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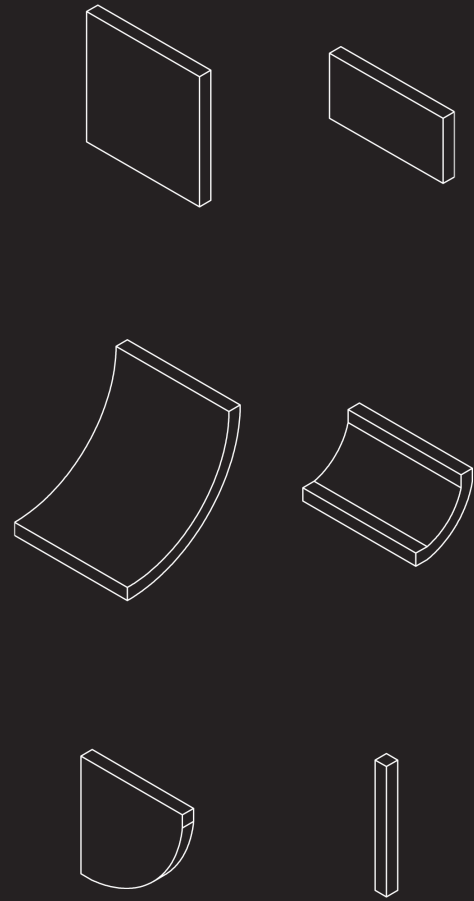
CATEGORY | ARCHITECTURE / URBAN PLANNING

multiwall mycetezoa-inspired modular construction

multiwall emerged from an open-ended biomimicry design process that began with studying a biological phenomenon of interest and exploring some potential design applications inspired by the results of that research.

I was interested in slime molds in part because despite some brief attention, they remain a very mysterious group of organisms to scientists, let alone designers. I had no prior design solutions in mind when selecting them as my object of focus, but the process that followed yielded what may be my favorite project in this collection.

multiwall

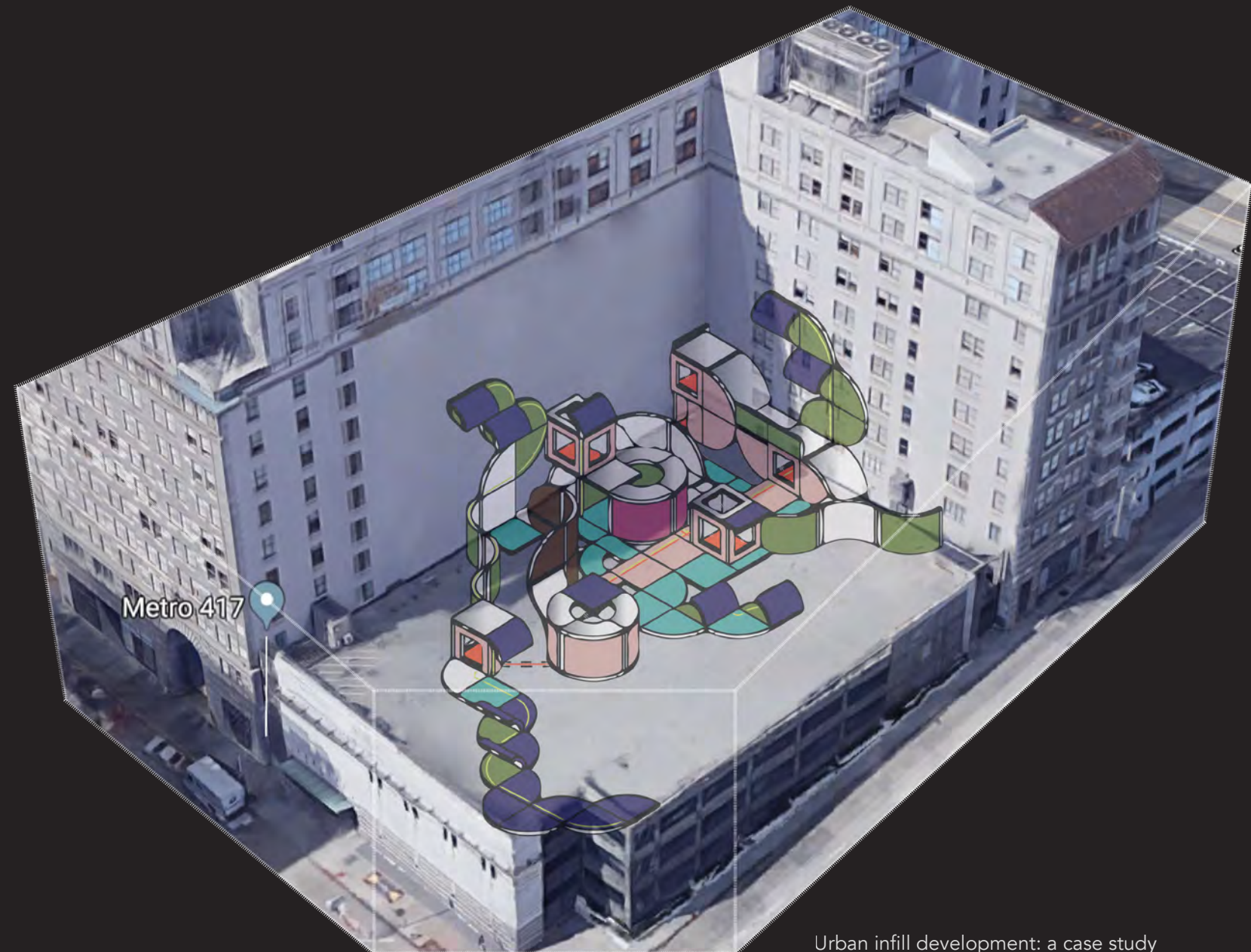


The six **multiwall** panels

MULTIWALL is an approach to modular construction informed and inspired by the Mycetoza, aka "slime molds."

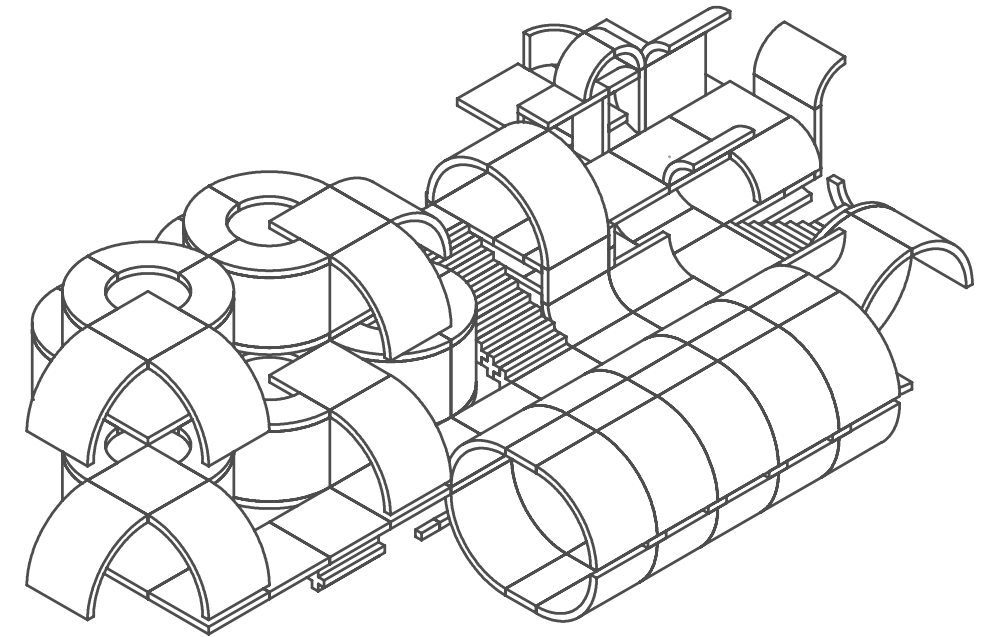
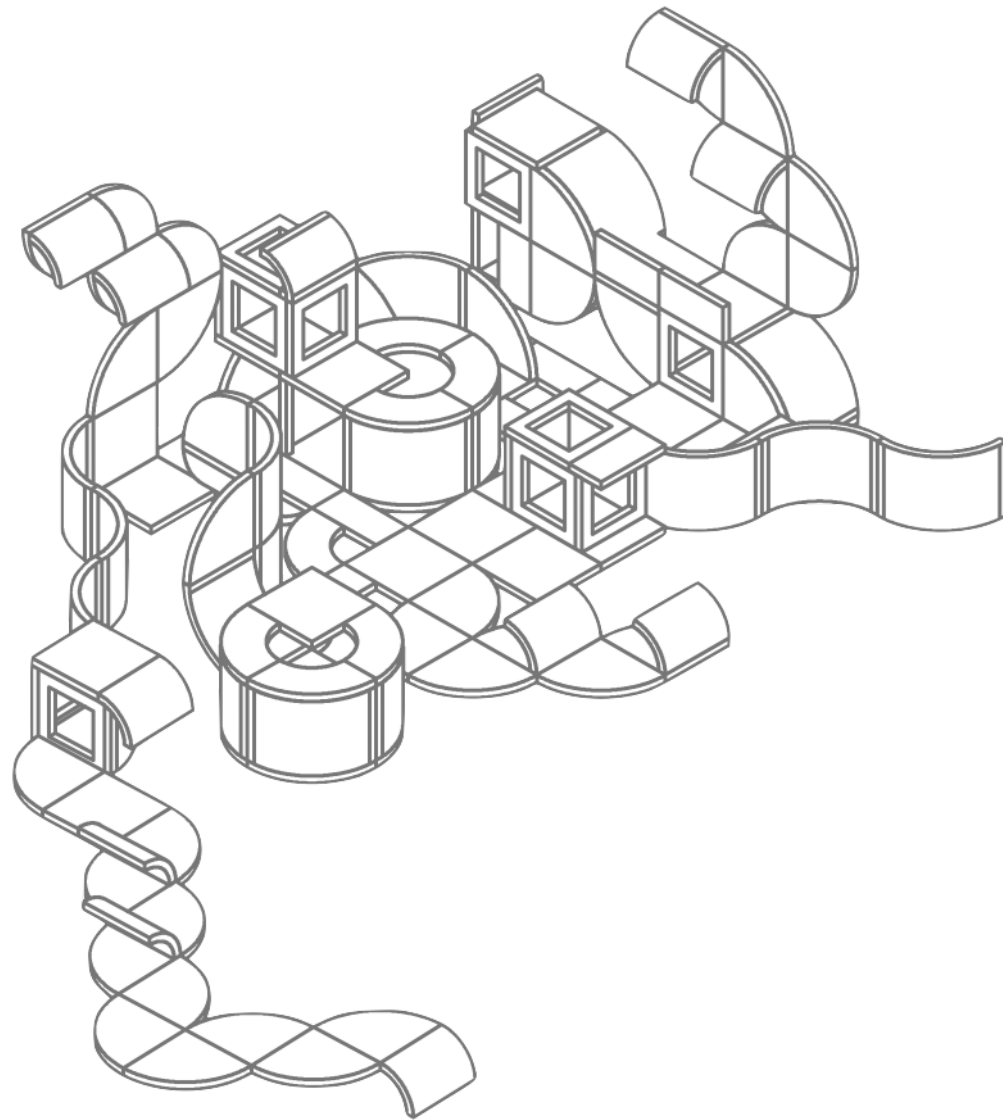
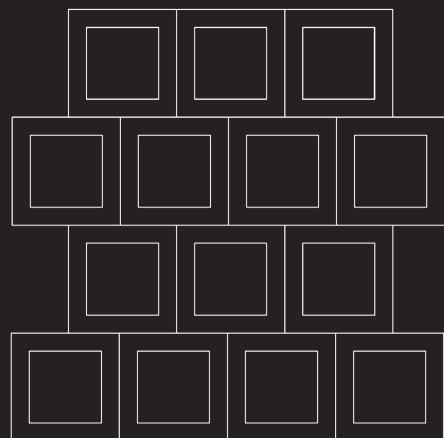
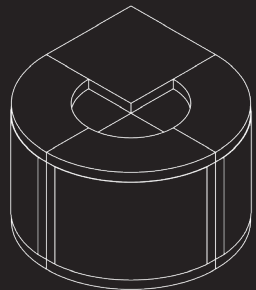
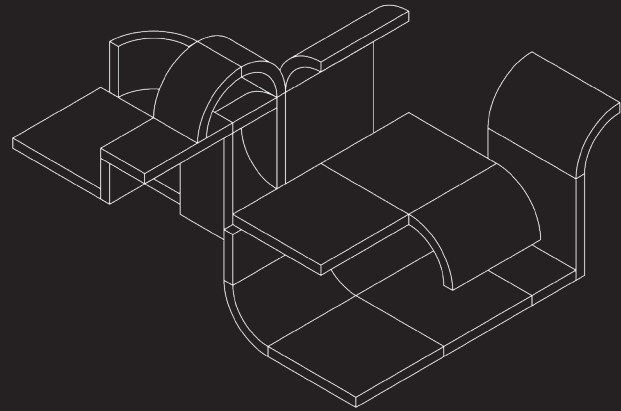
Like these molds, the panels can be combined into ambulating shapes that morph between private and public spaces, between interiors and exteriors.

The panels do not differentiate between use as ceiling, wall, or floor. Once installed, they can be equipped with claddings, fittings, fixtures, and internal fillings and pipings to establish their role in the building - but they are always ready to become something new.



Urban infill development: a case study

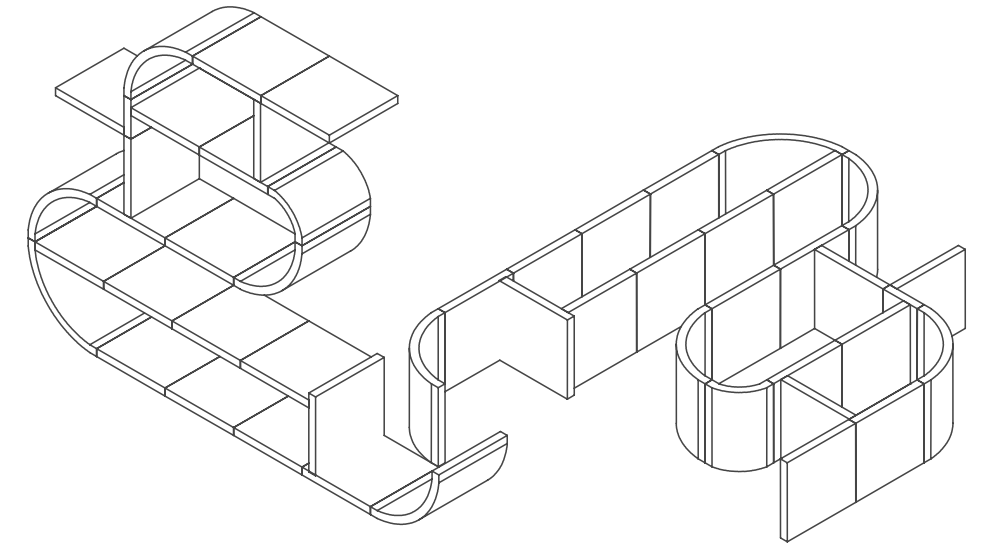
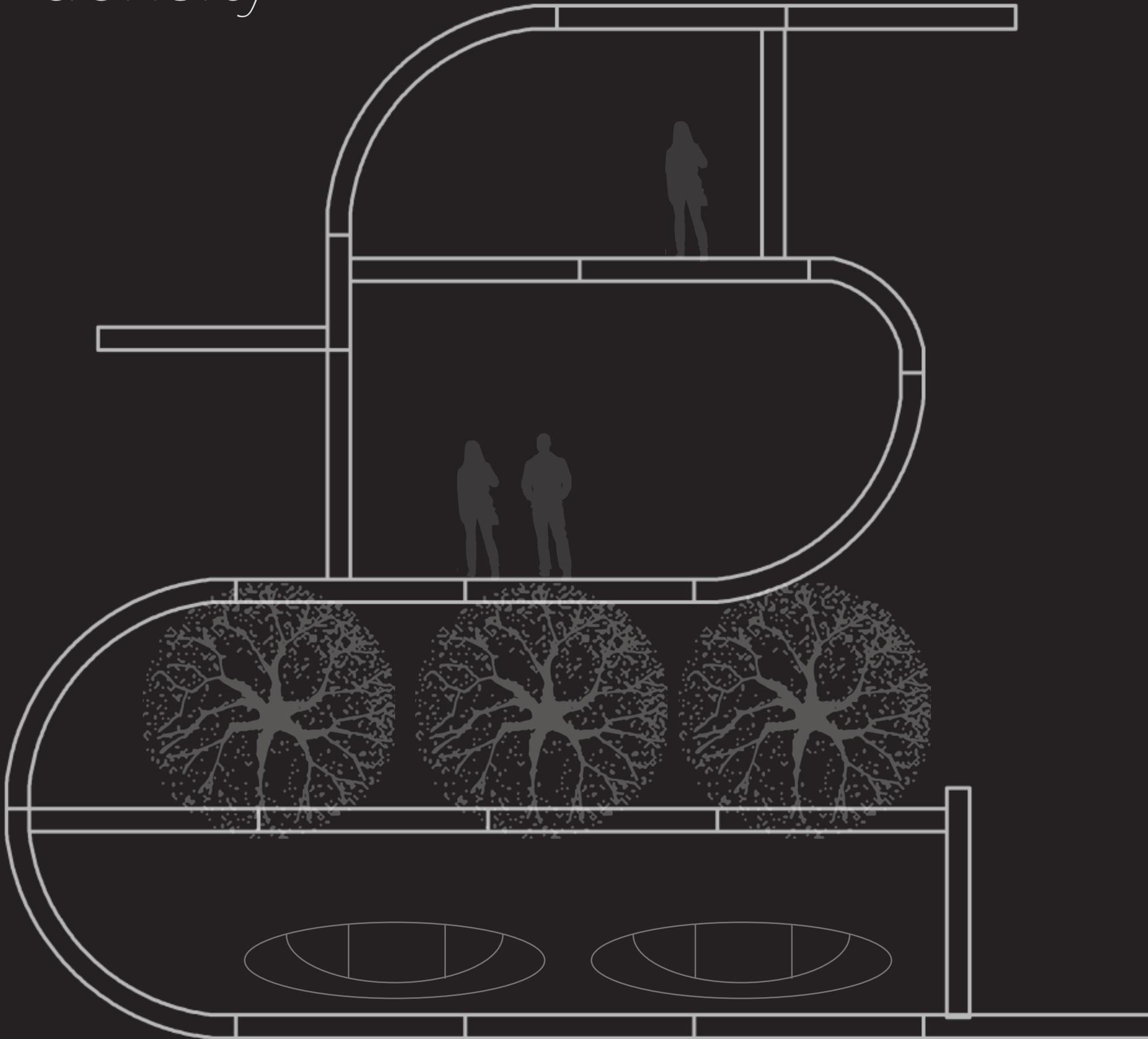
order



Depending on the community profile, site, and usage needs, the modules may take on a wide variety of forms. In general, the organization of these forms can be thought of as ranging from increasingly anarchic, decentralized, and opportunistic (chaotic/random) to increasingly planned, controlled, and monitored (ordered/designed).

Different formal languages that define certain usage zones may flow and transform into each other abruptly or with imperceptible gradation, but in both cases the essential rhythmic continuity of the panel geometry persists.

density

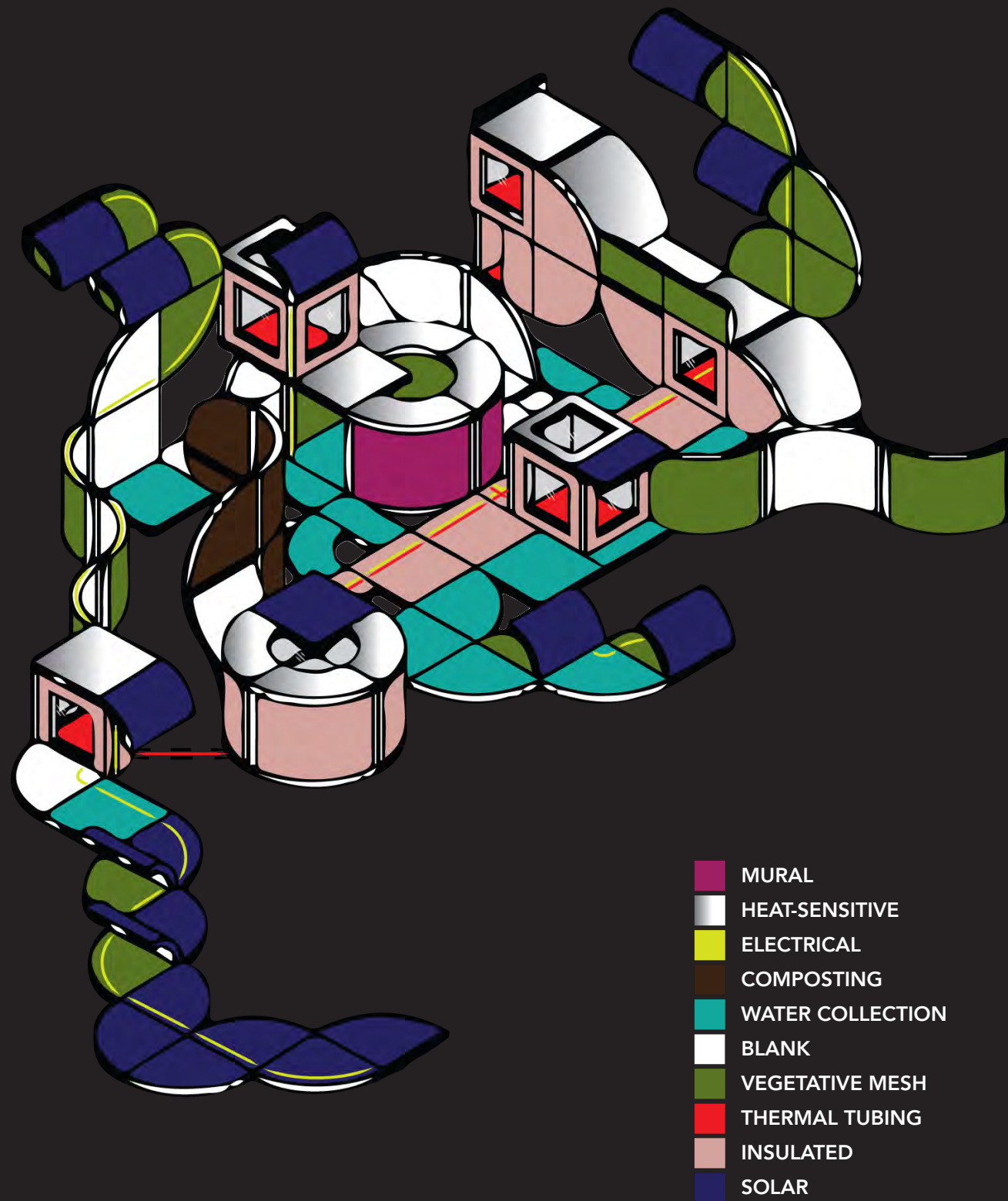


The figure to the left might be interpreted as either elevation or plan. The panels can weave back on themselves to partition off space in a visually interesting manner that may proceed along multiple axes.

For example, consider a start-up that begins with a modest arrangement of panels. As they grow, their workspace grows organically with them.

Live structural sensing might adapt with the addition of each panel, showing particularly good places to consider expansions and facilitate structurally sound vertical growth.

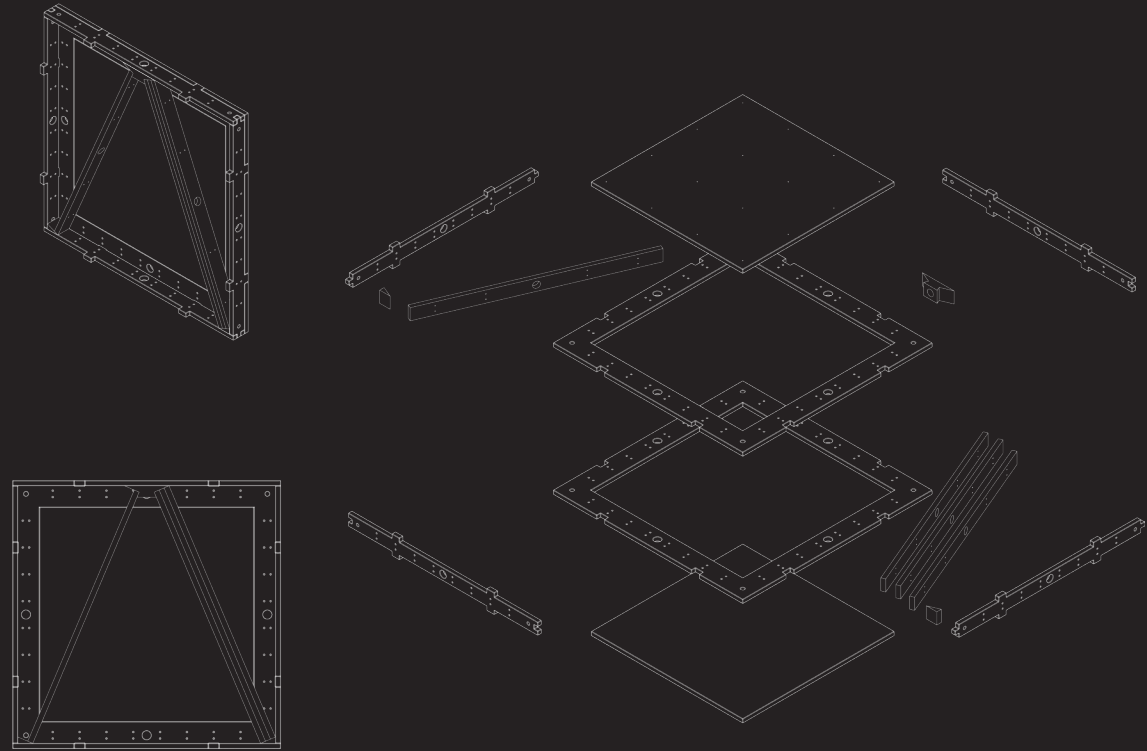
adaptability



The panels can be modified with a variety of types of cladding or internal pipings and fillings. Attaching heat and pressure etc. sensors to the panels might enable real-time analysis of how efficiently certain rooms are heated, where air tends to accumulate etc.

This information could help guide adjustments to the infrastructure of the system, redirecting resources as necessary and identifying the most resource-efficient areas for expansion.

evolution



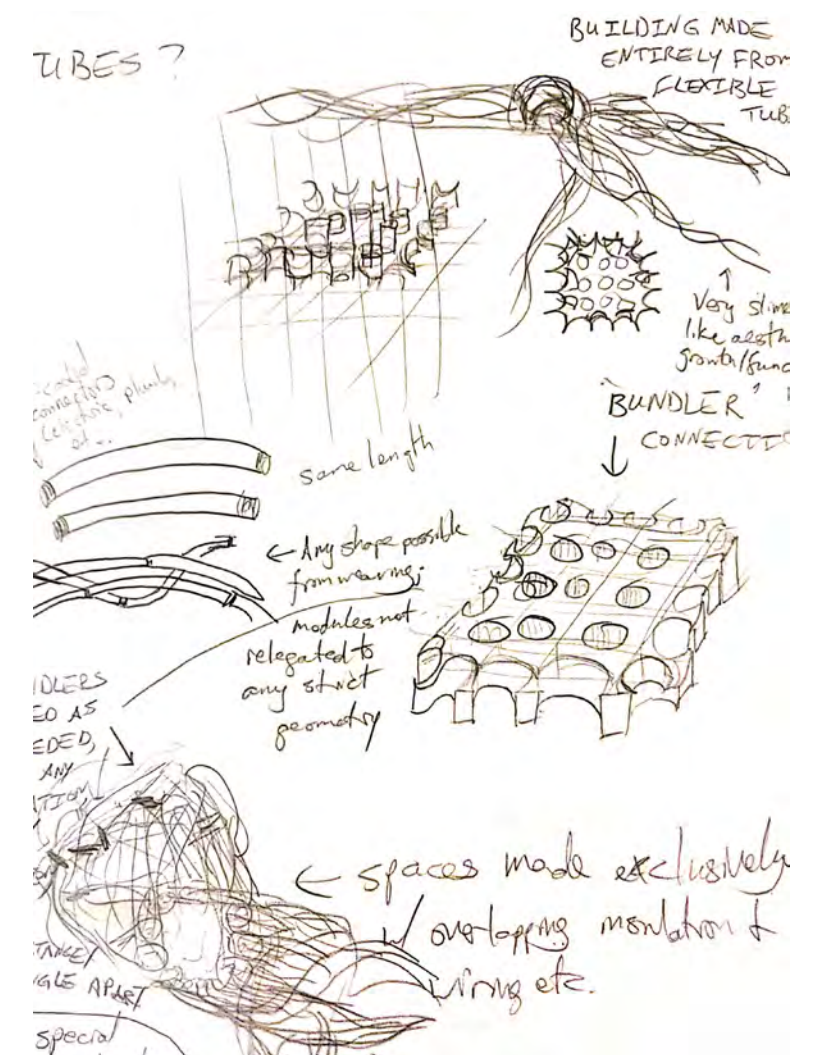
STANDARD FLAT PANEL

GROSS DIMENSIONS: 250cm x 250cm x 25cm

PROPOSED MATERIAL: Cross-laminated timber (prototype phase)

TOTAL PIECE COUNT: 8-17 (depending on trussing elements)

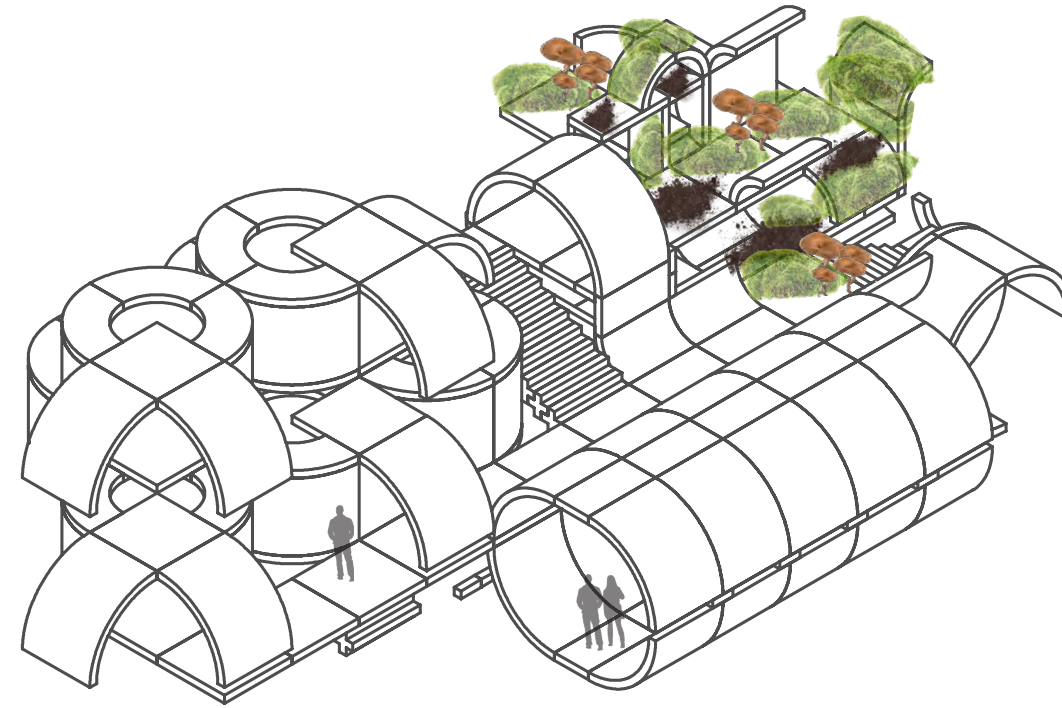
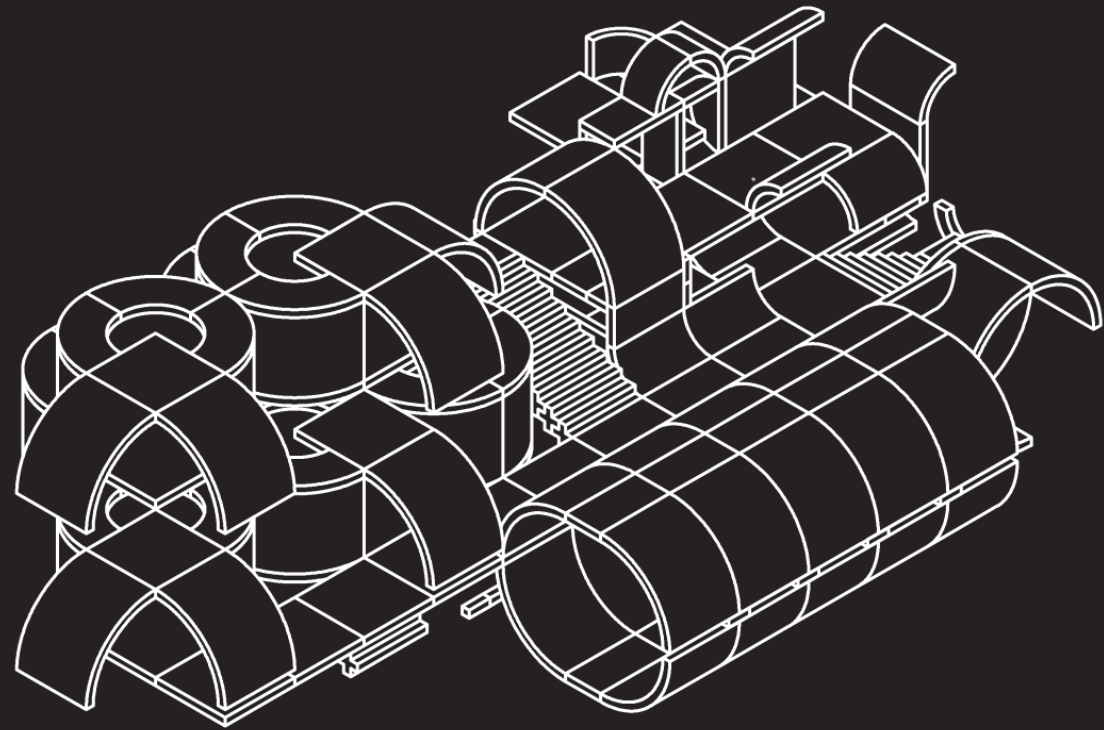
CONNECTION: Friction fit for pieces, standard hardware (bolt/nut) between panels



While this initial iteration proposes a conventional wooden frame, the system as a whole may "evolve" into increasingly organic and fluid construction methods using biological materials that "grow" into position.

As an intermediate step, perhaps the panels could be connected with a sort of structural tubing, breaking the orthogonal imperative of the current geometric logic. These tubes might then be the lattice for a growth-based construction.

decay and rebirth



With the evolution of multiwall as a system, prior iterations and heavily-used panels may become obsolete. Perhaps as the modules trend towards safe biological materials, no longer needed regions could be left to a "controlled burn" - allowing reclamation by nature in a fashion that efficiently decomposes unneeded material while providing greenery, food, or other resources.

design process documentation

RESEARCH
IDEATION
PROTOTYPING

multiwall emerged from an open-ended biomimicry design process that began with studying a biological phenomenon of interest and exploring some potential design applications inspired by the results of that research.

I was interested in slime molds in part because they remain a mysterious group of organisms to scientists. I had no prior design solutions in mind when selecting them as my object of focus.

Inspiration came partly from a building I saw in a dream after much time spent reading about slimes.

slime molds

MYCETEZOA

STRUCTURAL ADAPTABILITY
MODULAR | AMODULAR LIMINALITY
DECENTRALIZED COMMUNICATION

DOMAIN: Eukaryota
(UNRANKED): Unikonta
(UNRANKED): Amoebozoa
SUBPHYLUM: Conosa
INFRAPHYLUM: MYCETOZOA

The slime molds are a collection of single-celled **eukaryotic organisms** that have repeatedly defied easy categorization. They are known for the production of fruiting

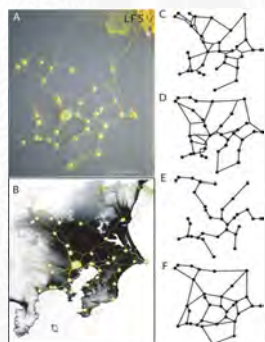
bodies that release **spores** and for either **swarming** behavior (the "social amoebas") or for sprawling **symplasms** in which a single-celled individual grows to an immense size. In all cases, species have a variety of **morphologic phases** undergone in response to stimuli.

The name **mycetezoa** roughly means "fungus animals." Slime molds were originally classified under kingdom Fungi but are now part of the informal Protista kingdom, which contains a variety of hard-to-categorize eukaryotes. Research is ongoing, with some suggesting they are their own kingdom - alongside plants and animals.

Currently, "true" slime molds are found under **Amoebozoa**, where they are split into three classes: **MYXOGASTRIA**, **DICTYOSTELIIDA**, and **PROTOSTELEA**.

DESIGN CASE STUDIES

TOKYO METRORAIL

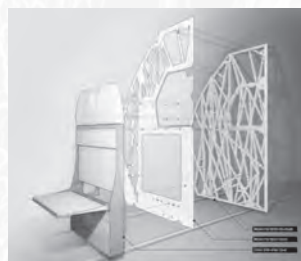


In 2010, Dr. Toshiyuki Nakagaki of Hokkaido University arranged food in a pattern analogous to major population centers in Tokyo and installed *Physarum polycephalum* nearby. The plasmodium created a feeding network

with remarkable similarity to the Tokyo metrorail networks.

AIRBUS PARTITION

In 2015, architect David Benjamin used algorithms of slime mold and bone growth patterns in generative design software to develop a lightweight, low material "bionic" airplane cabin partition for Airbus.



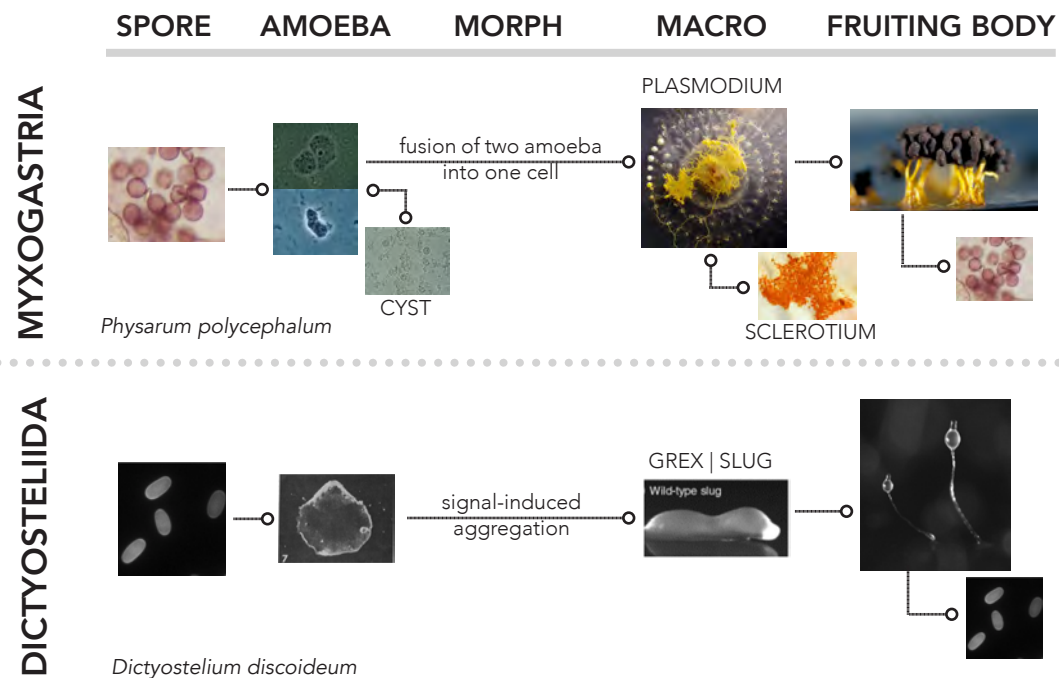
MYXOGASTRIA
 Unicellular symplasms: division without end
Myxogastria are single-celled, but exhibit a wide variety of growth behaviors in response to various stimuli. They can morph by dividing their nucleus without dividing the cell.



Clockwise from top left: *Hemitrichia serpula* (plasmodiocarp), *Arcyria incarnata* (sporangia), *Trichia varia* (sporangia), *Trichia varia* (capillitium and spores), *Badhamia utricularis* (sporangia).

While plasmodia tend to have a similar "veined slime" appearance, the shift into the fruiting body is highly diverse depending on the species.

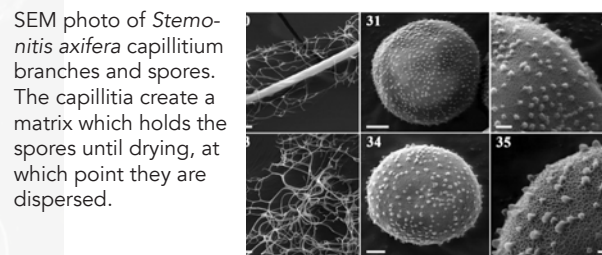
LIFE CYCLE
 All three classes of mycetezoa have analogous life cycles and morphological variations, but there are some critical differences, particularly between *Myxogastria* and *Dictyosteliida*.



Above: dense network of *Stemonitis fusca* sporangia.



Right: smaller *S. fusca* sporangia. The stalks contain a network of capillitia with spores. The stalks attach to a hypothallus rooted to the substrate (moss in this photo).



SEM photo of *Stemonitis axifera* capillitium branches and spores. The capillitia create a matrix which holds the spores until drying, at which point they are dispersed.

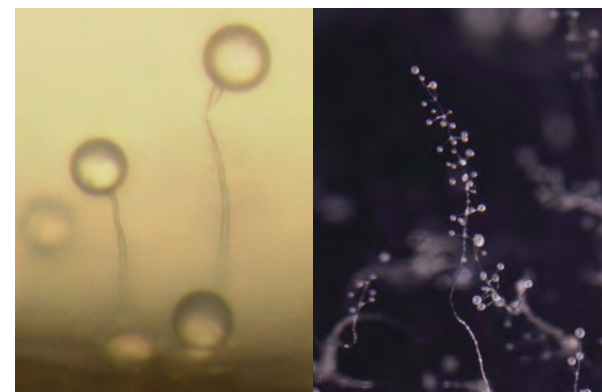
PROTOSTELEA

Lingering uncertainties

Protostealea have characteristics similar to both *Myxogastria* and *Dictyosteliida*, but may be more related to other amoebae.



Above: *Ceratiomyxa fructiculosa*, with sporangia behavior similar to *Myxogastria* (porioides "net" morph shown)



Comparison of the fruiting bodies of *Protostealea mycophagy* (left) and *Dictyosteliida Polysphondylium pallidum* (right)

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 - <https://www.pnas.org/content/94/22/12007.long>
 - [https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_\(Boundless\)/23%3A_Protists/23.2%3A_Characteristics_of_Protists/23.2B%3A_Protist_Life_Cycles_and_Habitats#Plasmodial_slime_molds](https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_(Boundless)/23%3A_Protists/23.2%3A_Characteristics_of_Protists/23.2B%3A_Protist_Life_Cycles_and_Habitats#Plasmodial_slime_molds)
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- See images page for image references

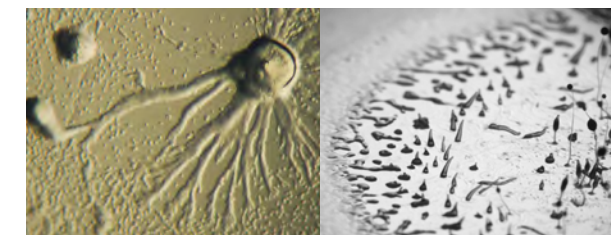
GENERAL FACTS

DISTRIBUTION: worldwide
HABITAT: terrestrial (forest)
CLIMATE: temperate | cool
FUNCTION: decomposers
DIET: fungus spores | bacteria
KNOWN SPECIES: ~900

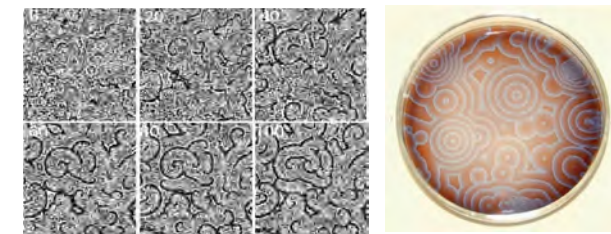
DICTYOSTELIIDA

Cellular slime molds: the "social amoebas"

Dictyosteliida swarm under stress, coming together as a pseudo-multicellular organism.



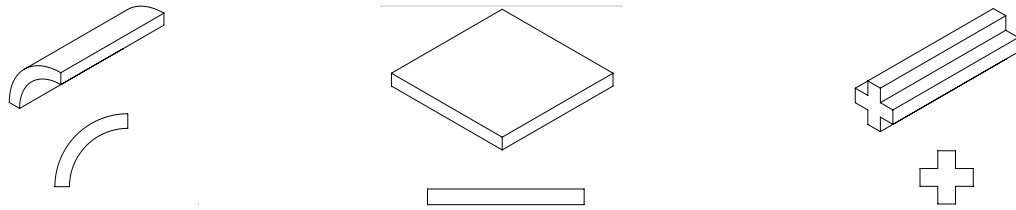
Single-celled *D. discoideum* aggregate when food is scarce, creating fruiting bodies that "stand up" to release spores.



Inter-cell communication among *Dictyostelium discoideum* (left) generating patterns similar to a Belousov-Zhabotinsky (BZ) chemical oscillator (right).

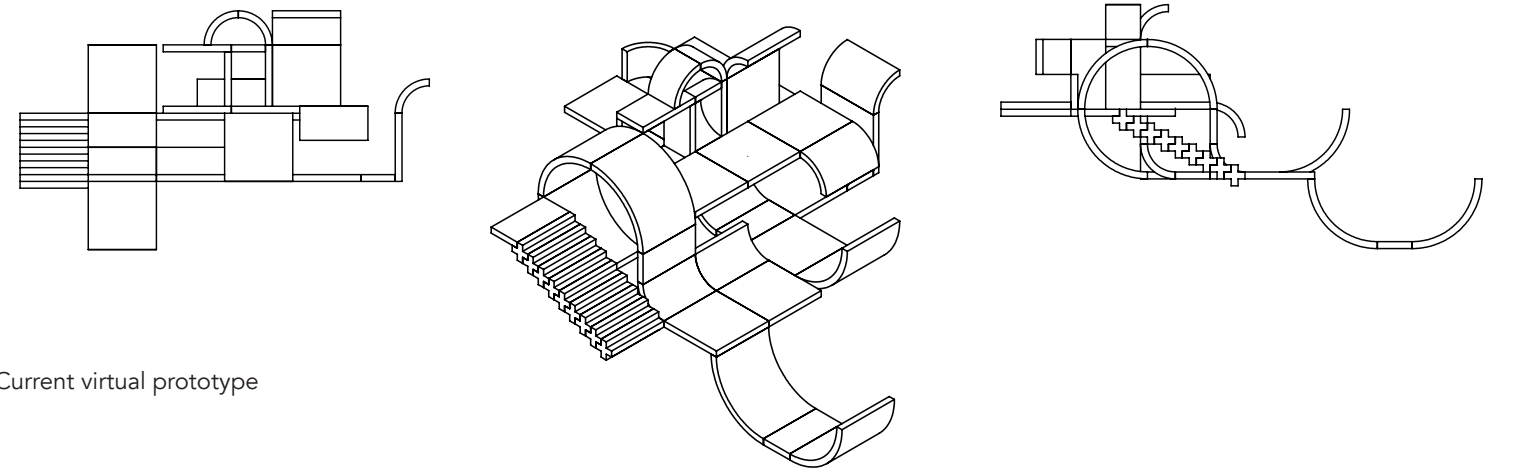
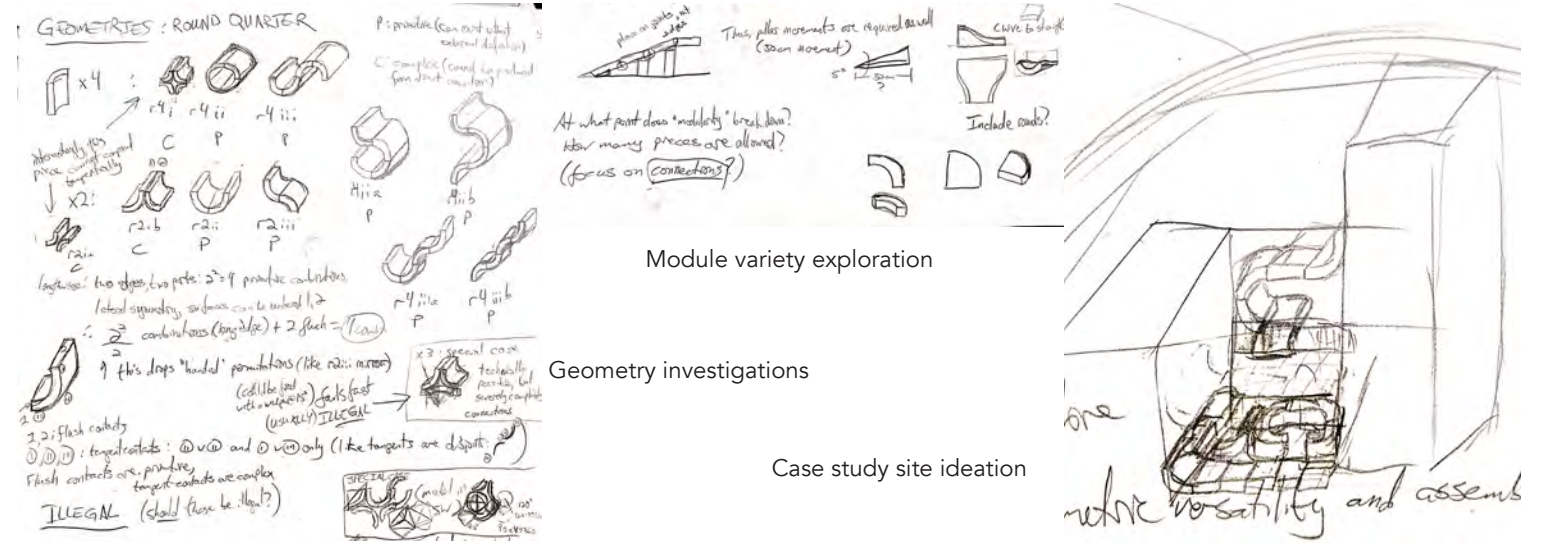
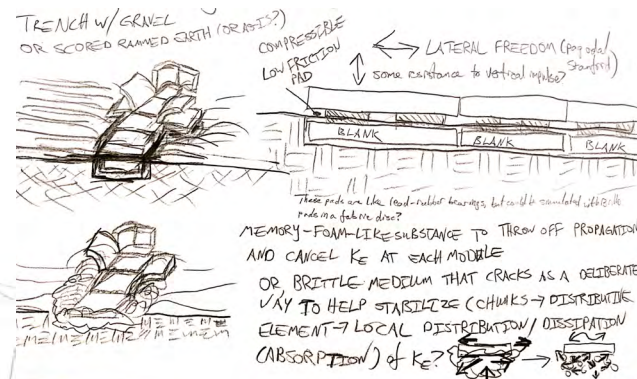
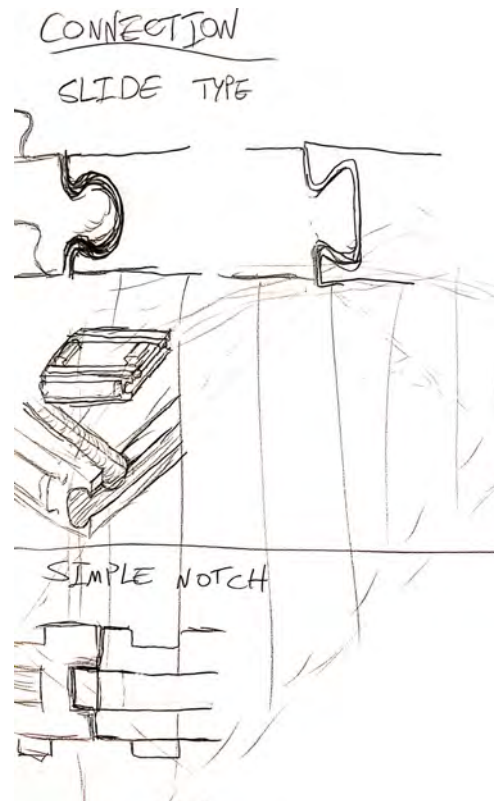
multiwall

In order to get a sense of the boundaries of the space, I began by building with the basic components I had sketched in rendering software. This helped me start to get a feel for the logic of the pieces and observe inconsistencies or dead-ends in their combination.



Out of a desire to establish a semblance of pragmatism, I put some thought into foundation, material, earthquake resistance, and physical connection as well.

In grappling with foundational concerns, I noticed that the sporangia phase of the slime mold has a "foundation" physiology of its own - the hypothallus. This structure connects the fruiting bodies containing the spores to the substrate (the location of attachment for the organism).



Current virtual prototype

REFLECTIONS:

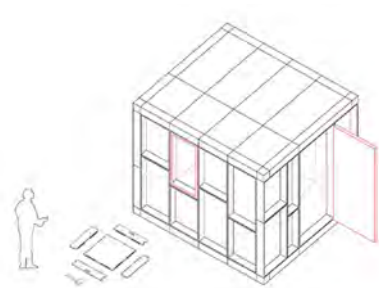
I think more groundwork needs to be done before attempting a fabrication of a large number of pieces, even at model scale. I have a good enough sense of the practical limitations for a more theoretical or experimental exploration of the concept, but I would like to compile more lists of piece combinations and select my real-world case study sites.

I expect that attempting to fill a real-world space (virtually) will answer some questions about where I would like to go with module connection and motility, which should in turn help me figure out what to fabricate and how to fabricate it.

These efforts will also better inform investigations into possible applications as well as provide something of a basis for conjecture regarding urban-scale combinatorial organization and its social implications, if I have the time for it.

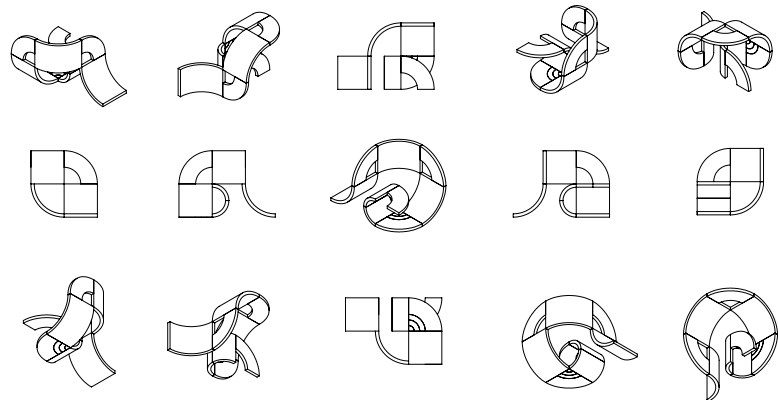
multiwall encounter with an existing project

Soon after the first prototyping round I saw an article posted on Dezeen about a modular architecture project called U-Build. U-Build has some similarities with this project, in being composed of panel modules that can be arranged by amateurs and used as floor or ceiling pieces.



U-Build

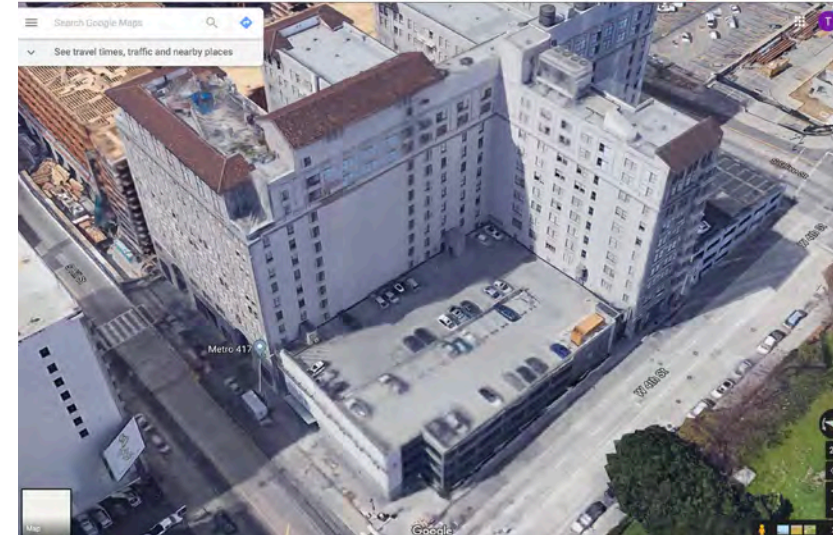
The U-Build project doesn't appear to explore disintegration of interior/exterior boundaries or infinite and location-responsive expansion. It also does not seem to position itself as a multistory/multi-unit solution or as an alternative approach to urban development in an integrated sense. However, these panels offer a basis for thinking about what a "multiwall" panel would look like and can serve as a template for a prototype design of the same.



Space possibilities resulting from rotation of a continued curve shape

COMPONENTS

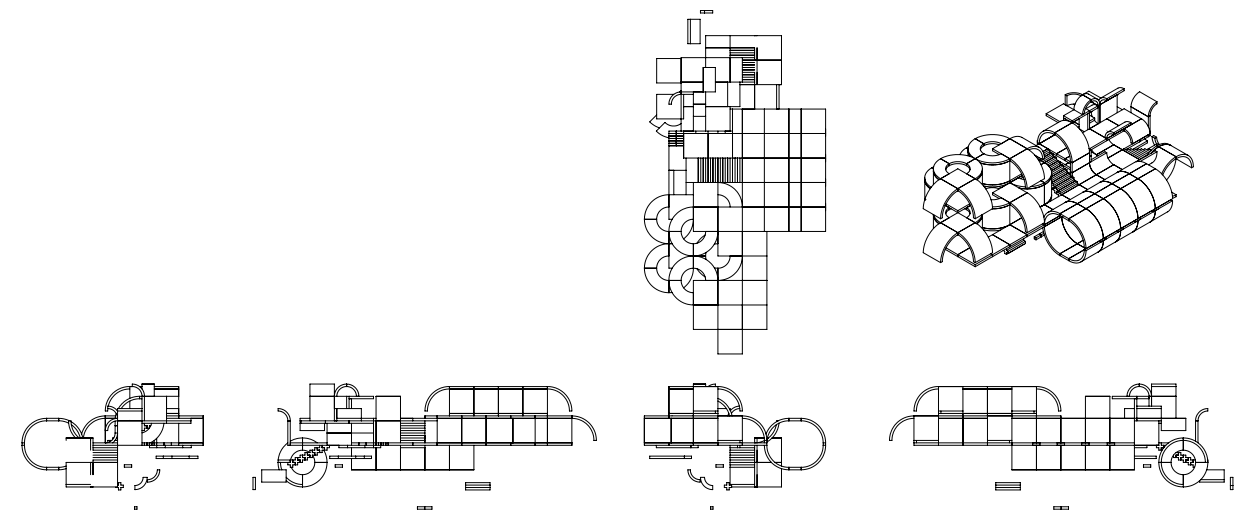
Introduction of a flat curve piece enables uninterrupted curve tangency between modules. The flows that result make for some very organic combination options, but they also highlight an issue with the curved modules: the difficulty of closing off spaces in a sealed or structural fashion. A solution may be a sort of gasket to affix between curves and flats, or leaving open spaces to finishing by users.



Proposed case study site

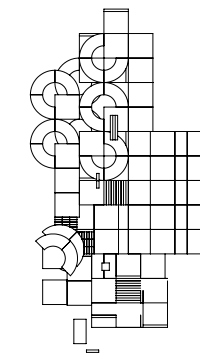
CASE

I looked into possible case study sites, and found this parking garage near Angel's Flight in Downtown Los Angeles. The visibility of the space - as well as the open stretch of wall on the building behind - makes for an appealing virtual installation site.



COMPOSITE

The current prototype incorporates a small 'development' of repeated circular module units, contrasting with the more 'bespoke' tangle of panels adjacent.



Current virtual prototype

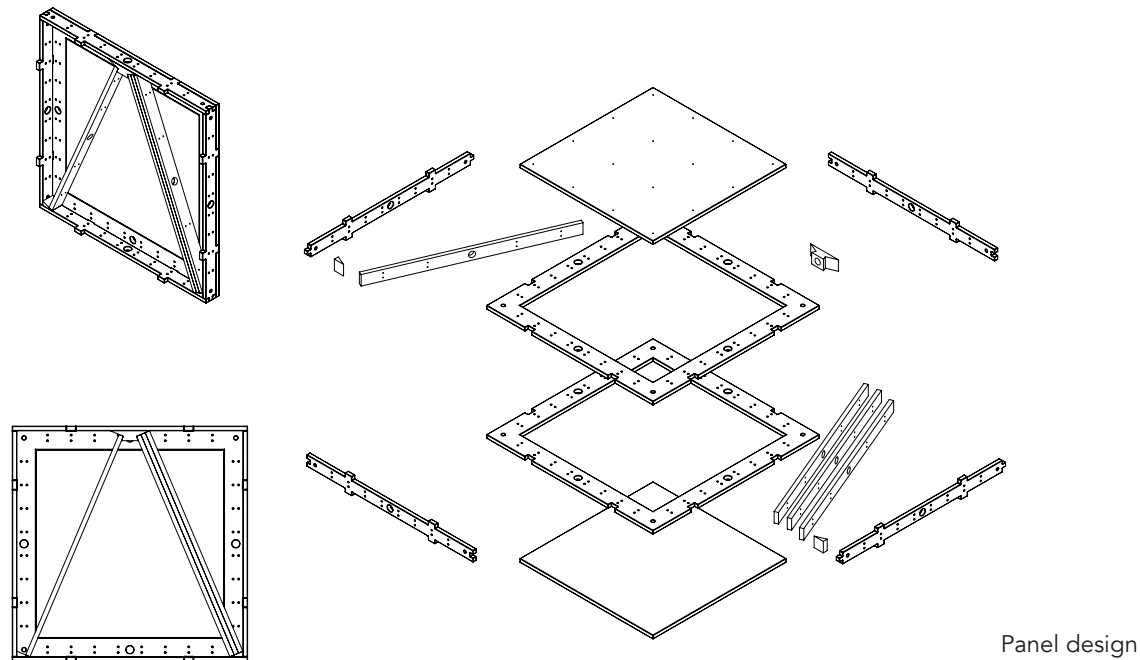
REFLECTIONS:

I now have some very clear avenues to pursue. I am going to focus on constructing units to put together, establishing the "rules" for different states based on slime molds, putting together a prototype design for the panel itself, and making some add-on elements.

multiwall making a model

DESIGN

Before moving into the case study and some renders, I wanted to see if I could put together a design for the panel itself to help me think about connections and panel functionality based on its contents (insulation, soundproofing, plumbing, electrical, ventilation etc.).



I used U-Build as a template. As I am interested in the possibilities of CLT and U-Build panels appear to be plywood, they offer an analogue for considering a larger-scale system.

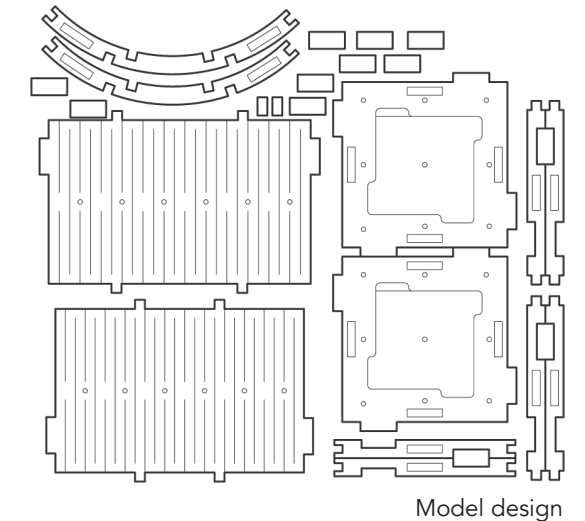
The smaller holes are used with standard connectors to connect panels. Unused holes are used for electrical or radiant heating/as additional cladding or fixture fasteners - or plugged if not otherwise in use. The larger holes are for plumbing or ventilation.

The trussing is configurable to offer increased structural support as needed. The removable central panel provides access to the interior for installation or for swapping out fillings without needing to remove the entire module, and also offers additional fenestration or other aperture configurability. This sort of interior access may also enable piecemeal deinstallation such that - with the use of a temporary support beam acting as a jack - even loadbearing panels could potentially be replaced with relative ease.

RESEARCH

I looked through some books and magazines to either confirm the viability of some of my more "ambitious" ideas or find new inspiration to help guide and shape the project and aid in better defining its nebulous goals - an issue that, while very slime mold-like and not entirely unproductive, is also very time-intensive.

While I do not go into the details here, some of these ideas include all-building sensing and ongoing reconfiguring to best meet user needs (informed by in-operation BIM and op-tioneeing) and use of novel biological materials (such as mycelium).



MODEL

The model (in progress) provides some tactile sense of how the panels fit together. The design is a simplified version for general demonstration.

REFLECTIONS:

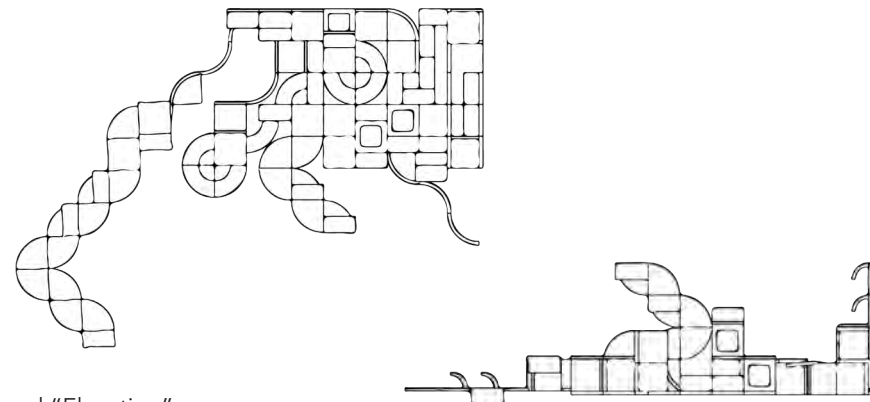
I am satisfied with the model. Additional research has provided some confidence in the "bigger picture" of the project that I am going to start sketching out. I will work towards a more site-agnostic render or the case study and develop whichever moves more quickly.

multiwall case study groundwork

GOAL

The case study will serve as the central "exhibit" for describing the functions and potential of the multiwall system, as well as its major drawbacks and possible alternatives.

The most plausible application for the panels may be mixed-use infill development, with the possibility for use as anything from shelters for the homeless or storage units to pop-up stores, installations, or student housing. The formal language of the structures assembled for any of these uses may vary - leading to distinct zones - or remain amorphous/mosaic.

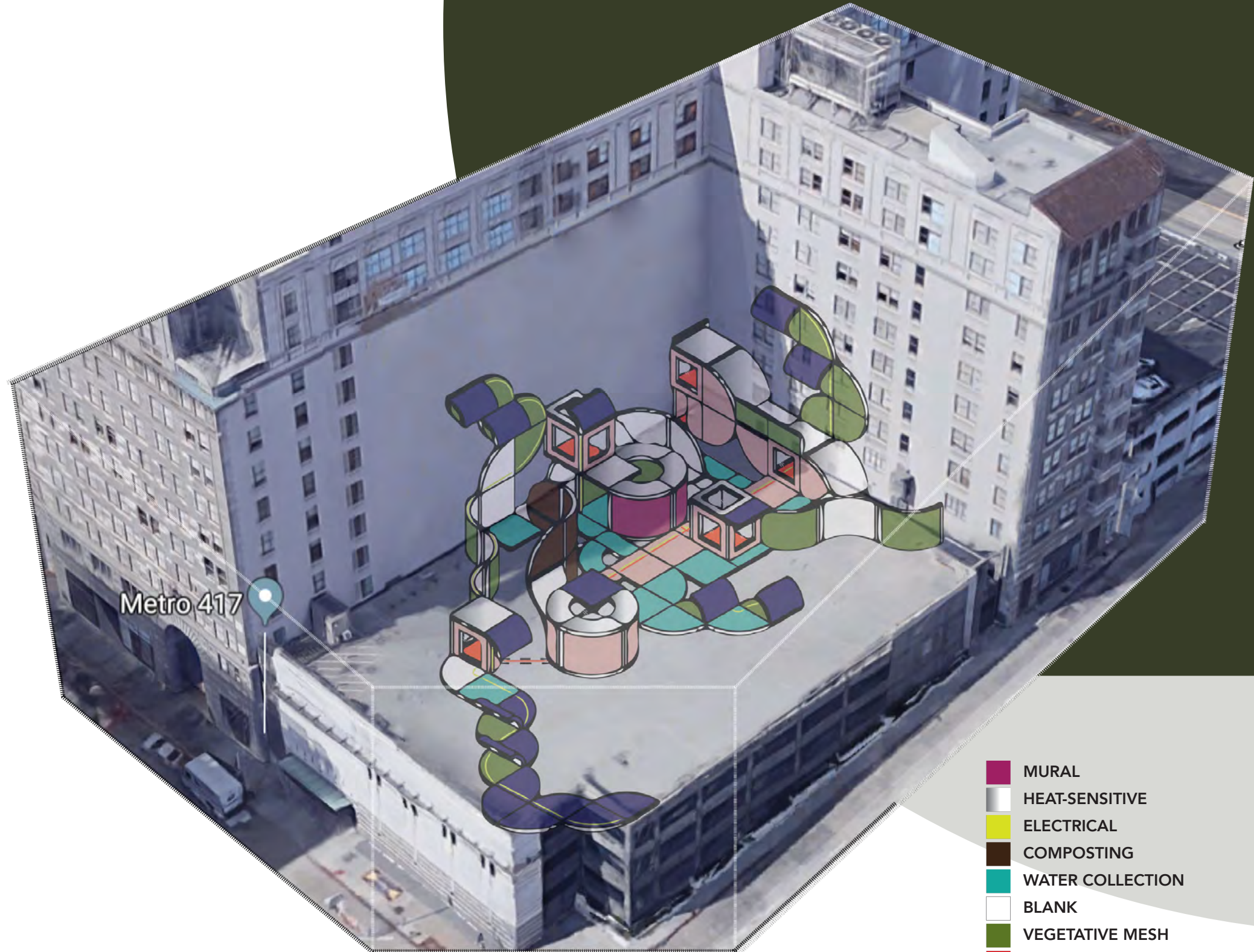


"Plan" and "Elevation"

ANALYSIS

This configuration recapitulates previously developed elements while exploring some novel combinations. The repetition of curved panel "tendrils" is a deliberate attempt to emulate the slime mold plasmodium morphology, with the solar panel curved caps suggesting the development seeking out underutilized resources and opportunities for growth.

I have concerns about the possibility of this development approach to lend itself to slumming/unsafe conditions, which I hope to address in the final presentation.



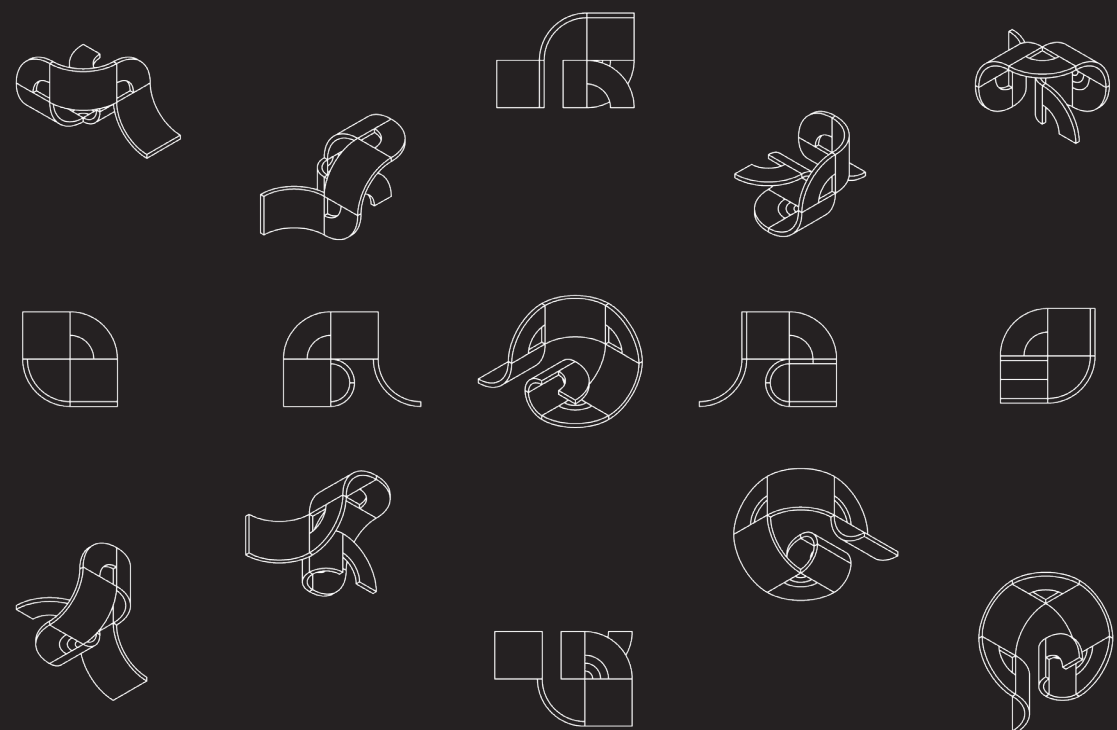
- MURAL
- HEAT-SENSITIVE
- ELECTRICAL
- COMPOSTING
- WATER COLLECTION
- BLANK
- VEGETATIVE MESH
- THERMAL TUBING
- INSULATED
- SOLAR

REFLECTIONS:

The case study offers much-needed grounding. There remain many avenues to explore and without an "anchor" of sorts, the rush to map them out could have become very disjointed.

I'm not satisfied with the aesthetics, but it seems to communicate the needed sense of space.

analysis I



There are a few notable issues with the system worth addressing.

The first and most glaring set of issues concerns, simply, whether or not this approach would work in a practical sense. For example, would the geometric limitations result in higher infrastructure inefficiency, sensoring notwithstanding? Can the panels be structurally sound enough to be built to over 2 stories or so? How realistic is panel replacement *really*?

Efficiency can likely only be assessed with a full prototype. Testing a range of configurations with BIM software first, however, may be a good way of determining the viability of such a full-scale experiment.

Structural viability is a problem that, with changing materials, has no lasting answer. If the panels are made from CLT and a sensor-driven piecewise construction method is utilized, I would think that structures could reach a reasonable height.

It is unclear how the combination of that many free panels would react in an earthquake - the connections would take a lot of strain, but energy might be dispersed fairly evenly throughout all panels.

analysis II

While I like the idea of a decentralized approach to development, I think there would need to be oversight of some kind in order to ensure safe and equitable growth. The iterative and somewhat "sedimentary" nature of replacing and layering panels could quickly run into code problems or create cramped conditions. Furthermore, if the panel configuration requires some structural amendment, too much tenant freedom to carry it out could lead to injury or health hazards.

For example, a shelter or small dwelling at a multiwall site may have limited natural light access on the site. It may only take the adjustment of a few panels to deprive them of that access. A tenant in an "open" shelter may get too zealous about modification and attempt to drill into the panels unsupervised.

In a similar fashion, it would be difficult to ensure all tenants are familiar with their fire escape routes if the hallways/paths were constantly morphing.

Another issue is plumbing. While the panels can support plumbing fixtures and piping, installment into the local system would require a permanent connection of some kind.

To remedy these issues, a management structure would need to impose some sort of restrictions based on a central plan for fire routes and light access etc., as well as act as liaison with local infrastructure services. They could also supervise modification activities to ensure the result is effective and safe.



CATEGORY | SUSTAINABLE DESIGN / PACKAGE DESIGN

ikikaza

Package-as-product decoration platform

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DESIGN PROCESS DOCUMENTATION

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ARTIFACT ANALYSIS AND DESIGN STATEMENT

ARTIFACT ANALYSIS

FOUND OBJECTS

People see value in objects differently.

An object may not be of much interest on its own, yet is evocative to someone of a memory or story. This, in turn, yields a subtle charm apprehensible to that individual alone.

However, objects of this kind have little "com-munication" with each other. They exist as iso-lated units in a person's mind, distinct.



In the past, I designed a board game that uses found objects as game pieces. Anything can be used – from a twig on the ground to an important piece of jewelry.

The greatest fun in the game is seeing what objects other people gravitate towards and what they see in them.



Left: Italian Striped Marble Balls, Pinus Taeda Pinecone, Grapette Soda Bottle Cap.

Above: Jade Lingam, Statuette of A Hunchbacked Beggar, Dahlia Blossom



Box and manual for found object game

I began considering an "agnostic" pack-age that can bring together objects in a similar way: a generic board game map, or a platform for trinkets – a "DIY Kit" for still lifes and interactivity.

DESIGN STATEMENT

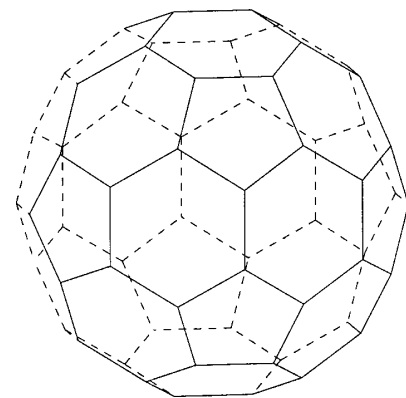
ææYrY

geoflora

ikikaza - a contraction of いきなり (ikinari, "suddenly") and 飾り物 (kazari-mono, "decoration") - is a platform for portable minigames and modular decoration.



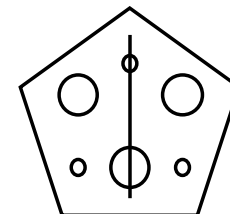
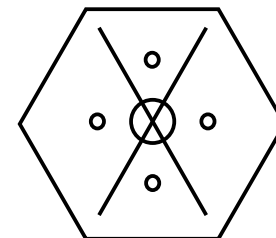
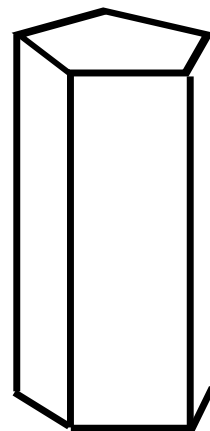
Concept Sketch



ææYrY folds into a sphere, acting as both product and package. The subname "geoflora" evokes a sculpture garden: a confluence of the organic and inorganic.

Slots in the tiles offer options for placing objects - business cards, pens, coins, lowers, etc. The individual tiles provide each piece its own dais.

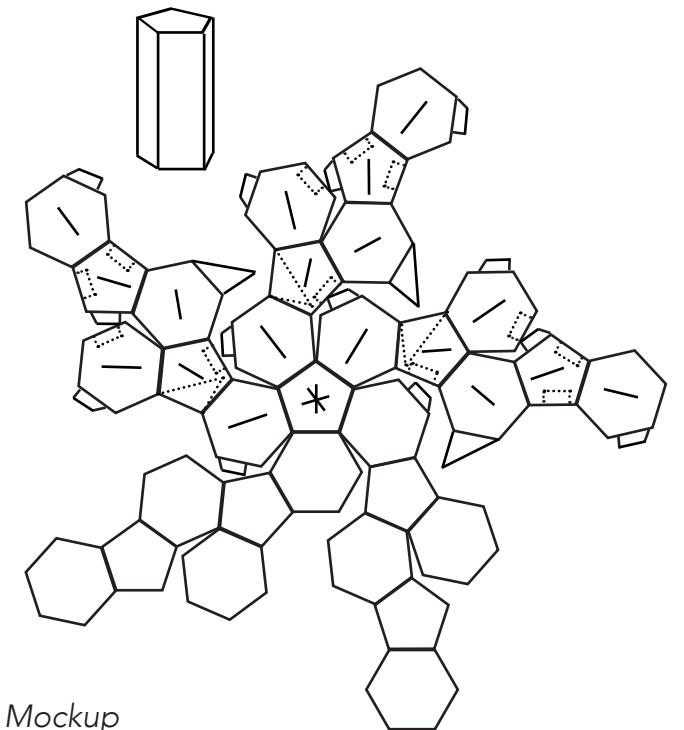
A central pillar holds parts or favored objects, and provides stability when closed.



STRATEGY

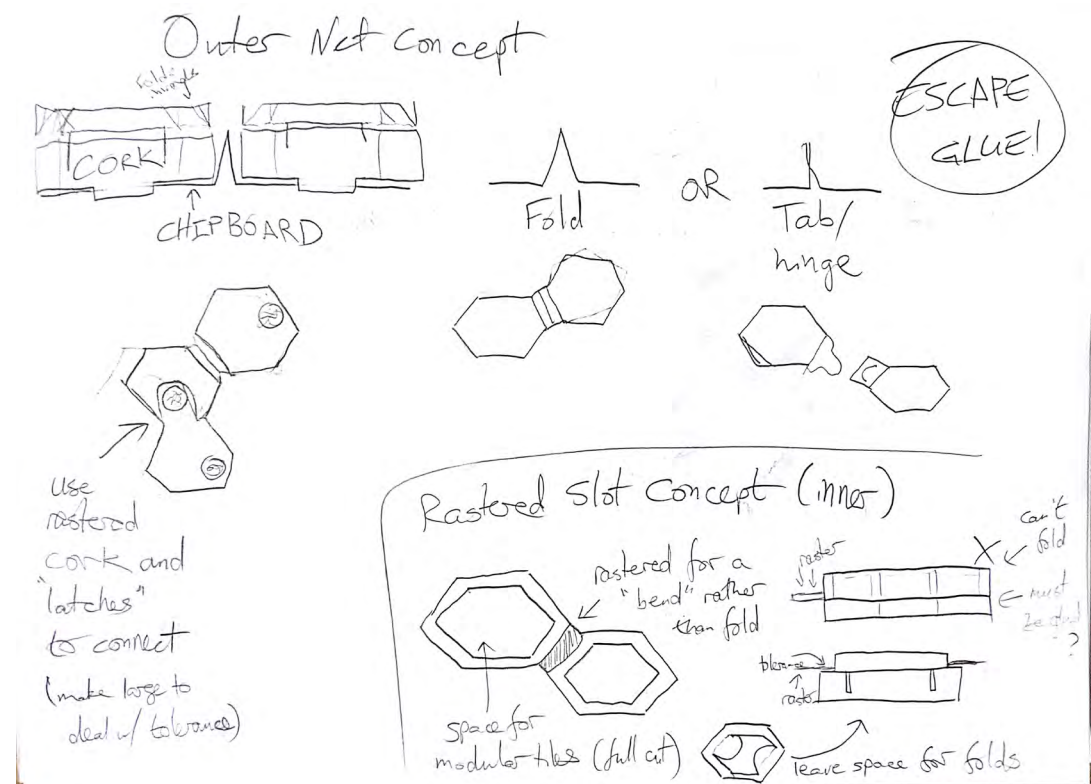
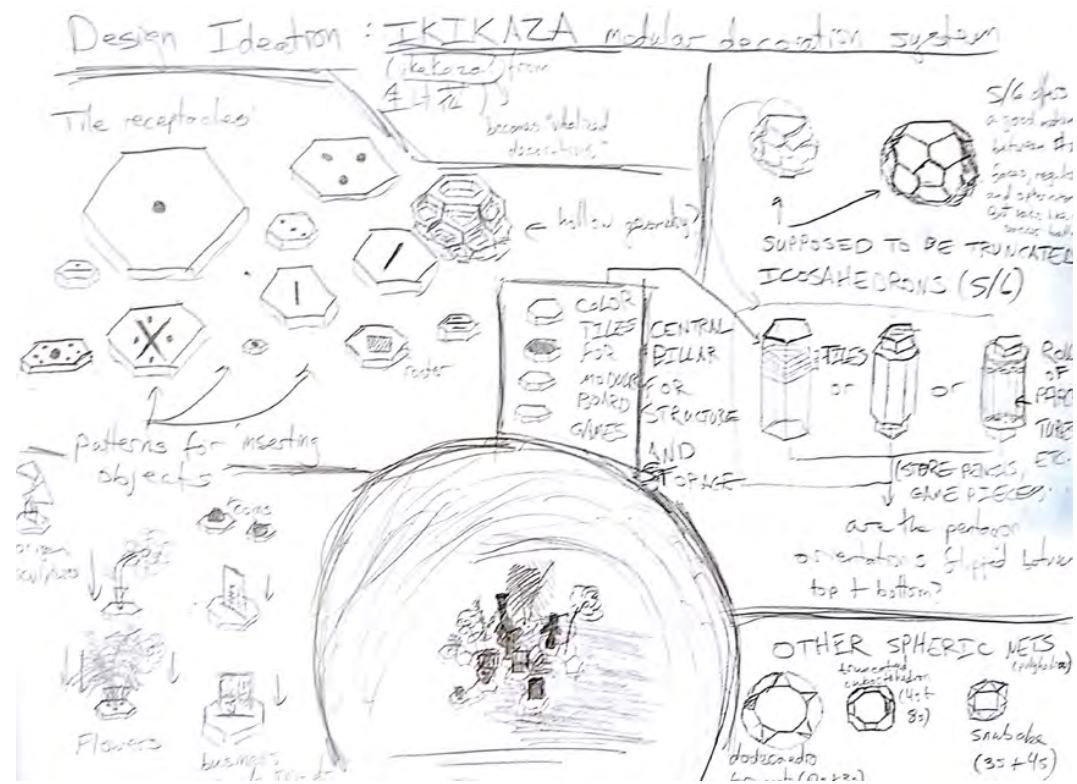
The net shown here utilizes a standard hexagon and pentagon pattern for its main structure.

A tabbing mechanism ensures that the sphere can be opened and closed multiple times, while a central pillar holds parts or favored objects.



Net Mockup

DESIGN IDEATION AND HAND MODELING



TIMELINE

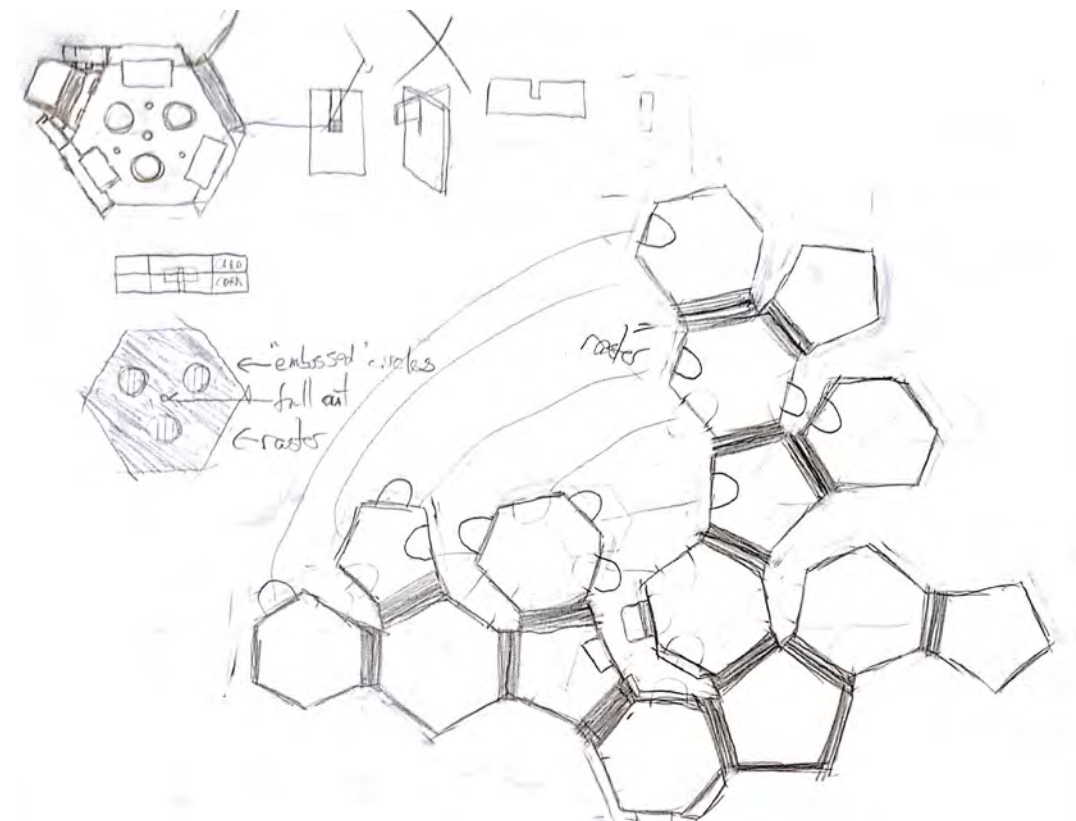
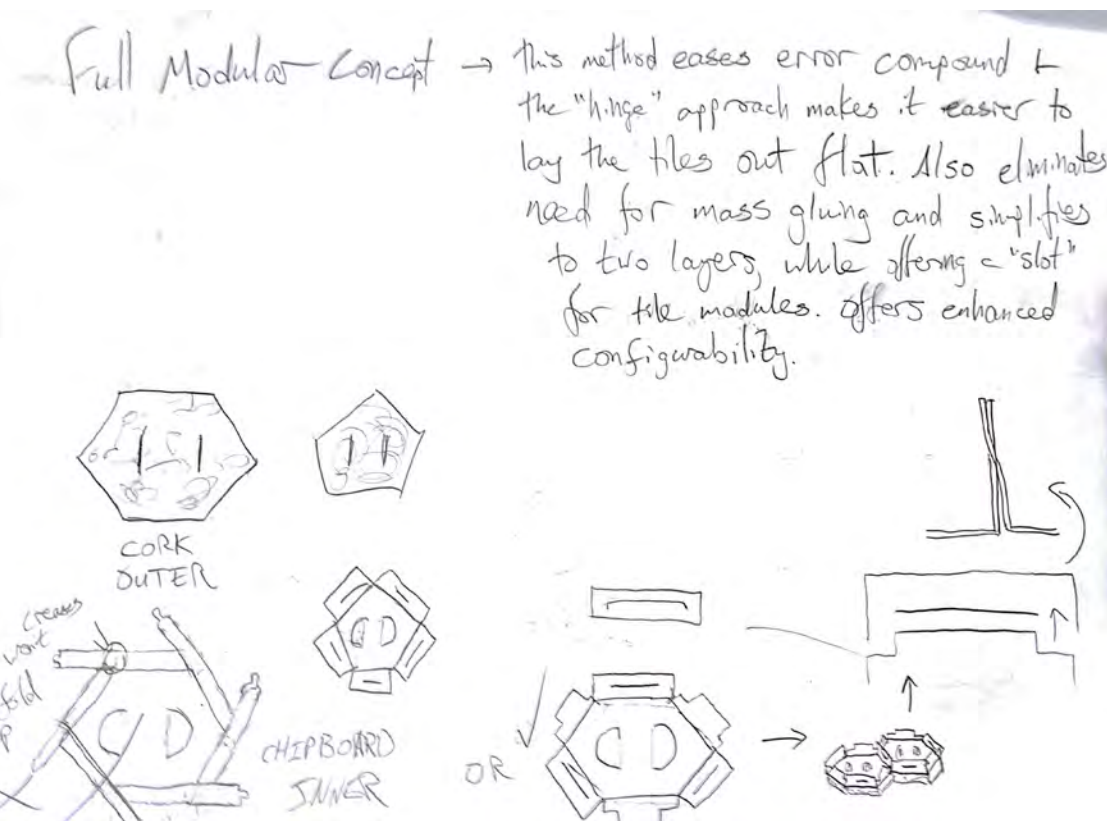
Timeline text (partially illegible)

Timeline text (partially illegible)

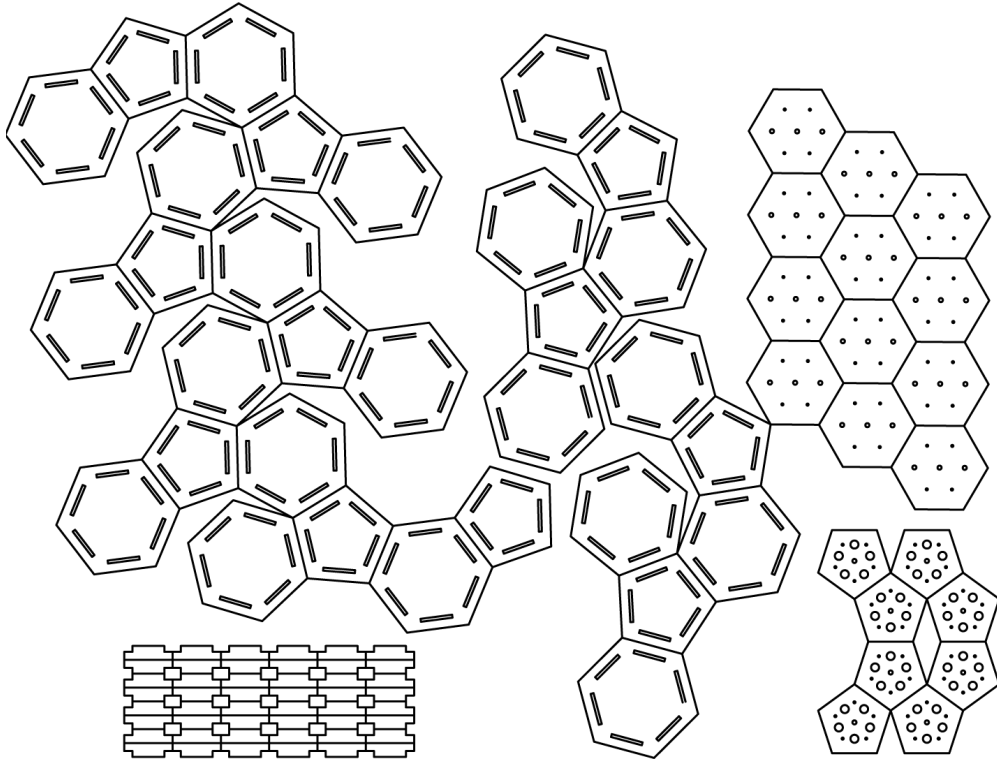
CHALLENGES

Challenges text (partially illegible)

Challenges text (partially illegible)

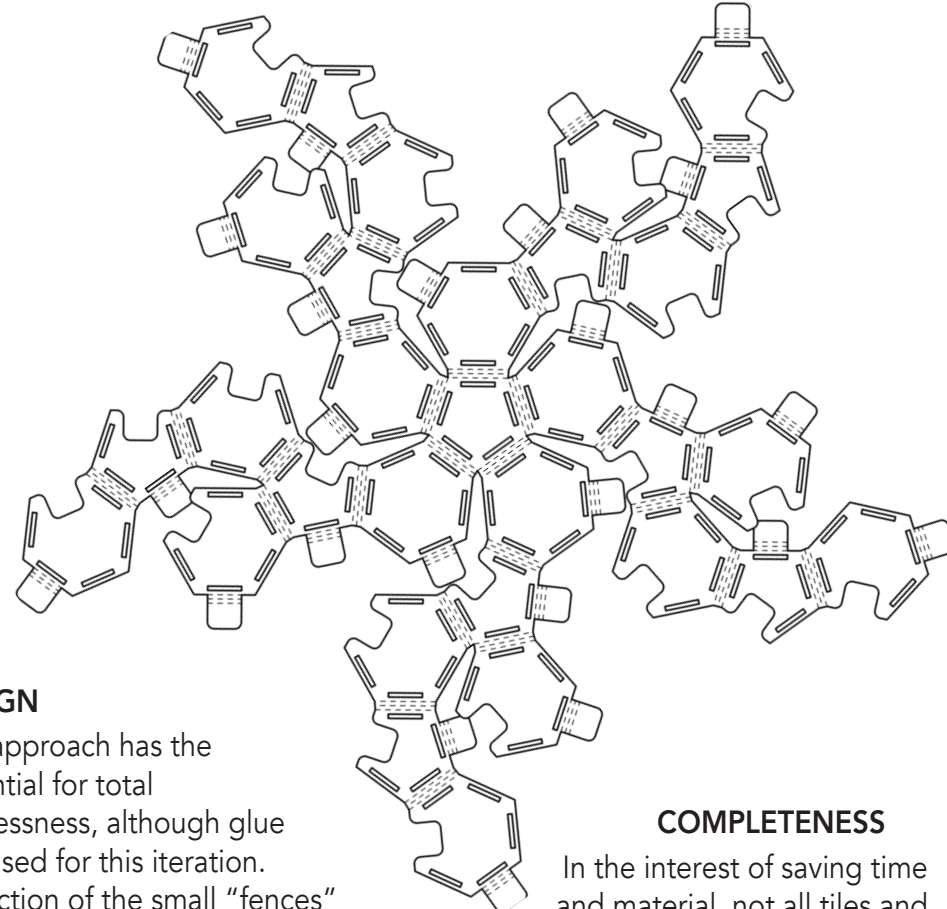
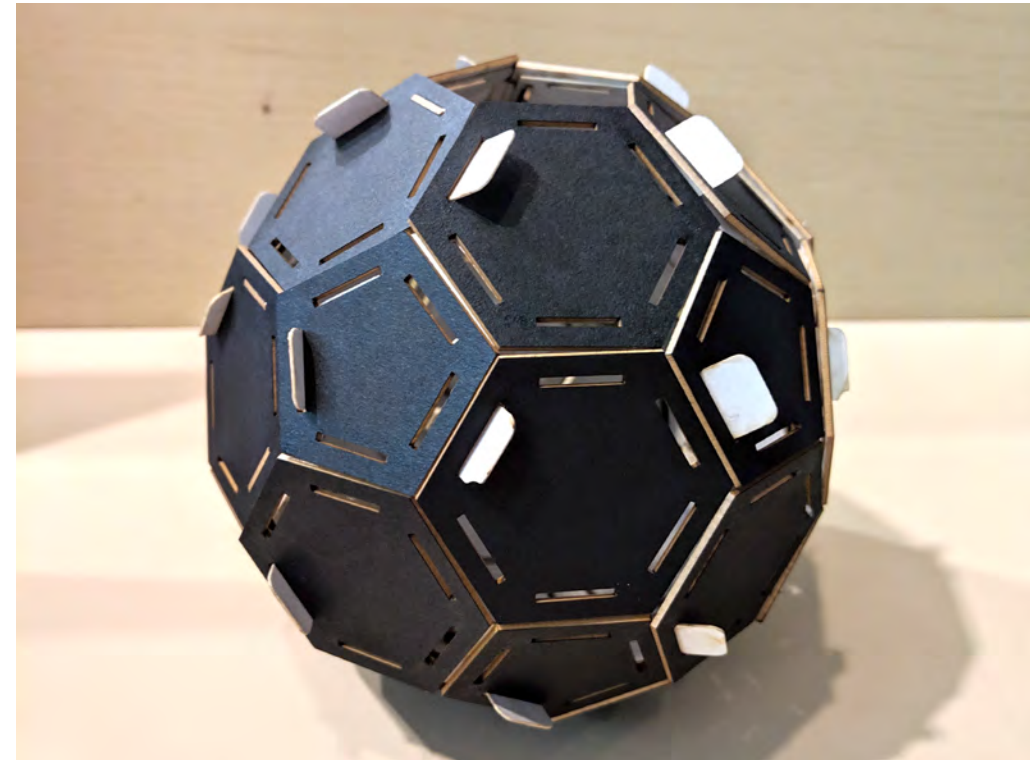


Hand modeling proved to be impractical.



AutoCAD Nets (not to scale)

Physical Model



DESIGN
 This approach has the potential for total gluelessness, although glue was used for this iteration. Perfection of the small "fences" will allow them to be used like nails. The result should be stronger than glue, as well as more elegant.

COMPLETENESS
 In the interest of saving time and material, not all tiles and fences were printed.

ikikaza

geoflora

BUILD ANALYSIS

...özü...
 ...

AESTHETICS

...
 ...

...
 ...

INTEGRITY

...
 ...

...
 ...

SUSTAINABILITY

Despite the purported reduction in waste by combining package and product, the net shape yields significant unusable material. Future iterations must address this issue.



ikikaza

PROTOTYPE 3: STRUCTURE



PROCESS

This version uses two layers of mat board separated by spacers to create a .125" cavity between the inner and outer shell. This cavity provides a space through which mat board latches cut with a living hinge can pass.

Once reaching the aperture on the outer tiles, the latches spring back to catch on the edge of the tile. From the outside, they can be pressed to enable them to slide back out under the outer tile perimeter.

DESIGN

Much of the design remains the same. The latches are of a similar shape to the previous connections; "permanent" connections between always connected tiles have been simplified and made smaller. However, like the last version, all connecting elements are re-placeable.

EFFECT

The open space and layers create a sense of discrete "islands" between each tile. The black on the inside might be better replaced with an off-white board or the tile on the outside with natural cardboard to break up the black, as it currently has too much of a "technical" feel.

REMARKS

The two goals for this variant were to make the entire product 100% recyclable with no processing necessary on the part of the end user and to devise a more secure tabbing mechanism for constructing the sphere.

Due to the amount of dye used to make the black mat board, it may not be the most eco-friendly approach. Natural .0625" cardboard is a viable alternative.

The hinging latch mechanism works well to keep the sphere secure, but it can be a bit confusing to unlock it once assembled. An advantage of the prior iteration was that the sphere could essentially be pulled apart.

The space between the two layers and the flexibility of the hinges create a flimsy feeling. The nails have a tendency to slide out when assembled. Cardboard scraps from production could be used to make a simple glue to hold certain nails.

While not fully recyclable, the cork tiles from the previous iteration are compatible with this version, so this design could be "upgraded" with the cork for a deluxe edition.

MATERIALS

0.0625" black mat board

DIMENSIONS

OUTER HEX: 1" edge
OUTER PENT: 1" edge
SOLID: ~2.5" radius

STRUCTURE

Some adjustments need to be made in order to fully realize this design. The interior tiles are a bit too large and the latches are a bit too long. Both of these issues prevent flush connections between the outside tiles - an easy fix.

Assembly is even more time-consuming than the previous version. Short of creating a novel production process, the design would likely need an overhaul for mass manufacture.



ikikaza

PROTOTYPE 3: USE



VERSATILITY

Like prior iterations, the open **ikikaza** net can be used for decoration by placing tiles with various shapes into the spaces provided. It can also be hung up flat on the wall as a decoration in itself.

Different versions might be suited to different uses.

One version might have an empty space on both layers, so that when the net is folded into a sphere, it can be attached to a lightbulb to act as a lamp.

Another version might make use of the cavity between the two layers, to allow for planting small plants.

ASSEMBLY

This is the first design to actually produce and incorporate the central pillar. This pillar acts as an internal support for the sphere as well as acting as storage. It is hexagonal in shape with enough space to hold all of the cork tiles (if used) or game tiles within.

Extra cartridges (the smaller pillar pictured) might contain preferred objects or be used as additional space for holding accessories and tile packages. Up to 6 can fit onto the central pillar within the sphere.

These cartridges could be sold separately and mix-and-matched at initial purchase so users can decide what functionality they want for their **ikikaza**.

All kits would come with spare connector pieces and nails for user repair.



MATERIALS

0.0625" mat board,
various colors

DIMENSIONS

OUTER HEX: .75" edge
OUTER PENT: .7" edge
PIECE HEIGHT: .75"

mahabhuta player reference

TURN SEQUENCE

LAND: Use the land ability of the tile you are on.
PLACE: Place one of your land tiles on a space.
MOVE: Move 0+ spaces until the level or type changes.
DRAW: Take a tile from the main stock.



VICTORY: Collect all five rings and reach the center space.

LAND TILES

- abyss**
Ends Move phase (no ability).
- cave**
Use the ability of any land tile.
- lake**
Trade in any number of tiles.
- vista**
Draw a land tile of any type.
- cloud**
Move one space.
- volcano**
Place or remove a tile.
- forest**
Place a tile from your stock.
- gate**
Move to space with gate of same shape (if present).

AFFINITY (OPTIONAL)

- form** If on an Abyss, place a land tile of any type on any Abyss. This can be from your stock or the main stock.

GAME

Mahabhuta is a Sanskrit word referring to the 5 elements of fire, water, wind, earth, and void or ether. The same word has been transmitted to Japan via Buddhism as *godai*.

Players seek to acquire one each of five rings located at the far end of each of the 5 arms of the **ikikaza** net. As they do so, they place tiles that represent different types of land that each have their own powers that players can draw upon.

Because the game board is blank, players can create their own tiles and invent their own games that take advantage of the uncommon board structure that the **ikikaza** net provides.



CATEGORY | PRODUCT DESIGN / TOY DESIGN



frollicking egg

Spring 2019

frollicking egg is a 3D puzzle developed under the following criteria:

- Fits within a volume of 10 cubic inches
- Composed of 4 interlocking pieces
- Contains a hidden volume for storage

What made this challenge especially interesting was the search for a theme or implicit narrative that “justifies” the geometry of the product.

There are plenty of puzzles of this kind that present themselves solely on the merits of the spatial challenge they offer - this attempt seeks to offer something new.



CASE STUDIES I: OBJECTS

RETICULATED SPHERE | COLLAPSIBLE LANTERN | GLASS ARMONICA



RETICULATED SPHERE

ORIGIN: CHINA
DESIGNER: TRADITIONAL ARTISANS
MATERIAL: IVORY (sometimes jade)
DATE: 14th CENTURY ONWARDS (or earlier)

These puzzles involve rotating the inner spheres in order to make all apertures align. They were usually ornamental, as attempting to solve them can easily damage them.

I admire the simplicity of the puzzle, the fact that it need not rely on trial and error, and its integration of form with function.



COLLAPSIBLE LANTERN, "SOUL CELL"

ORIGIN: SWEDEN
DESIGNER: JESPER JONSSON
MATERIAL: CANVAS, PLASTIC
DATE: 2011

This lantern design embraces the material traits of the fabric that acts as the shading element via its collapsible design, leading to added functionality.

The Soul Cell's contribution to the ideation process is general: I wanted to find a way to design function into the puzzle.



GLASS ARMONICA

ORIGIN: USA
DESIGNER: BENJAMIN FRANKLIN
MATERIAL: GLASS, CORK, WROUGHT IRON
DATE: 1761

The glass armonica was invented by Benjamin Franklin to "instrumentalize" singing wine glasses. By rotating the central shaft and wetting the bowls, it can be played similarly to a piano.

I took a look at these after deciding I wanted to incorporate sound. I am drawn to its tone, and admire the elegance of the solution.

CASE STUDIES III: PROCESSES

IMPLICATE/EXPLICATE ORDER | HOLOGRAMS AND ANALOG SOUND

IMPLICATE | EXPLICATE ORDER

Implicate/explicate order is a concept developed by physicist David Bohm to resolve strange observations in quantum mechanics. As I was thinking about ancient tools, I was reminded of the idea.

While the mathematical justifications are not accessible to me, the concept is that phenomena in the universe may be modeled as abstractions of a unified phenomenal ontology at a "deeper level" of reality: the "implicate" or "enfolded" order.

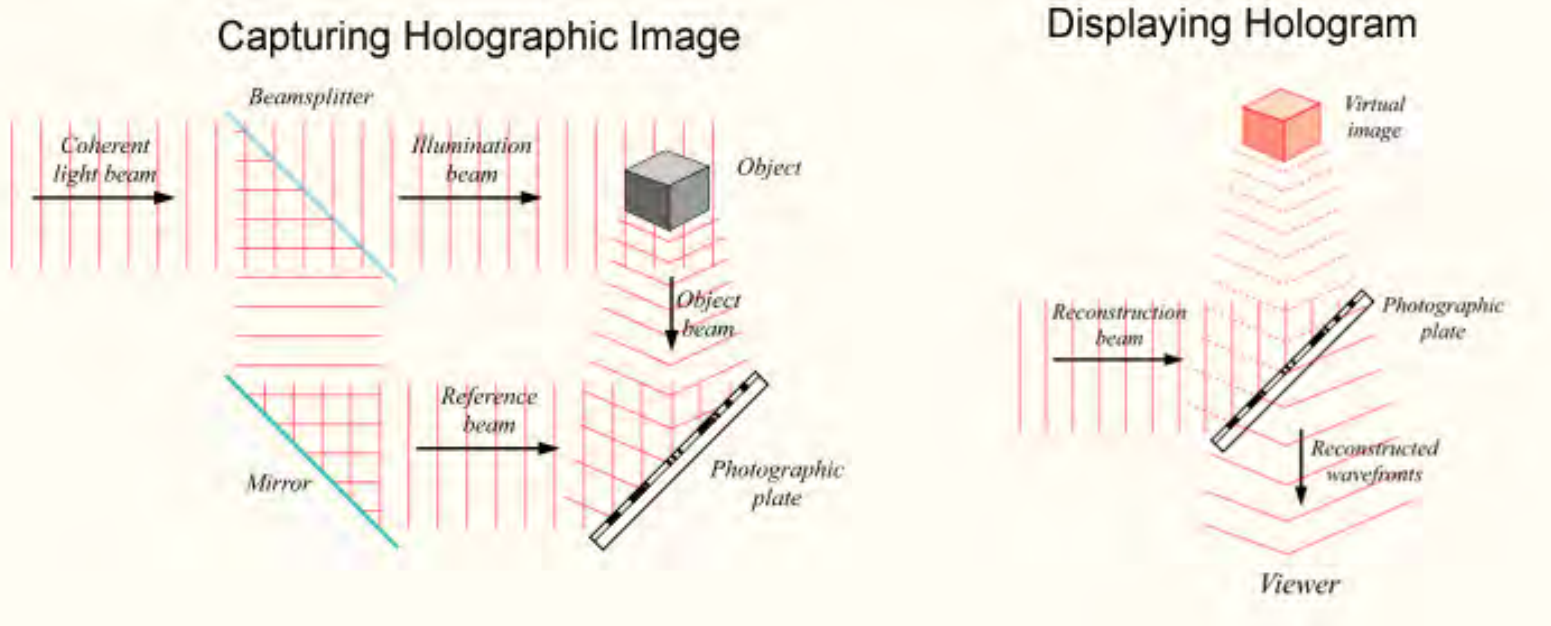
This relationship between two levels of information struck me as an interesting theme for a 3D puzzle.

ANALOG SOUND AND HOLOGRAMS

Holograms are one way to think about the relationship between an implicate and explicate order. 3D image information is encoded onto a 2D substrate, which can then be activated to project the 3D image - but no matter how real the image appears, it is ephemeral in comparison to the coding on the substrate.

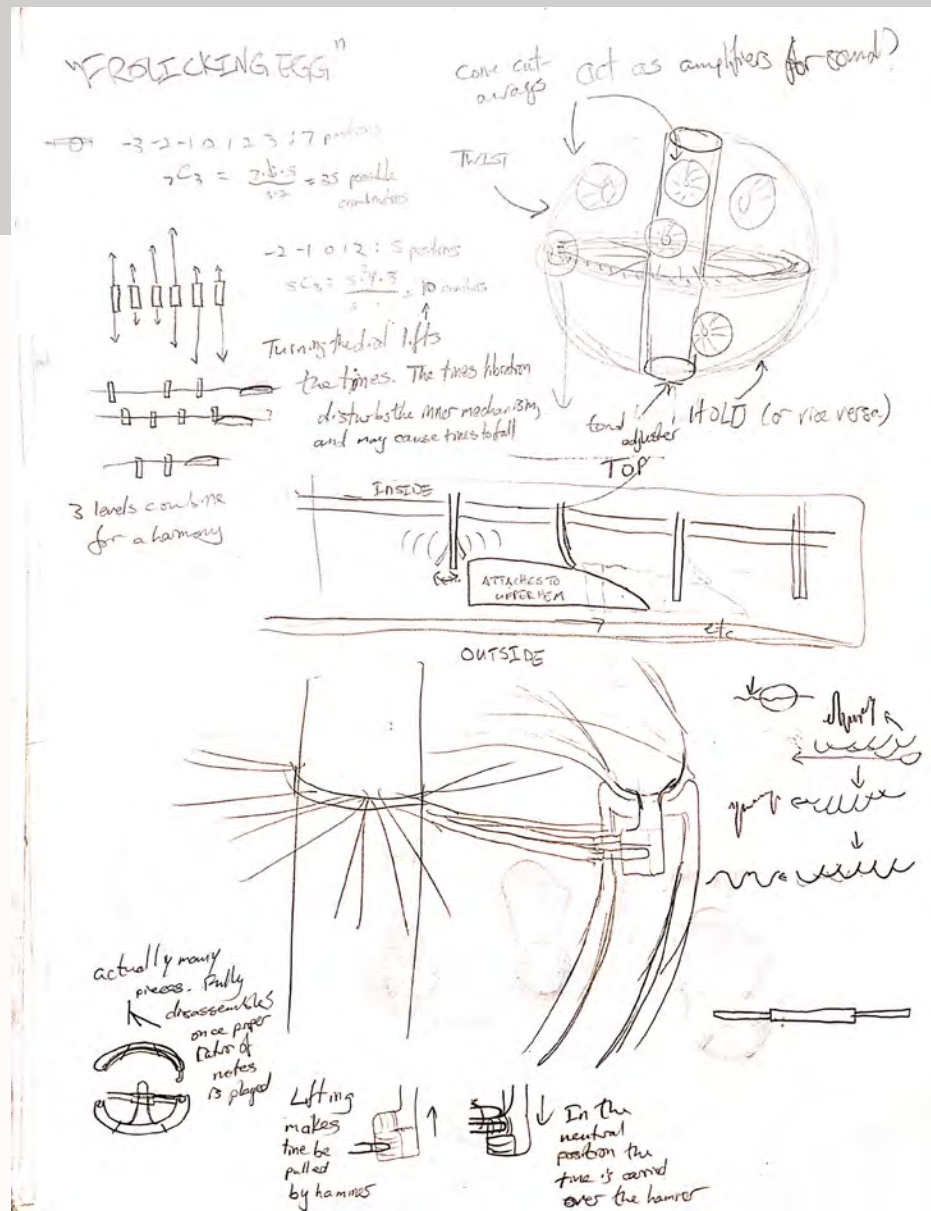
There is a similar relationship between vinyl records and sound waves. Analog sound recording is essentially the engraving of the shape of a waveform itself onto a physical medium. The recorded wave can be "induced" by using a needle to create vibrations "shaped" by the etched channel.

I started thinking about a puzzle design that has layers of meaning or information. The puzzle would have an "explicate" interface with an "implicate" logic that cannot be directly accessed. I liked the idea of using sound - given its transience - as the bridge between these levels.



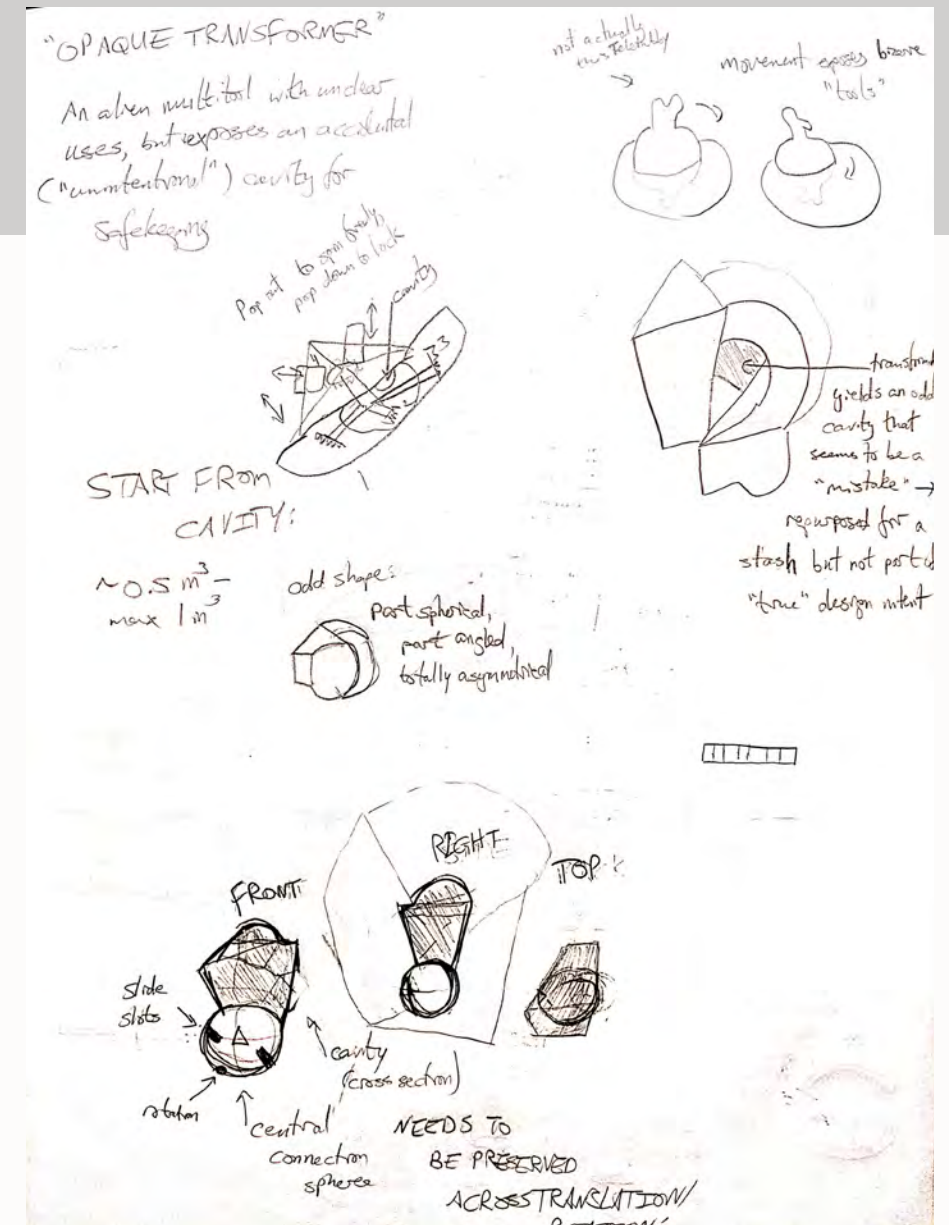
DESIGN IDEATIONS

i. frolicking egg



frolicking egg is a sound-based puzzle with two interlocking hemispheres with free rotation. When the top hemisphere is rotated, tones are produced from parts attached to the central pillar. Playing the proper sequence unlocks the hemispheres via a central mechanism.

ii. opaque transformer

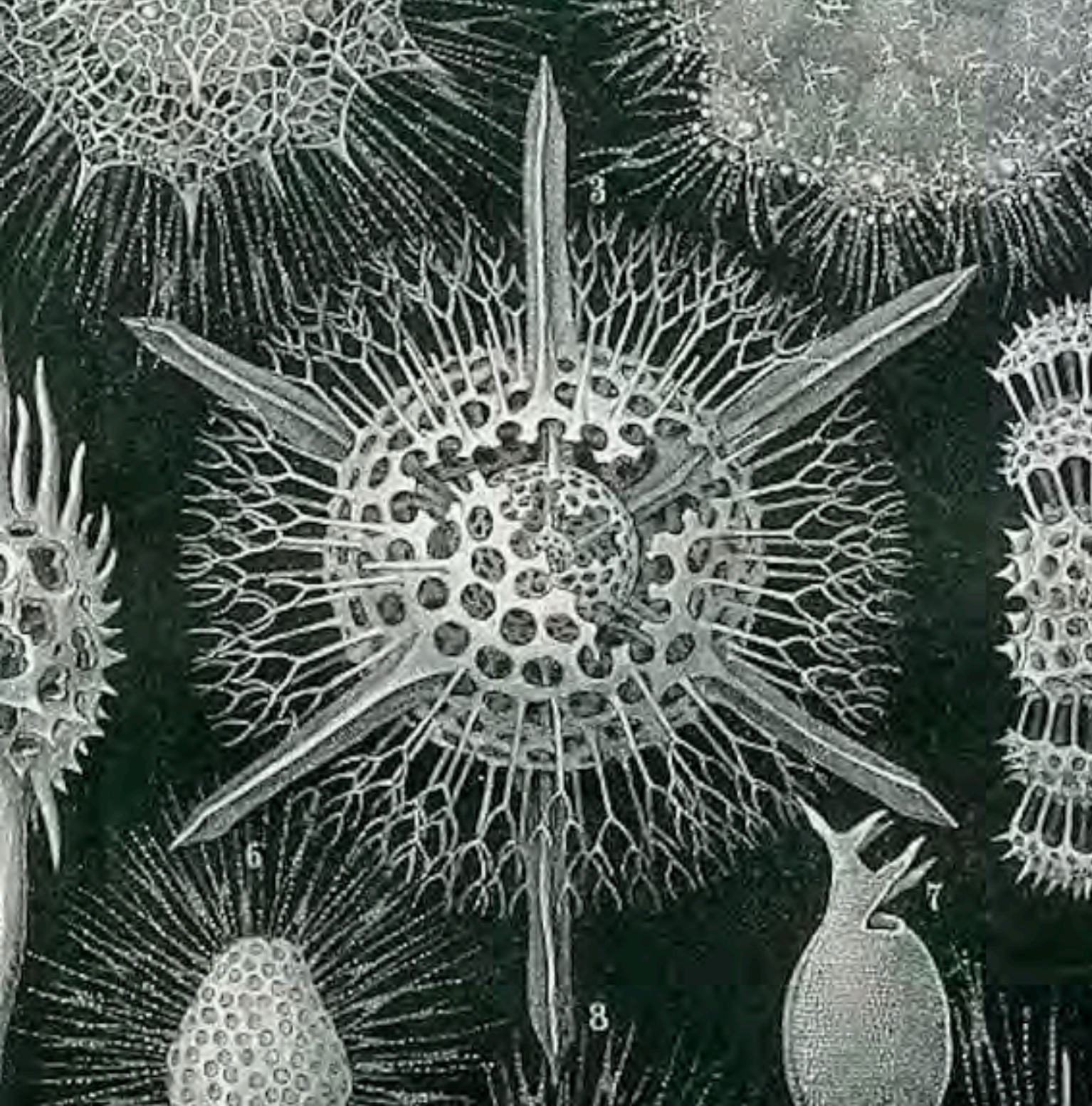


opaque transformer is a block-based puzzle with a number of obscure features that present as tools for an inscrutable purpose, to be used by some (non-human?) user. A cavity is revealed by finding the right parts to revolve and position, but its ugly asymmetry suggests it was never part of the original intent.

INTERESTS | AIMS | DESIGN INTENT

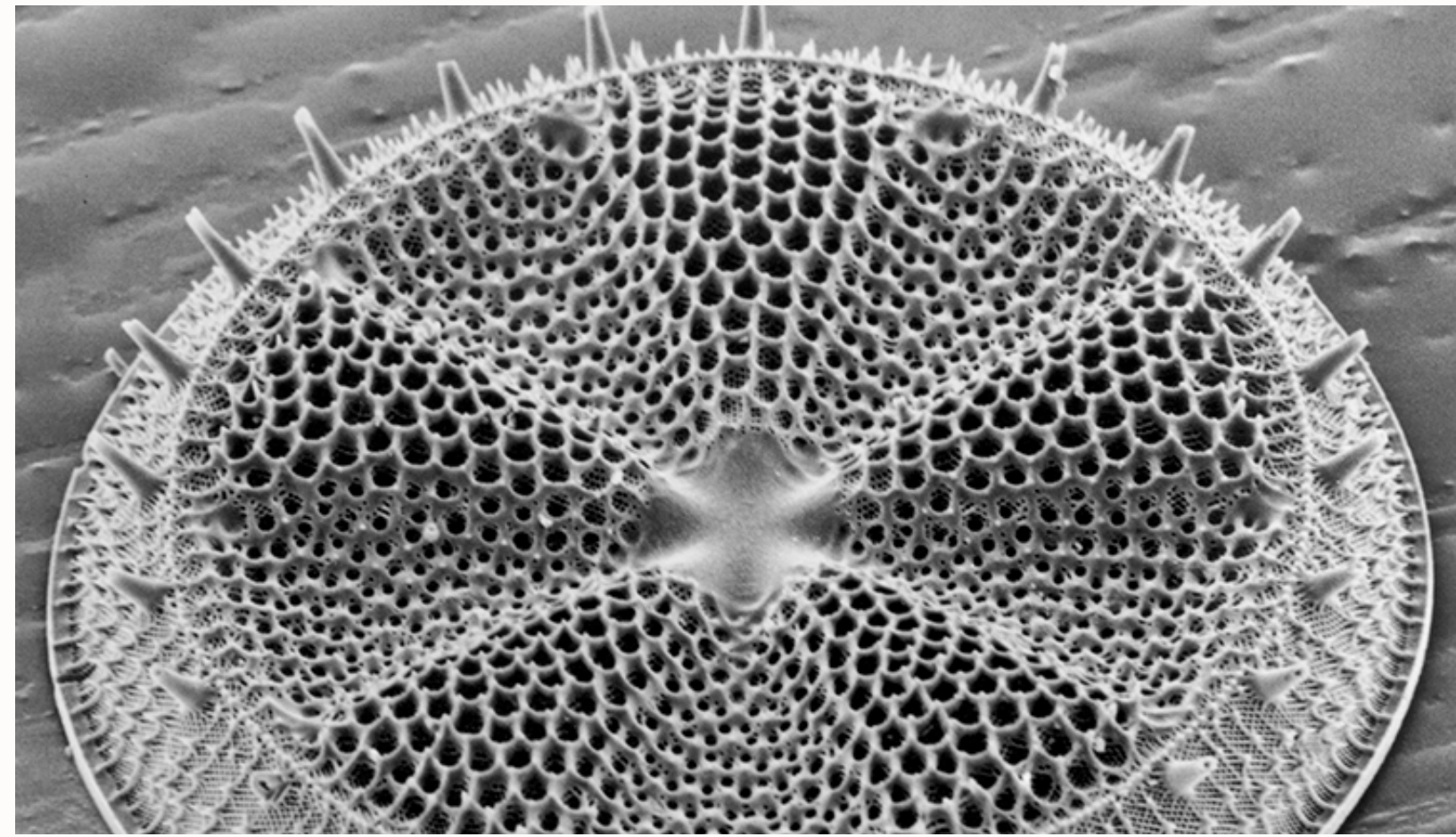
- +ALTERNATIVE FUNCTION OR IMPLIED FUNCTION
- +SOLUTION HAS NO GUESSWORK OR IS A DISCOVERY PROCESS
- +SENSE OF MYSTERY OR OF THE UNKNOWN

- +PARSIMONY OF FEATURES (FORM/FUNCTION UNITY)
- +VISUALLY INTRIGUING
- +PROPERLY SATISFIES ALL CONSTRAINTS



frollicking egg

Formally, frolicking egg draws heavily from the Chinese reticulated sphere puzzle. The strange organic appearance of the spheres is reminiscent of diatoms, radiolaria, and other unicellular organisms with patterned "skeletons." Not only might these patterns be used as geometric inspiration, but the holes might potentially be engineered as "speakers" to amplify the sound by forming them into cones from the interior to the exterior.



USER PROFILE

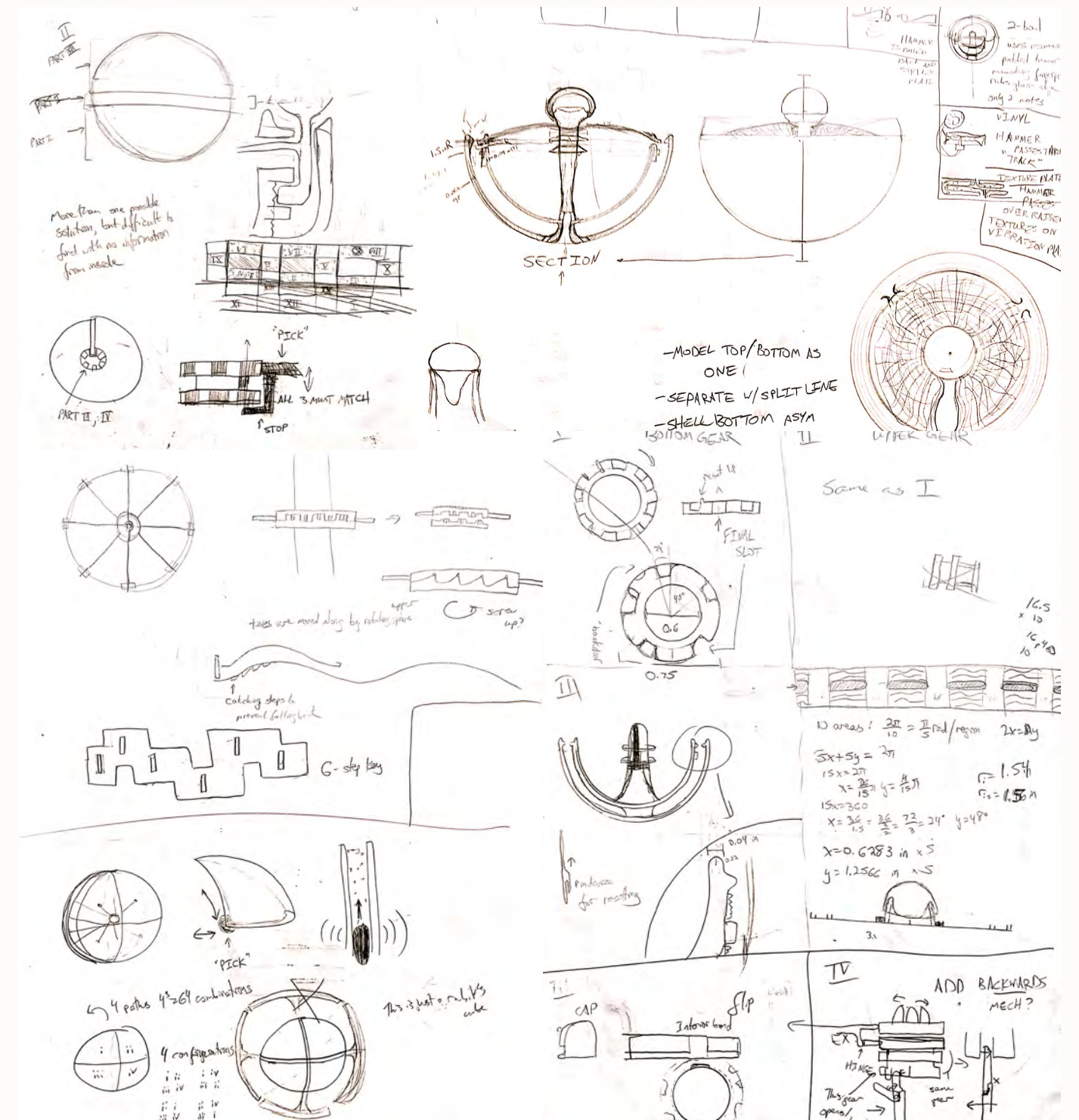
My process, rather than selecting a target user, has instead been to ask myself what I would like more of, what I would like to see, what I think would be interesting etc. The aim is something of a conceptual or experimental one: I would love to stumble across an inscrutable object like this, and want to know if it can produce a similar feeling of interest in others.

I envision the final product as closer to "art piece" than "main-stream consumable." If sold, I think it might fit in museum gift shops or design boutique stores. Preferably, this would be without a package or explanation - almost like an antique or curio.

In keeping with that, at risk of pretension, I think the design would be most successful if made with high quality or obscure materials and attention to detail, aiming to appeal to people who like collecting strange objects, unique design pieces and the like. Its musical qualities may make it appealing to musicians as well.

While a cheap "toy" version of it could be made, I think seeing rows of them on a shelf in gaudy packaging and an instruction manual would destroy the sense of mystery and discovery I would like it to produce. Then again, children may not be that picky about it.

frollicking egg



Further ideation sketches



frollicking egg



The puzzle consists of turning a hemisphere to produce sounds in a sequence that will enable the hemisphere to disengage. Rather than the tine approach considered in early ideations, this approach focuses on the possibilities of a “resonant bowl” for sound production.

An unofficial thematic goal emerged in the design process to seamlessly blend biological and technological cues - to make the object hover as much as possible between organic object and human artifice - in an attempt to create an otherworldly effect that is simultaneously accessible and pleasant, yet alien.

The biological formal influence can be seen in the stem plate (radiolaria/diatoms) and in the ribs of the upper part (mushroom gills). To push this a step further, the puzzle could potentially be made out of a type of chitin - the cellulose-like polysaccharide found in arthropod carapaces and mushroom stalks. Sustainable bioplastics made from this material are already under investigation.

4

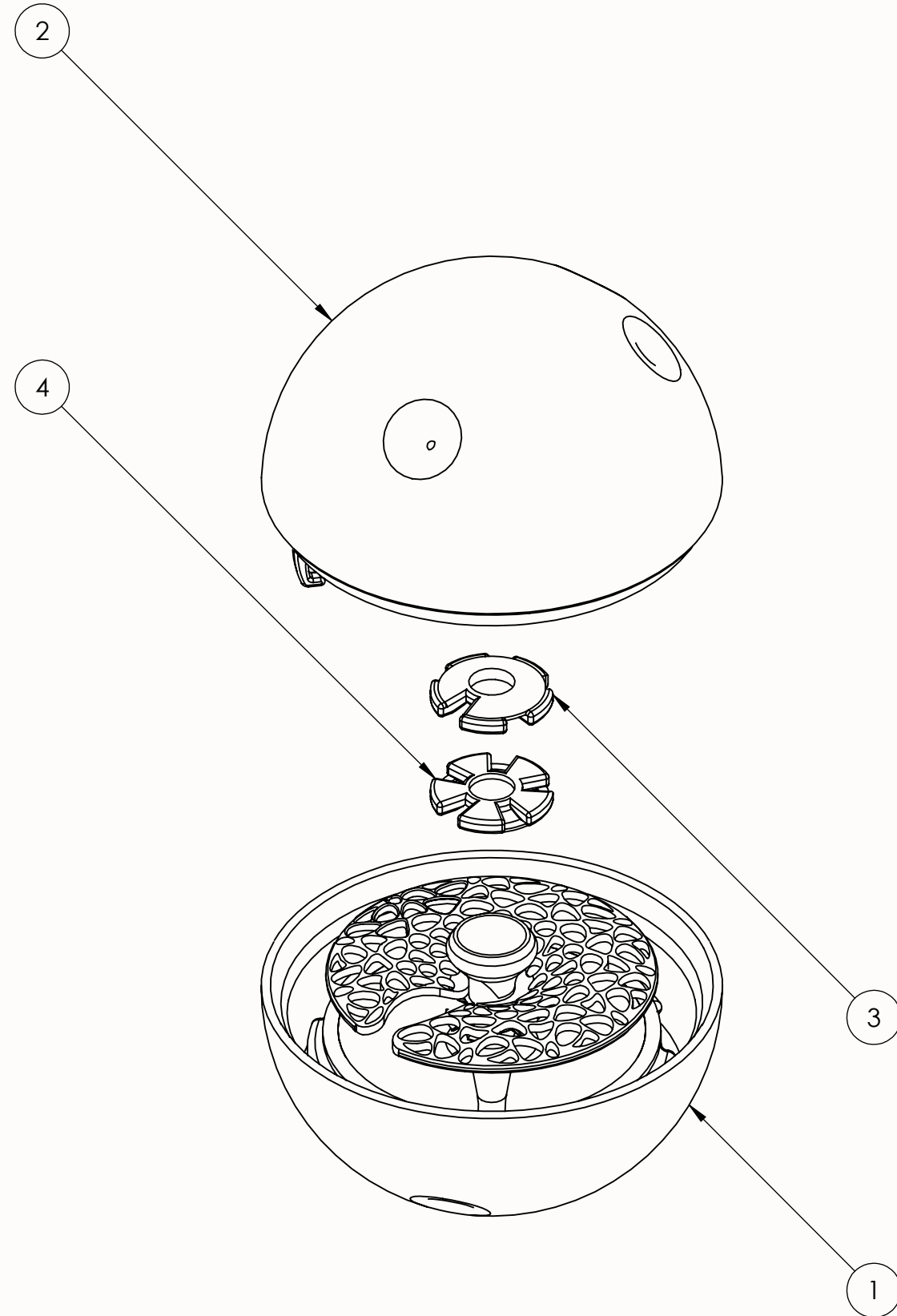
3

2

1

PART NO.	PART NAME	DESCRIPTION	QTY.
1	LOWER HEMISPHERE	CHITIN	1
2	UPPER HEMISPHERE	CHITIN	1
3	UPPER GEAR	CHITIN	1
4	LOWER GEAR	CHITIN	1

DETAILS	
MASS	0.244 lbs (as plastic analog)
VOLUME	6.77 cubic inches
CAVITY VOLUME	.065 cubic inches
PIECE COUNT	4



(SCALE: 1:2)

THOMAS S. EVANS

TITLE:

FROCKLING EGG
ASSEMBLY

SIZE	DWG. NO.	REV
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B		
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SCALE: 1:1	WEIGHT:	SHEET 1 OF 1
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4

3

2

1

B

B

A

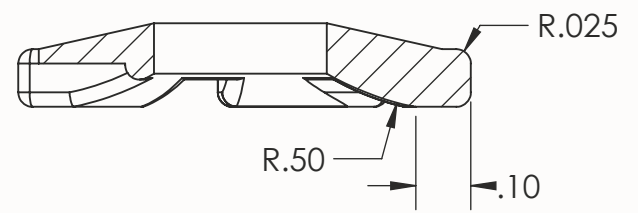
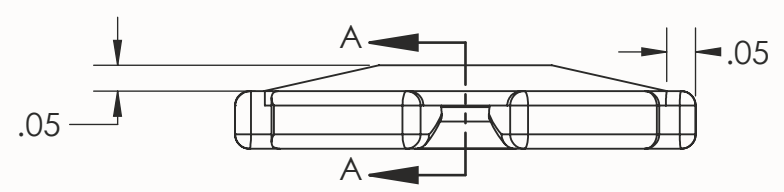
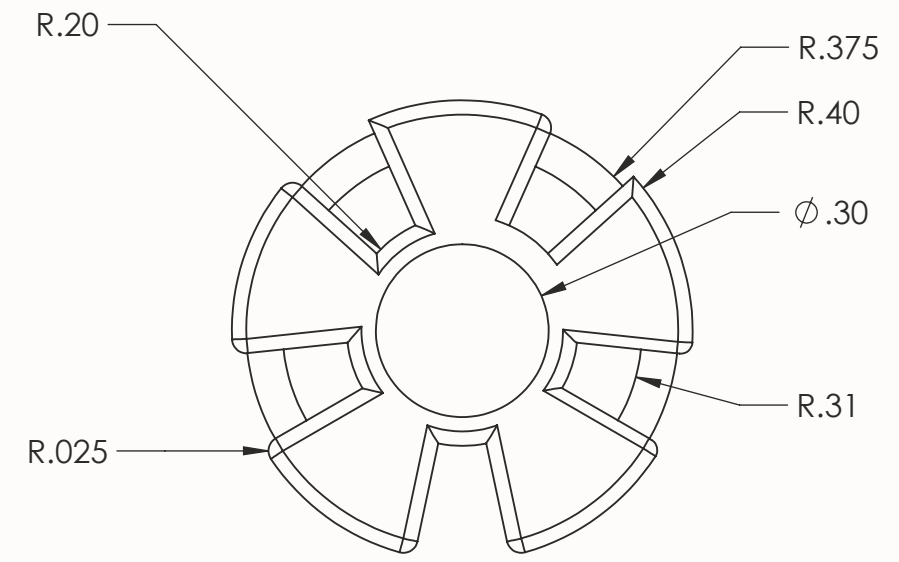
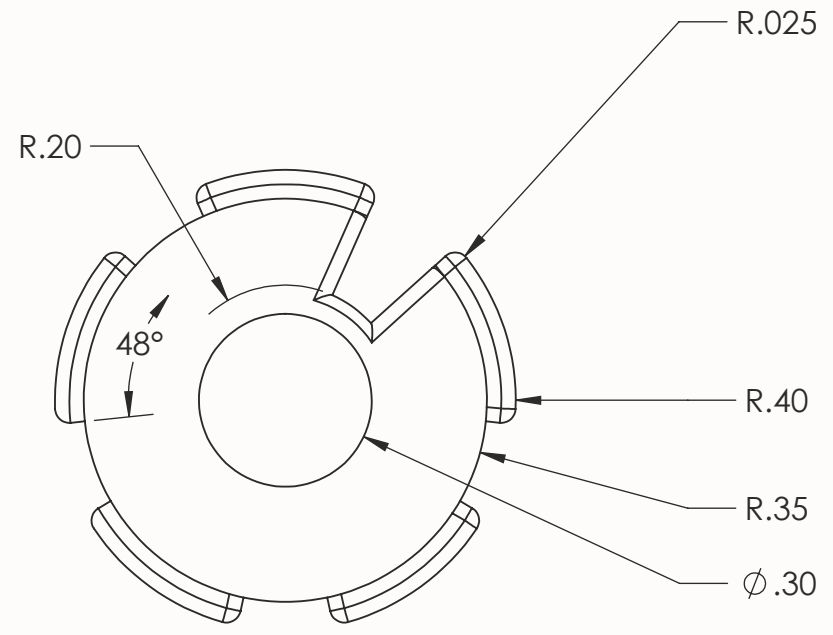
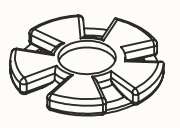
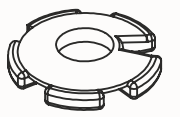
A

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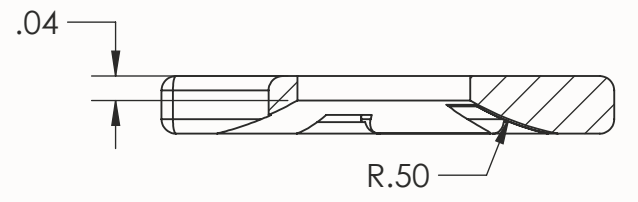
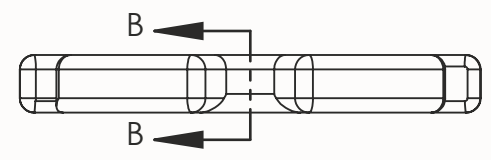
3

2

1



SECTION A-A
SCALE 3 : 1



SECTION B-B
SCALE 3 : 1

UPPER GEAR

LOWER GEAR

THOMAS S. EVANS

TITLE:
UPPER GEAR
LOWER GEAR

SIZE	DWG. NO.	REV
B		

SCALE: 2:1		
------------	--	--

4

3

2

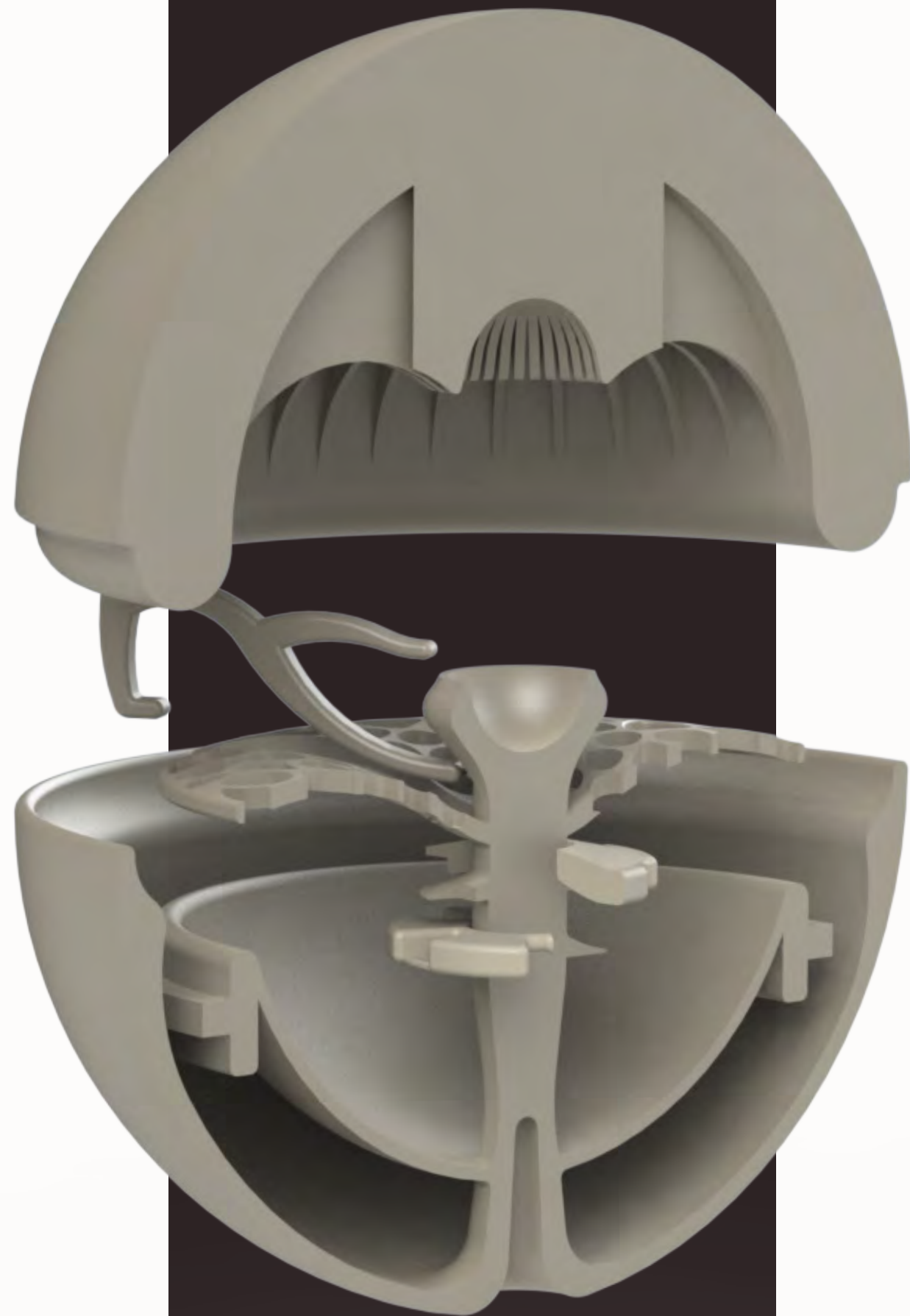
1

B

B

A

A



CENTRAL MECHANISM

The Egg locks with hooded gears that are associated with the sound producing regions. Rotating the Egg leads to the prong becoming entangled in the gears. These gears have one location each with no hood; alignment of these locations with the entry site unlocks the Egg.

The position of the gears cannot be seen directly from the outside. Rather, on the exterior, solutions for each position would be encoded to guide alignment. The solutions refer to sounds, and the sounds have to be identified by rotating the Egg. These solutions would not necessarily be the most straightforward approach, but may have aesthetic value in the melody they produce.

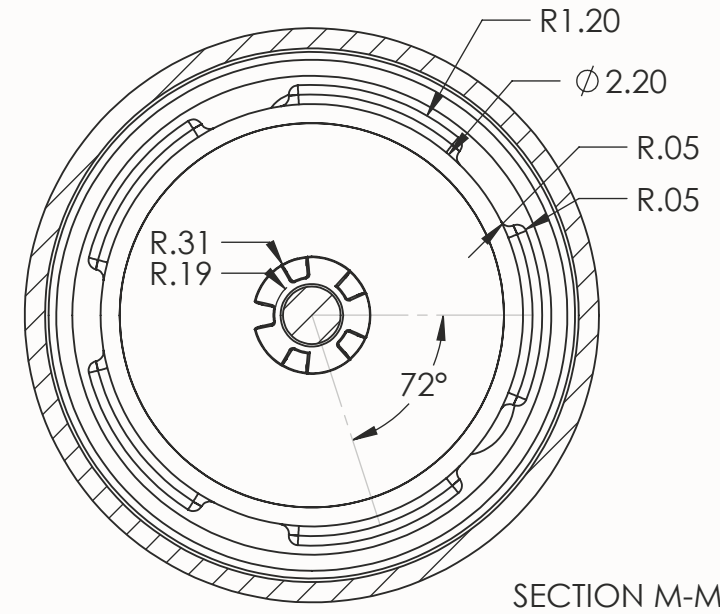
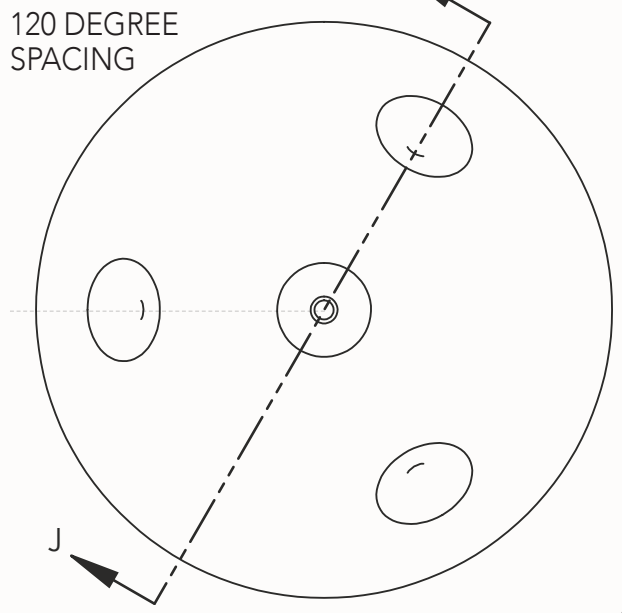
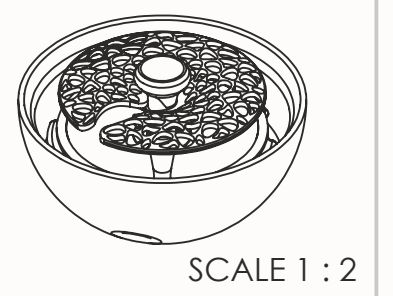
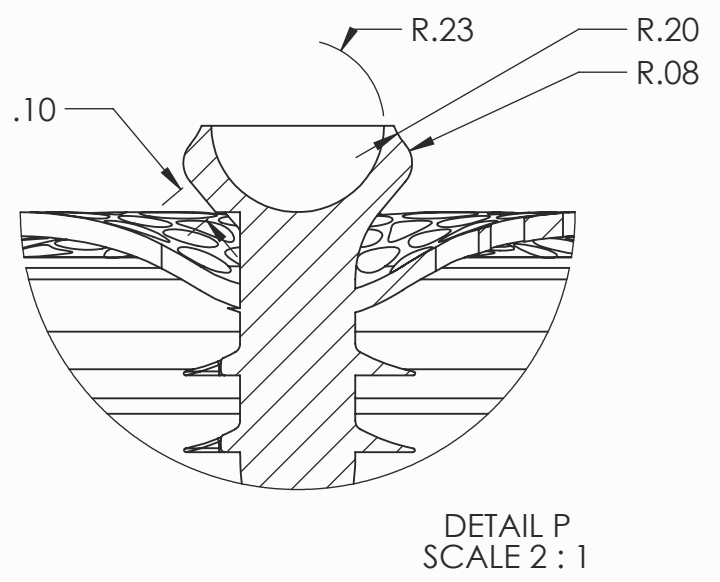
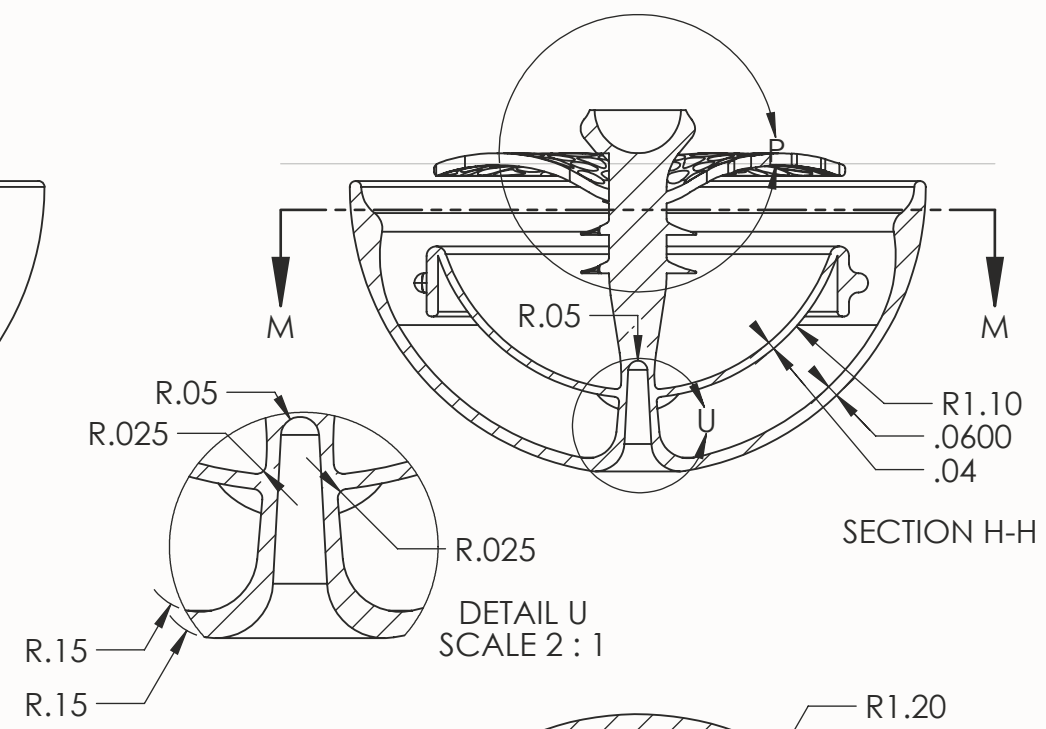
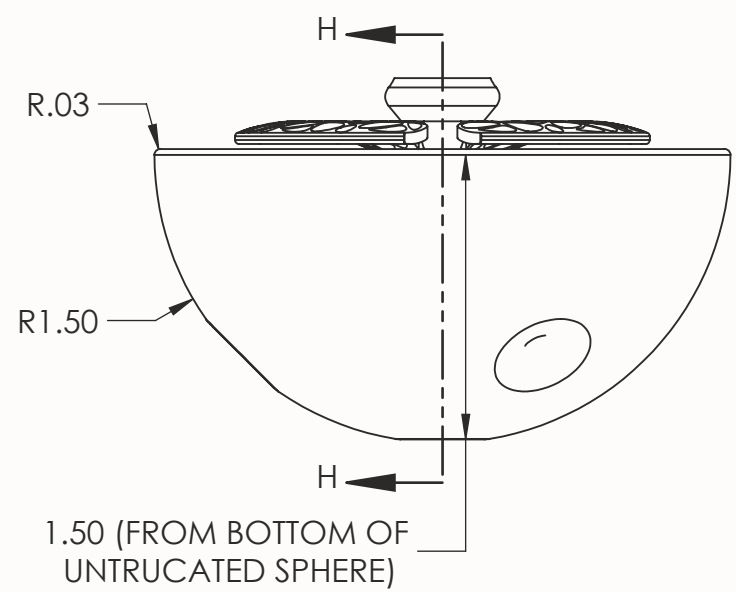
Originally, I thought there would be 25 (5×5) unique positions for the gears, but because the prong cannot disengage, they are locked in a modulo 5 pattern that keeps the gears and prong in the same relative position. There are thus only 5 unique positions, despite 2 5-toothed gears. Future iterations might explore ways of making this more complex.

4

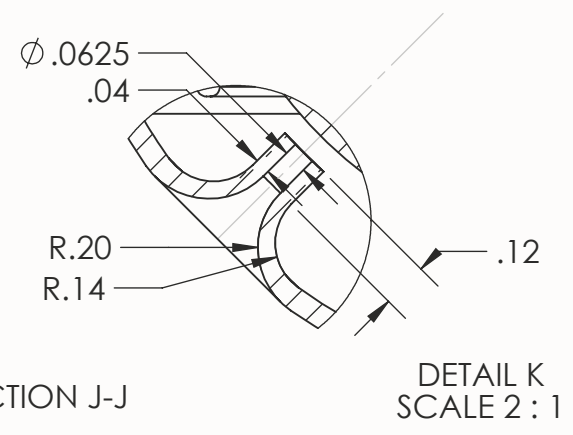
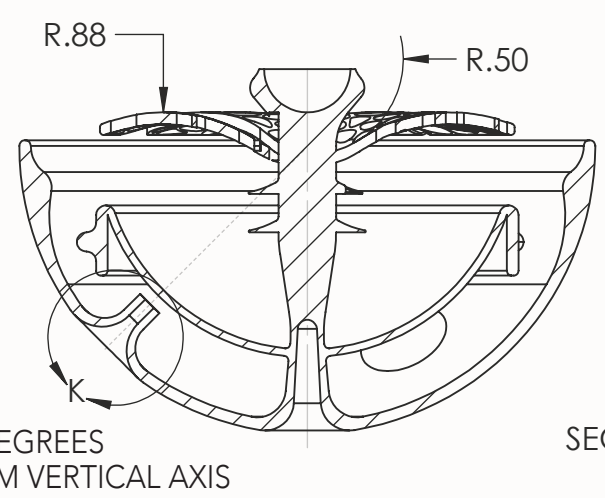
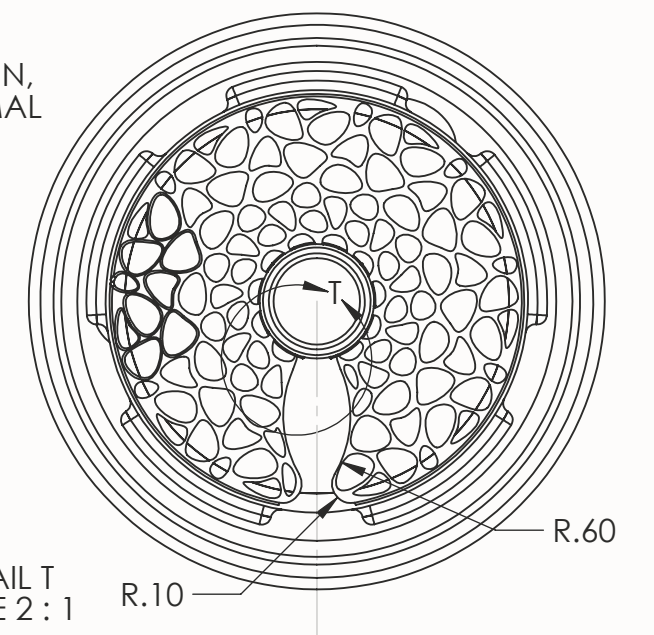
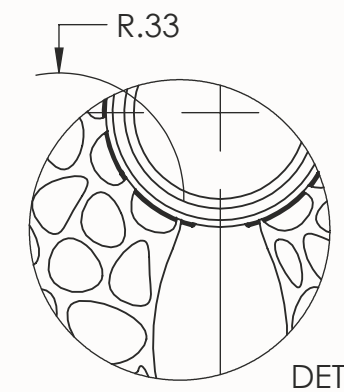
3

2

1



SHAPE SPLINES AT DISCRETION,
PATTERNED RADIALLY NORMAL
TO LATERAL DIAMETRIC AXIS



THOMAS S. EVANS		
TITLE:		
EGG LOWER HEMISPHERE		
SIZE	DWG. NO.	REV
B		
SCALE: 1:1		

4

3

2

1

B

B

A

A

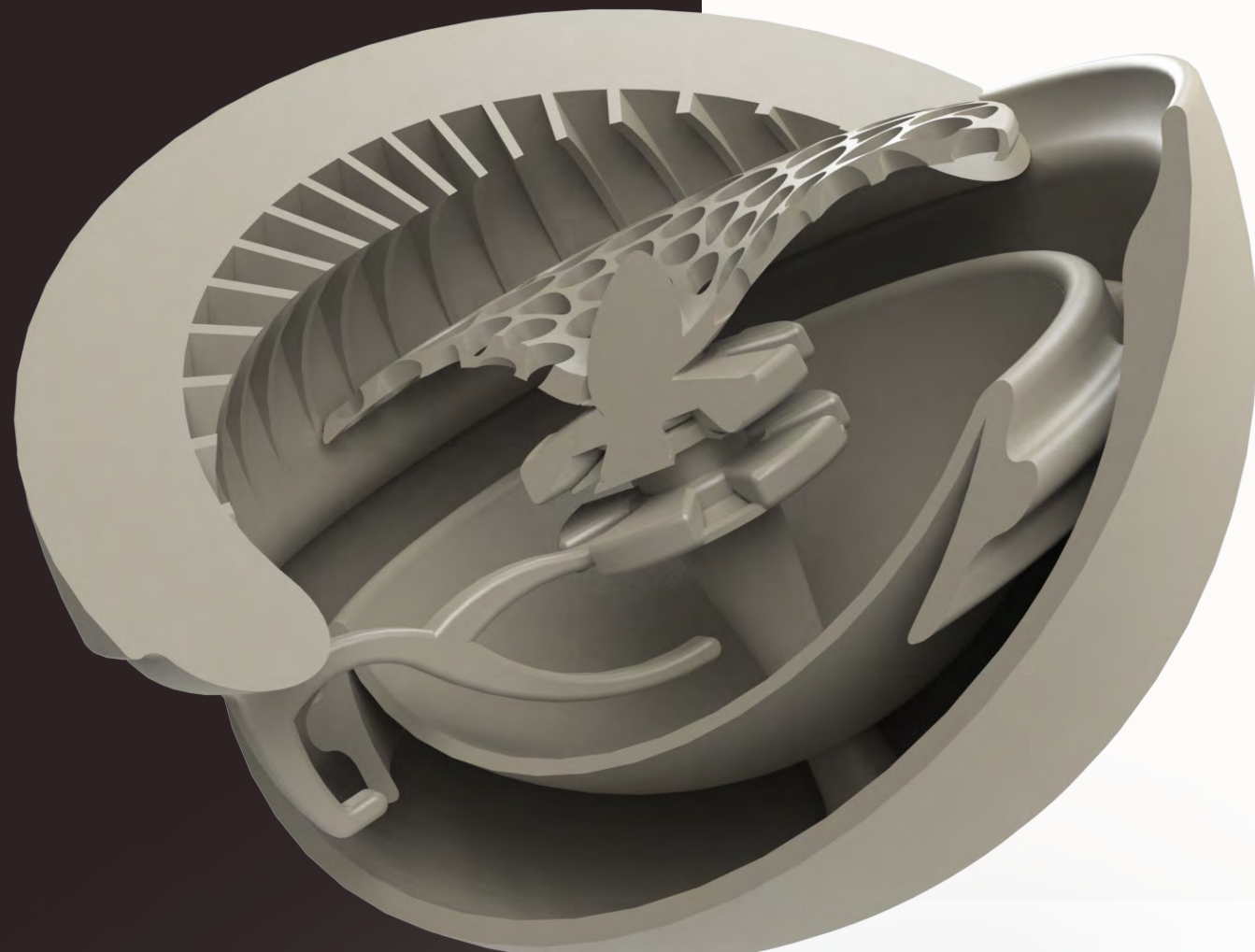
LOWER HEMISPHERE

The lower hemisphere is the central part of the puzzle. It consists of two bowls - an outer shell and the resonance bowl inside - a central stem with frills that houses the gears, the cavity cup, and an upper plate.

The resonance bowl (inner bowl) houses the sound production interface. In the analog waveform iteration to the left, the foldover region of the inner resonance bowl would be inscribed with a waveform like a vinyl record at each of the sound production sites. When a needle (attached to the prong visible to the left) passes across these channels, the bowl itself would vibrate, producing sound. This is a hypothetical approach that may not work.

The volume of the cavity cup is quite small. Future iterations could position it asymmetrically opposed to the prong entrance channel; this approach may make it easier to modify the gears to be involved in forming the cavity to properly satisfy the cavity constraints.

The stem plate currently needs more finessing to look properly like its inspiration. Two additional small insertion points placed along the edge of the stemplate (with corresponding hooks for the upper part) would offer additional rigidity.

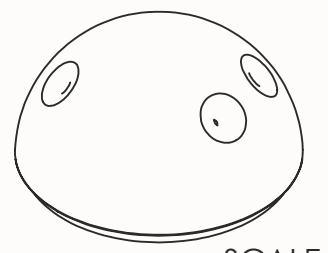
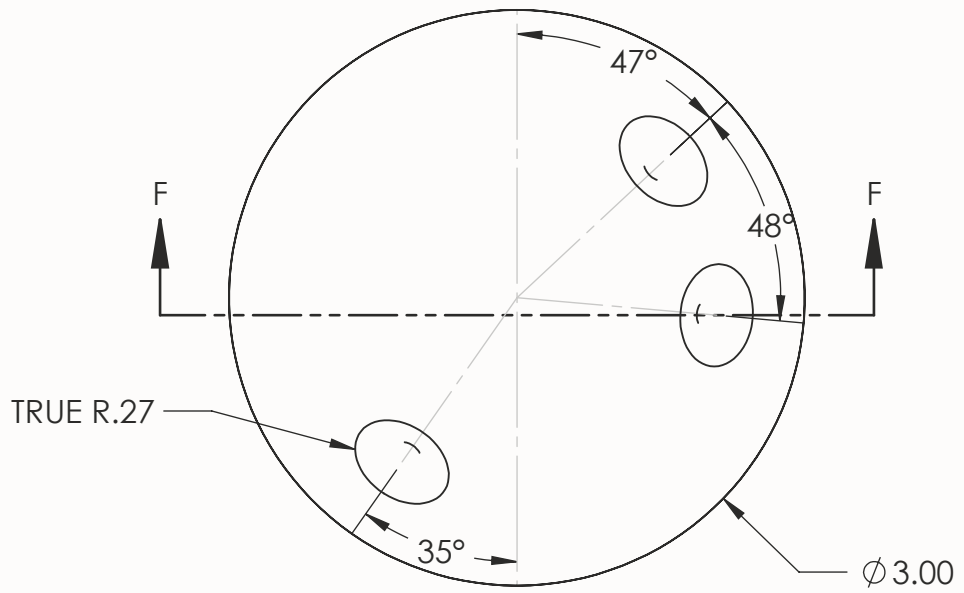
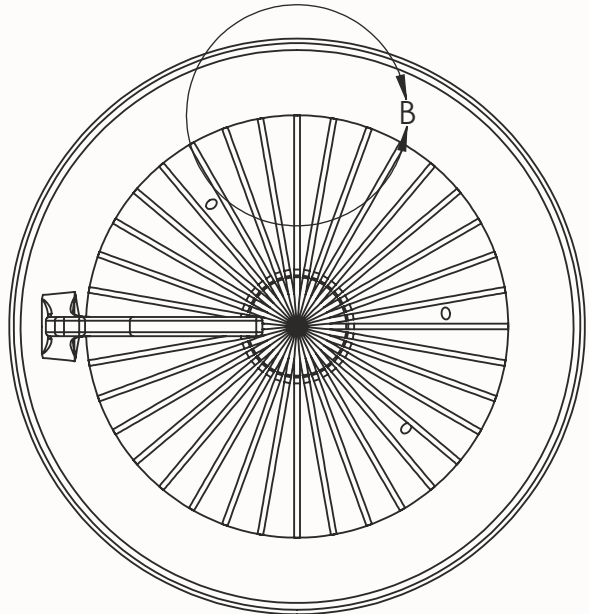


4

3

2

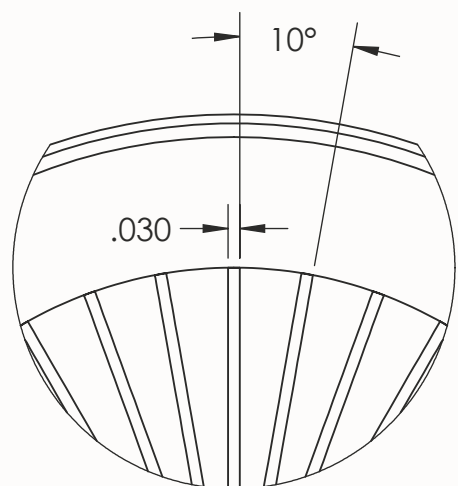
1



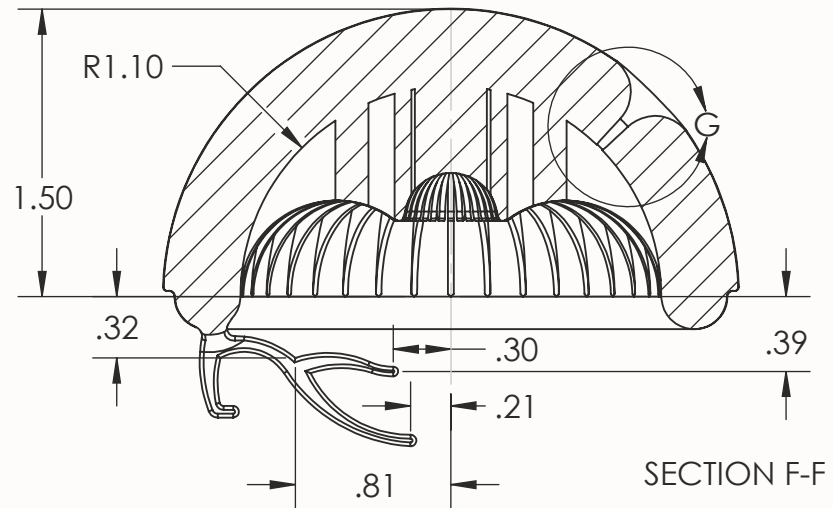
SCALE 1 : 2

B

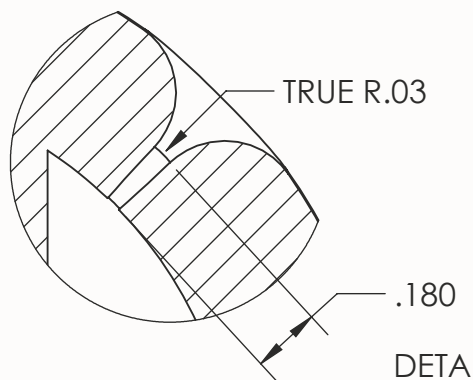
B



DETAIL B
SCALE 2 : 1



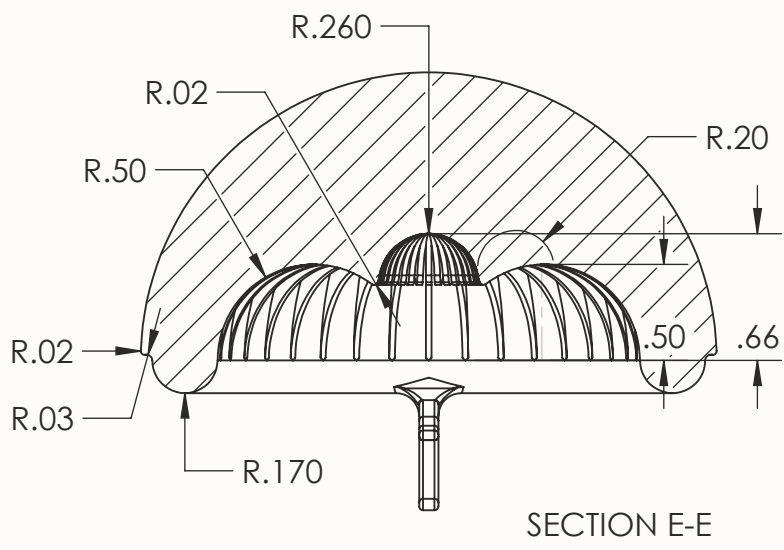
SECTION F-F



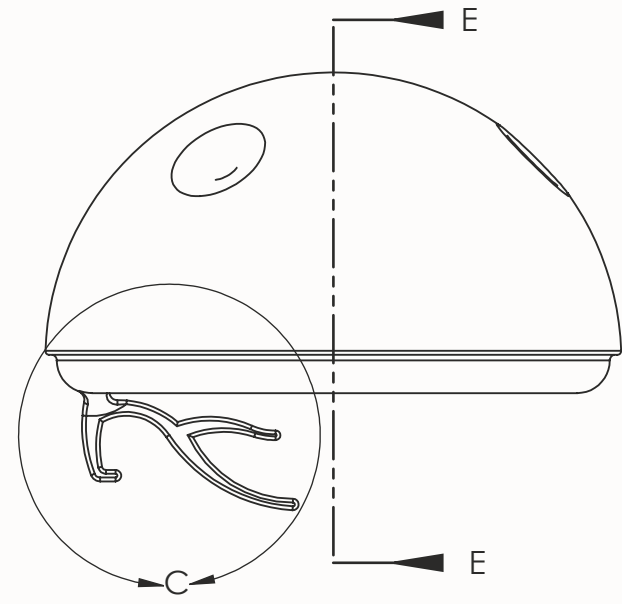
DETAIL G
SCALE 2 : 1

A

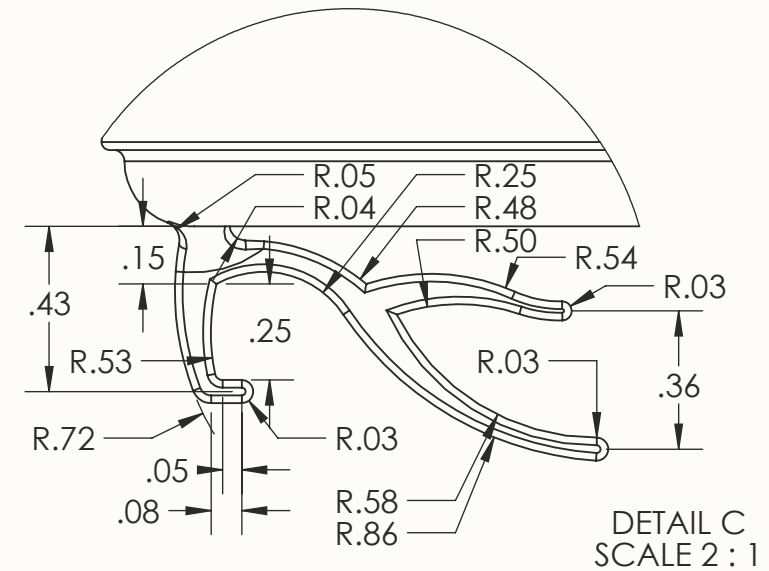
A



SECTION E-E



3



DETAIL C
SCALE 2 : 1

THOMAS S. EVANS		
TITLE:		
EGG UPPER HEMISPHERE		
SIZE	DWG. NO.	REV
B		
SCALE: 1:1		

4

3

2

1

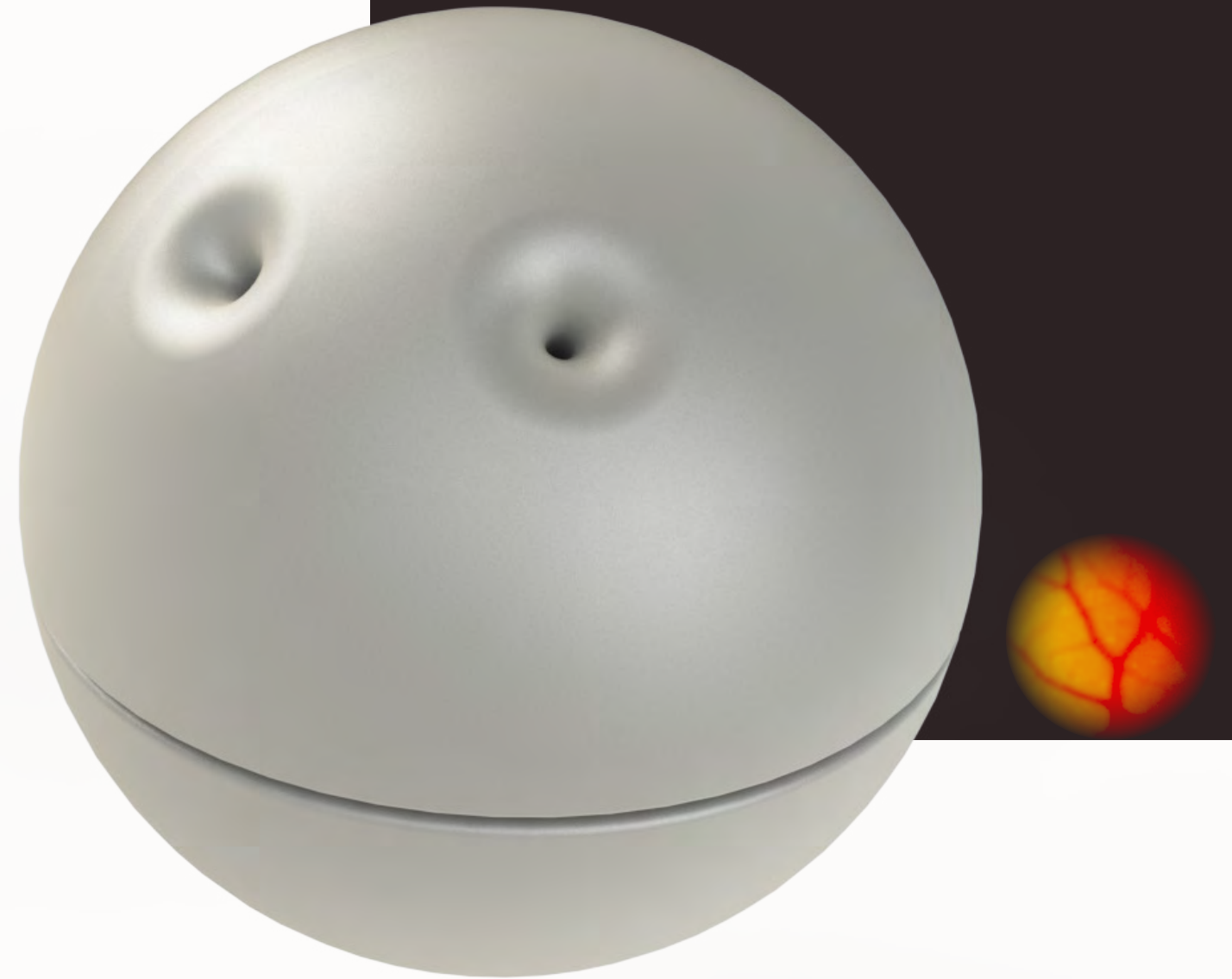
UPPER HEMISPHERE

The sound horns of the upper hemisphere may not contribute much to actual sound output, but they could potentially be used to see into the Egg to locate the current gear positions. Given that there are only 4 non-solution gear positions in this iteration, this may not be as necessary, but for a more complex version this feature would be critical.

After some thought into how to use light in a way that would maintain the “mystery” or “darkness” of the interior, I thought of the effect of illuminating eggs or one’s hand from behind. The semi-opaque glow it gives off seems to convey the proper mood.

By thinning the material at the proper locations, glowing dots might be visible through the upper hemisphere speaker horns, but these quasi-apertures would not be apparent when the hemisphere is removed.

When raising the hemisphere, too much of the interior is visible. Addition of a “perimeter shield” around the circumference tangent to the prong may rectify this.





FINAL ANALYSIS

Experimenting with sound production is the next major phase for development. The first step would involve casting the lower hemisphere and testing its resonance as an initial proof-of-concept.

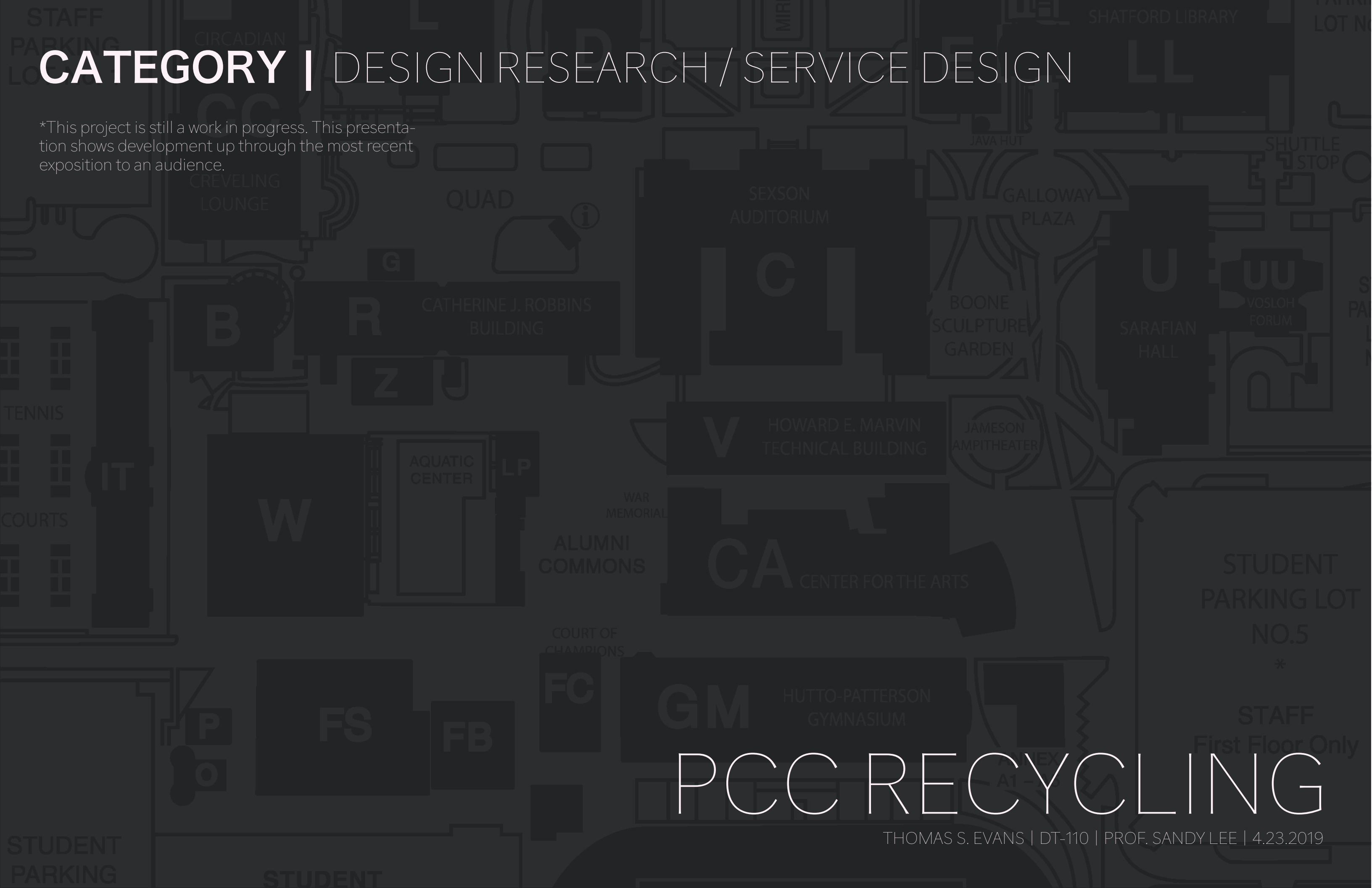
The inclusion of the light-based reset, the perimeter shield, the extra locks, etc. are all minor updates. The exterior patterning may be a phase of its own; while a provisional graphic code could be quickly wrapped onto the surface, satisfactory thematic/formal integration will take more thought.

Because of the somewhat ad hoc approach to this stage of the design process, some of the modeling strategies were a bit messy, which ended up impacting the schematics as well. Once a final design is settled on, a complete rebuild would allow for a more integrated design plan that would allow for swapping out different sound production configurations and the like.

Finally, a better presentation would aid in dynamic communication of the product. This particular rendition is too utilitarian.

CATEGORY | DESIGN RESEARCH / SERVICE DESIGN

*This project is still a work in progress. This presentation shows development up through the most recent exposition to an audience.



PCC RECYCLING

THOMAS S. EVANS | DT-110 | PROF. SANDY LEE | 4.23.2019

BACKGROUND

OVERVIEW

While Pasadena City College has made overtures towards sustainability in the past - with some notable successes - there may be problems with follow-through on some matters. The current vision is somewhat unclear.

The Measure P bond awarded to PCC roughly 20 years ago led to a dramatic overhaul of the campus - and funded the LEED-recognized Center for the Arts building - but going by recent budget reports, sustainability is not a major thematic pillar of its allocation.

While once there appears to have been more variety to the recycling system, the current system seems to lack support for some materials regularly discarded on campus.



PCC had at least some outdoors paper bins as recently as 2017



The LEED-recognized Center for the Arts building

APPROACH

RESEARCH

PCC SUSTAINABILITY
PASADENA RECYCLING
GENERAL WASTE SERVICES

INSTITUTIONAL WEBSITES
ARTICLES & VIDEOS
ENCYCLOPEDIA → SOURCES

ASSESS

DESIGN PARADIGM (FACILITIES)
BEHAVIORAL RESPONSE
USER (STUDENT) AWARENESS

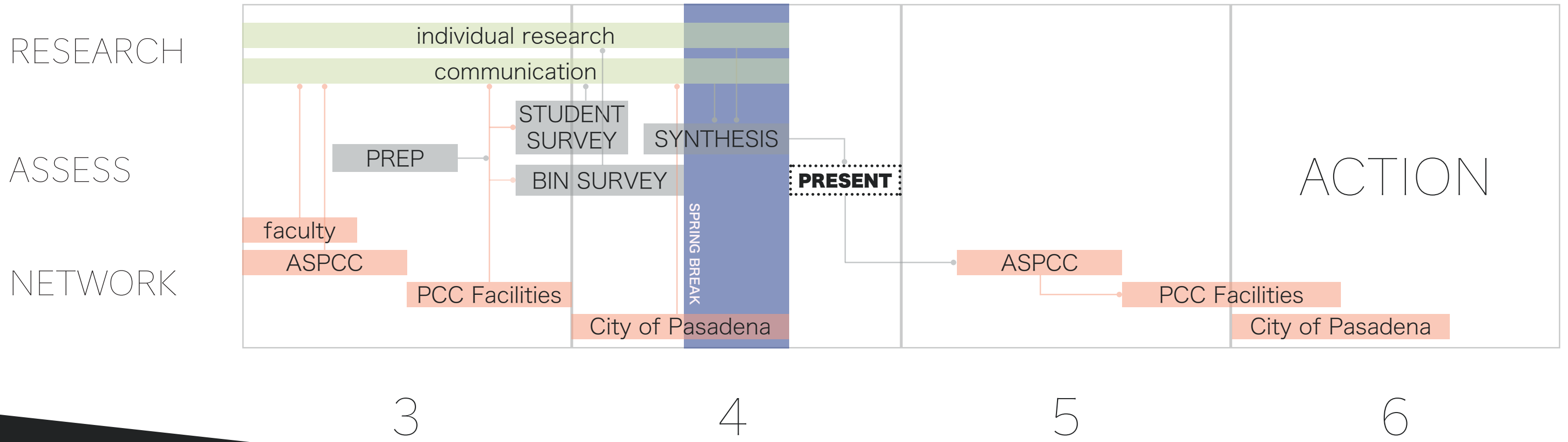
BIN DISTRIBUTION MAP
BIN CONTENT SAMPLING
STUDENT SURVEY

NETWORK

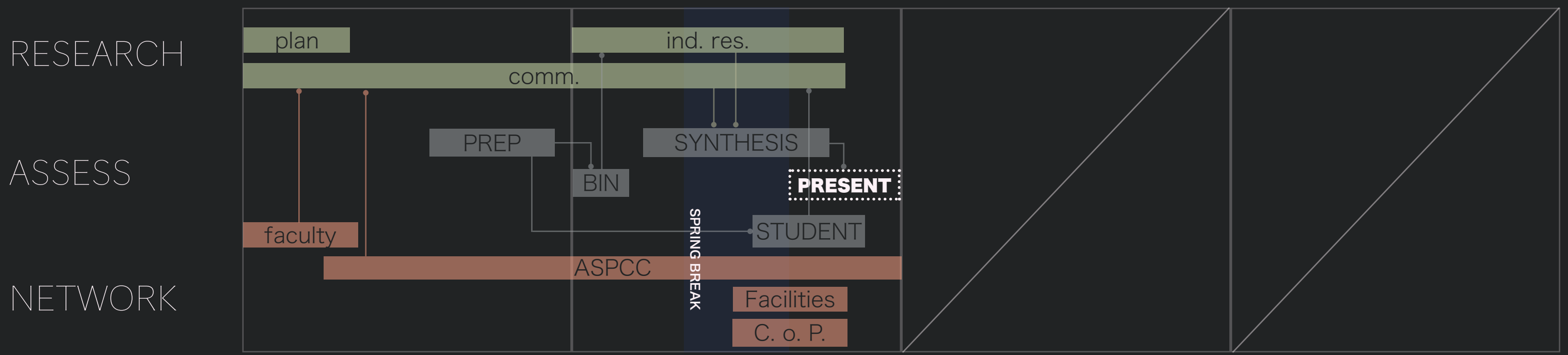
INSTITUTIONAL/MUNICIPAL
STUDENT/FACULTY
OUTSIDE DONORS

CITY OF PASADENA
PCC FACILITIES
PCC ASSOCIATED STUDENTS

IDEAL



ACTUAL



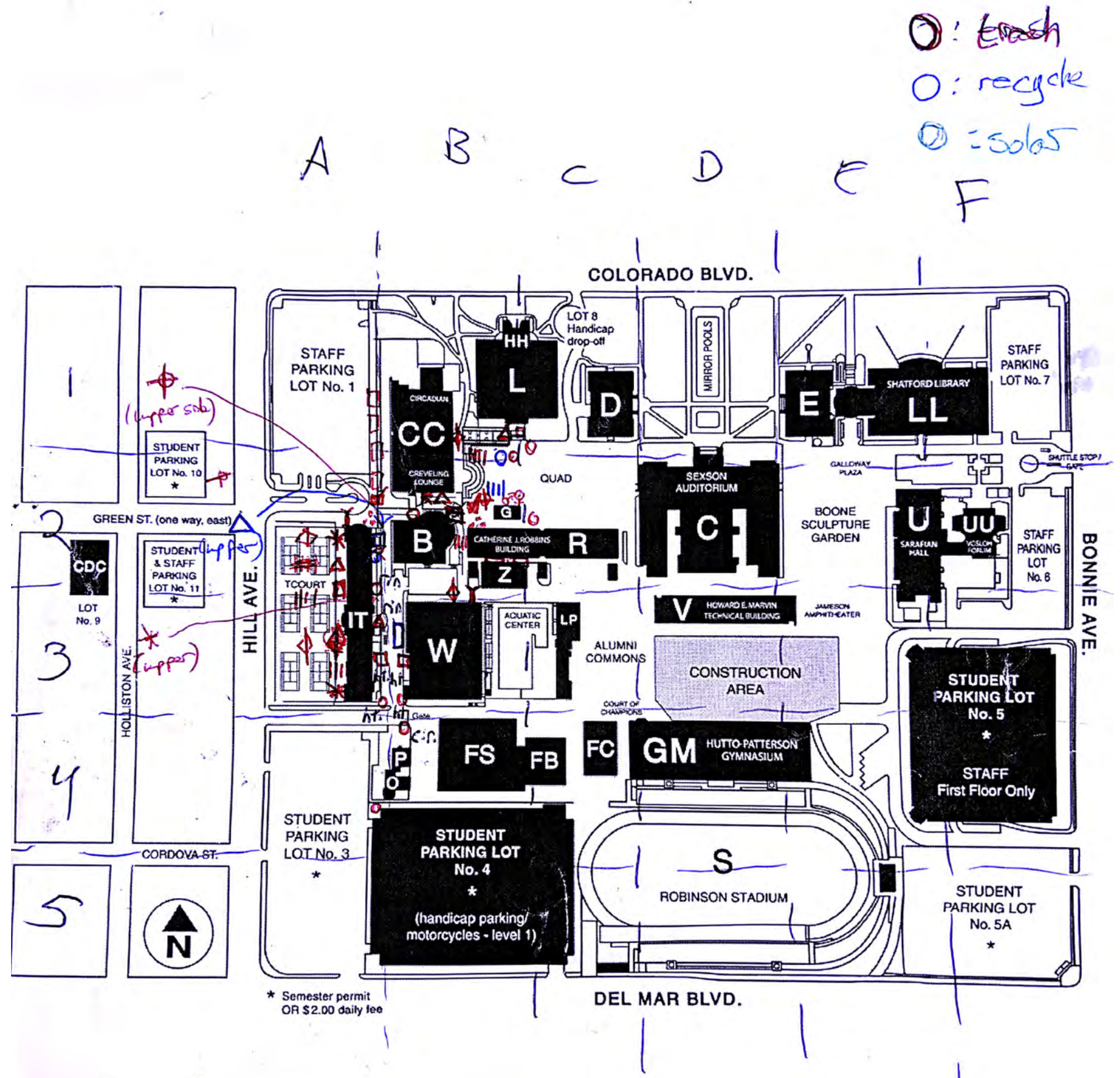
ASSESS

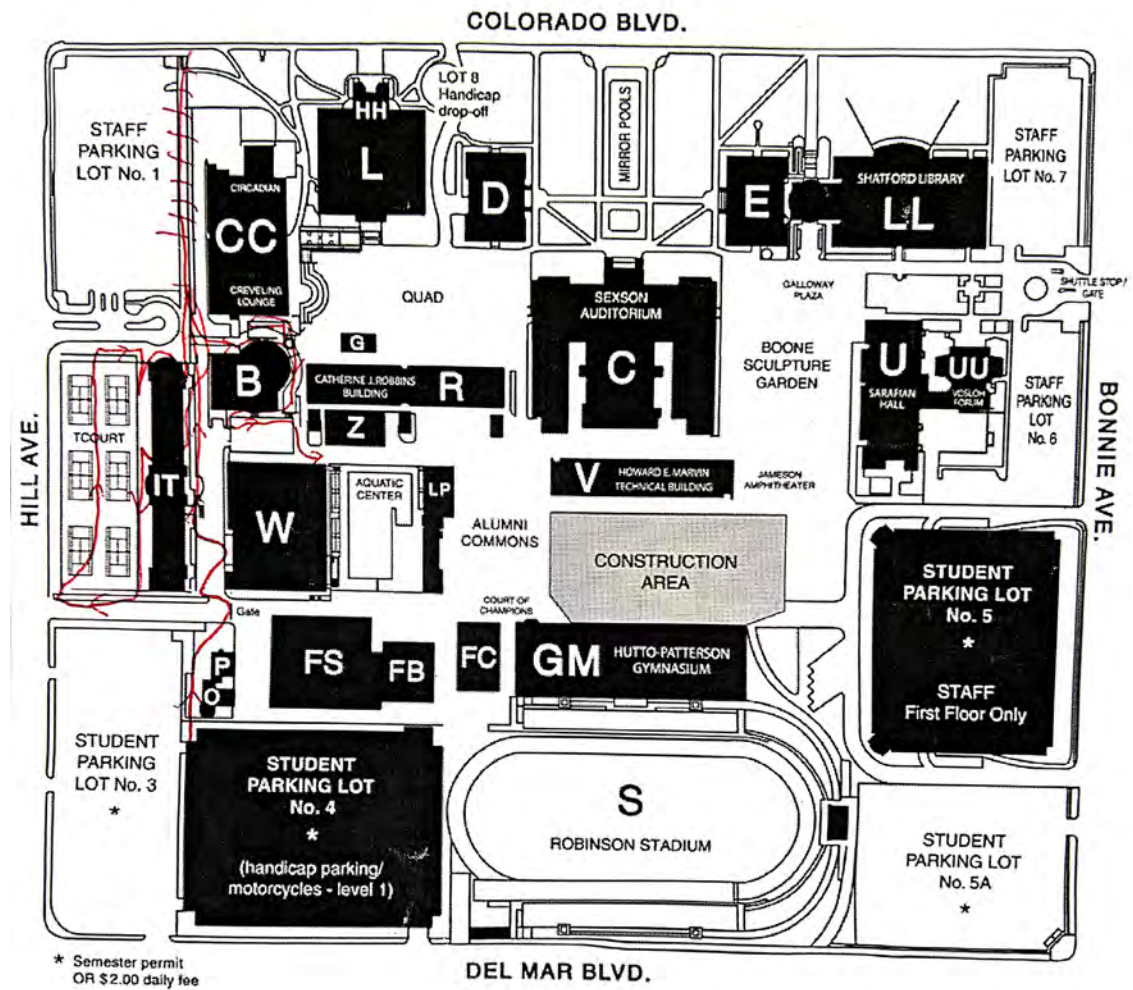
SURVEY DATE: APRIL 1st, 2019

This preliminary sampling of PCC bins provided a firsthand look into the state of trash and recycling on campus.

An improvisational approach informed the cataloguing scheme, under the assumption that distilling a formalized categorization method from the data collected and symbols used would result in superior comprehension.

First survey map with ad hoc notation. The map used was outdated, preceding completion of the Center for the Arts building.





* Semester permit
OR \$2.00 daily fee

TYPE

: dumpster
 : covered trash
 : skate-top
 : open-top
 : bin
 : fitted (bottle/can)

LEGEND

: trash
 : recycle
 : solar

INSTANCE OF TYPE

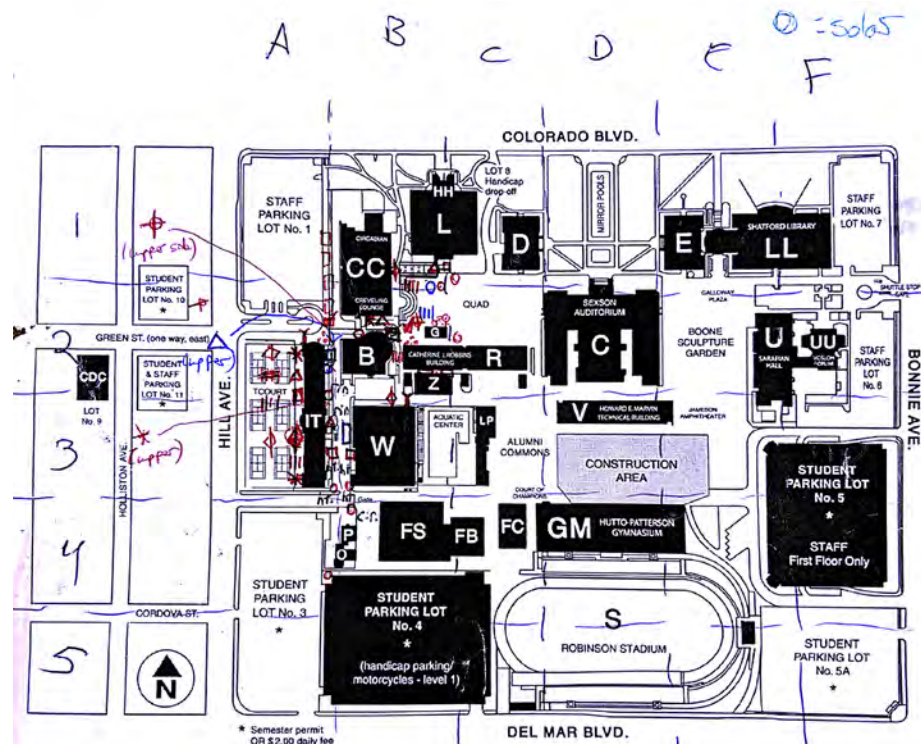
1st
 2nd
 3rd
 4th
 5th
 6th

Map recording route taken on initial sampling

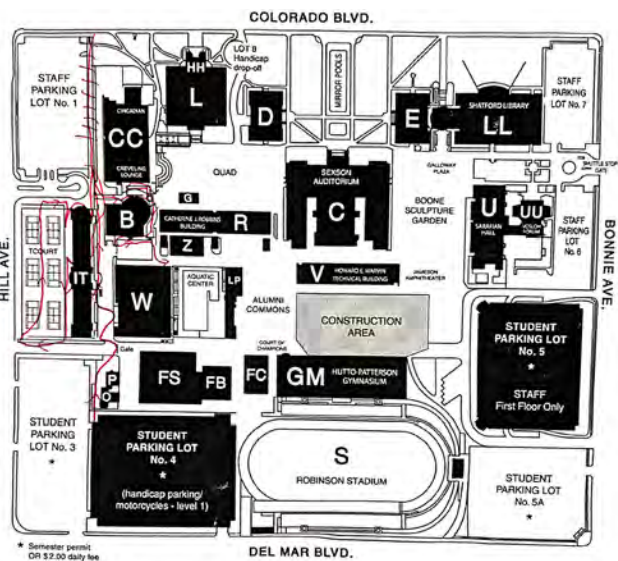


Photos of sampled bin contents

FORMALIZE

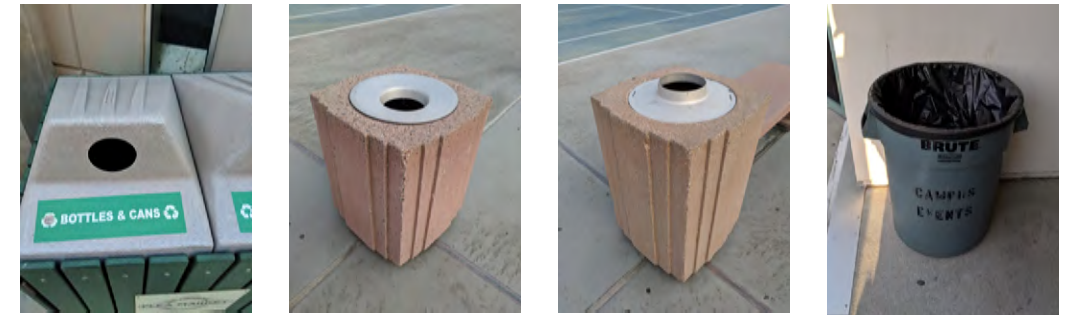


The original grid was split according to major planning lines



TYPE	LEGEND	INSTANCE OF TYPE
dumpster	π: covered trash	○ 1st
	∩: skate-top	□ 2nd
	○: open-top	△ 3rd
	∪: bin	* 4th
	⊞: filled (bottles/cans)	5th
		⊕ 6th
		○: solar

A2: ○/□ too recycling bins not obviously being used for recycling. In a "dump zone" of trees, milk waste etc. contain mainly paper waste & plastics. G: glass. FC: food container. Bx: Box.
 F: full
 ME: mostly empty
 A3: * mostly empty (ME), PIB & PaC w/L (ca 1)
 A2: □ ↑ PaBx, G/B, P/B, P/FC
 A3: ⊕ ||| ME | PIB
 A3: * ↑ PaFC w/P/L, P/B, MC, P/C w/P/L, Pa^S
 A3: ⊕ P/B (29), PaFC, PaC
 A2: ||| ○ ME | P/B, P/C w/P/L, MC
 A2: ⊕ P/B (26)
 A2: * ↑ P/FC (23), PaC w/P/L, PaFC (23) w/P/L (1)
 note proximity to food strip to North
 A2: △ ↑ PaFC (22), P/C (22) [G: green fence] [U: blue bin]
 A2: ∩ ↑ MC, P/B, P/FC, PaBx
 A2: ∩ ↑ G/B, PaC w/P/L (22), P/C (22)
 A2: △ FULL
 A2: ⊕ ME | PaC

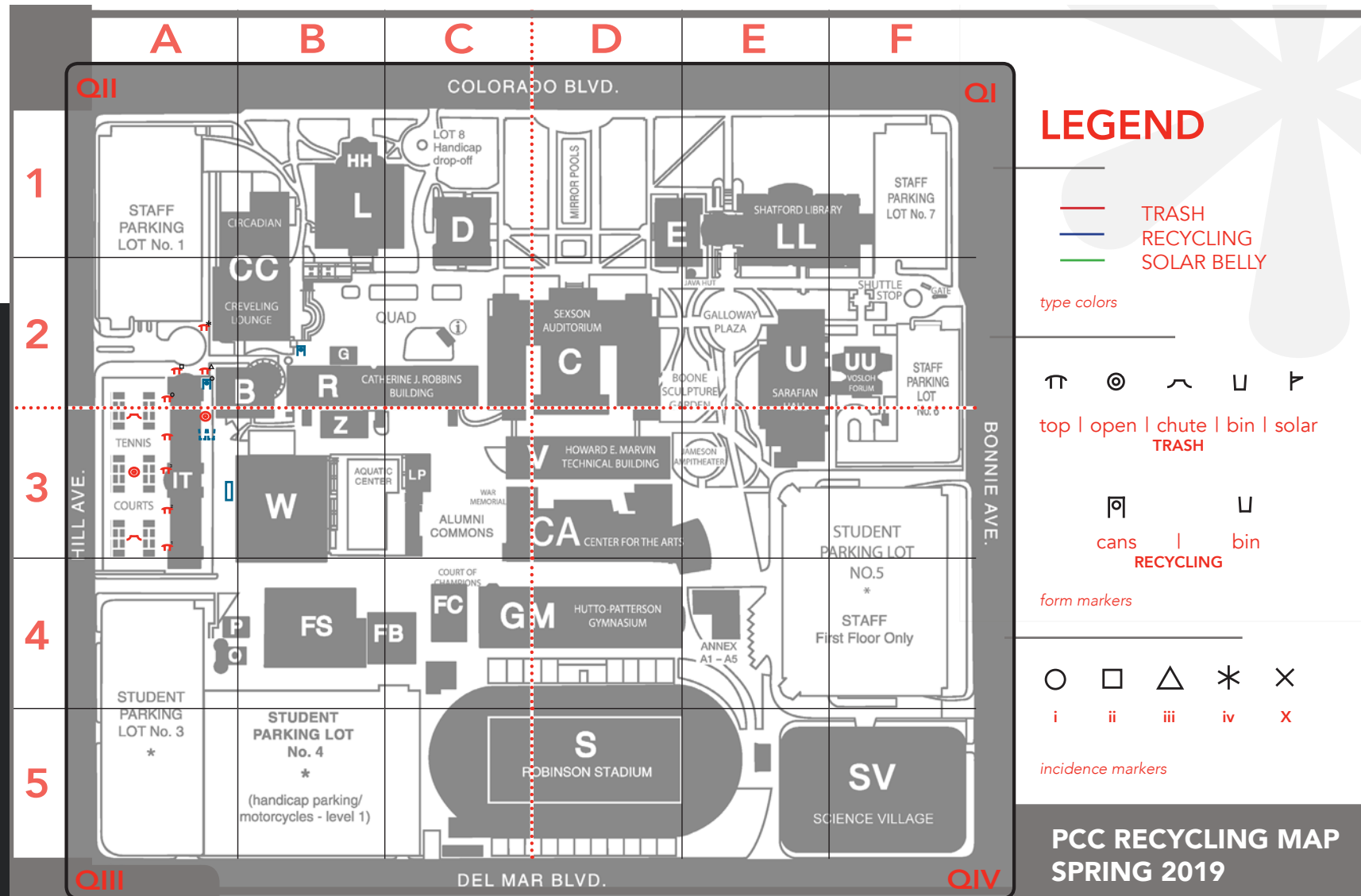


Bin form code examples

PI	Pa	M	O
PLASTIC	PAPER	METAL	OTHER
C	L	Bo	Bx
CUP	LID	BOTTLE	BOX

Material and product type code examples

Development of the legend in an ad-hoc fashion based on what was found in real-time



The blocks are of uniform area in the formalized map, by convention.

Instructions show how to catalog bin contents to keep records uniform.

PCC RECYCLING CHART

BLOCK

+Mark bins on the Map with a symbol and number.
 +The symbol records the bin shape. The number records how many of that shape you find.
 +Inspect the top layer contents and report what you see below, using the codes.
 +Only record items that should NOT be in that bin (recycling in trash and vice versa).
 +Specify material/type for "Other" in NOTES, along with other observations.
 +Take a picture of what you see.

MATERIAL CODE	PAPER	PLASTIC	METAL	OTHER
	Pa	Pl	Me	O
CUP				
LID				
BOTTLE				
BOX				
CAN				
OTHER				

TYPE CODE	CUP	LID	BOTTLE	BOX	CAN	OTHER
	Cp	L	Bo	Bx	Ca	O

BIN		CONTENTS											
FORM	#	MATERIAL	TYPE	#	MATERIAL	TYPE	#	MATERIAL	TYPE	#	MATERIAL	TYPE	#
NOTES													
NOTES													
NOTES													
NOTES													

CASE STUDY

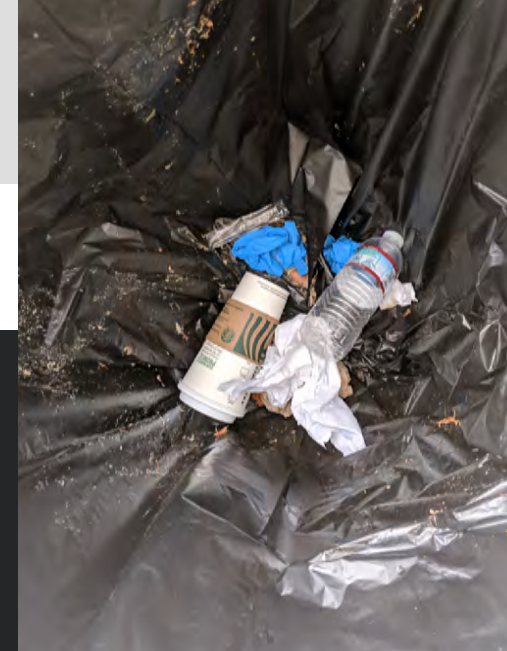
BLOCK A3 (SECTION)



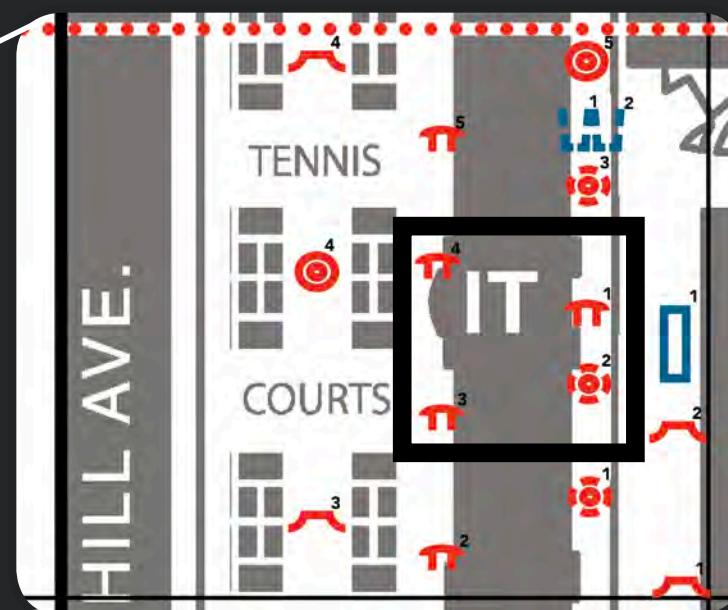
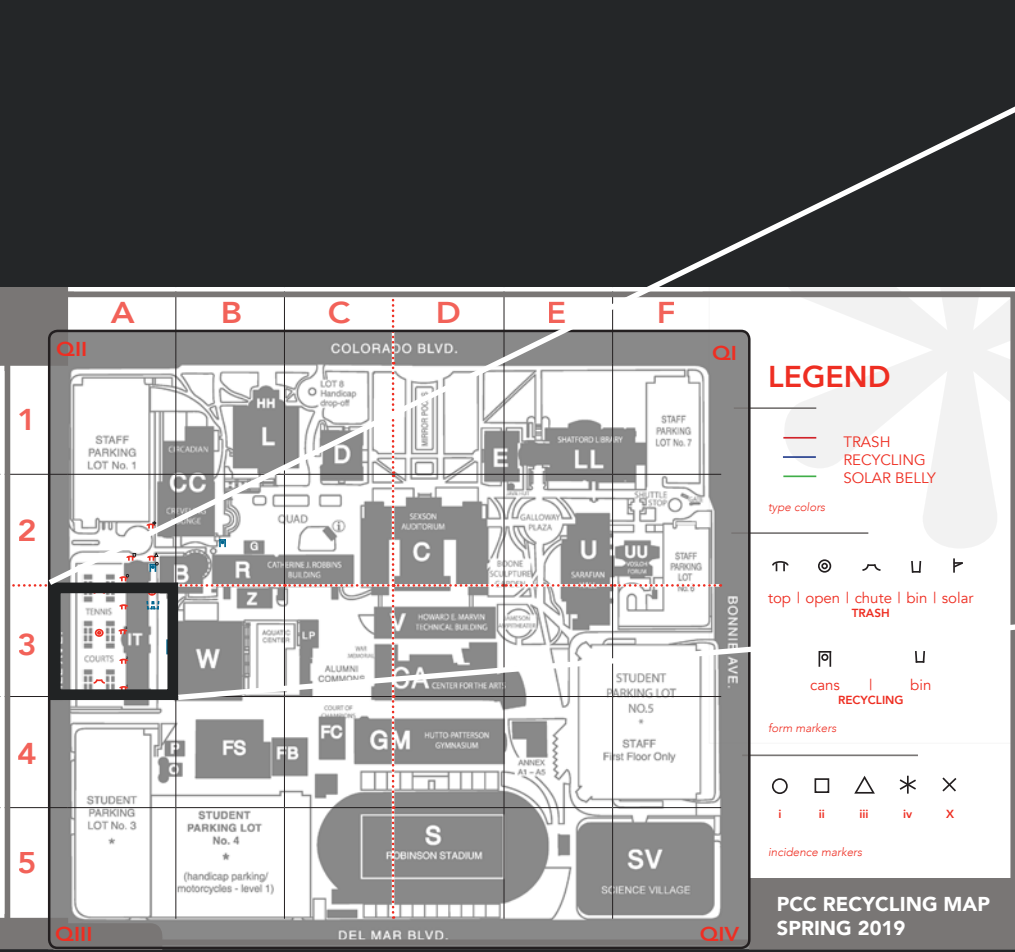
PaBx | GIBo | PIBo | PIBx



ME | PIBo



ME | PIBo | PaC | PIL



PaBx | PaC x2 | MeCn |
PIC | PILx2

NETWORK

For any research to translate into action - and to avoid wasting time collecting information that already existed - making contact with parties already involved in the current paradigm was critical.



Informal conversations with faculty revealed aspects of the “unwritten history” of sustainability efforts on campus, providing familiarity with the issue and aiding with strategy.



Sarah Jo, the Associated Students of PCC Vice President of Sustainability, was contacted by e-mail on 3.13.2019.

The exchange led to a collaboration with the AS Sustainability Committee, which is also concerned about this issue.

This approach increases legitimacy, creates intramural dialogue, and avoids redundancy.



The PCC Facilities office was contacted by e-mail on 4.18.2019 with questions regarding existing maps, budgets, future plans, etc. with regards to waste management at PCC.

Carl Sheaffer, the newly installed Manager of Facilities and Operations, replied on 4.22.2019 expressing willingness to help provide information.



Simone Blackwell, Recycling Coordinator for the City of Pasadena, was contacted by e-mail on 4.18.2019 with questions concerning the process and costs for obtaining additional institutional-scale recycling services (ongoing).

SURVEY

SURVEY DATE: APRIL 22nd, 2019

On April 22nd, 2019, the PCC Associated Students Sustainability Committee held an Earth Day event near the reflecting pool (block D1).

The student body at PCC is roughly 25,000 students. In order to conduct a statistical analysis with a 95% confidence interval and a +/-10% margin of error, the survey required a minimum sample size of n = 96 responses.

PCC RECYCLING SURVEY



We are collecting student opinions on the PCC trash and recycling system!

On a scale from ① for VERY POOR to ⑤ for VERY GOOD, please rank the following:

AVAILABILITY OF TRASH CANS

① ② ③ ④ ⑤
VERY POOR VERY GOOD NO OPINION



AVAILABILITY OF RECYCLING BINS (BOTTLES | CANS)

① ② ③ ④ ⑤
VERY POOR VERY GOOD NO OPINION



AVAILABILITY OF RECYCLING BINS (OTHER PLASTICS)

① ② ③ ④ ⑤
VERY POOR VERY GOOD NO OPINION



AVAILABILITY OF RECYCLING BINS (PAPER | CARDBOARD)

① ② ③ ④ ⑤
VERY POOR VERY GOOD NO OPINION



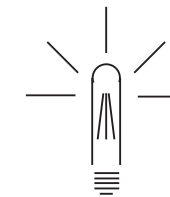
AVAILABILITY OF COMPOST BINS

① ② ③ ④ ⑤
VERY POOR VERY GOOD NO OPINION



WHICH BEST MATCHES YOUR VIEW?

- PCC is a leader in sustainability.
- PCC is above average with regards to sustainability.
- PCC is average with regards to sustainability.
- PCC is below average with regards to sustainability.
- PCC is far behind with regards to sustainability.
- Don't know/unsure



PLEASE CHOOSE ONE:

- Sustainability is of great importance to me.
- Sustainability is of some importance to me.
- I have no opinion/am unsure about sustainability.
- Sustainability is of little importance to me.
- I don't think sustainability is important at all.

FREE RESPONSE

Do you have any additional thoughts?
Have any particular concerns?
Please use the back side
of this paper to tell us!

THANK YOU for participating in our survey.

The survey used.

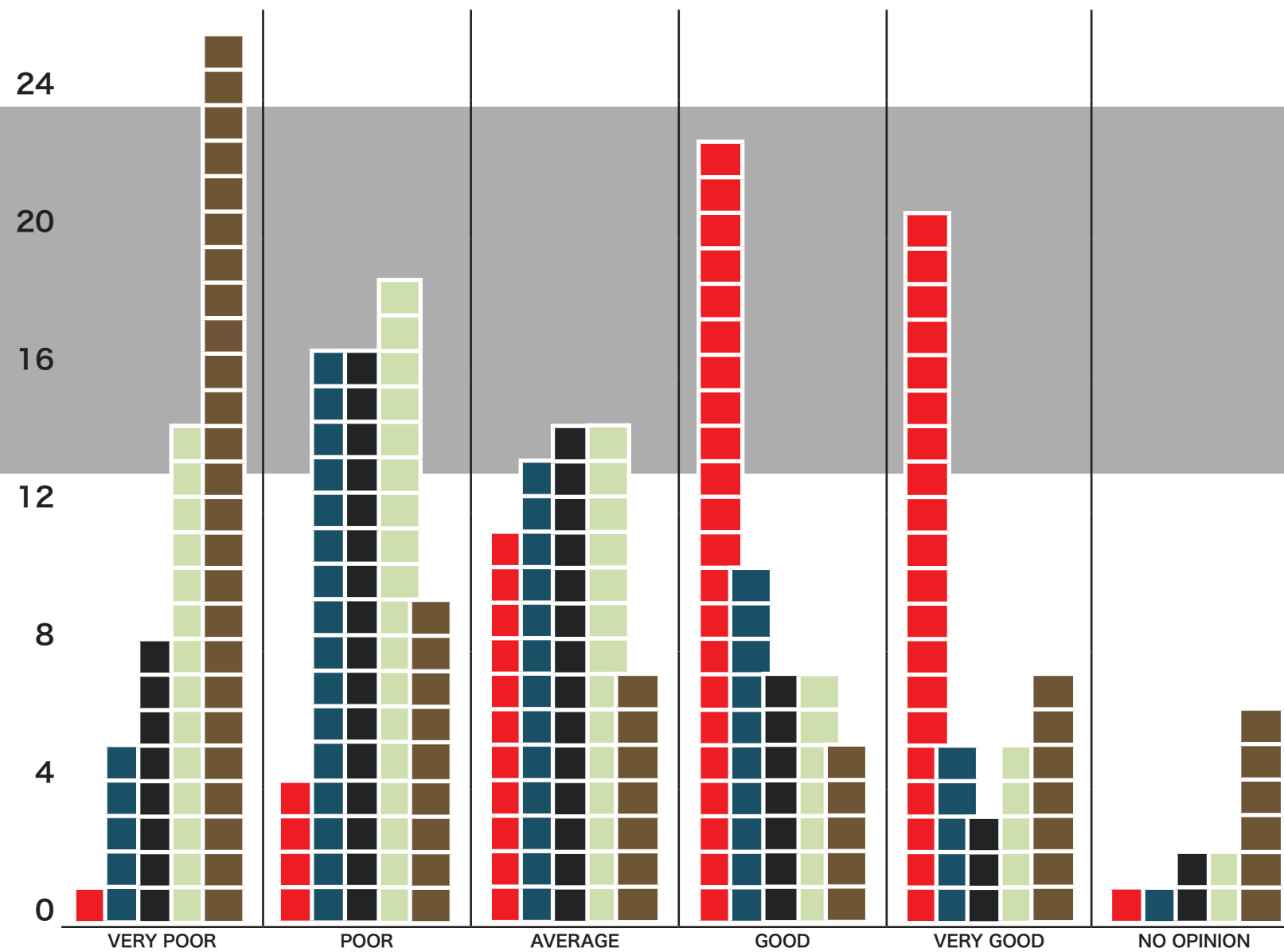
RESULTS

responses

ONLINE | 36
PAPER | 21

p | 25000
n | 57
CI | 95%
MoE | 12.9%

- TRASH
- BOTTLE | CAN
- PLASTICS
- PAPER
- COMPOST



CAMPUS BIN AVAILABILITY

highest satisfaction
trash can availability
42 positive

lowest satisfaction
compost bin availability
34 negative

PCC SUSTAINABILITY

leader | 8
good | 17
average | 20
poor | 6
behind | 2
don't know | 4

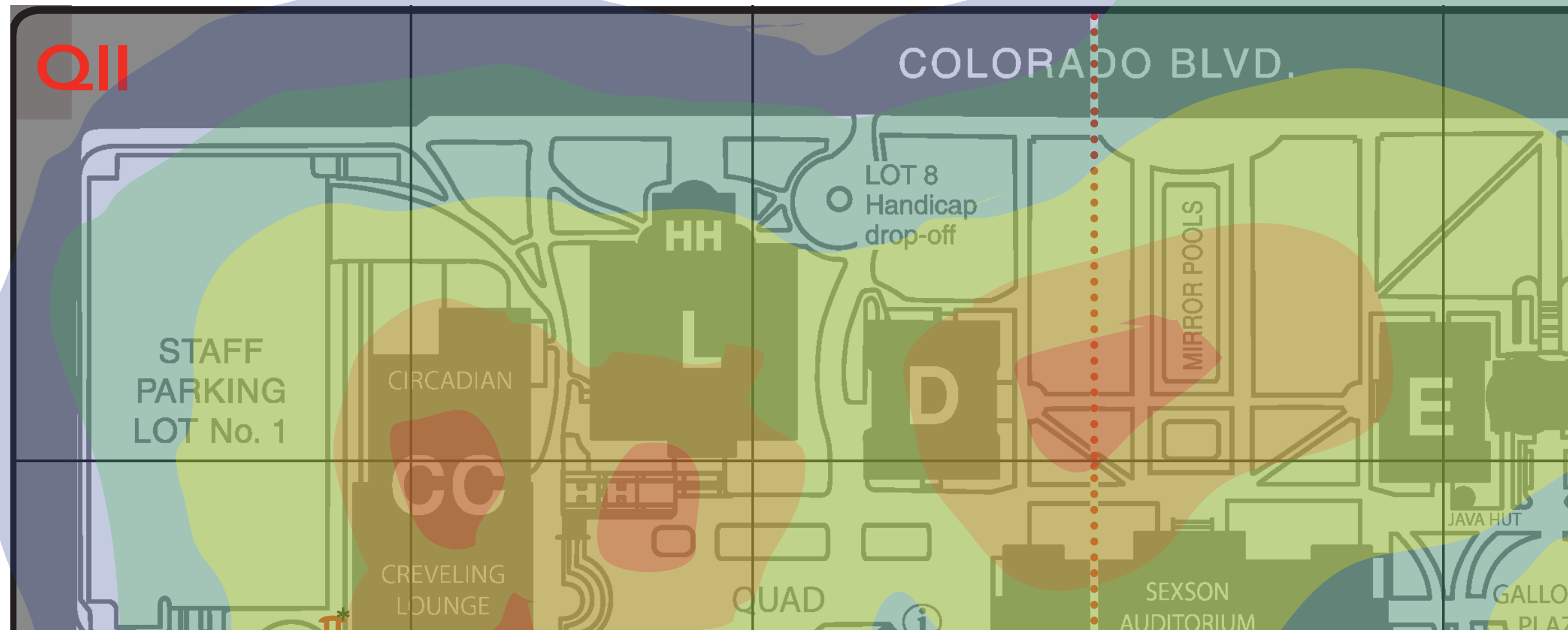
IMPORTANCE TO YOU

very important | 36
somewhat important | 16
unsure | 5
not very important | 0
not at all important | 0

Additional surveys to be conducted on Thursday, 4.25.2019. Because the event is an environmental documentary screening, there may be a self-selection bias to those results.

NEXT

- +Formal statistical analysis of survey
- +Review of materials from Facilities
- +Review of materials from City of Pasadena
- +Complete bin survey of campus, if necessary
- +Production of heat maps for most efficient placement of new bins
- +If warranted, discussion with Facilities and City of Pasadena on how to expand recycling at PCC



REFERENCES

<http://www.pcccourier.com/main-story/pccs-sustainability-seeks-a-step-up.html>

<https://pasadena.edu/measure-p/>

<http://www.pccpiano.com/student-events>

Conversations with faculty and ASPCC Sustainability Committee

unformatted. only those referenced in presentation
all resources accessed 3.15.19-4.22.19

THANK YOU