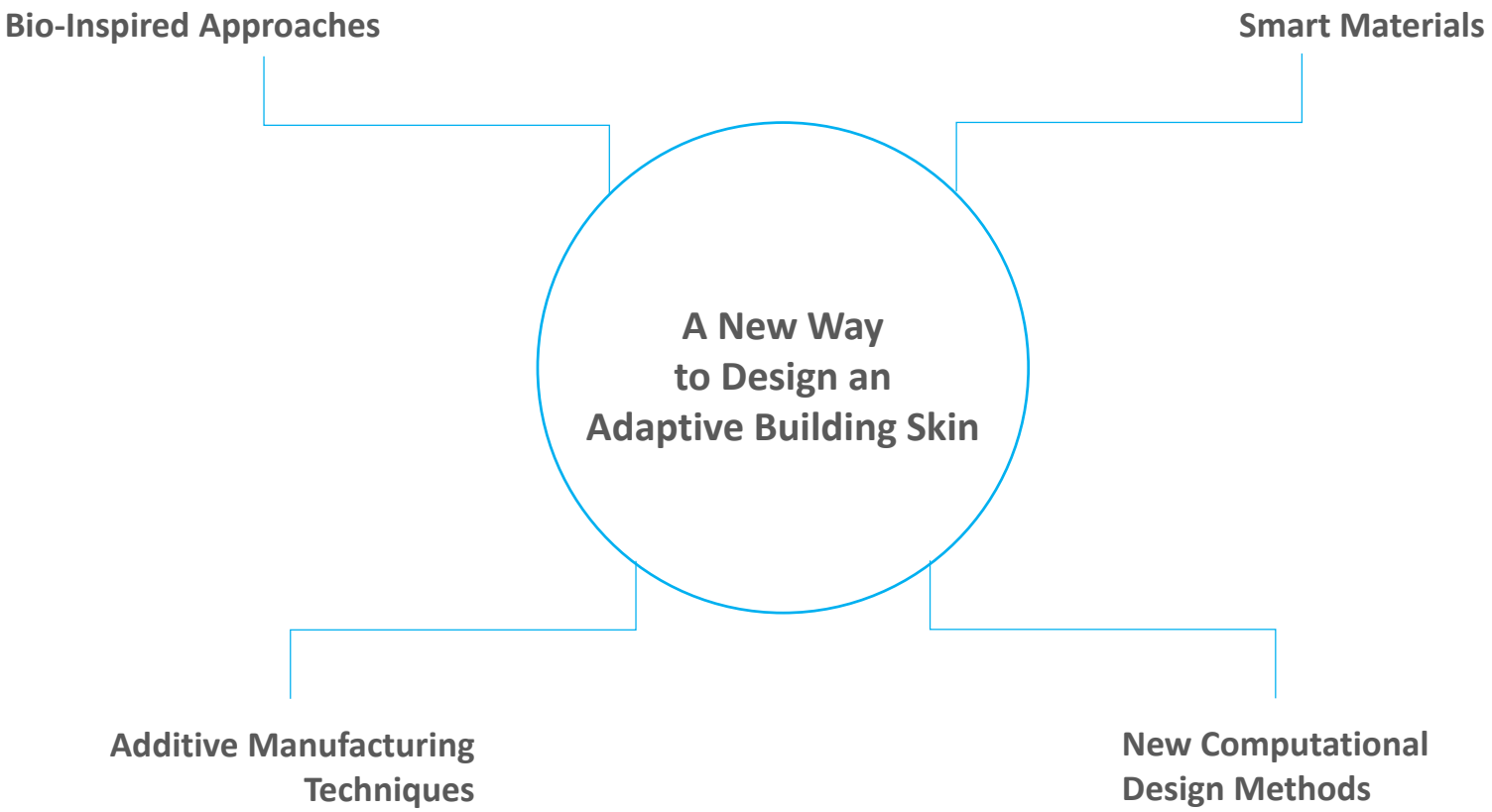
↓

More material + Less complex forms





Images sources: https://www.pinterest.com/explore/natural-structures/



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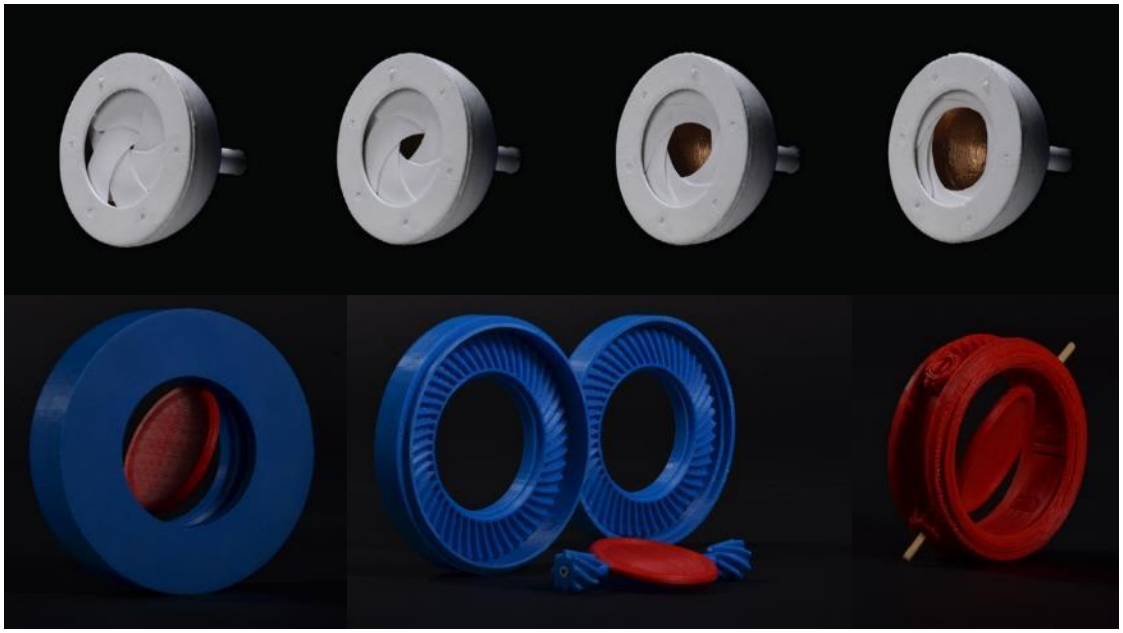
Benefits of Additive Manufacturing in Adaptive Design:

- **Local customization** of geometry to change the properties of material
- Reducing the number of **susceptible mechanical** parts such as hinges
- **All-in-one multifunctional** component



3D Printing
in Adaptive Design

Geometrically-informed Approach
(Performative properties are linked to the geometry of mechanisms)

Displacements
Strategies

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Solar Aperture; Research Collaborators: Kalantar & Borhani

Material-based Approach
(A synergetic relation between the material thresholds and performance)

Deformation
Strategies

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ROTA: An Airless Tire; Research Collaborators: Kalantar & Borhani

Performative 3D printing Strategies

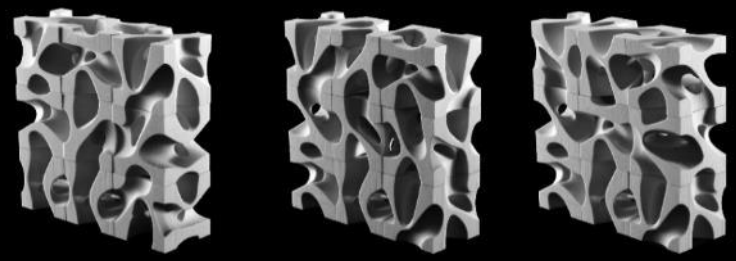
Passive Strategies

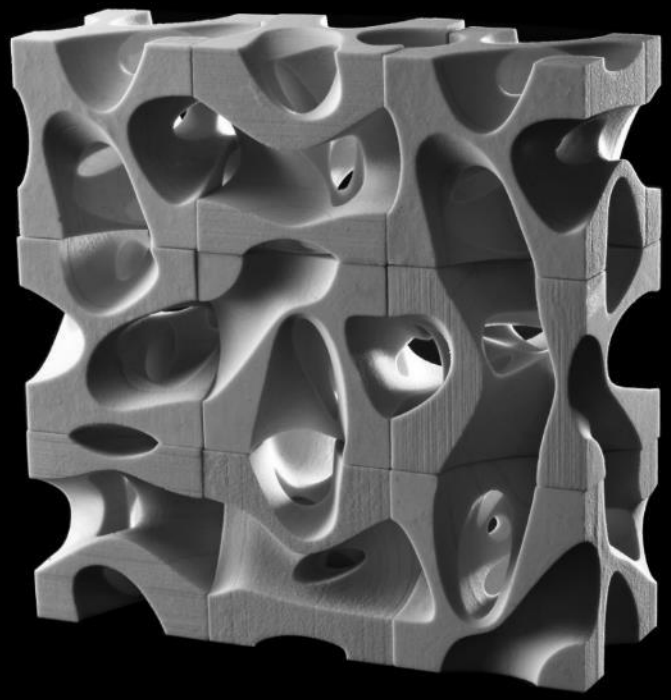
Active Strategies

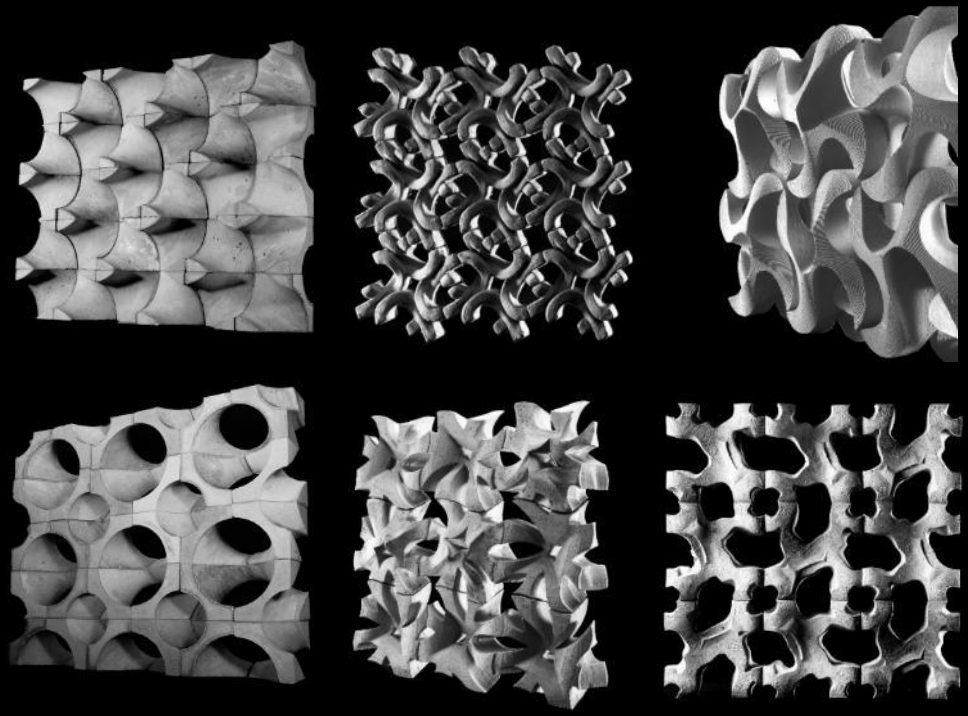
Performative 3D printing Strategies

Passive Strategies

Active Strategies







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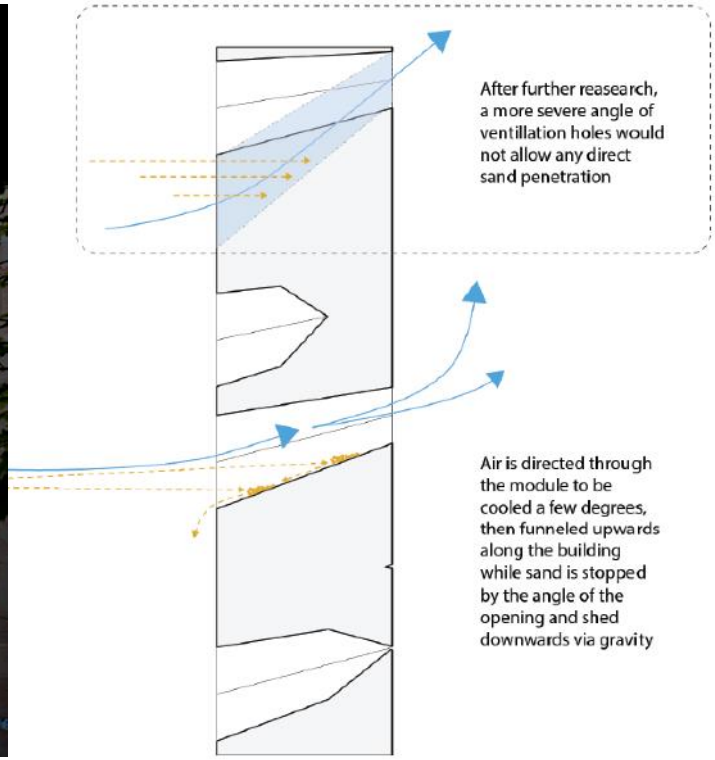
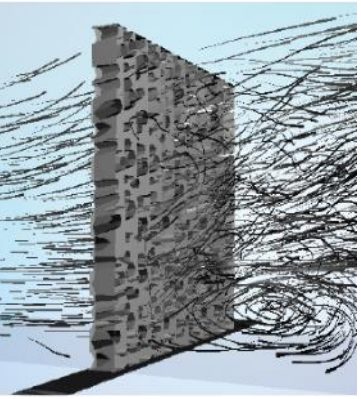
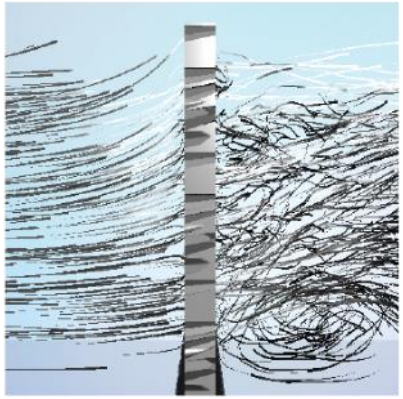
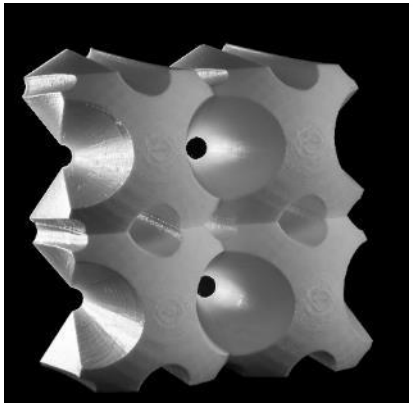
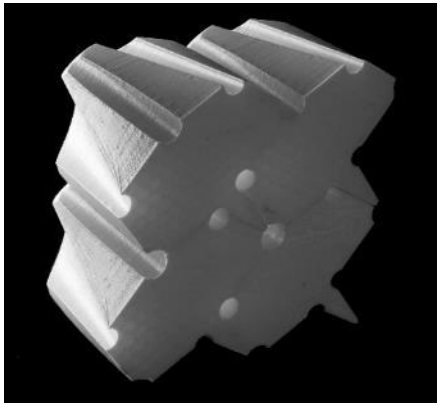
Research Collaborator: Borhani, Kalantar, Houser, Hergert, , Casto, Kim, Dempsey, Gregory, Morahan, Wilson , Clark & Kolodziej

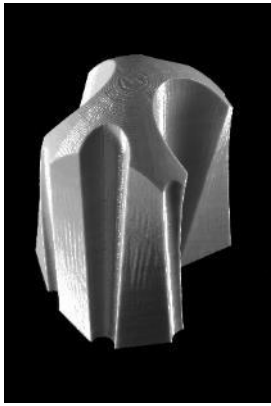












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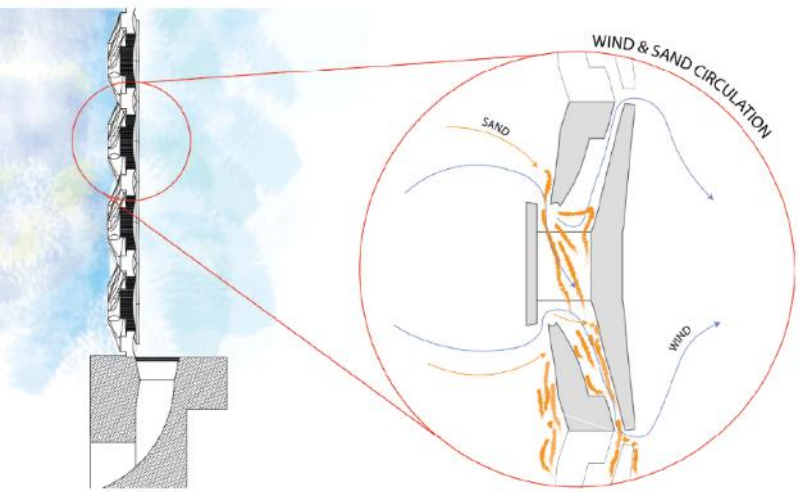

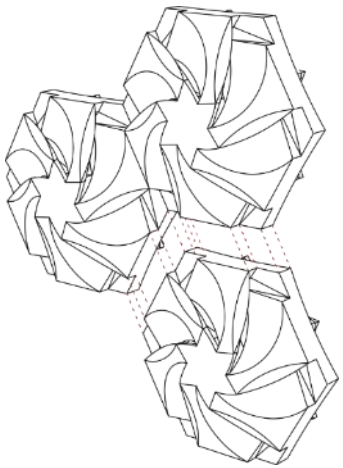

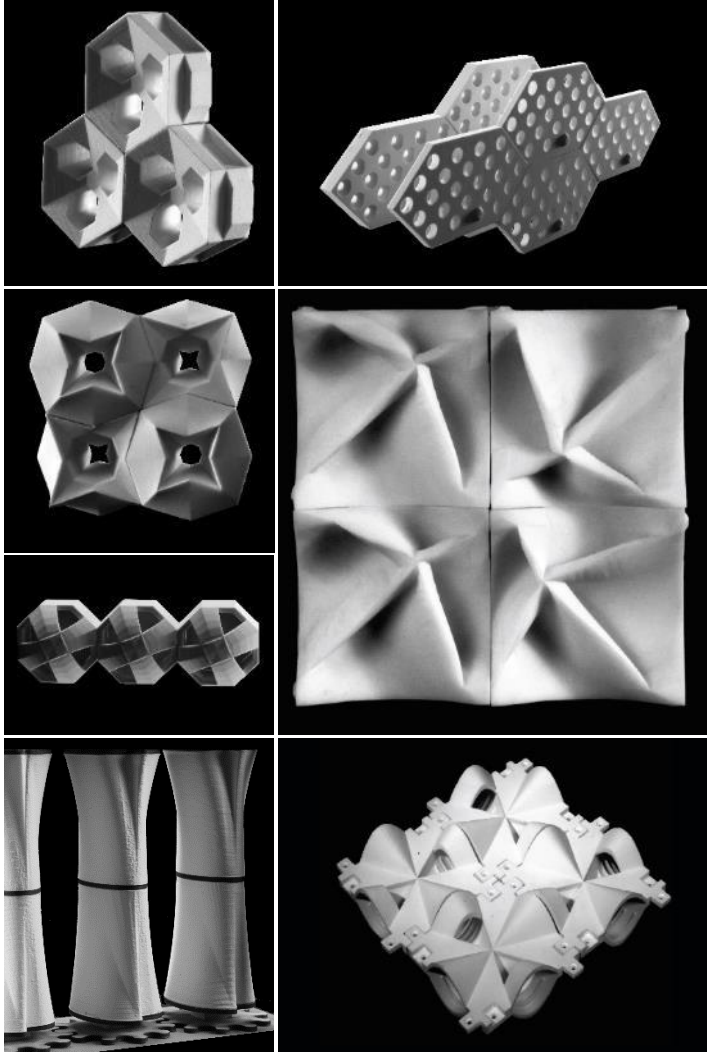

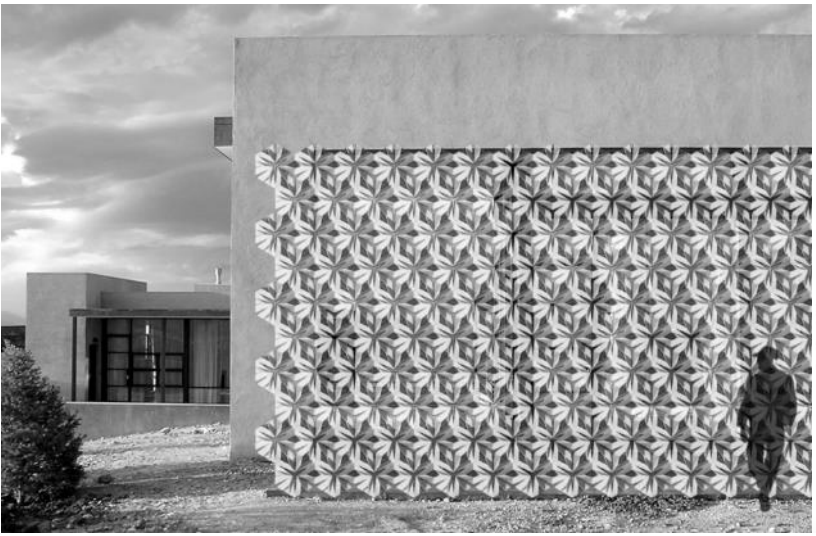

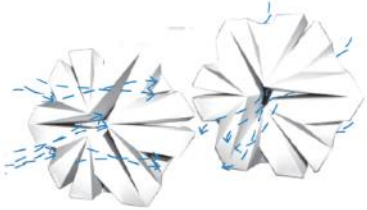

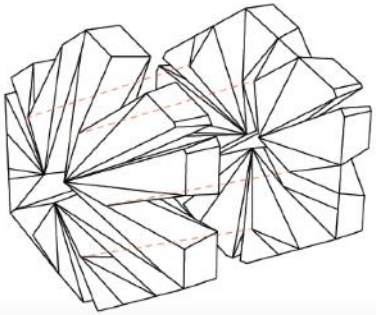

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The breathable wall system aims to satisfy the following criteria:

- **Get fresh air** into the building & exhaust air out;
- **Block sand** from penetrating into the building;
- **Cool down** the air as it travels through the shaded zones; and
- **Prevent light** from directly entering the space.

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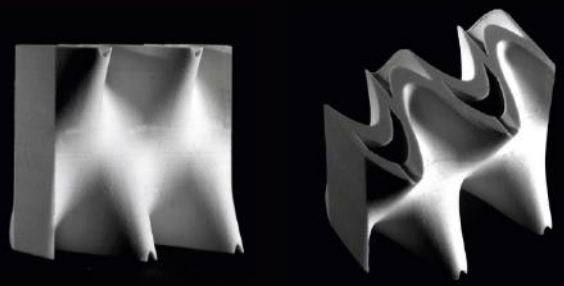

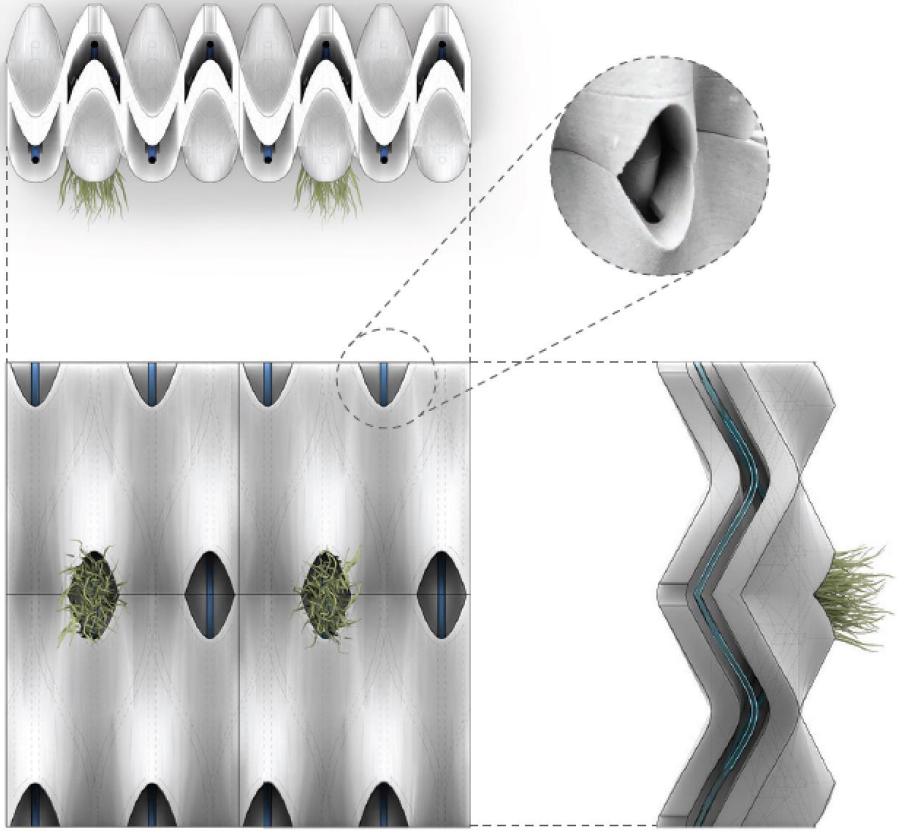

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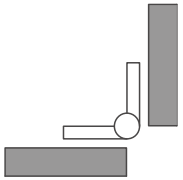
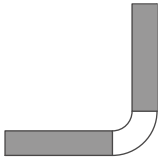
Performative 3D printing Strategies

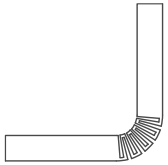
- Passive Strategies
- **Active Strategies**
  - With Joints (Rigid-link Mechanisms)
    - Distinct Joints (For linking multiple rigid elements)



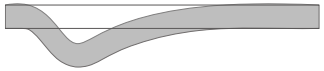
    - Embedded Living Joints (For linking multiple rigid elements)
      - Using 2 different materials



      - Using a single material

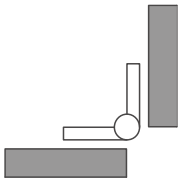


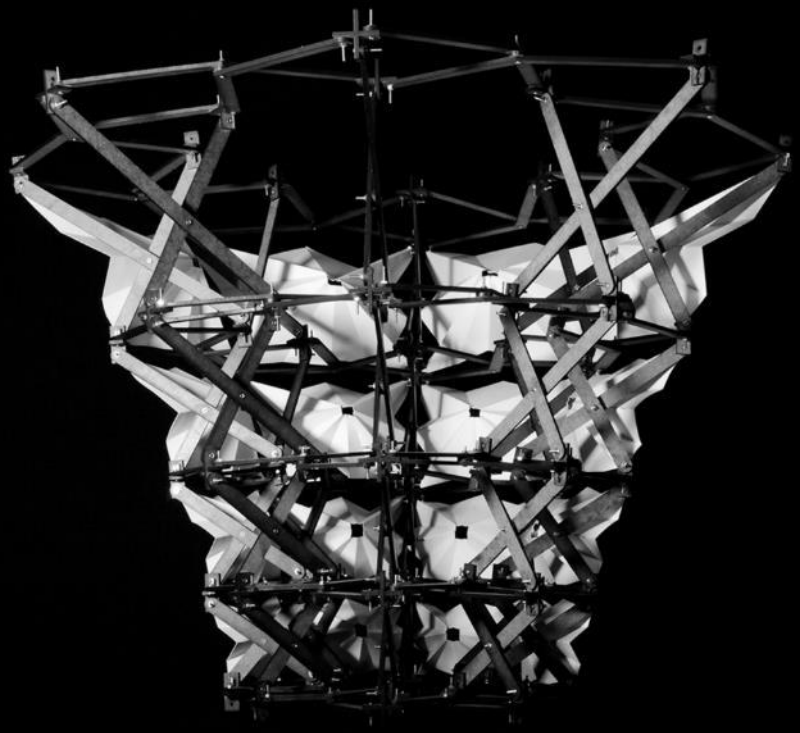
  - Without Joints (Flexures Mechanisms)
    - Local zones of flexibility to adjust stiffness

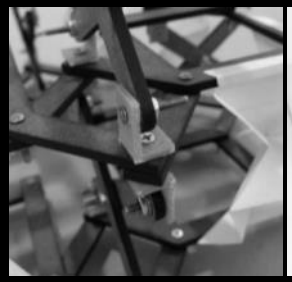


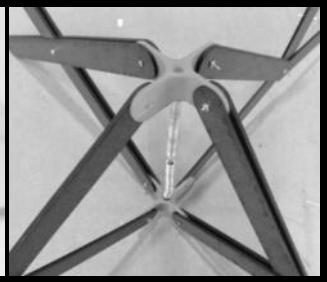
Performative 3D printing Strategies

- Passive Strategies
- **Active Strategies**
  - With Joints (Rigid-link Mechanisms)
    - Distinct Joints (For linking multiple rigid elements)
    - Embedded Living Joints (For linking multiple rigid elements)
      - Using 2 different materials
      - Using a single material
  - Without Joints (Flexures Mechanisms)
    - Local zones of flexibility to adjust stiffness









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Research Collaborators: Kalantar, Clark & Kato

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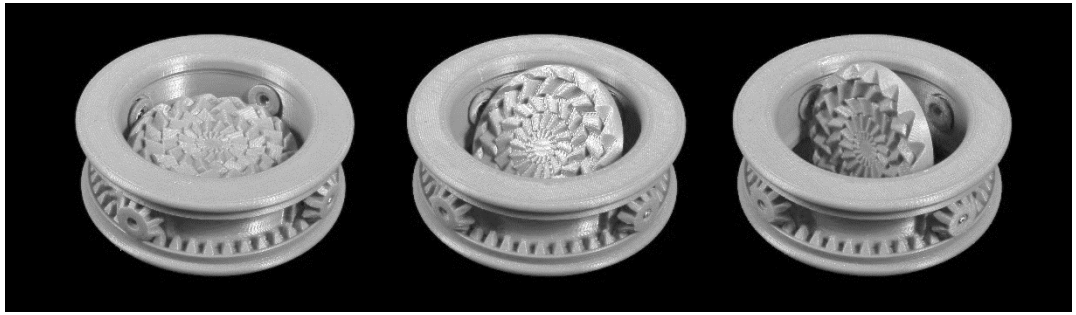

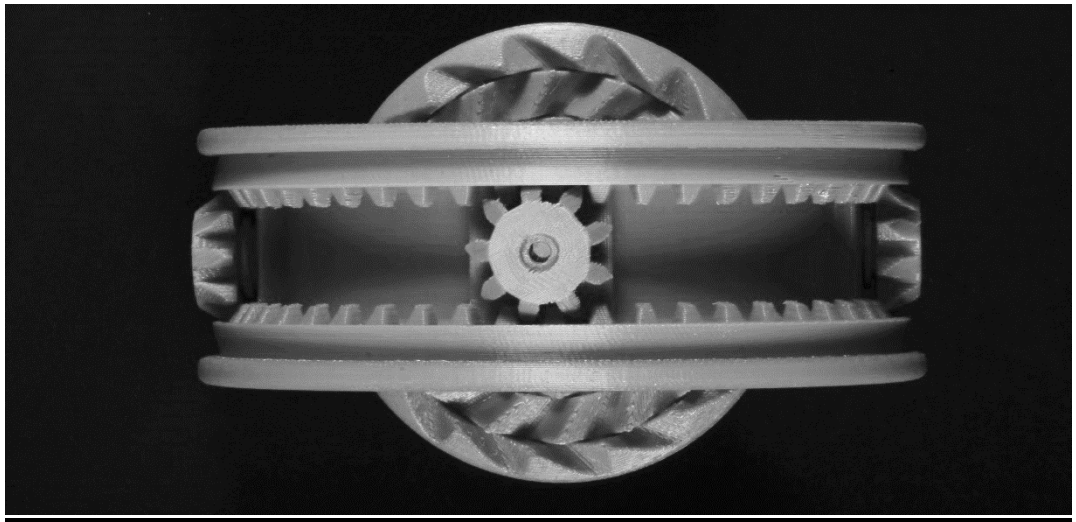

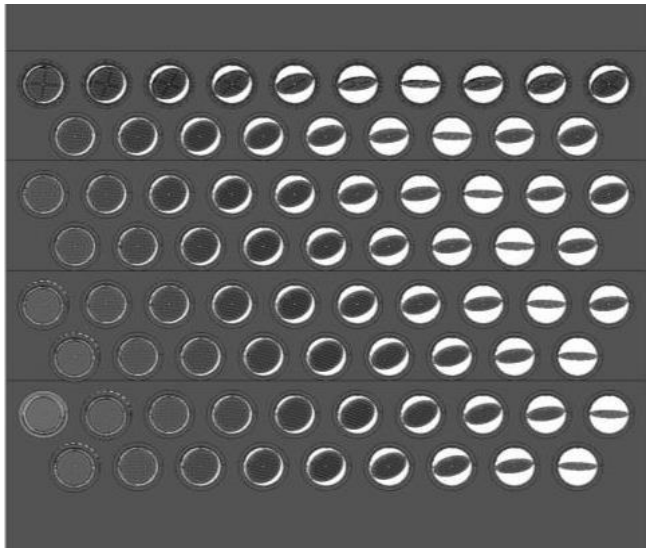

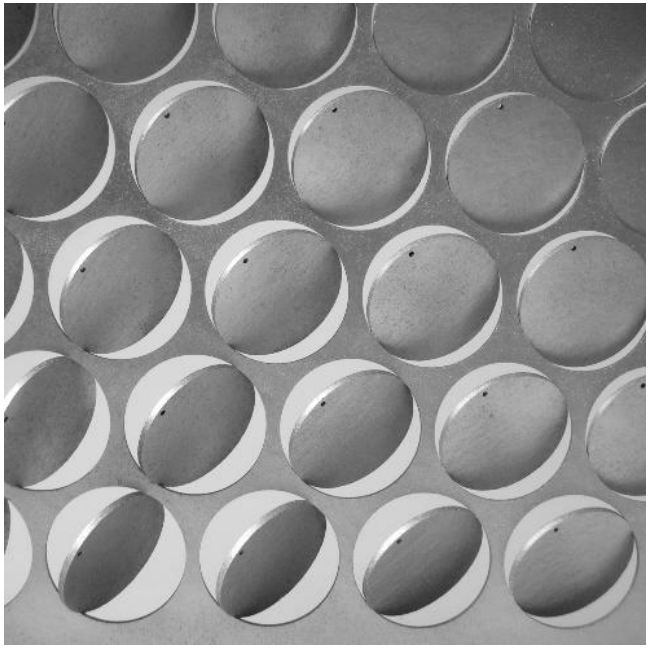

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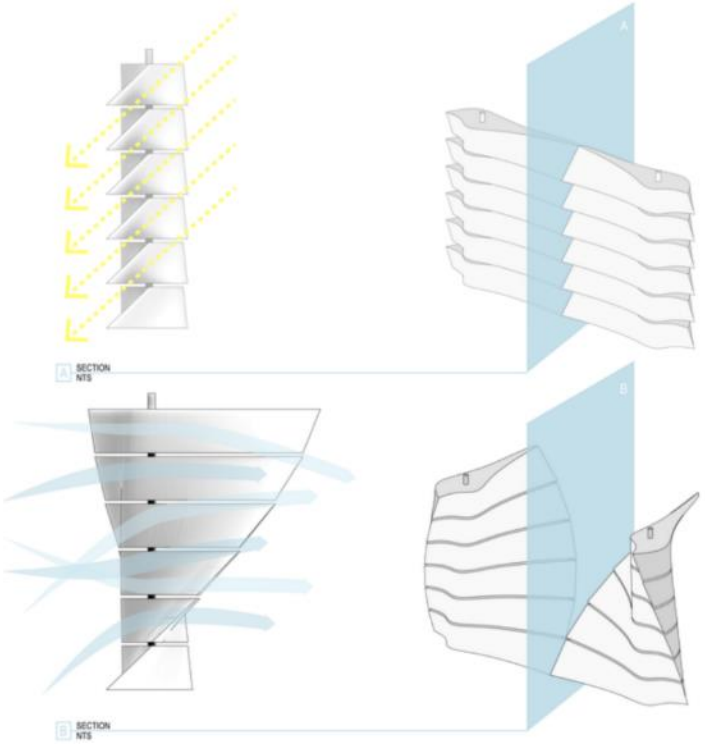
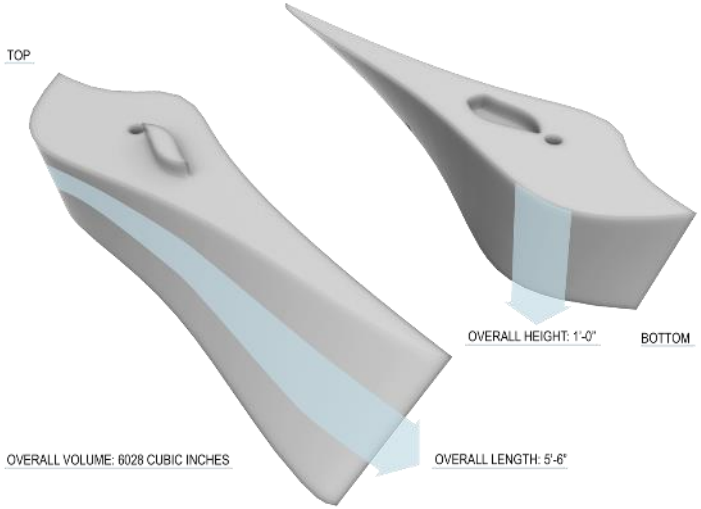
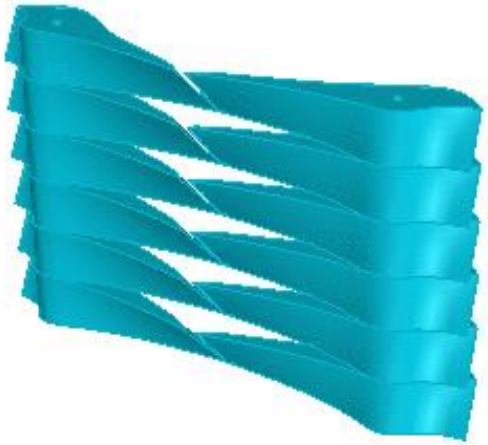
tranSTUDIO
Research Collaborators: Borhani & Kalantar







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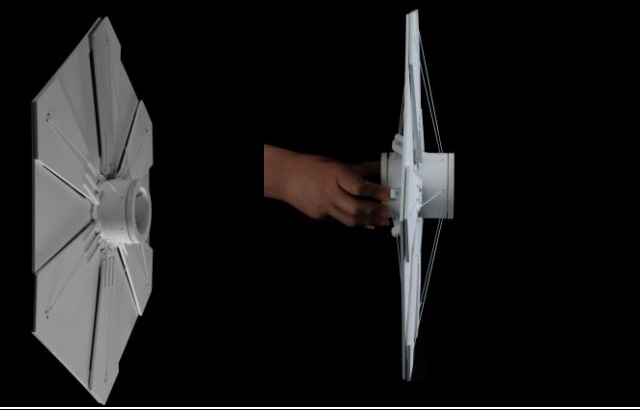
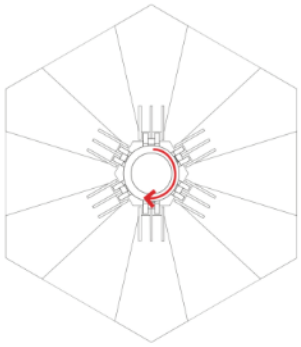
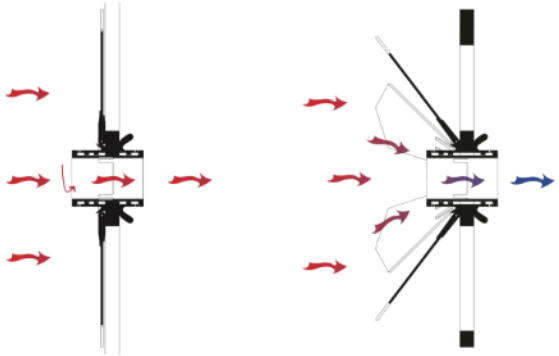
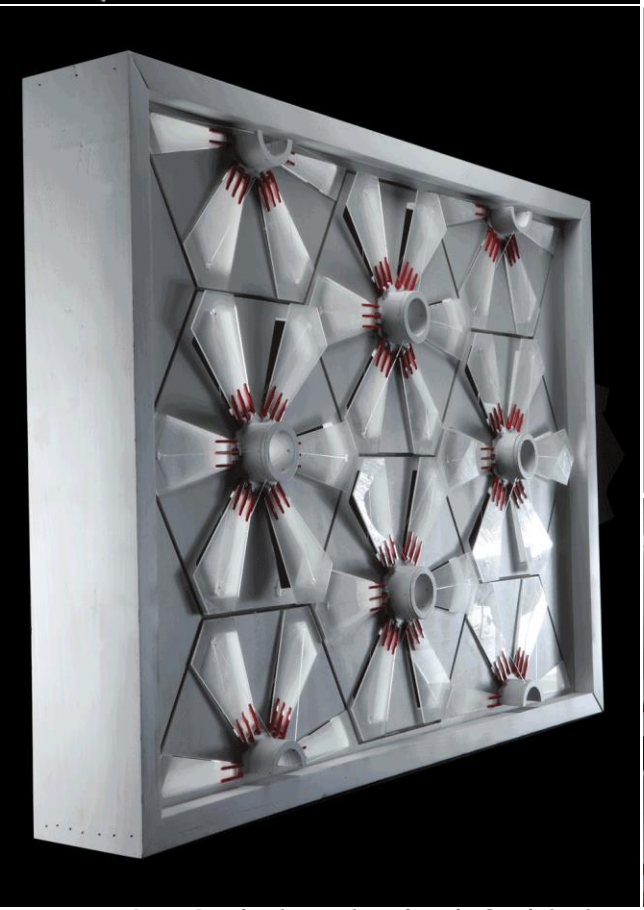
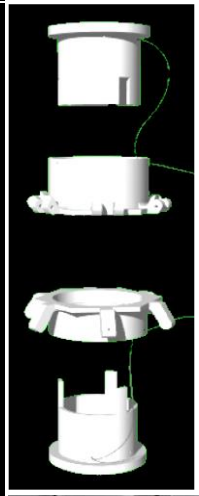
Research Collaborators: Kalantar, Roose & Thompson

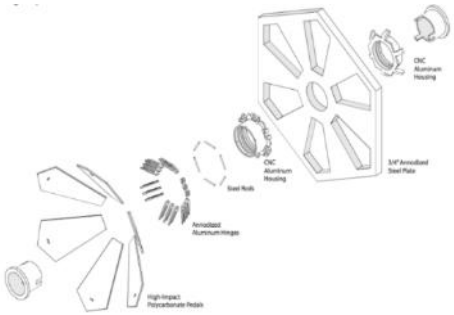


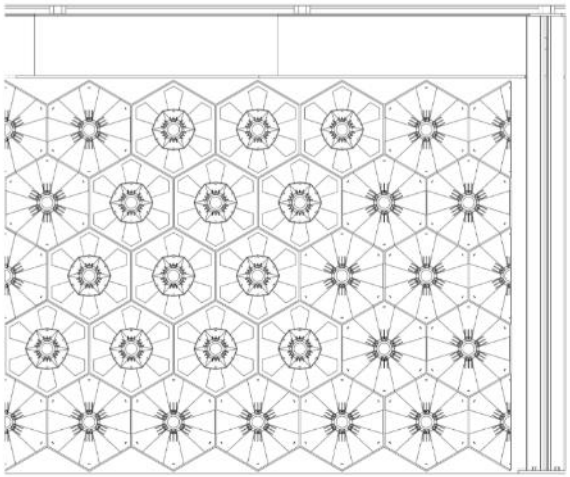


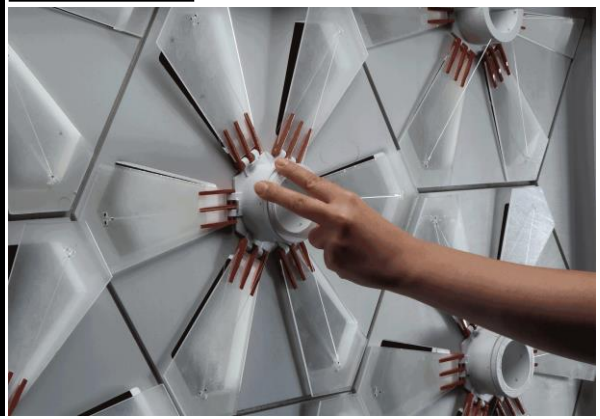












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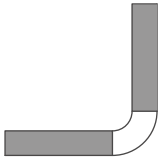
tranSTUDIO
Research Collaborators: Kalantar, Wells, Henry, Yamaya, Al-Sholi & Bucklley

Performative 3D printing Strategies

- Passive Strategies
- **Active Strategies**
  - With Joints (Rigid-link Mechanisms)
    - Distinct Joints (For linking multiple rigid elements)
    - Embedded Living Joints (For linking multiple rigid elements)
      - Using 2 different materials
      - Using a single material
  - Without Joints (Flexures Mechanisms)
    - Local zones of flexibility to adjust stiffness



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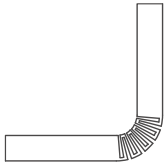

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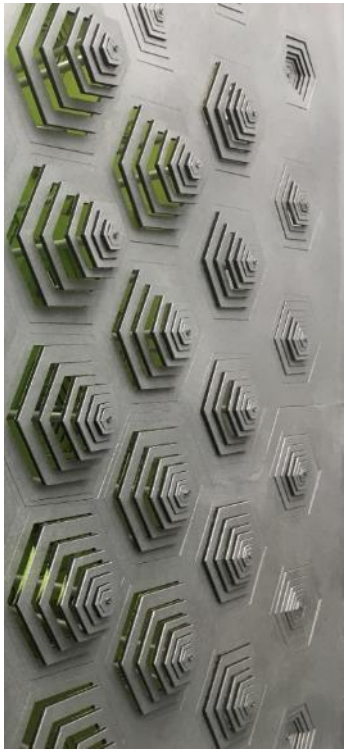
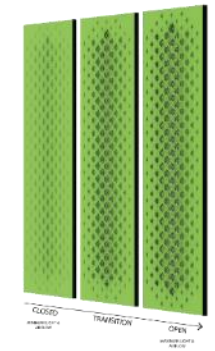
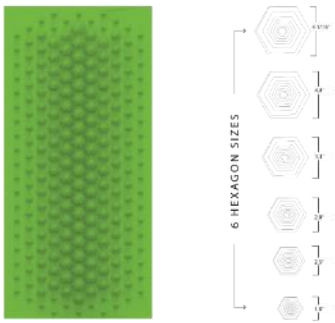
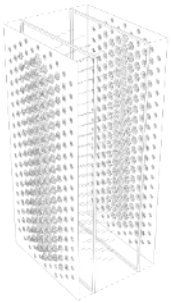
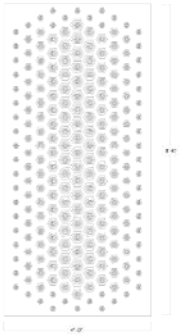






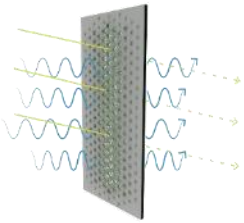


PERSPECTIVE VIEW

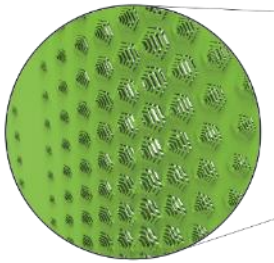


ELEVATION

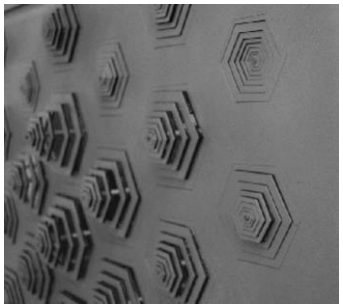
SIDE ELEVATION
(exploded)



SUN / WIND REGULATION



LIGHT & VISUAL REGULATION



FASTENING SYSTEM DETAIL

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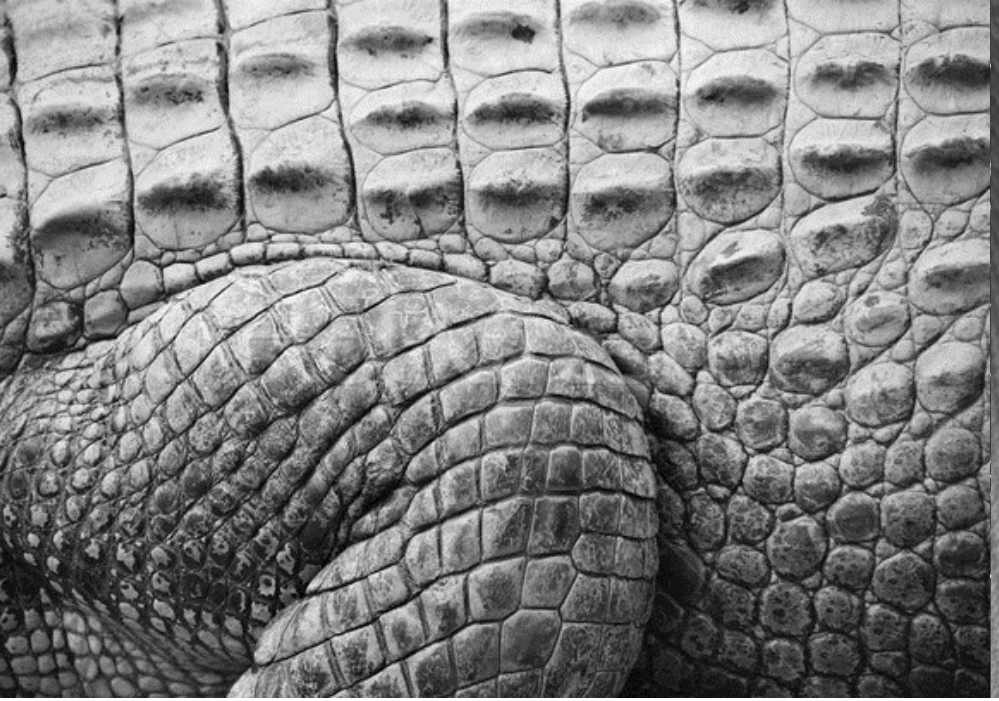
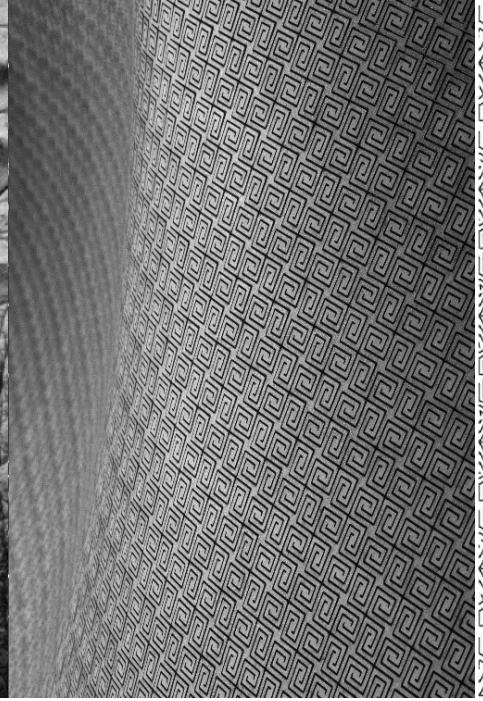
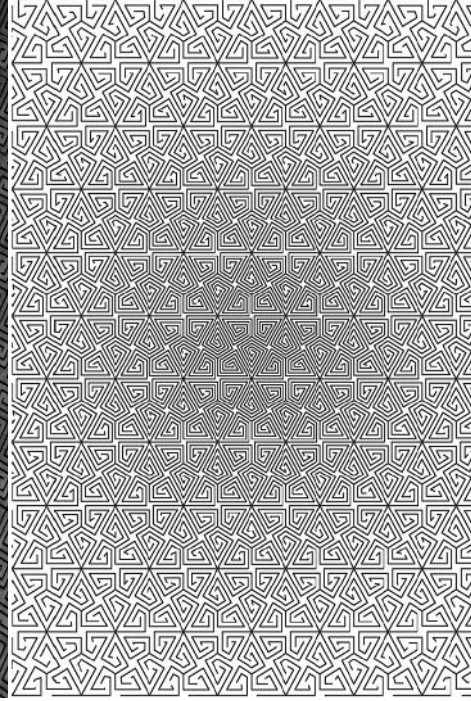
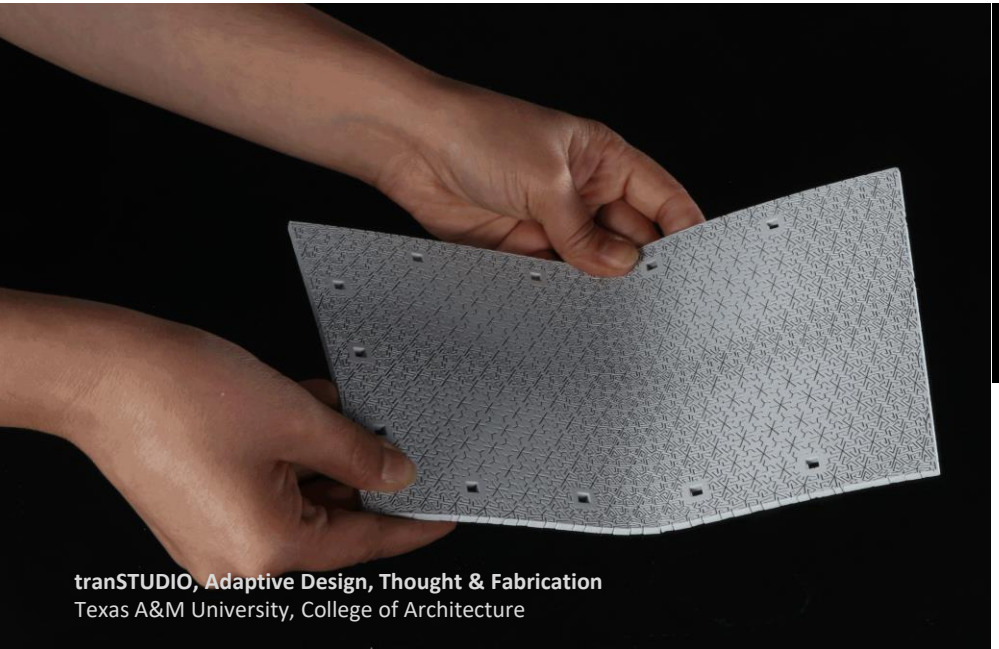
tranSTUDIO
Research Collaborators: Kalantar, Ritter & Higgins









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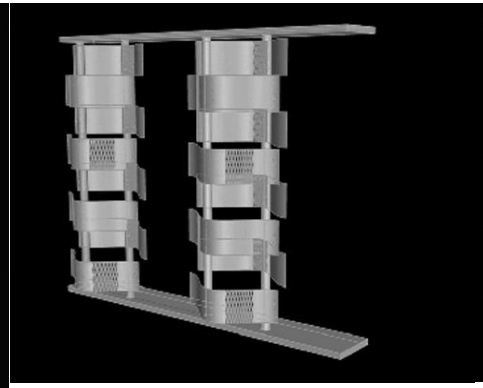
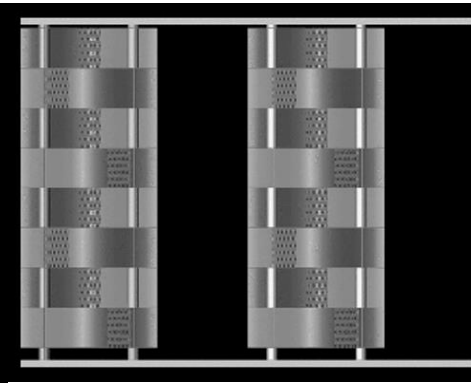
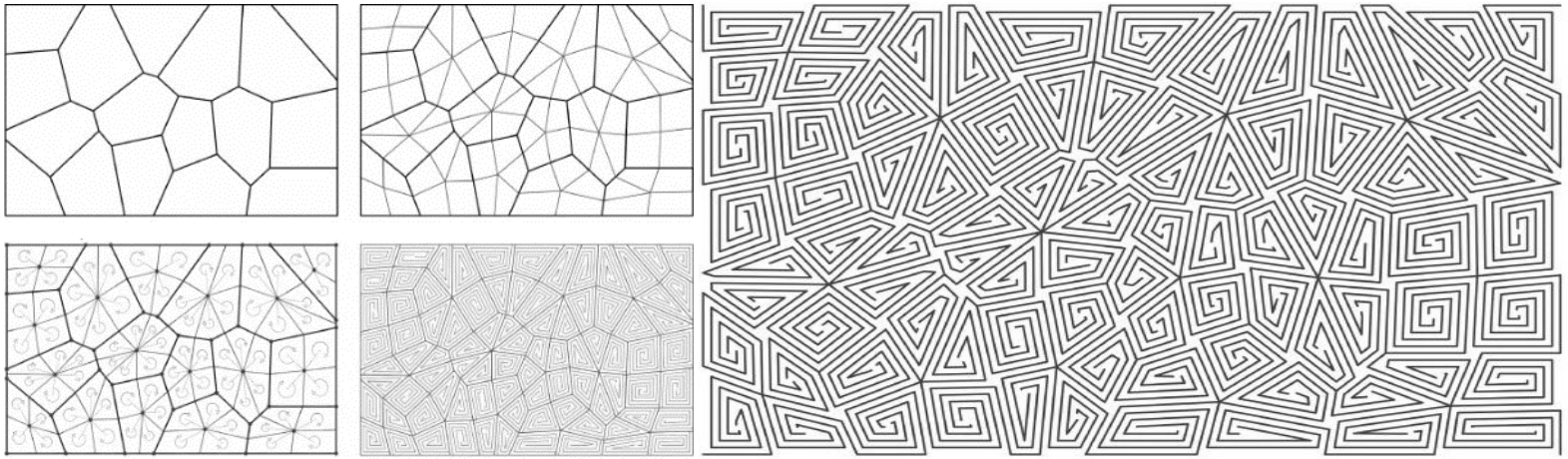
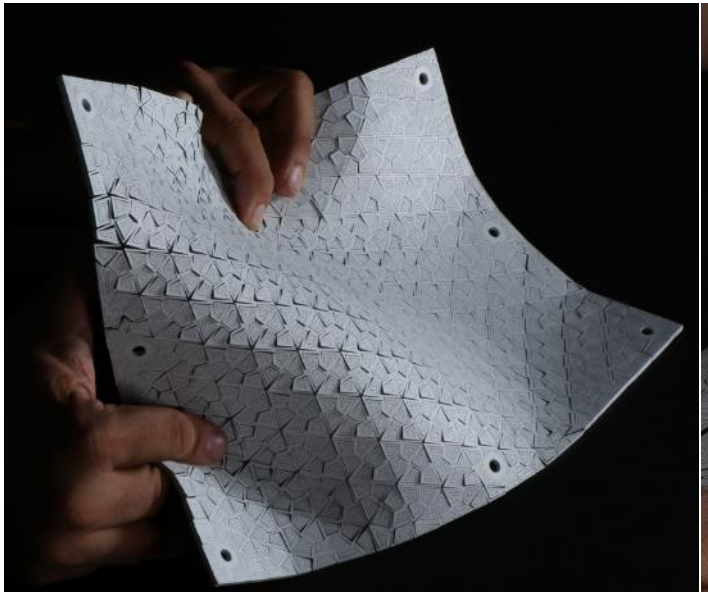
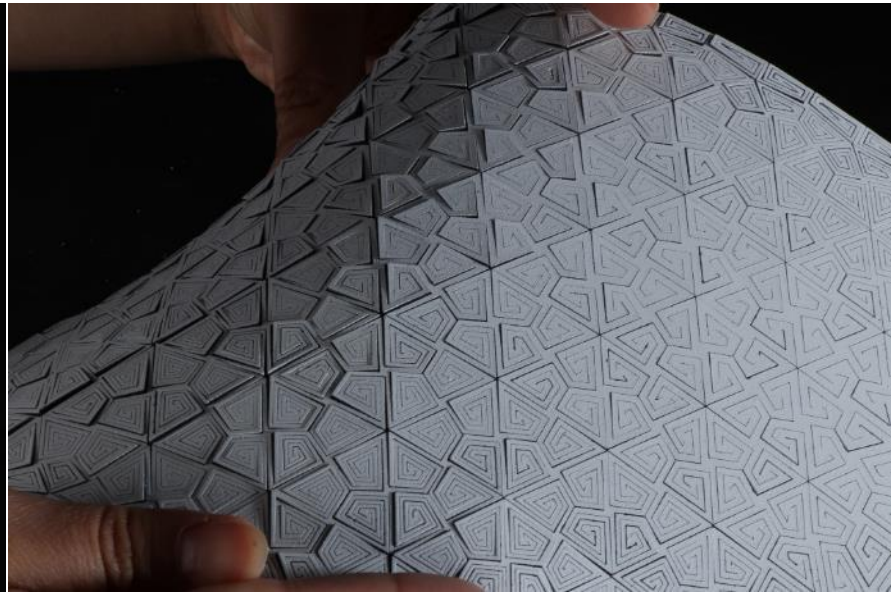




tranSTUDIO
Research Collaborators: Akleman, Zarrinmehr, Kalantar, Borhani, Ettehad & Sueda







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tranSTUDIO
Research Collaborators: Akleman, Zarrinmehr, Kalantar, Borhani, Ettehad & Sueda

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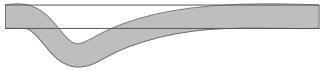
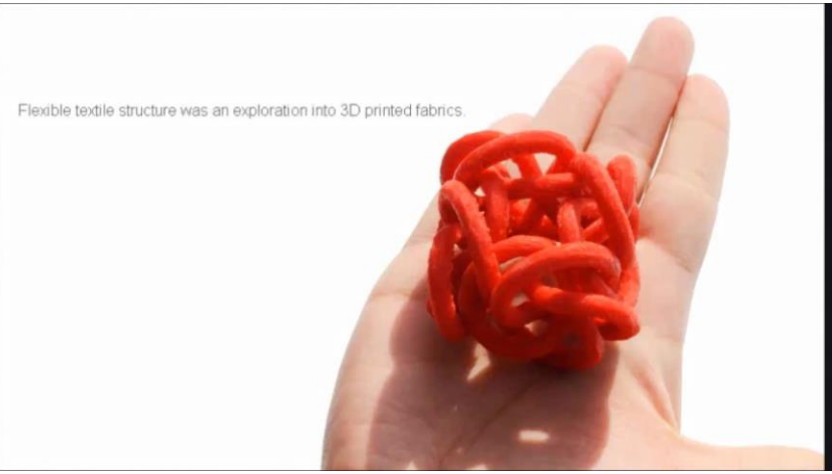
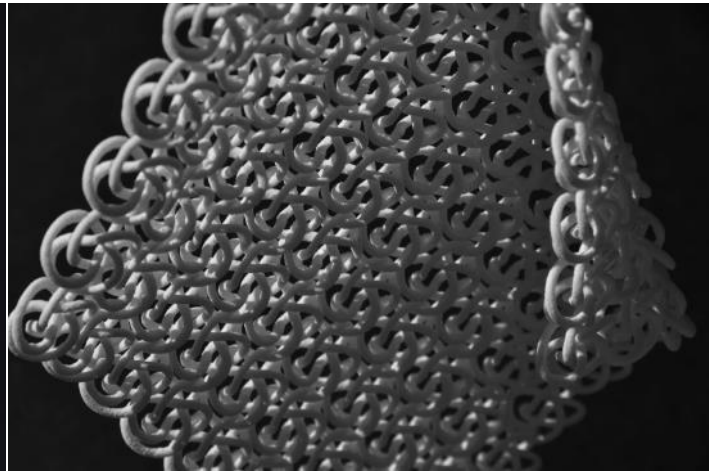
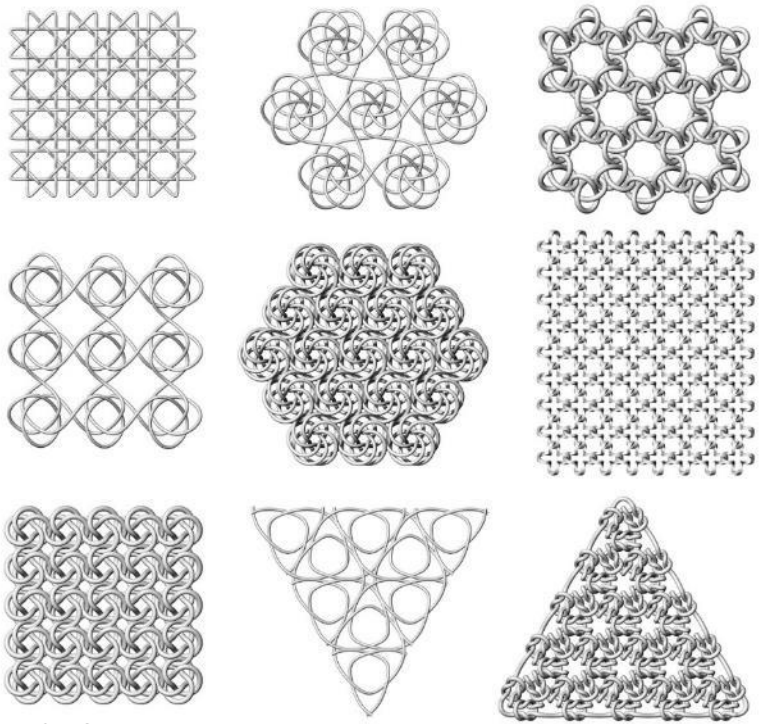
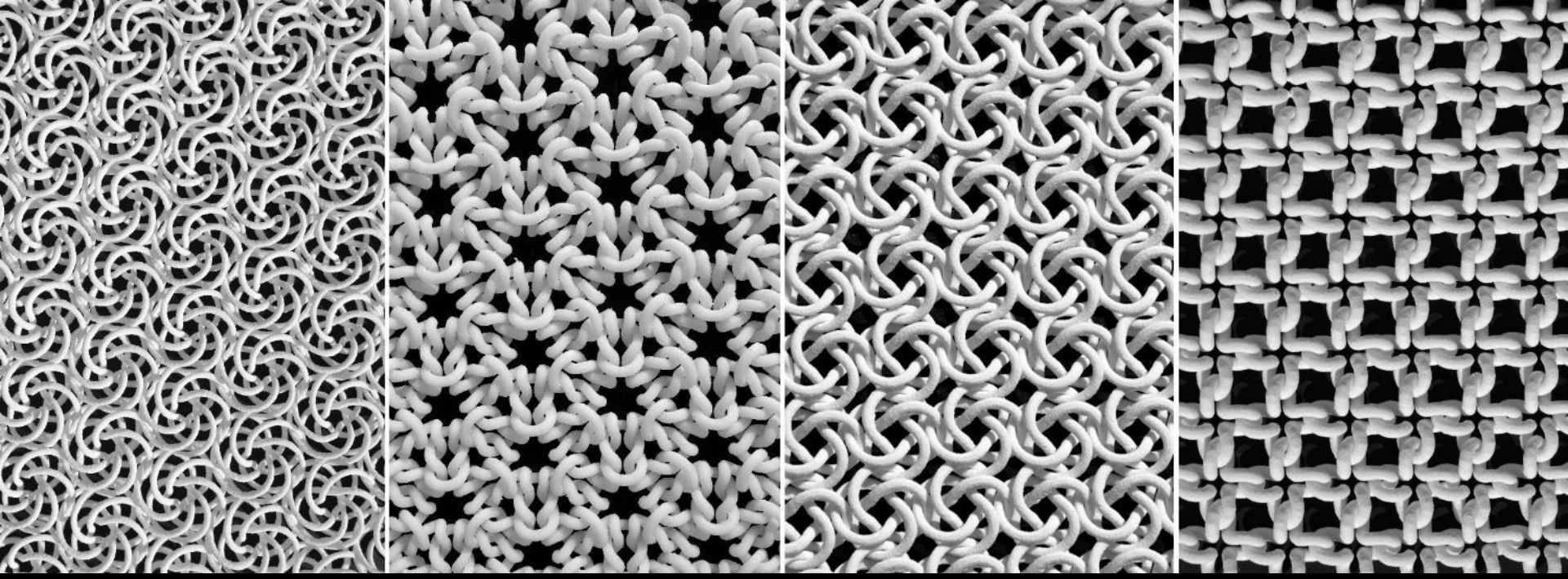


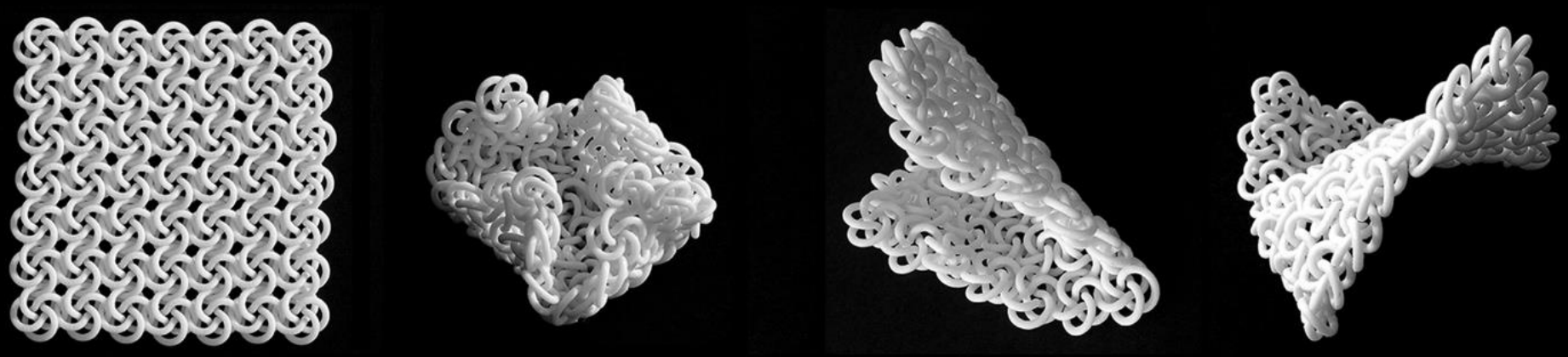






tranSTUDIO
Research Collaborators: Kalantar, Borhani & The Dream LAB at Virginia Tech





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tranSTUDIO
Research Collaborators: Kalantar, Borhani & The Dream LAB at Virginia Tech

Project Management Process

Weekly Meetings

Weekly Meetings

Weekly Meetings

NSF-EAGER Lab Meeting Minutes

Date: Friday, April 21, 2017
Time: 2:00-4:00 pm
Location: 3380, University Drive – E, Rm 106

ATTENDEES:

Faculty

- Dr. Terry Creasy, Associate Professor, Dept. of Materials Science and Engineering

Students

- Ms. Maryam Mansoori

REGRETS:

- Ms. Rana Al-Mezrakchi
- Mr. Parker West
- Mr. Saied Zarrinmehr
- Ms. Nikita Bhagat
- Mr. Diyar Dhannoon
- Mr. William Palmer
- Ms. You Wu
- Mr. Yuwei Zhang
- Dr. Ergun Akleman, Professor, Dept. of Visualization
- Dr. Tahir Cagin, Professor, Dept. of Materials Science and Engineering
- Dr. Negar Kalantar, Assistant Professor, Dept. of Architecture
- Dr. Zofia Rybkowski, Associate Professor, Dept. of Construction Science (PI)

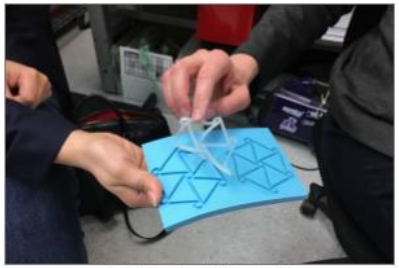
MINUTES PREPARED BY:

- Ms. Maryam Mansoori

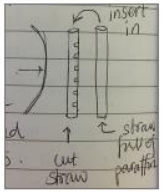
MEETING AGENDA

1. Making reversible polymer
2. Making wooden panel.
3. Preparing composite material with combine wooden panel and smart polymer.

MEETING MINUTES

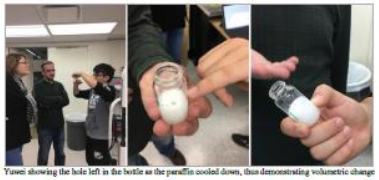


Peeling the SMA out of the mold- Mission Accomplished!



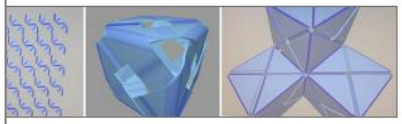
- Yuwei explained to the group how paraffin, on being heated showed considerable volumetric change, and how this property of paraffin wax, with the help of an assembly of cylinder and piston could be harnessed to bring about displacement.
- He was experimenting with different mixtures of varying proportions of paraffin wax & oil (0% - 40% wax) to see how the addition of mineral oil affected the melting point of the mixture.

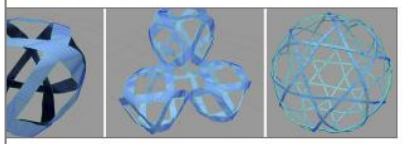
Samples of Mineral oil + Paraffin wax mixtures numbered 1 through 5, depending on the proportion of oil in it. (0% - 40%)



Yuwei showing the hole left in the bottle as the paraffin cooled down, thus demonstrating volumetric change

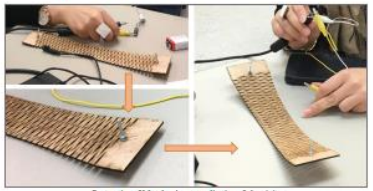
ne a tight weave.
as used the simplest 3D form, that of a cube.
ntent was to create a double-layered simple form that would result in a tight weave and have
ility of being 3D printed. Following are a few images of cube, followed by a few iterations
same.





alantar pointed out how connections cannot happen on the face in reality and hence need to
de on the edge.
ggested a subtle modification to You, of extending the edge pieces on to the face for a better
ore real connection.

3



Contraction of Muscle wire on application of electricity

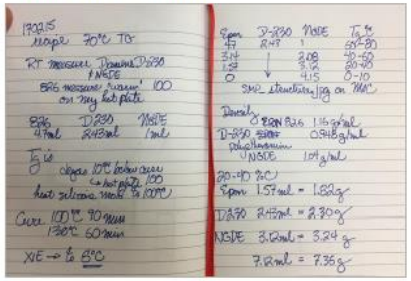
Contraction of SMA Spring on application of electricity

It was observed that the muscle wire took lesser time to transform after actuation in comparison to the SMA spring. Main reason behind this was the relative thickness of the two components.
Dr. Kalantar tried actuating the SMA spring using different power sources:
650mA phone charger showed no change in length whereas the 6A laptop charger actuated deformation.

Saied and Dr. Creasy discussed an idea of filling a cylindrical object such as a plastic straw with paraffin wax. This straw-like cylinder would be placed in another cylinder with grooves.
After applying heat to this assembly, it would bend in the intended direction. The following rough sketch illustrates this concept.

- Then Dr. Creasy set up the apparatus for setting shape memory alloys in the specific 3D-printed geometrical shapes as per Dr. Kalantar's requirements.
- The molds were 3D-printed with the specified geometry onto silicon pads.

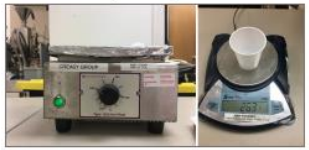
- The solution for the shape memory alloy was prepared with the proportions as noted down by Dr. Creasy, and as seen in the picture below.



The following procedure was followed to make the SMA mixture:
- Heat the container to 100°C.
- Spread a plastic paper sheet on the table to avoid spillage.
- Mix the contents of the mixture as per the given proportions.
- Heat the mixture until the vacuum bubbles out all the water.
- Pour it into the mold while it is kept in the microwave oven, scrape off excess liquid.
- Let it set.

4

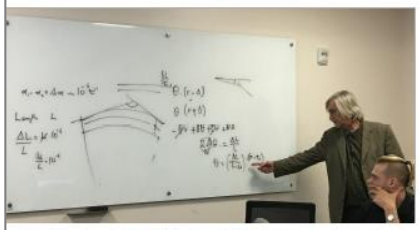
Apparatus for the Experiment



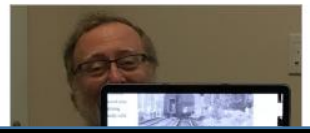
Setting up the apparatus before mixing mixture contents

The three mixtures to be mixed in the specified proportions to obtain the SMA

5



Is deduced that change in length of the bimetal will be directly proportional to change in
mperature and the angle theta (in radians).
Dr. Akleman raised concern about bimetals beings the best type of material for this project, given
he fact that they do not expand as much as one expects them to while fabricating the *'woven fabric'*.
Is suggested that we buy different samples of bimetal filaments, weave them and test their behavior
uring heating (electrocution may be) and cooling (ice packs).
Talking about thermal expansion, Dr. Creasy showed the group an interesting picture of railway
racks wherein long strips of metal were seen to be deformed, given the mistake of not having
ccounted for thermal expansion joints while laying the tracks.
The following image illustrates deformation due to variable thermal expansion in metals.



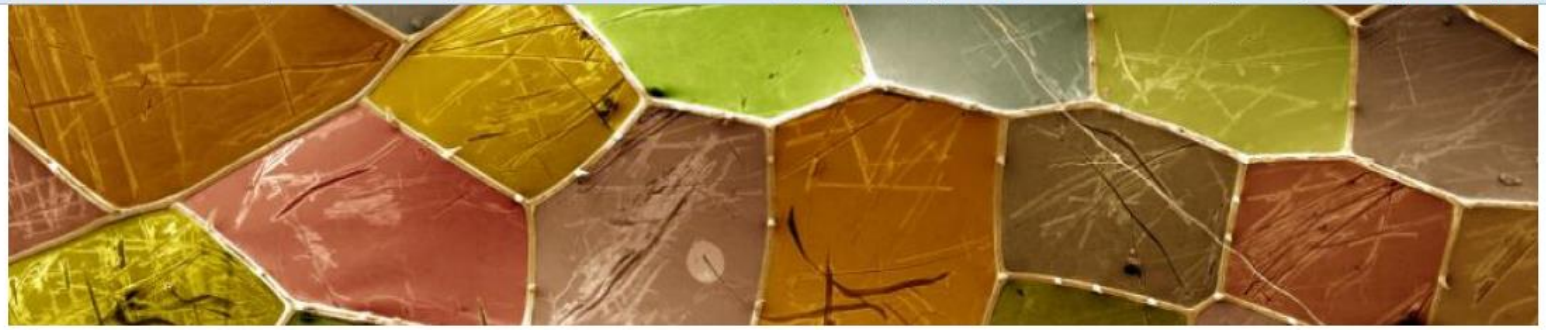
Smart woven materials:

4

Minutes: Thorough Documentation of Each Meeting and Lab Session

Articles – Inno-velope

https://innovelope.wordpress.com/library/articles/



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Articles

Reichert, Steffen, Achim Menges, and David Correa. "Meteorosensitive architecture: biomimetic building skins based on materially embedded and hygroscopically enabled responsiveness." Computer-Aided Design 60 (2015): 50-69.

Lopez, Marlen, et al. "Active materials for adaptive architectural envelopes based on plant adaptation principles." Journal of Facade Design and Engineering 3.1 (2015): 27-38.

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roject III

inetic Overlap : Pt. 2

art 2 We began building the nodel a couple of days before the onstruction science students eeded it for their presentation. nce we got the final approval on e final prototype we spent a full ay laser cutting and a

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ome

roject 4: KASS System Pt. 2

problems, but since we designed the prototype more than 3 times it was a piece of cake

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Home

Project 4: KASS System Pt. 3

Sydney Alford (partners with Emily Cloat) Final images of the KASS System. Enjoy! For our final model we have created simulations through grasshopper and rhino to ensure that our solar shading device would in-fact work and produce some shading aspect

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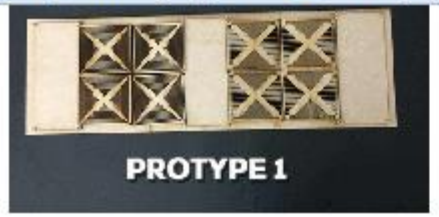

Project III

Kinetic Overlap : Pt. 1

Part 1 This project was about exploring a sun shading device that could control the light and wind that comes into the bridge connecting Langford A,B, and C. When we began this project I did not know what to expect.

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Diva 9 am 12 pm
3 pm 6 pm 12/21/xx
from 9 am

May 5, 2016 / Leave a comment

Home, Project III

OSMOSIS: Breathable Expansion Part 1

For our final project, partner Kristin Higgins and I developed an experimental building skin prototype that could be installed in places like the Langford bridge breezeway to create comfortable environments. This breathable wall system is intended to mediate environmental conditions in

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efinitely a lot of steps and a long
rocess. But we

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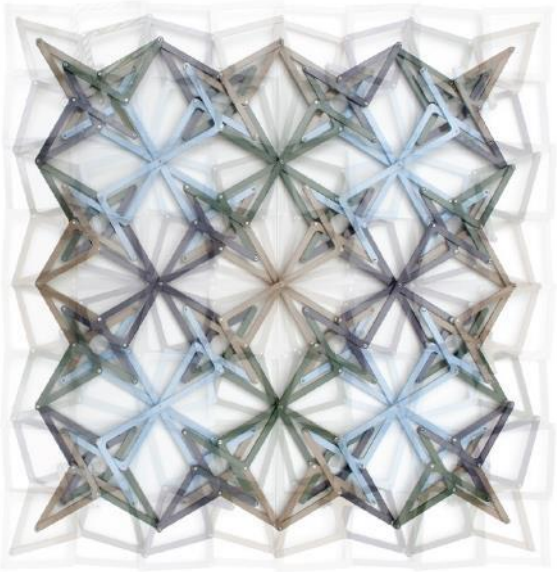

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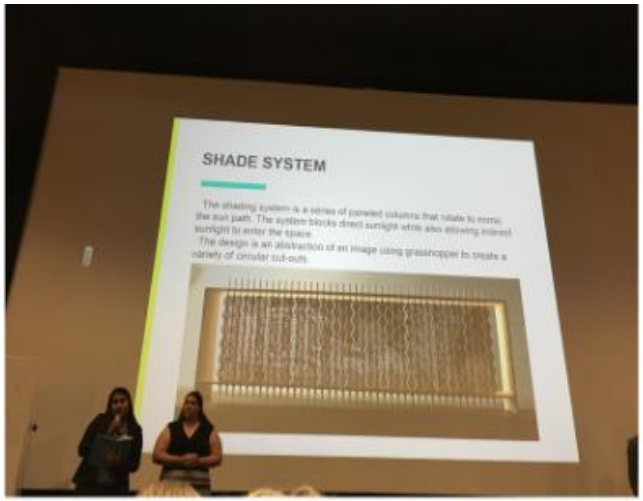
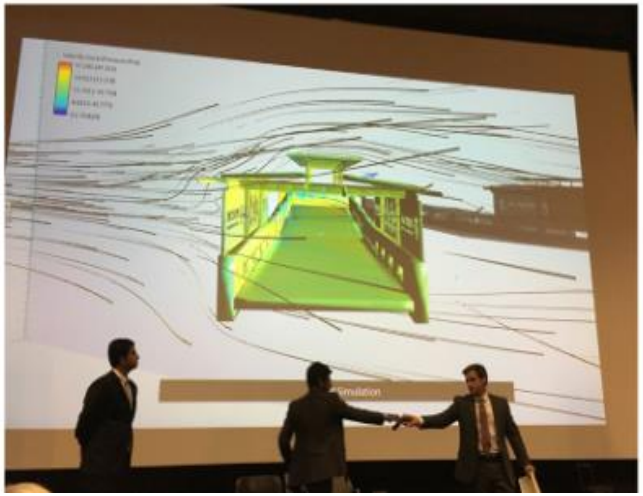
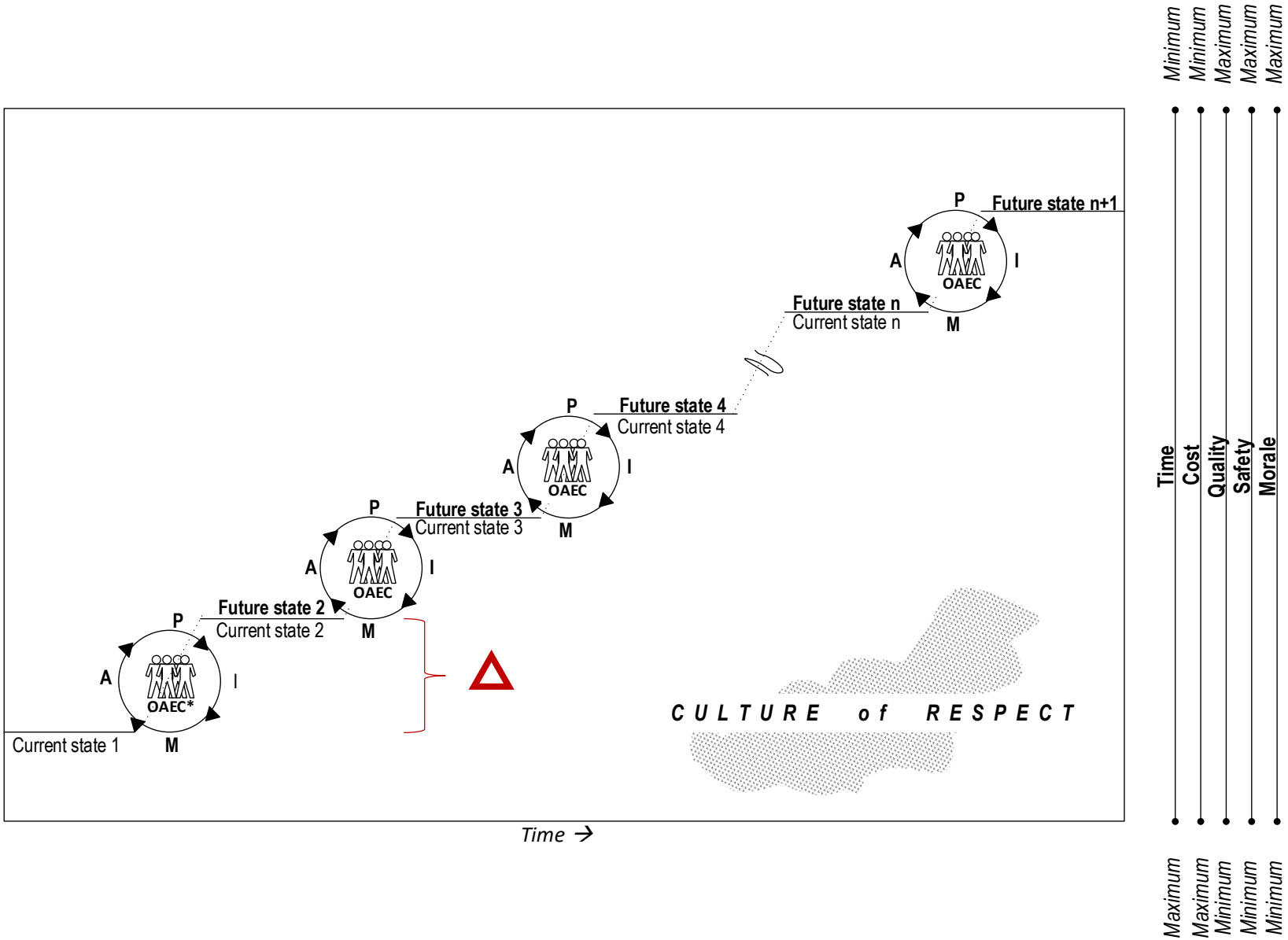




Presentation to Industry for Feedback

+	Δ
• Xxxx • XXX • Xxxxxxxx • Xxx • xxxxxx • Xxxx	• Xxxx • XXX

Plus-Delta Debriefings



Continuous Improvement

- IDEO idea generation method used
- Teams met at the same time each week
- Teams crossed into different departmental labs as well as studios
- Thorough documentation of each meeting
- Information shared on common websites
- Presentations to & feedback from members of industry
- End-of-semester debriefings (plus-delta)
- Continuous improvement “kaizen stairway”

Project Management Process

Zofia Rybkowski, PhD
zrybkowski@tamu.edu

Negar Kalantar, PhD
kalantar@tamu.edu