ALUMINUM COMPOSITE MATERIAL STUDY

GRAPHIC CATALOG

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ARCH 5306

Fabrication I

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INTRODUCTION

Our group chose to study ACM - or Aluminum composite material to diversify our understanding of composite materials and their unique isotropy. This is often overlooked while implementing these products in the building industry in favor of cladding over rigid forms to produce exterior systems. Other applications of composite and metal that can be explored entail; Metal stamping, Point forming and English wheel bending, our group hopes to elaborate on these methods through the use of Origami fold techniques and the application of CNC (a Computer Numeric Control) router to achieve different radiuses and score depths to take advantage of the material's half millimeter aluminum press over polyurethane.

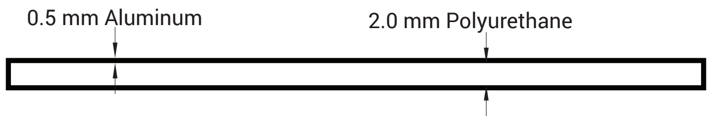
After creating our different cut patterns in Rhinoceros 3d modeling software, RhinoCAM plug-in allowed us to establish different tool paths, cut depths and speeds. This helped us to achieve our desired pocketing, engraving and profile cuts which we were able to translate the computer language (G code), then into tangible material exploration using the computer numeric controlled (CNC) router. For this we made use of two different carbide tip milling bits: a v-mill for engraving and end- mill for full material perforation we have been able to work through a number of different material tests and explorations in order to find new applications of this aluminum composite material.

PRINCIPLES OF ORIGAMI

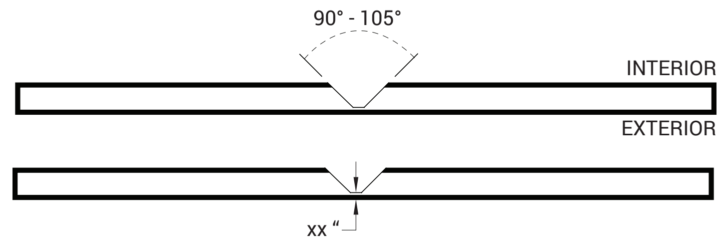
The initial experimentation took place with paper with the intent of finding geometries that were planar and potentially able to be recreated in a thicker more rigid material. The repeatable folded geometry of the origami was a good benchmark for introducing a more precise plan for recreating such a system out of ACM because once the paper was unfolded the creases remained leaving a flat diagram of its vertices. From the flat diagram we could translate the design to the ACM panels using the CNC to relieve stress in folding areas.

CUTTING & FOLDING METHODS

MATERIAL THICKNESS

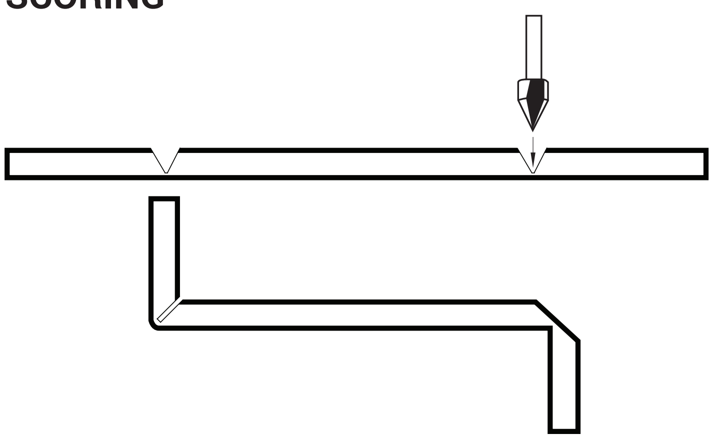


TYPE OF FOLD

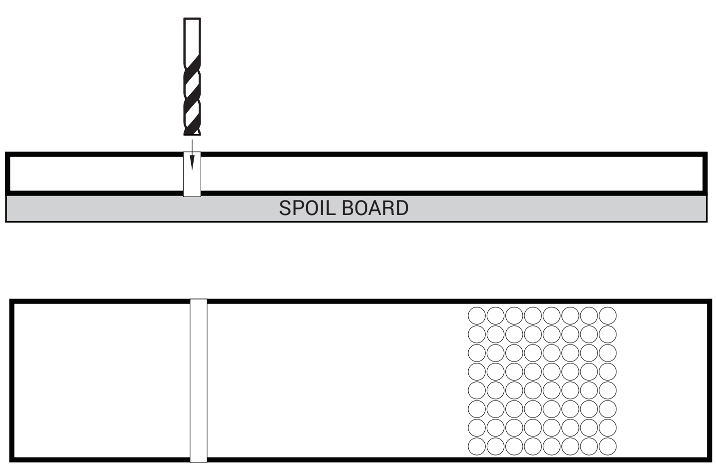


TYPES OF CUTS

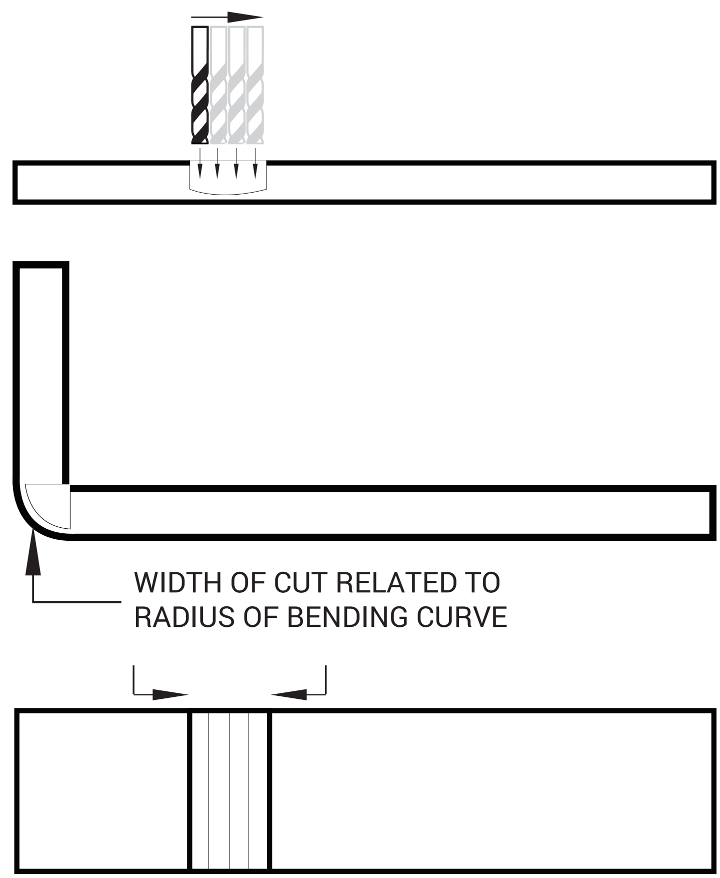
SCORING



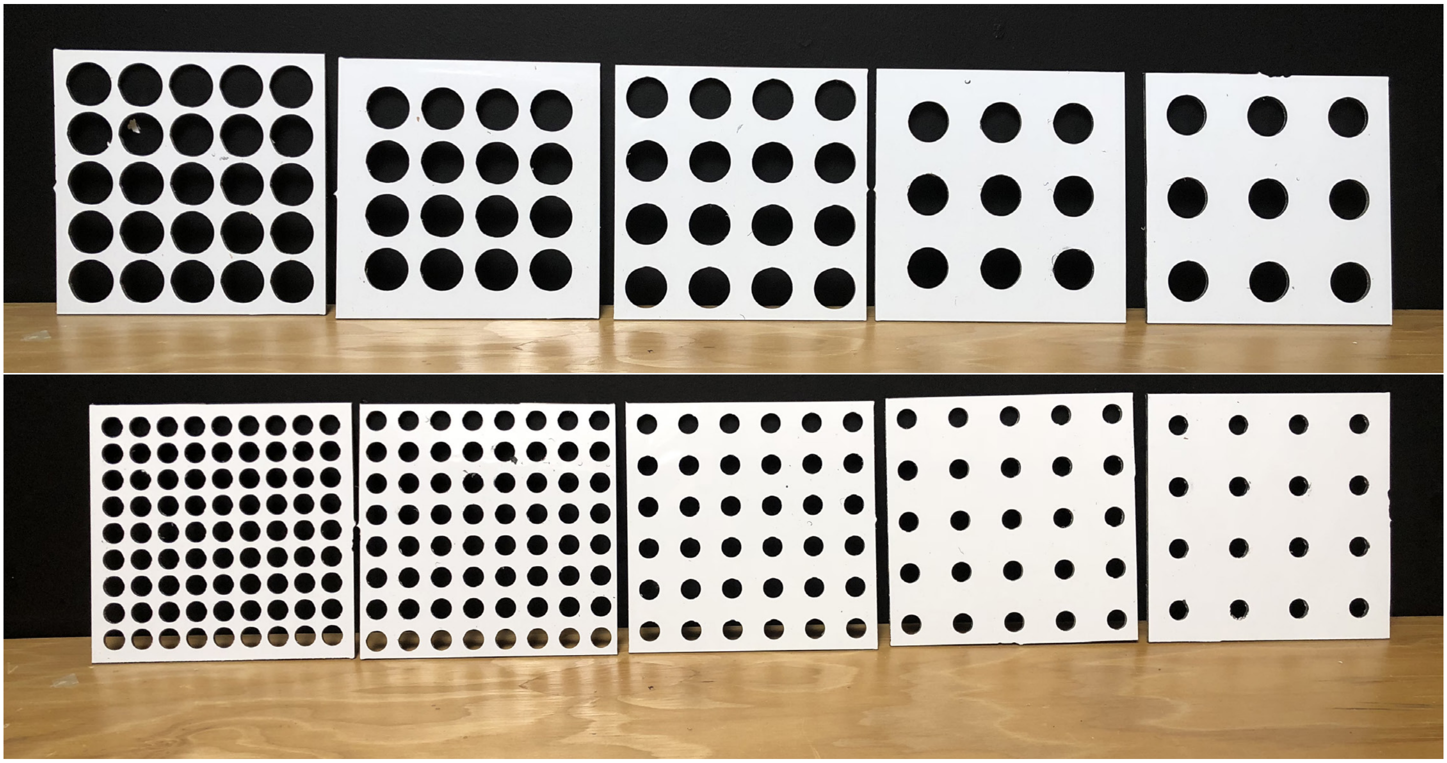
PROFILING



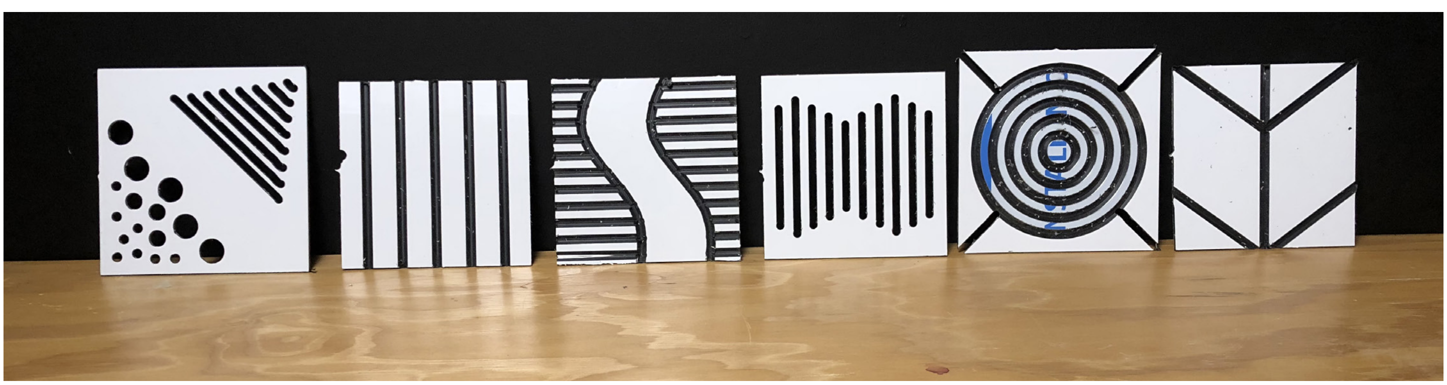
RADIUS FOLD



INITIAL MATERIAL EXPLORATION



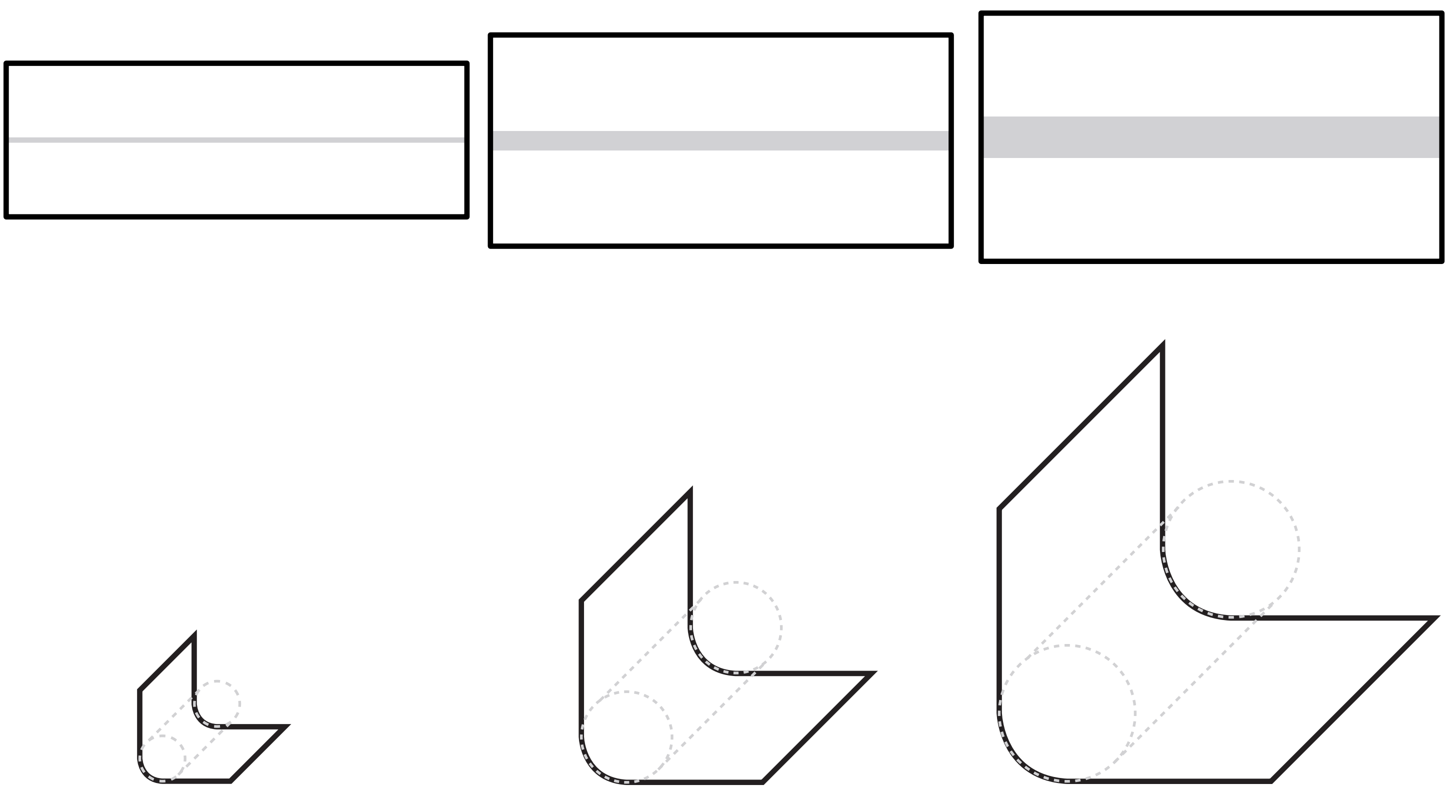
A series of 6”x 6” panels were created with varying degrees and sizes of circular perforations. The perforations were either a 1/4” or a 1/2” in diameter while the spacing between each varied (1/8”, 1/4”, 1/2” 3/4”, and 1”). After the perforations were completed it was determined that they did not dramatically impact the compressive strength of the ACM panels vertically or horizontally, allowing for future iterations to include them without great concern over compromising strength.



The initial CNC experiments were exercises in flexibility, folding and curving of the panels. Some designs were attempting to create perforations in the panels that might leave it more malleable, while others engraved on the surface to give paths for folds. Some were an attempt to achieve non-linear folds as well as testing the curvature of the material.

RADIUS FOLD

In order to achieve curved folds the width of the engrave must be modified. Since ACM can not be pocketed like other materials used on the CNC, we must ensure several passes using the end mill to create our desired widths. We created 3 panels with 1/4”, 1/2” and 3/4” width cuts which are proportionate to their desired fold radius.

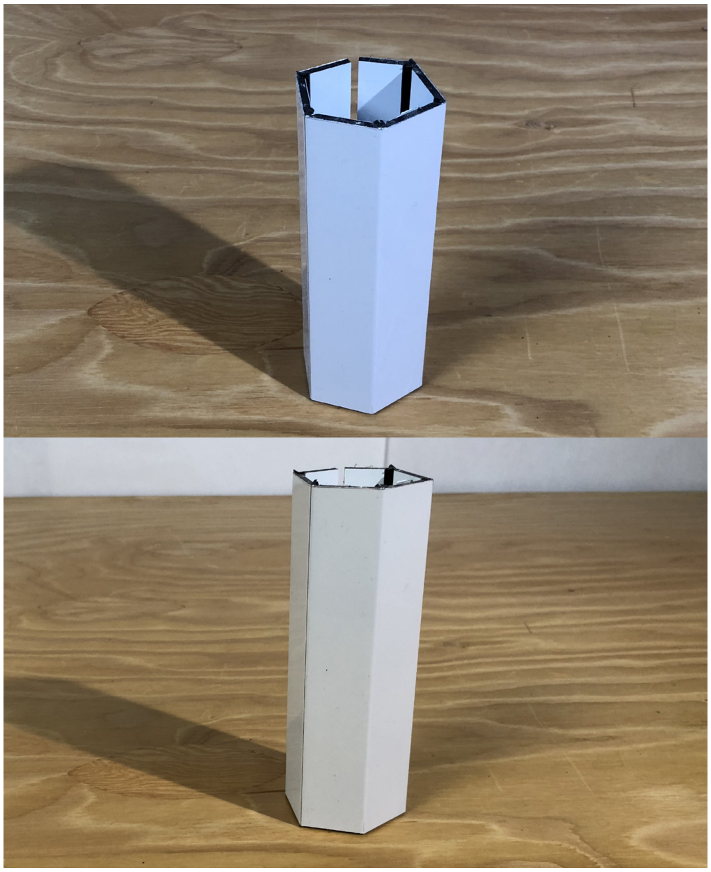


1/4” Radius

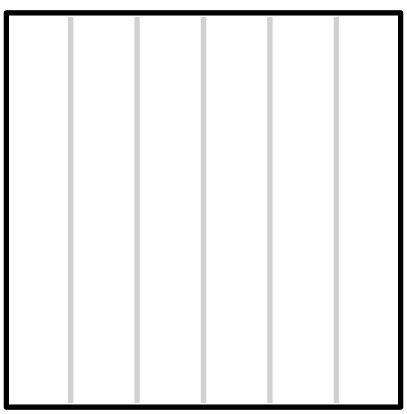
1/2” Radius

3/4” Radius

STRAIGHT FOLD TEST #1

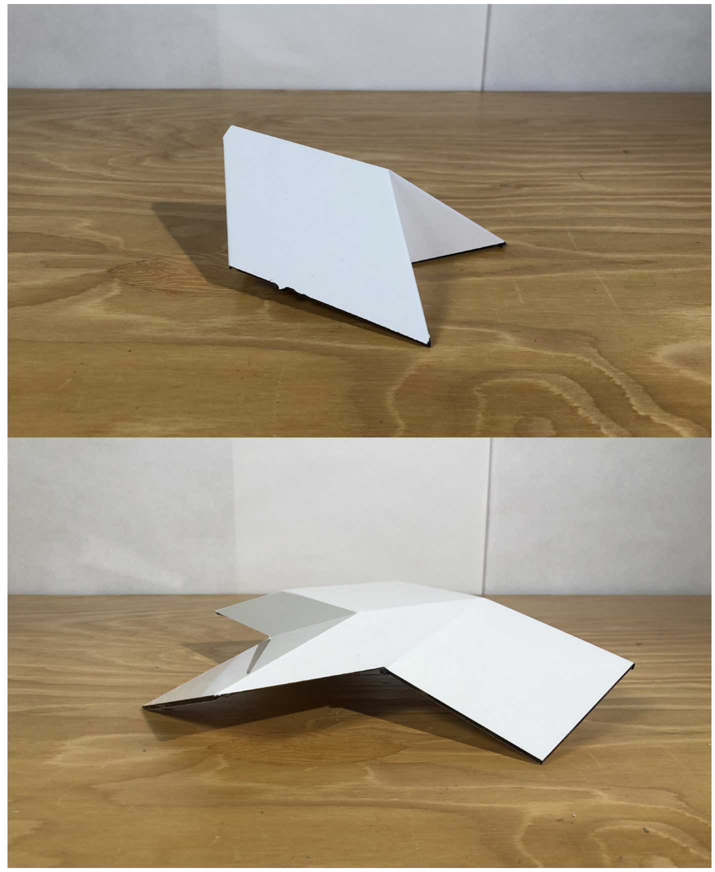


Cut Geometry:

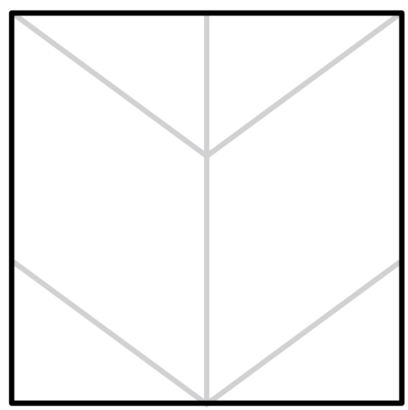


Size: 6”x6”
Cut type: Scoring & Profiling
Fold type: Obtuse, interior
Potential As A Module: Columns or strong vertical members
Issues: Multiple folding and unfolding caused weakness, too small the cut was off

STRAIGHT FOLD TEST #2

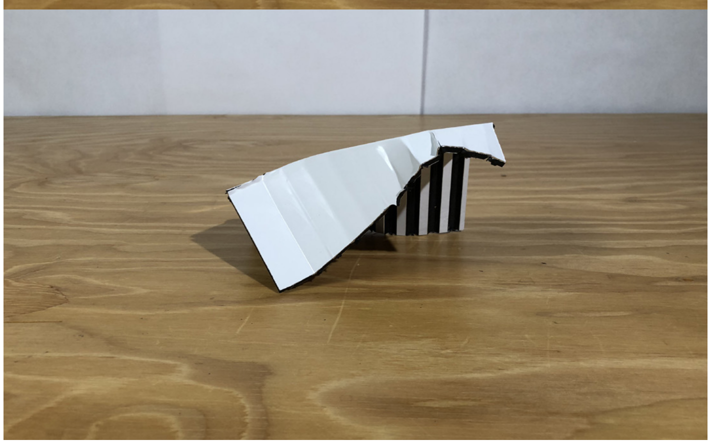


Cut Geometry:



Size: 6”x6”
Cut type: Scoring & Profiling
Fold type: Obtuse, interior
Potential As A Module: Single component in a system, wall system, cladding
Issues: Not rigid enough on its own, some kind of connection necessary

CURVED FOLD TEST #1

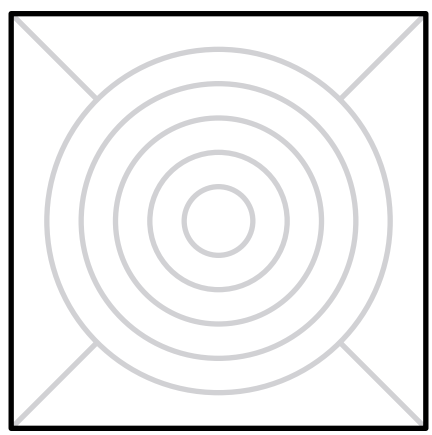


Cut Geometry:

Size: 6”x6”
Cut type: Scoring & Profiling
Fold type: Obtuse, interior
Potential As A Module: Maybe, roof system, wall system, decorative panel
Issues: Curve relief cuts too far apart and not perpendicular to curve, curve radius too small.

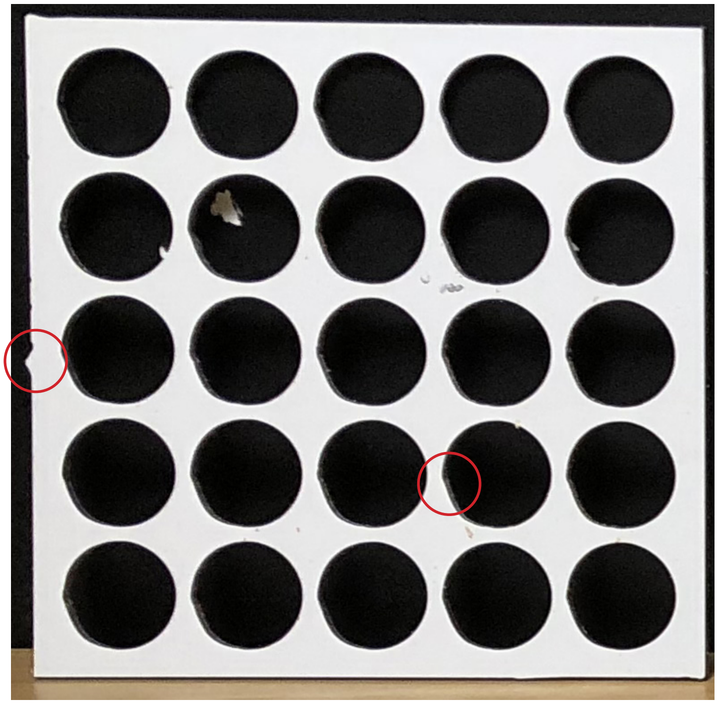
CURVED FOLD TEST #2

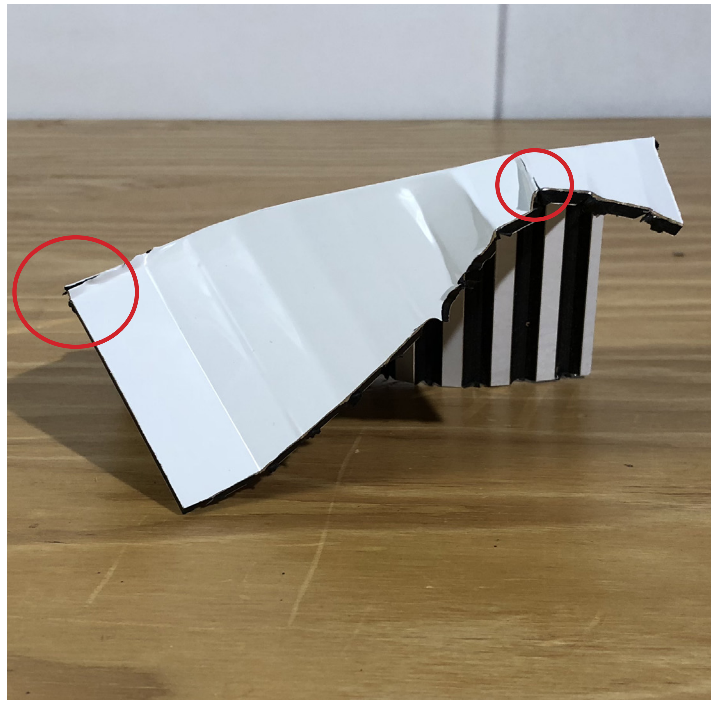
Cut Geometry:



Size: 6”x6”
Cut type: Scoring & Profiling
Fold type: Interior
Potential As A Module: YES
Issues: not enough relief cuts in the system for a dramatic curve, potentially not possible with single piece.

WHAT WE LEARNED





The material's glossy finish made it so that the router did not plunge perfectly into the material each time and would create defects in the perforations themselves.

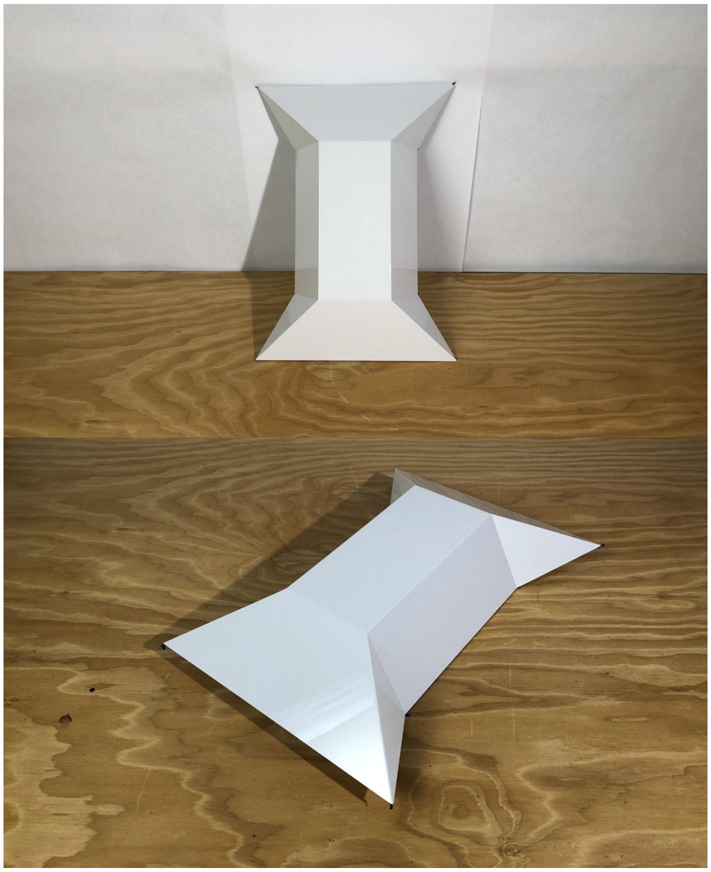
The scale of our experiments was too small, causing loss of suction on the cnc bed, resulting in odd 'bites' out of the material right before separation.

The material's isotropic nature allows for it to remain rigid even while perforated, the application of kerfing-like techniques can only be achieved through folding and curving radiuses, rather than full material perforations.

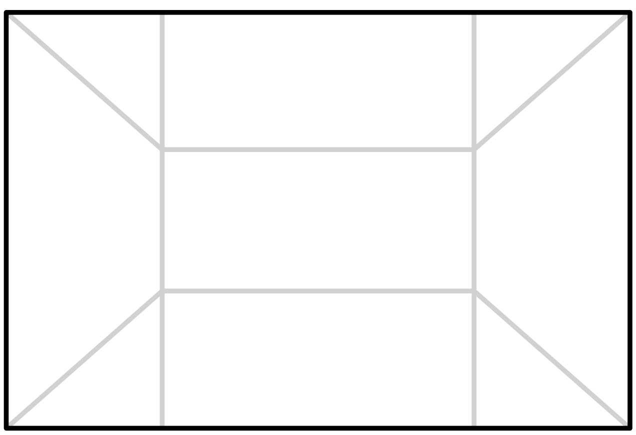
Like origami the material becomes more rigid through folded geometries.

Smaller curved radii proved more difficult to achieve based on their orientation to the folding geometry, the scores were best-oriented perpendicular to the intended curve.

MODULAR TEST #1

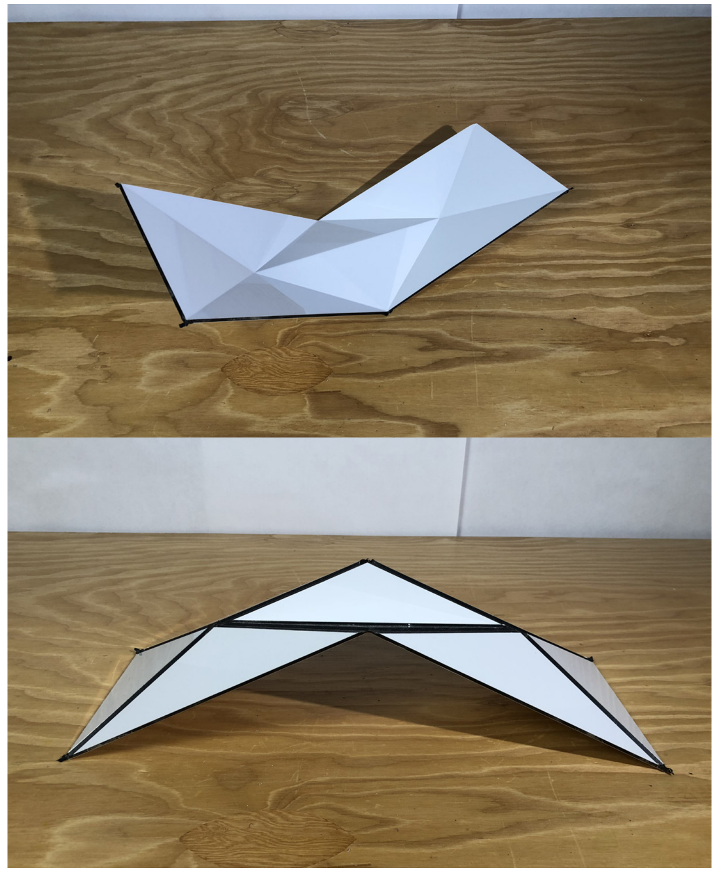


Cut Geometry:

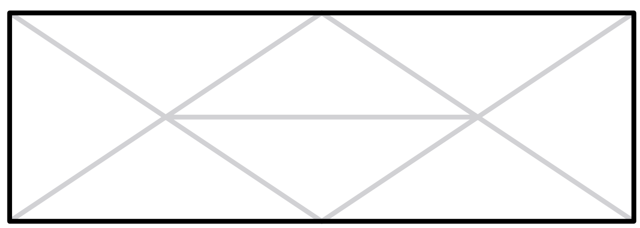


Size: 18” x 12”
Cut Types: Scoring & Profiling
Fold Types: Interior Folds
Potential As A Module:YES
Issues: Engraves need to be manipulated in order to allow for proper folding to permit modulation.

MODULAR TEST #2

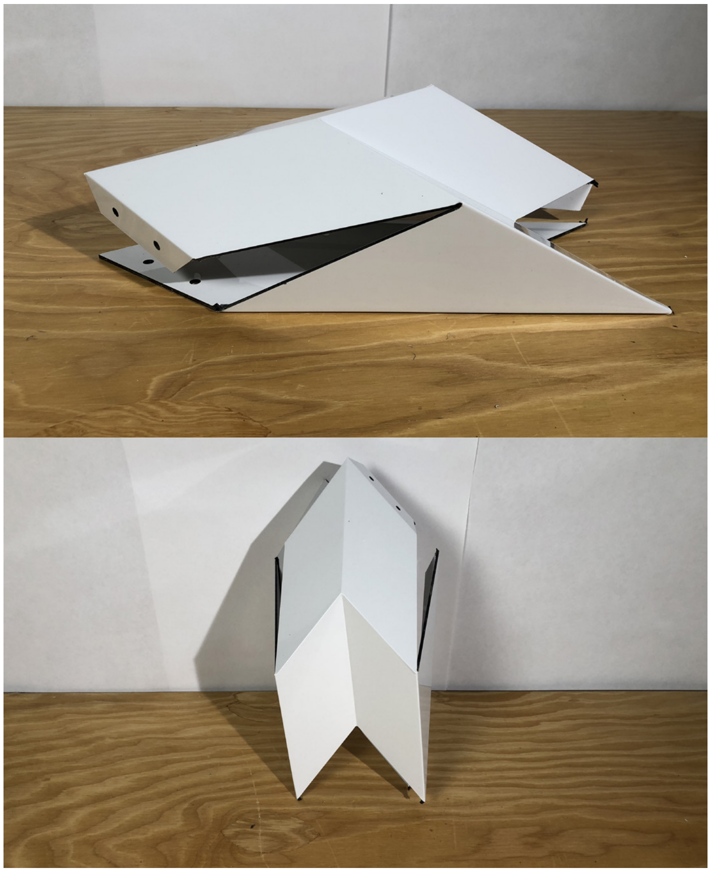


Cut Geometry:

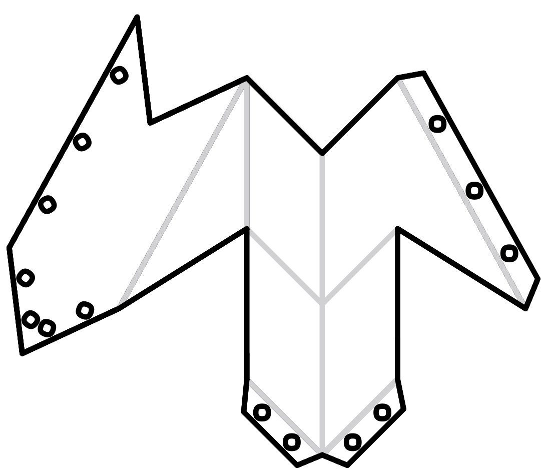


Size: 18” x 6”
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module: YES
Issues: Engraves were not wide enough to allow module to fold completely into Its desired form.

MODULAR TEST #3

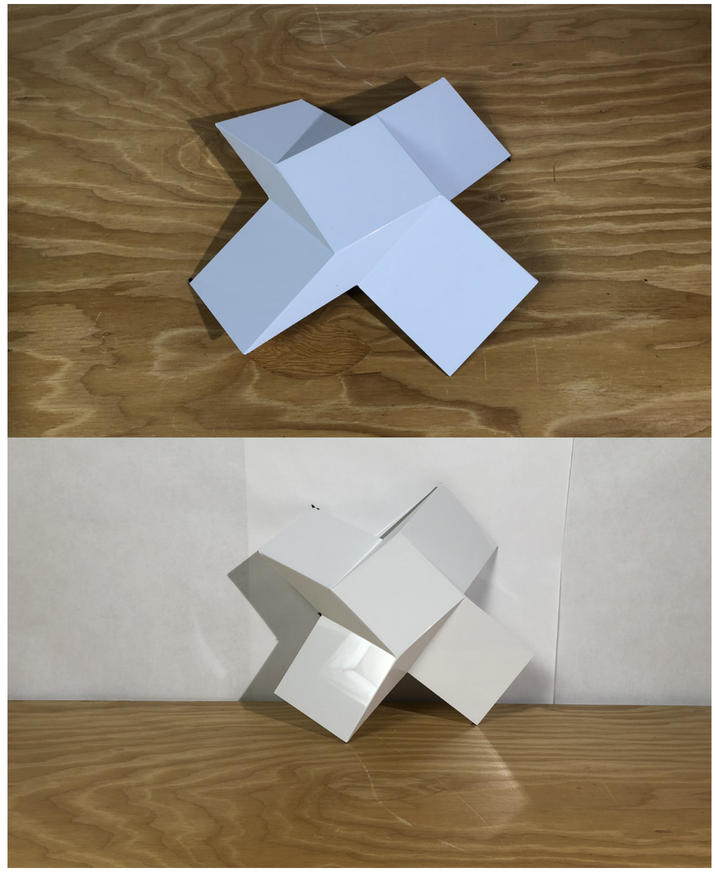


Cut Geometry:

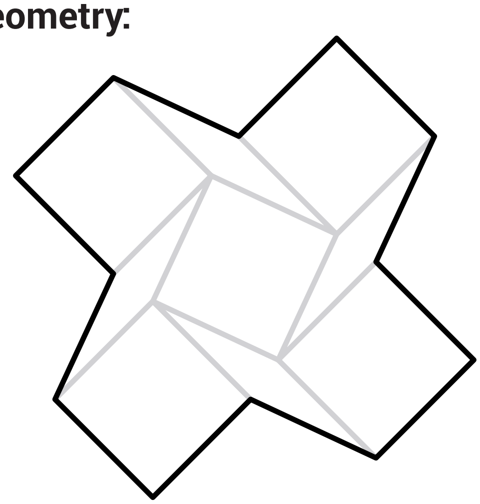


Size: 12”x18”
Cut type: Scoring & Profiling
Fold type: Interior & Exterior
Potential As A Module: Wall system, modular structures
Issues: Relief cuts and folds not wide enough to achieve acute folds, tabs for fastening needed.

MODULAR TEST #4

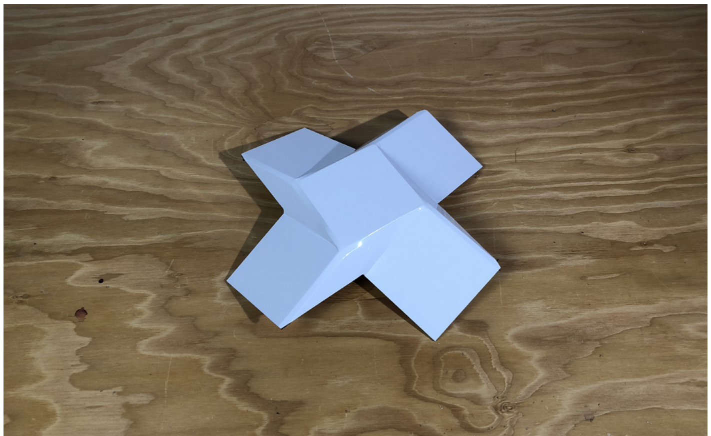


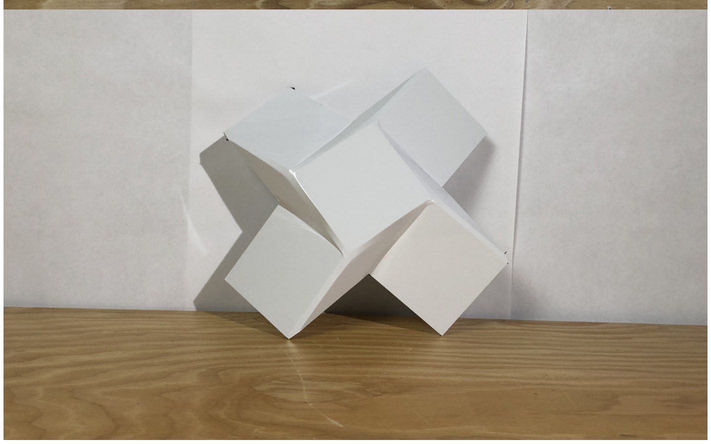
Cut Geometry:



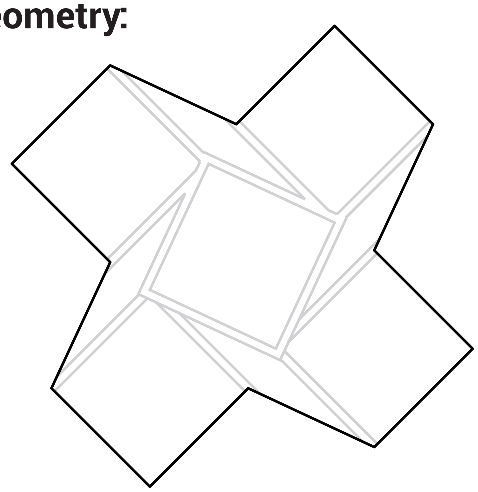
Size: 12” x 12
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module: NO
Issues: Angles limit ability to create module as connections become quite complicated and would require flush connections.

MODULAR TEST #5



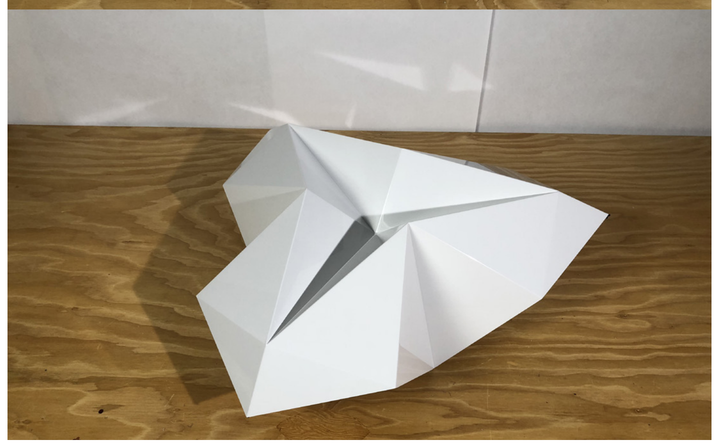


Cut Geometry:

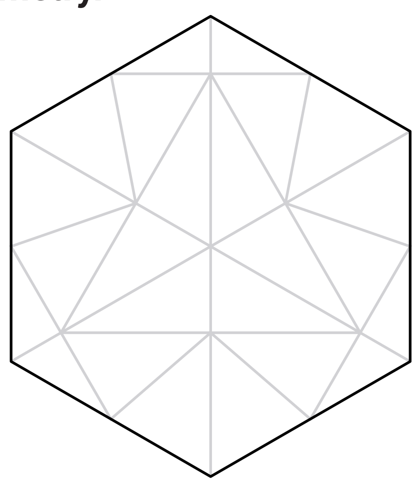


Size: 12” x 12
Cut Types: Scoring & Profiling
Fold Types: Radius Interior & Radius Exterior Folds
Potential As A Module: NO
Issues: Use of vmill to create radius fold created two edges rather than a smooth curve along the folded edges.

MODULAR TEST #6

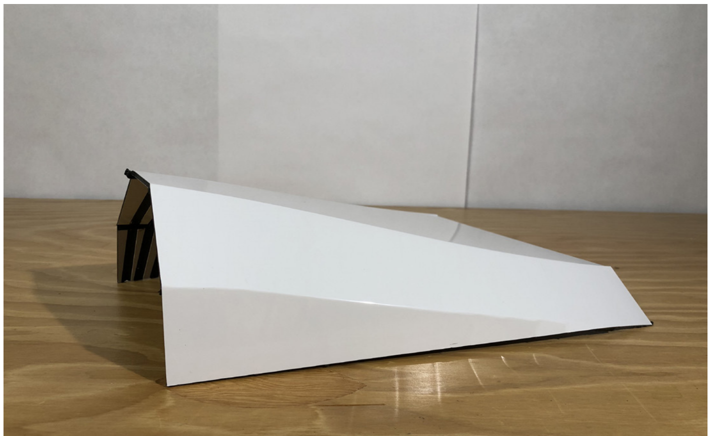


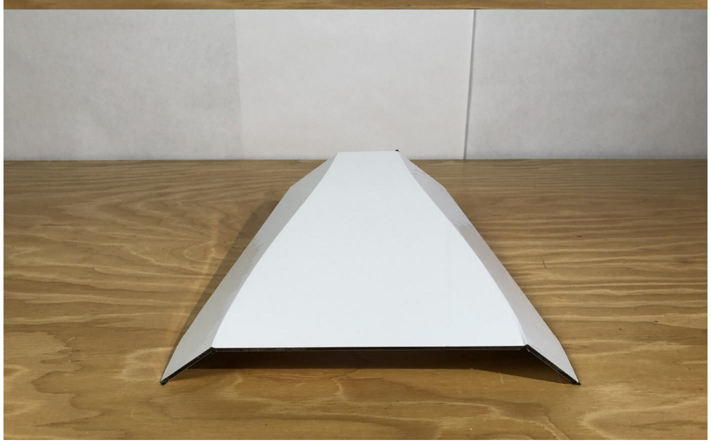
Cut Geometry:



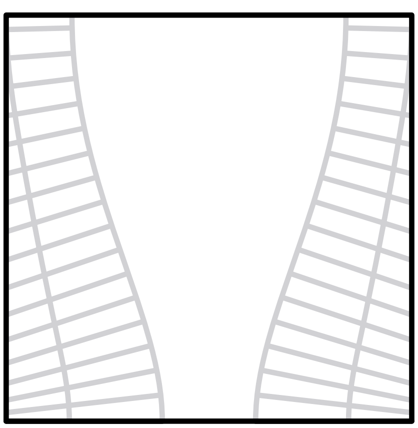
Size: 21” x 24”
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module: YES
Issues: Due to size and complexity of geometry, does not hold a distinct shape and is flexible. Need to establish set form for modulation.

CURVED FOLD TEST #1



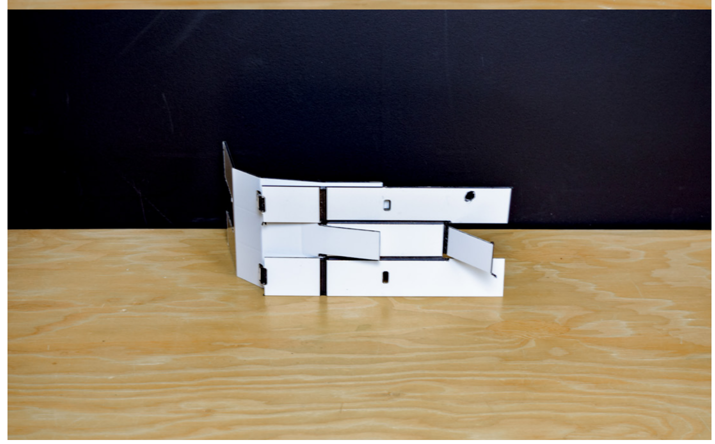


Cut Geometry:

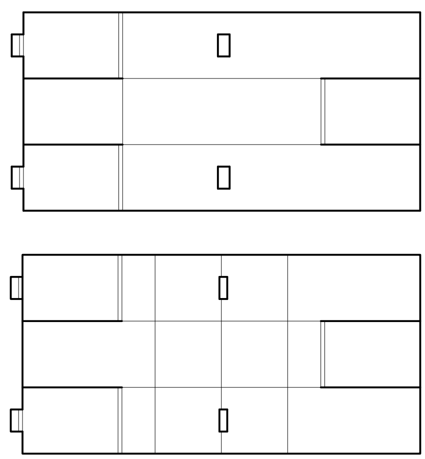


Size: 12”x12”
Cut type: Scoring & Profiling
Fold type: Interior
Potential As A Module: YES, roof system, simple structure
Issues: Needs another member to remain rigid, multiple engravings needed for curvature.

FINGER-TAB TEST #1

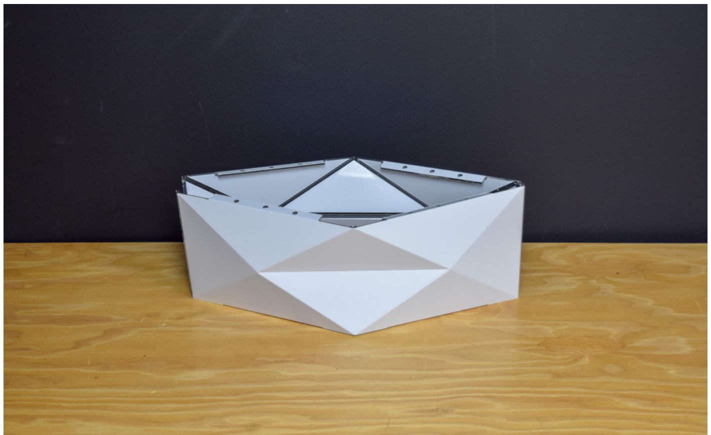


Cut Geometry:

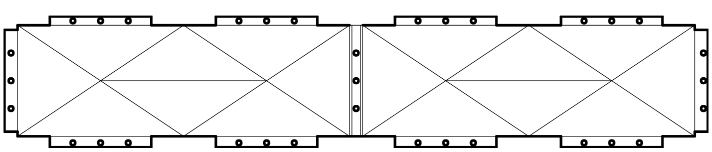


Size: 6”x12”
Cut type: Scoring & Profiling
Fold type: Interior
Potential As A Module: Could work as connection system in pair with other modules.
Issues: Tolerances for tab connections did not allow for the width of the tennon.

MODULAR TEST #7

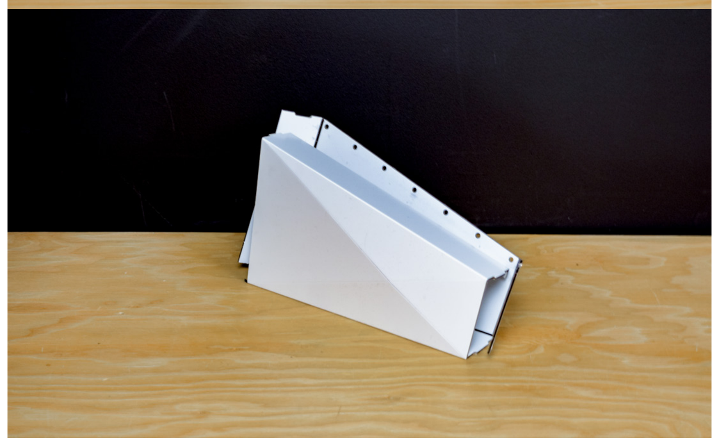


Cut Geometry:

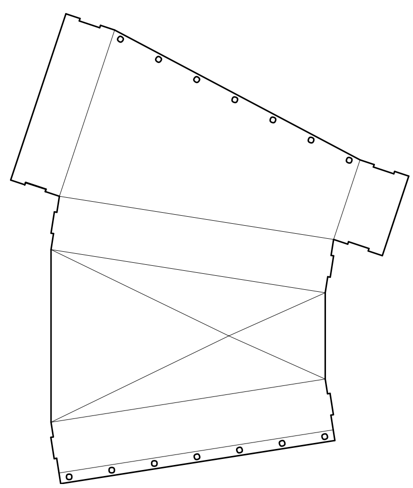


Size:
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module:YES
Issues: Was not fully enclosed, due to folding geometries the top and bottom edges were not planar.

MODULAR TEST #8

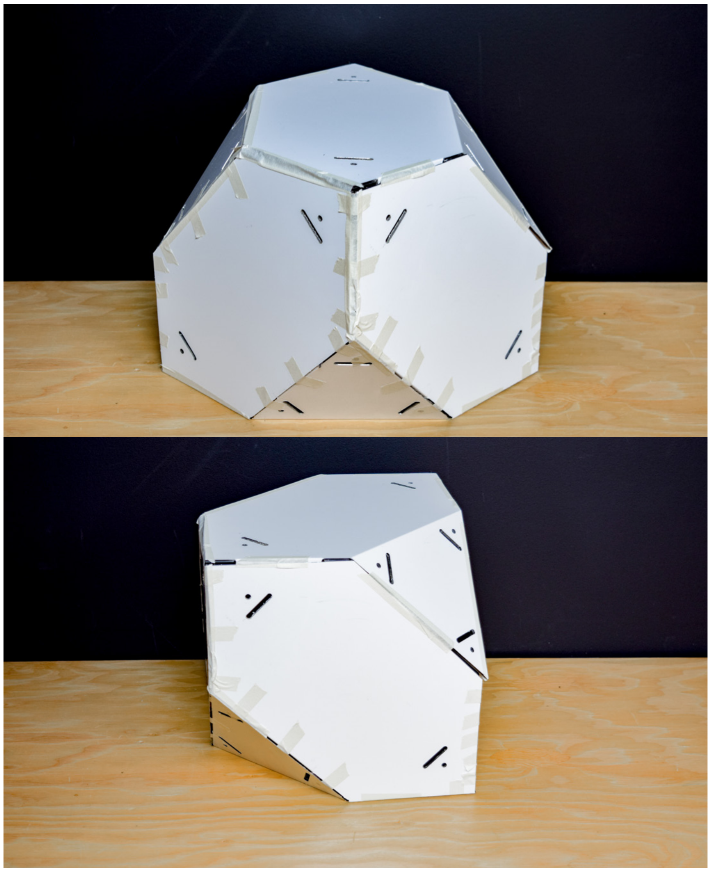


Cut Geometry:

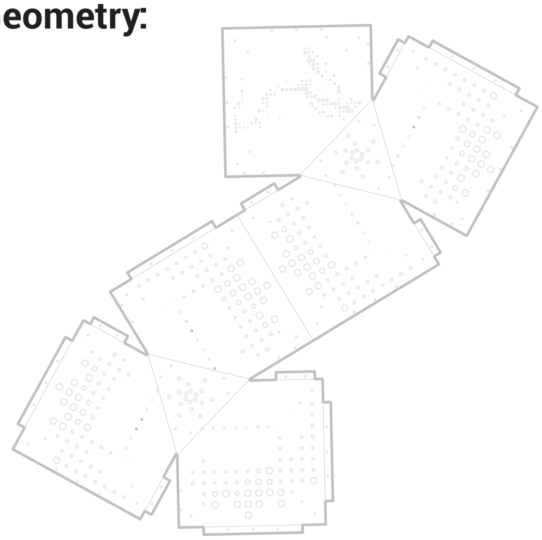


Size:
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module: YES
Issues: Engraves were not wide enough to allow module to fold completely into Its desired form.

FINAL MODULE #1a

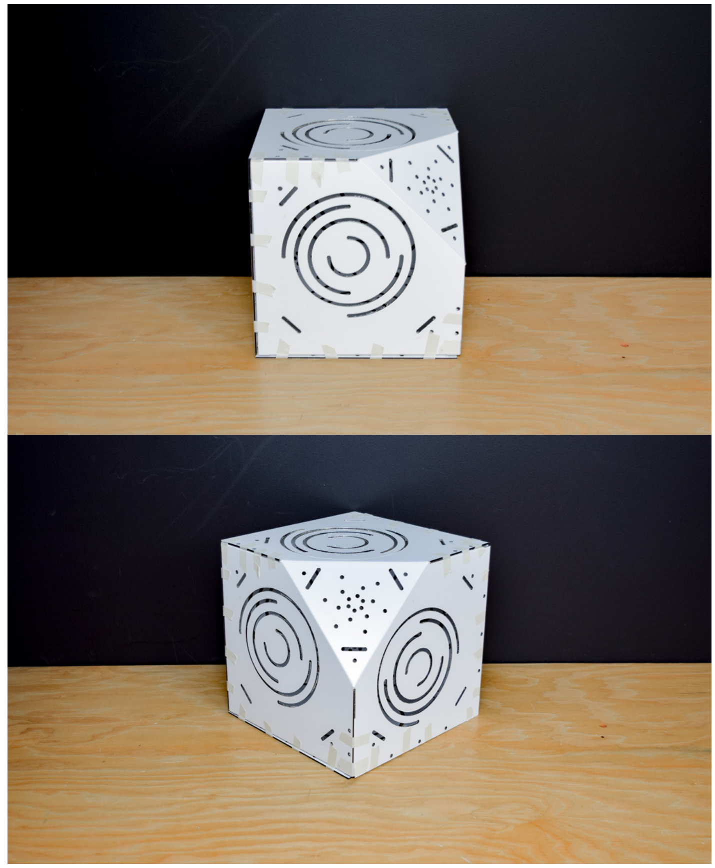


Cut Geometry:

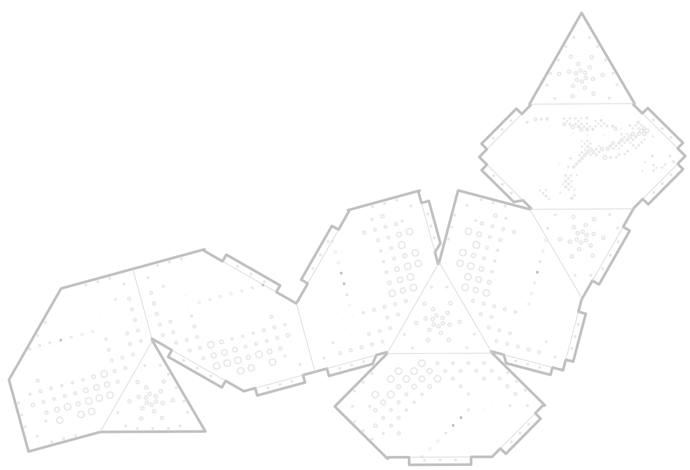


Size:
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module:YES
Issues: Lack of tolerance posed issues for assembly.

FINAL MODULE #2b

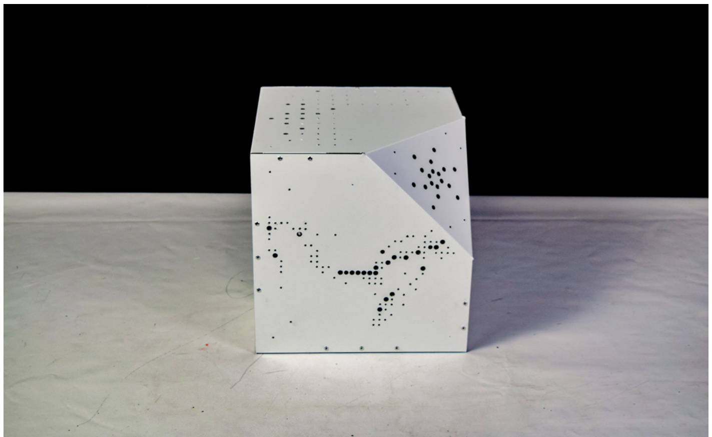


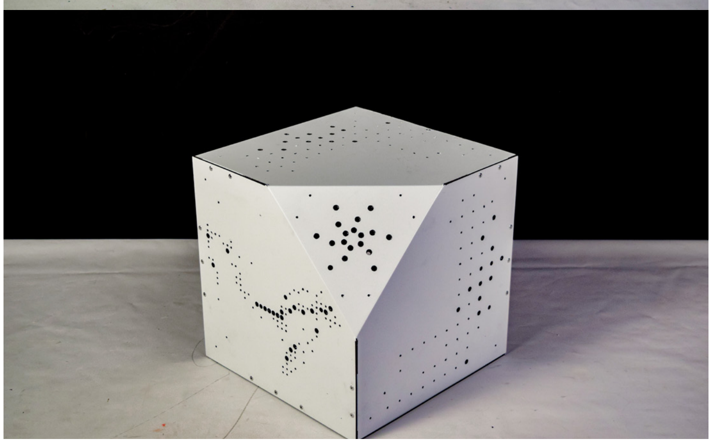
Cut Geometry:



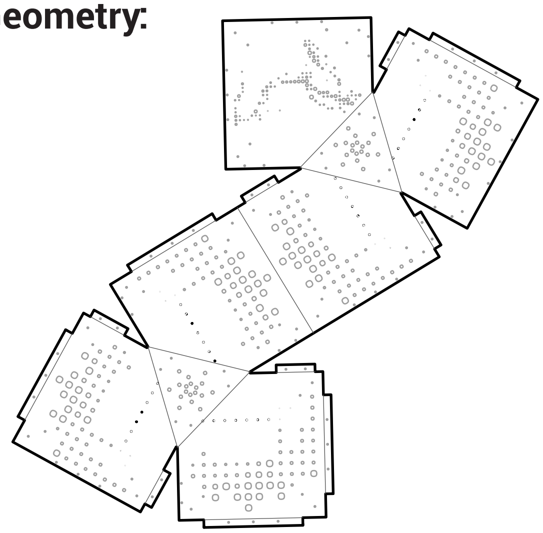
Size:
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module: YES
Issues: Cut lines reduced integrity of module.

FINAL MODULE 1



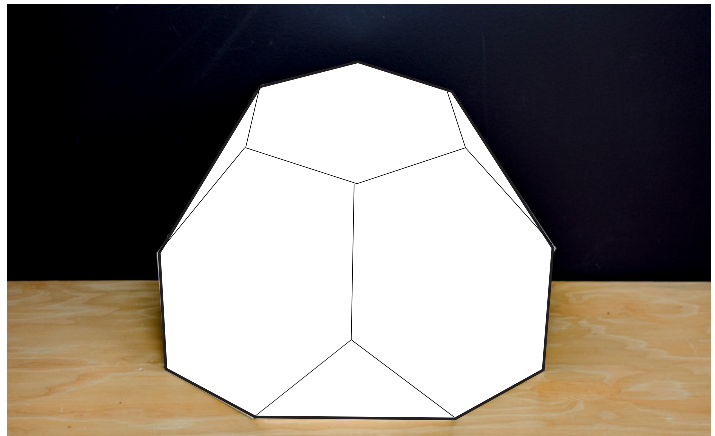


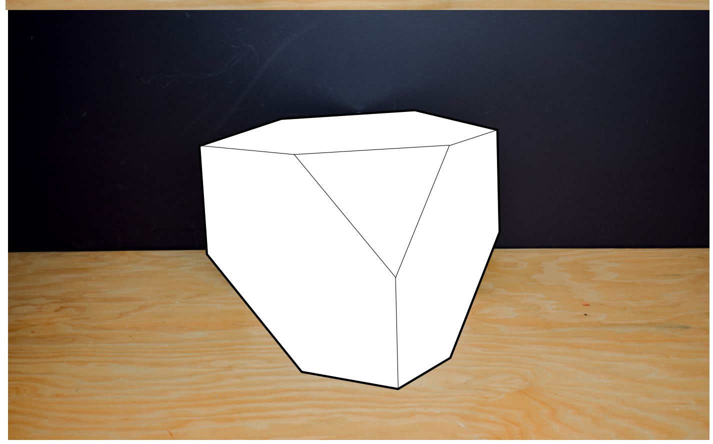
Cut Geometry:



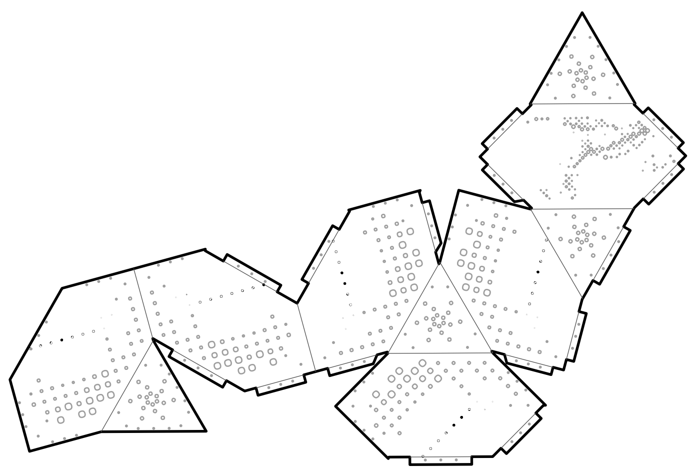
Size:
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module:YES
Issues: N/A

FINAL MODULE 2



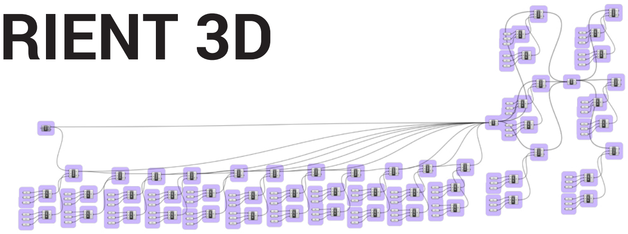


Cut Geometry:

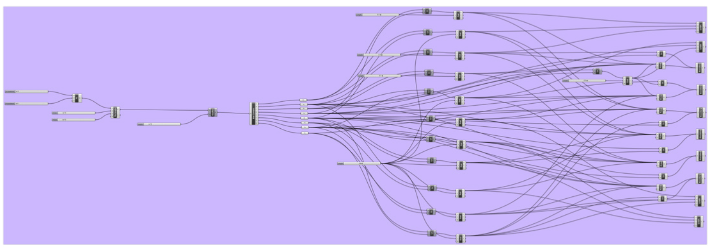


Size:
Cut Types: Scoring & Profiling
Fold Types: Interior & Exterior Folds
Potential As A Module: YES
Issues: N/A

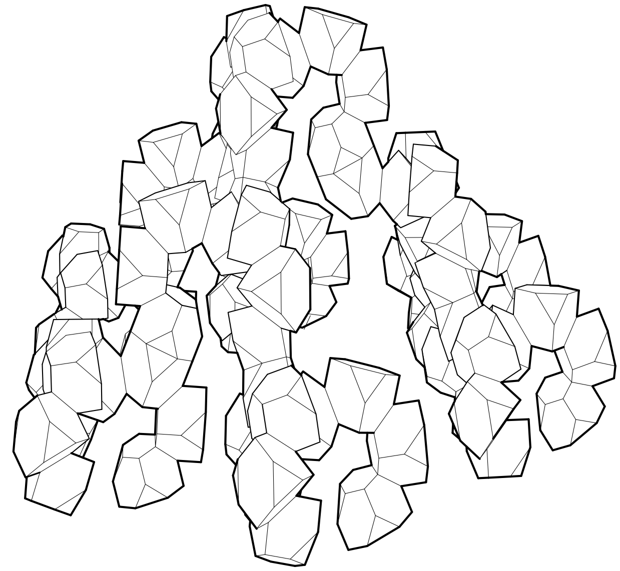
ORIENT 3D



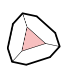
Orient definition in grasshopper



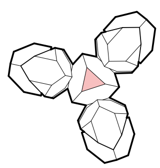
Module definition in grasshopper



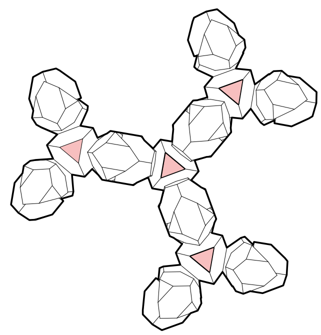
Parametric form derived from grasshopper



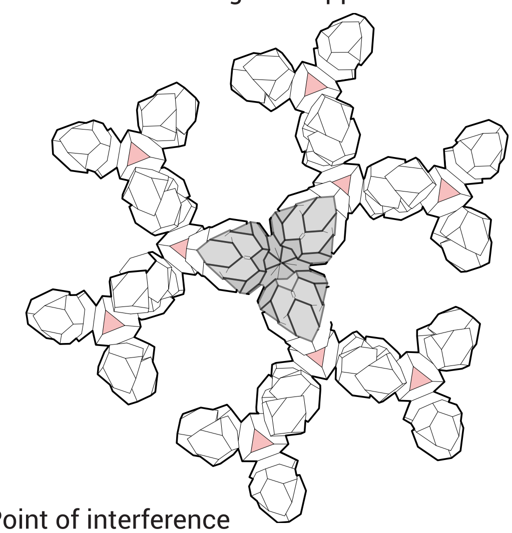
Module



Grouping 1



Grouping 2



Point of interference

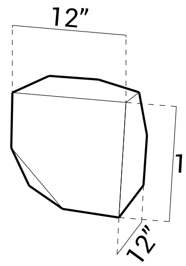
Using the *orient 3pt* command in Rhino and Grasshopper's equivalent *orient* function to explore form and geometry configurations using our desired modules, our group was able to draw a number of conclusions regarding the integration of parametric software in our exploration with ACM.

Once our final modules were produced using parametric models we were able to Orient the modules to themselves make groupings. Using those groupings as units, each can be oriented onto themselves to create a fully parametric assembly. By choosing the surfaces on which the groupings would originate from and revolve onto the direction and placement of geometries can be controlled.

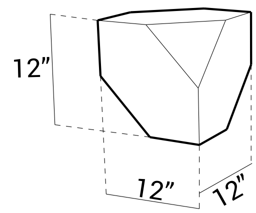
Unfortunately, without the addition of evolutionary based algorithms - such as the Galapagos plugin for Grasshopper - or carefully designed modules that will not interfere with other continued geometries the orient tool is primarily limited to the module's manipulation by the user in that it will create overlapping geometries if not properly managed.

CONNECTIONS

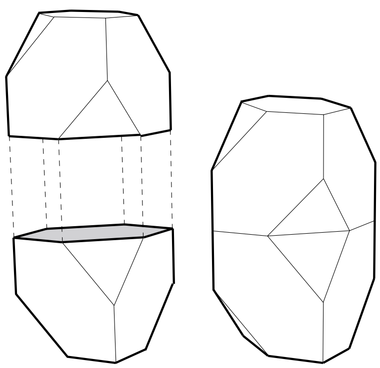
MODULE #1



MODULE #2



FACE TO FACE



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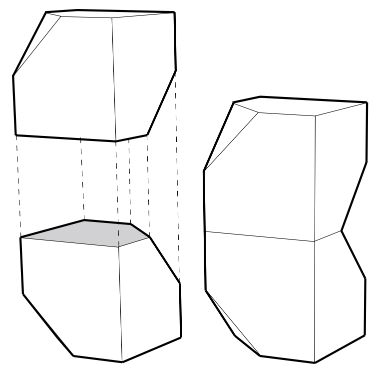
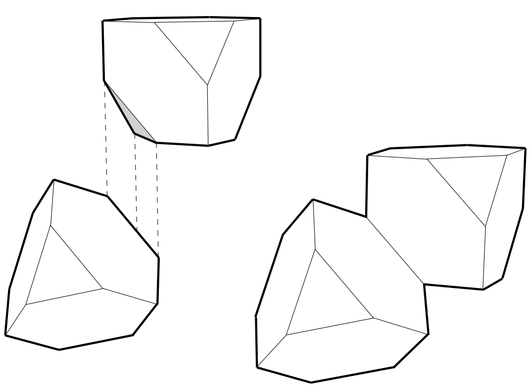


SIDE TO SIDE



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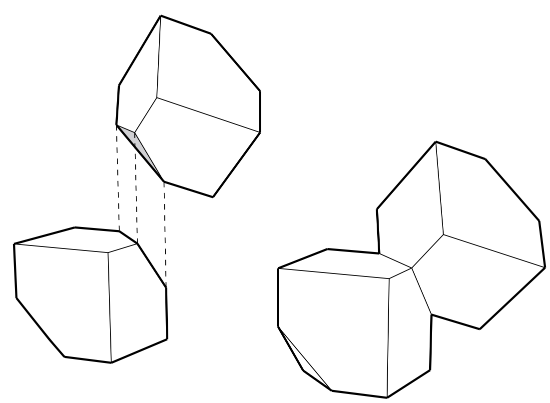
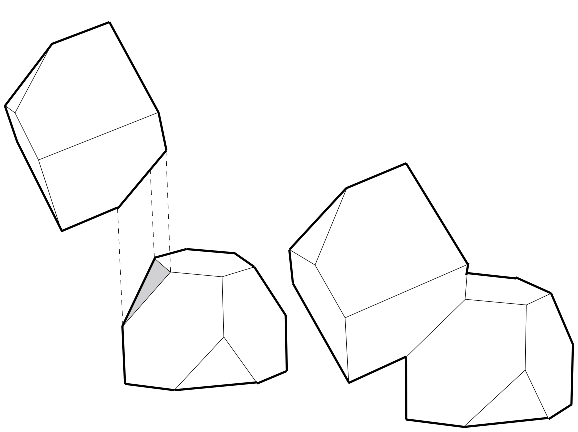
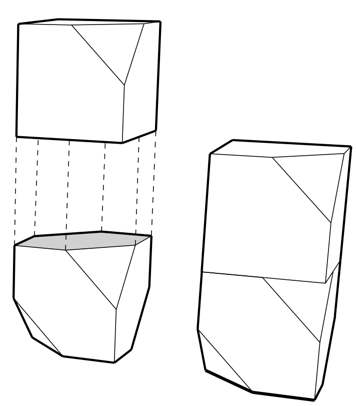
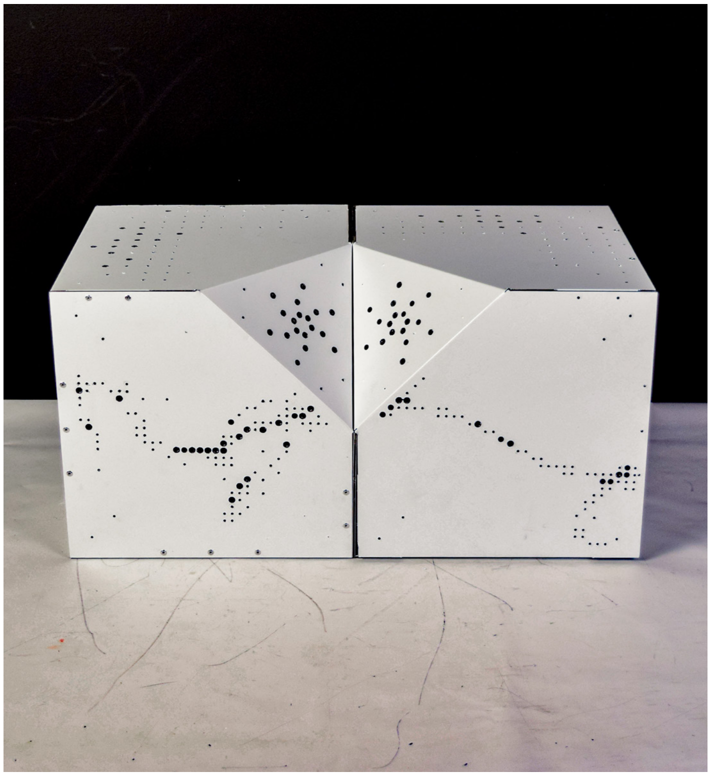
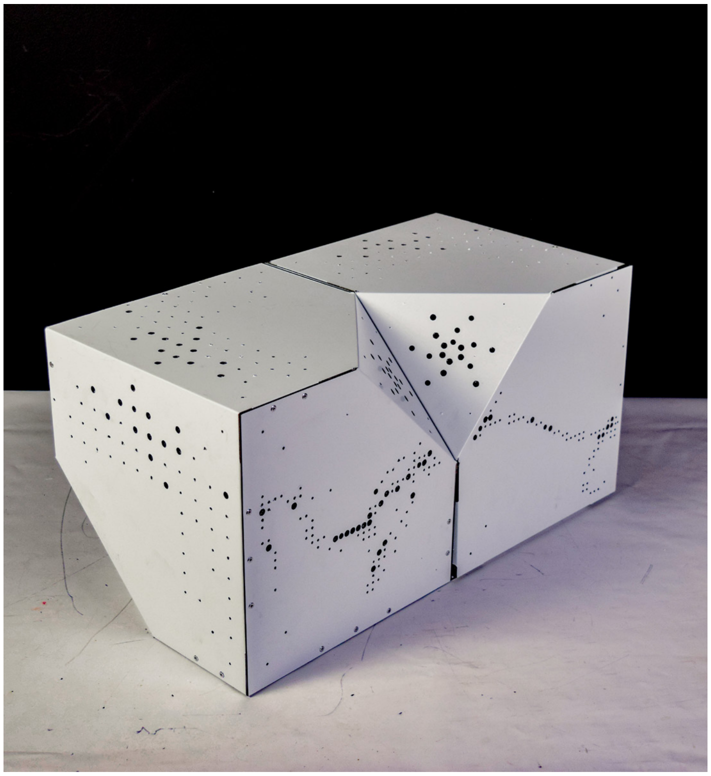
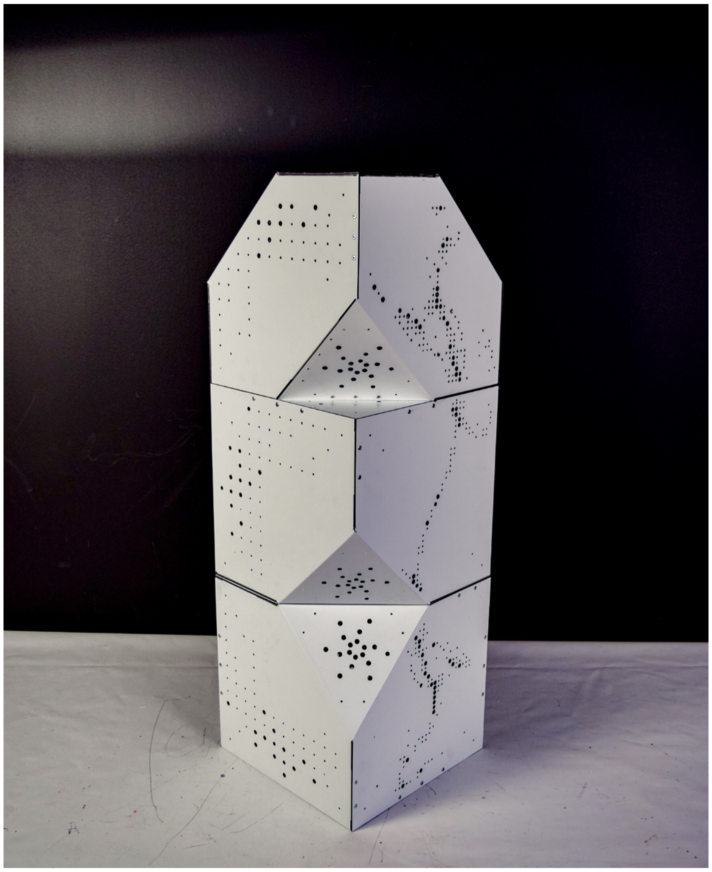
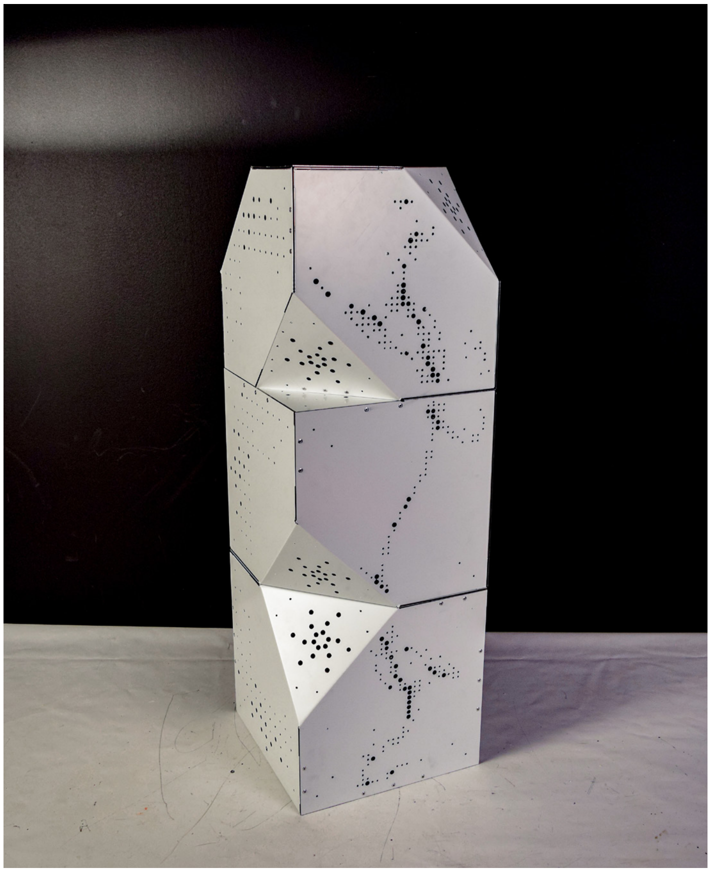


MODUEL 1 & 2 SIDE TO SIDE

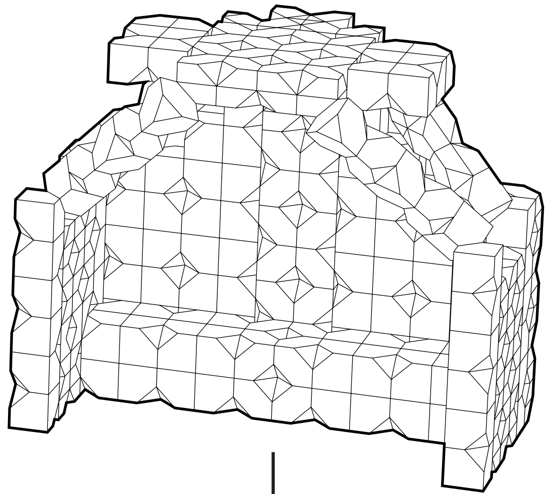


MODUEL 1 & 2 FACE TO FACE

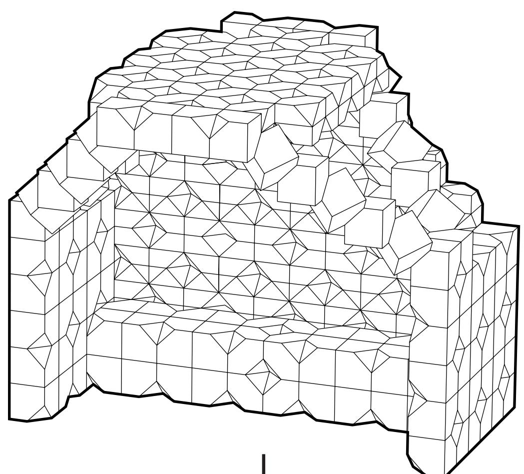


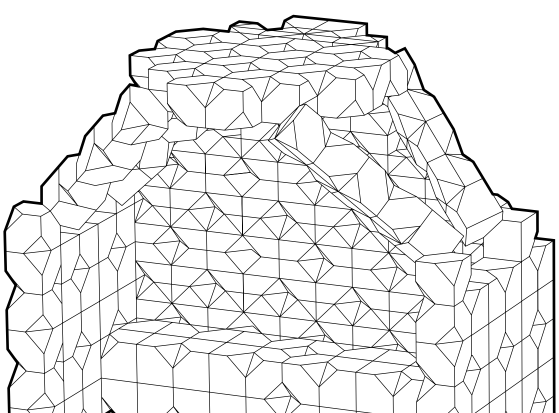
ITERATION #1



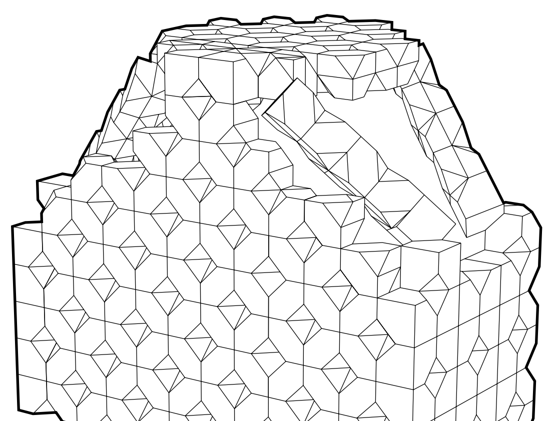
ITERATION #2

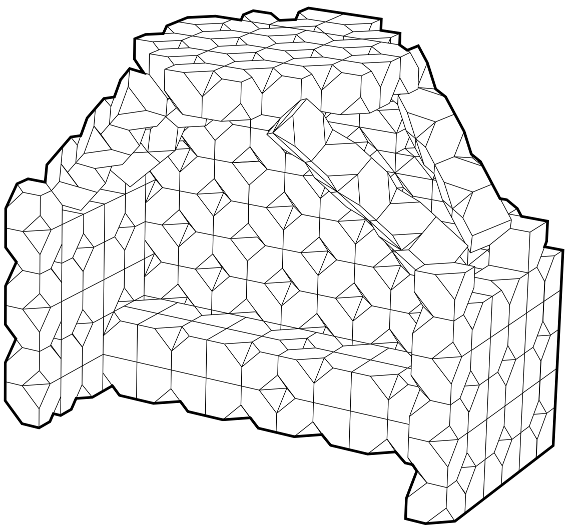


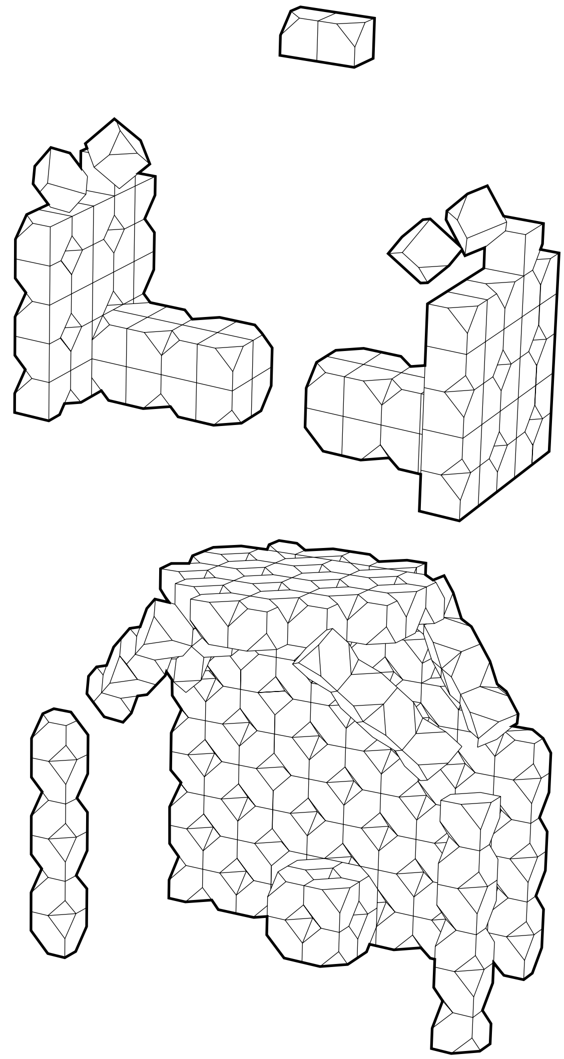
FINAL ITERATION FRONT

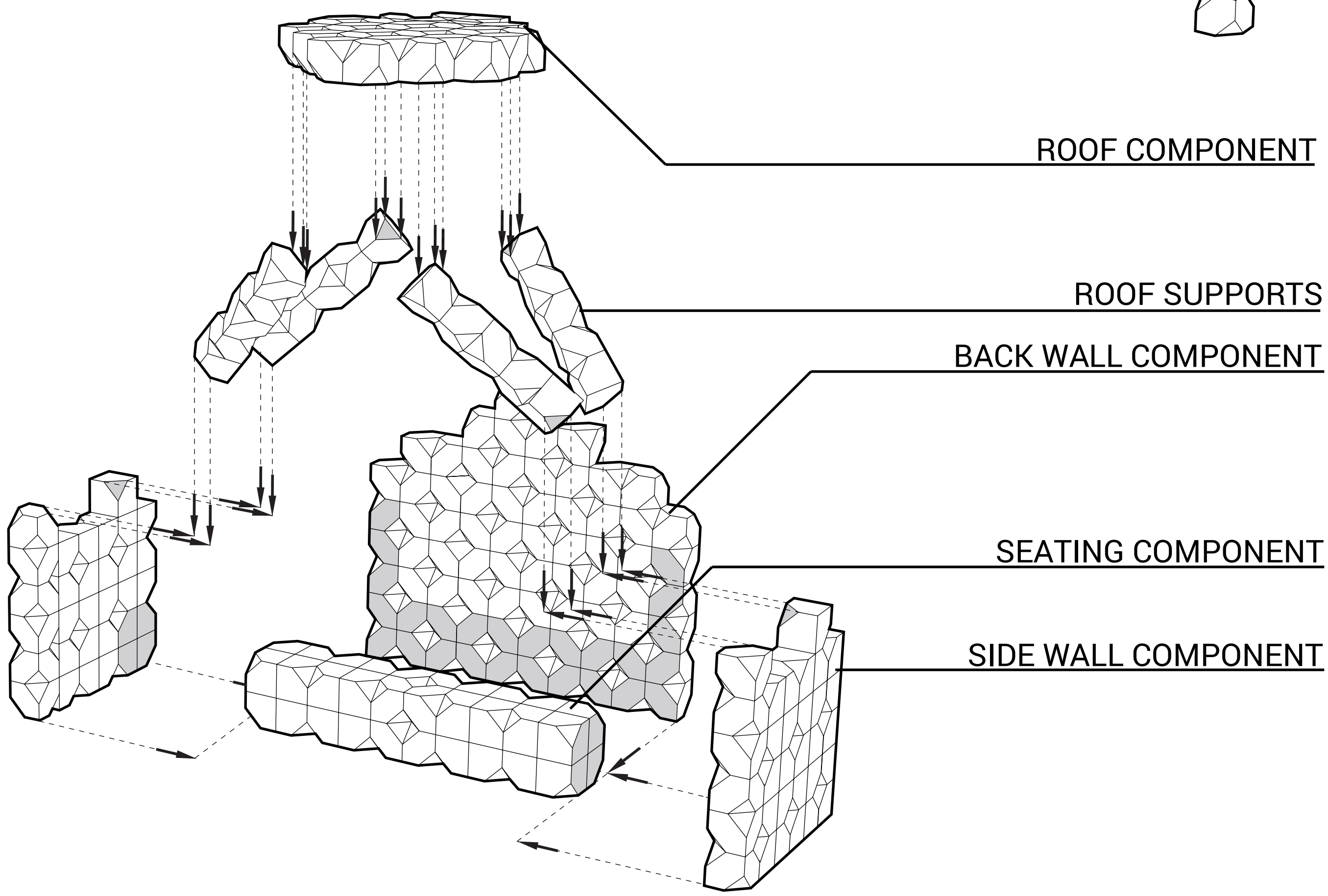


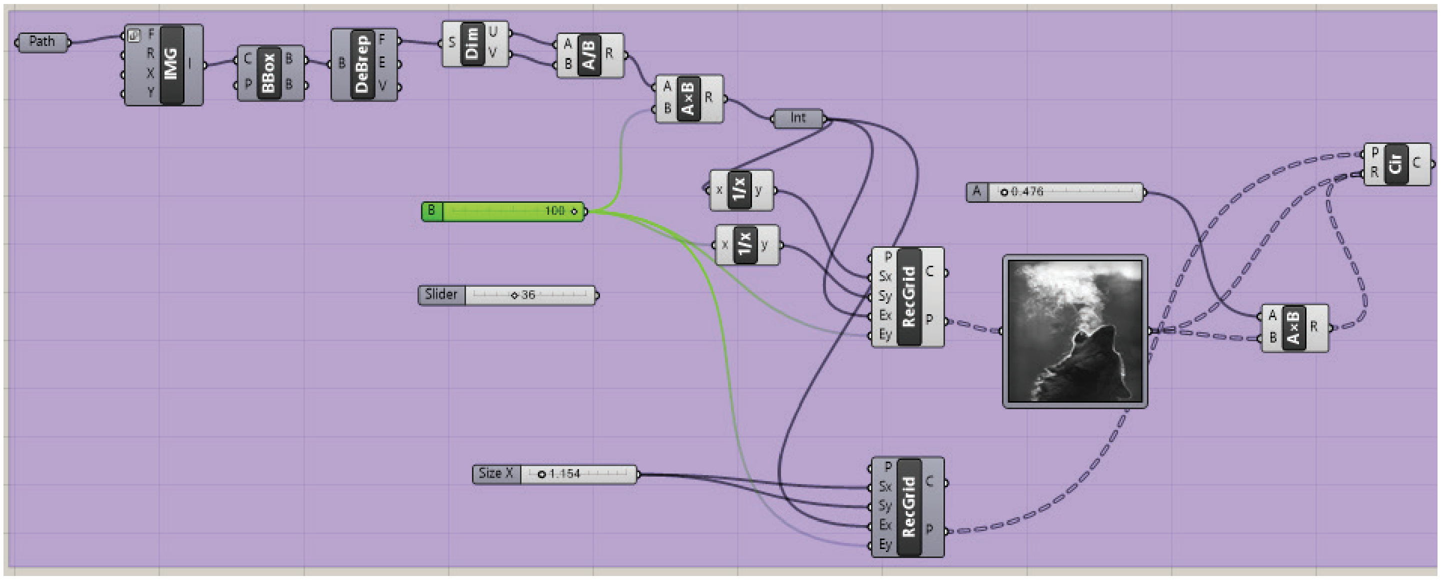
FINAL ITERATION BACK

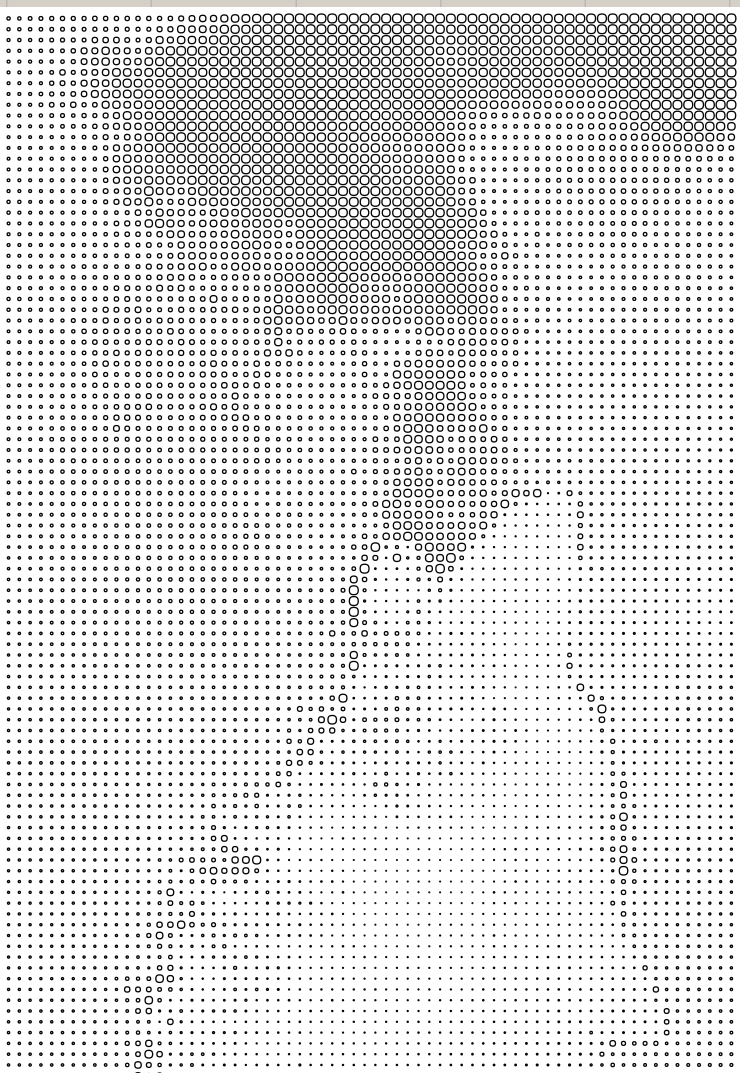




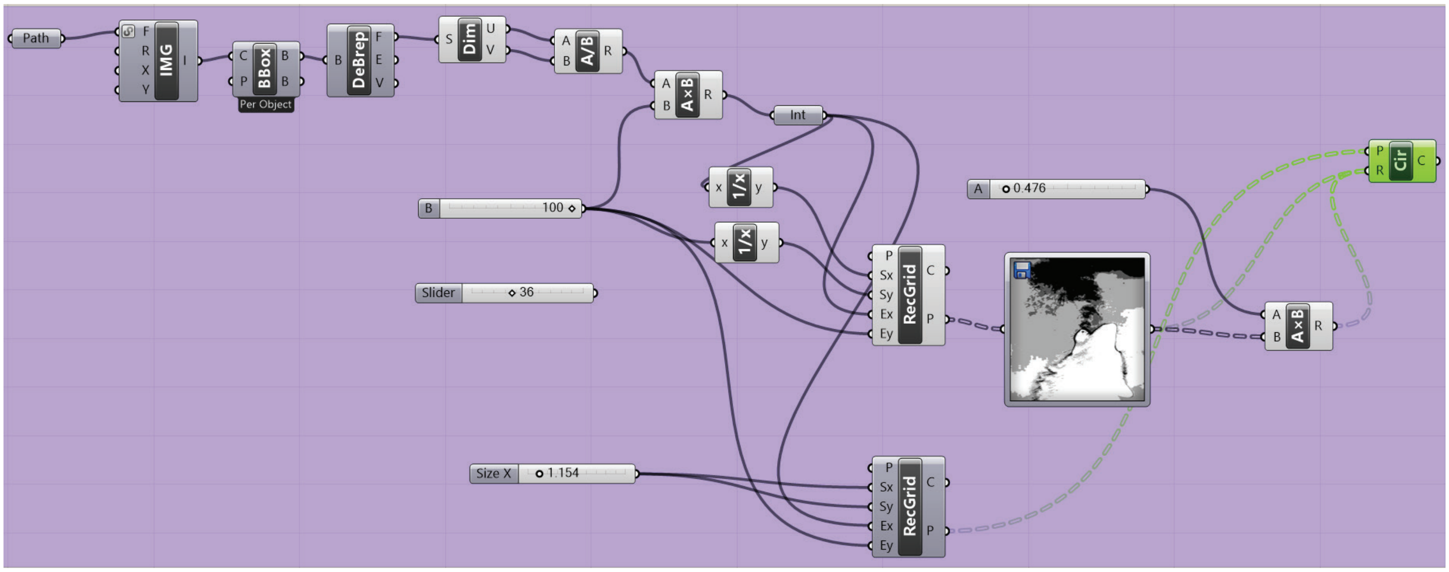



ROOF COMPONENT
ROOF SUPPORTS
BACK WALL COMPONENT
SEATING COMPONENT
SIDE WALL COMPONENT



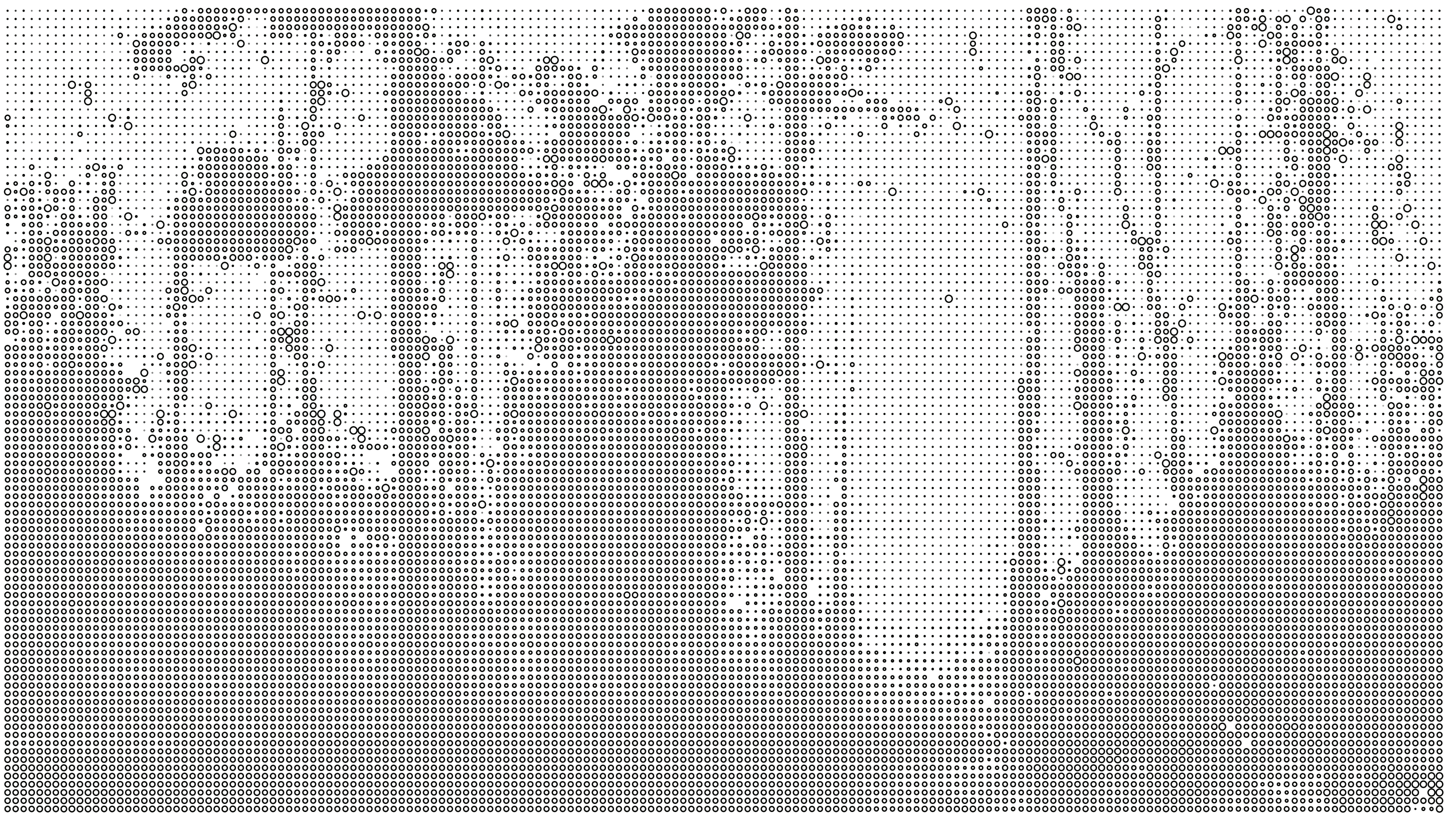


Using Grasshopper to create an aesthetic design for the main facade of our structure was a goal of ours. By setting up a square grid of points and assigning circles of different radii to those points in association with a subject image we were able to create a stylized version of the image. This script is adapted to be able to adjust the size of the grid, spacing of the points and relative radius of the circles that form the image so it can be adjusted to fit different sized facades. Moving forward we would like to explore better control of the individual circle sizes to set a more specific hole size for drilling on the CNC which would likely require moving away from the point grid structure.

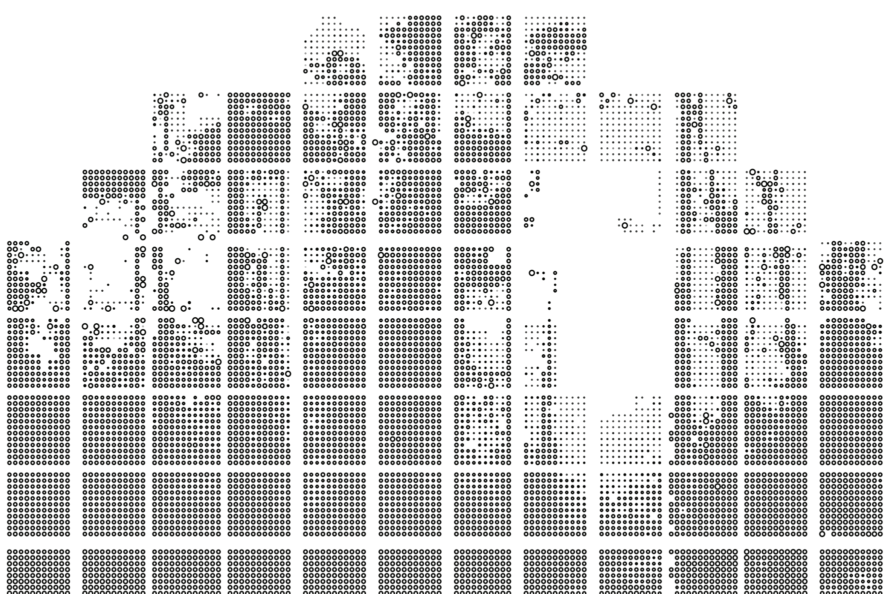


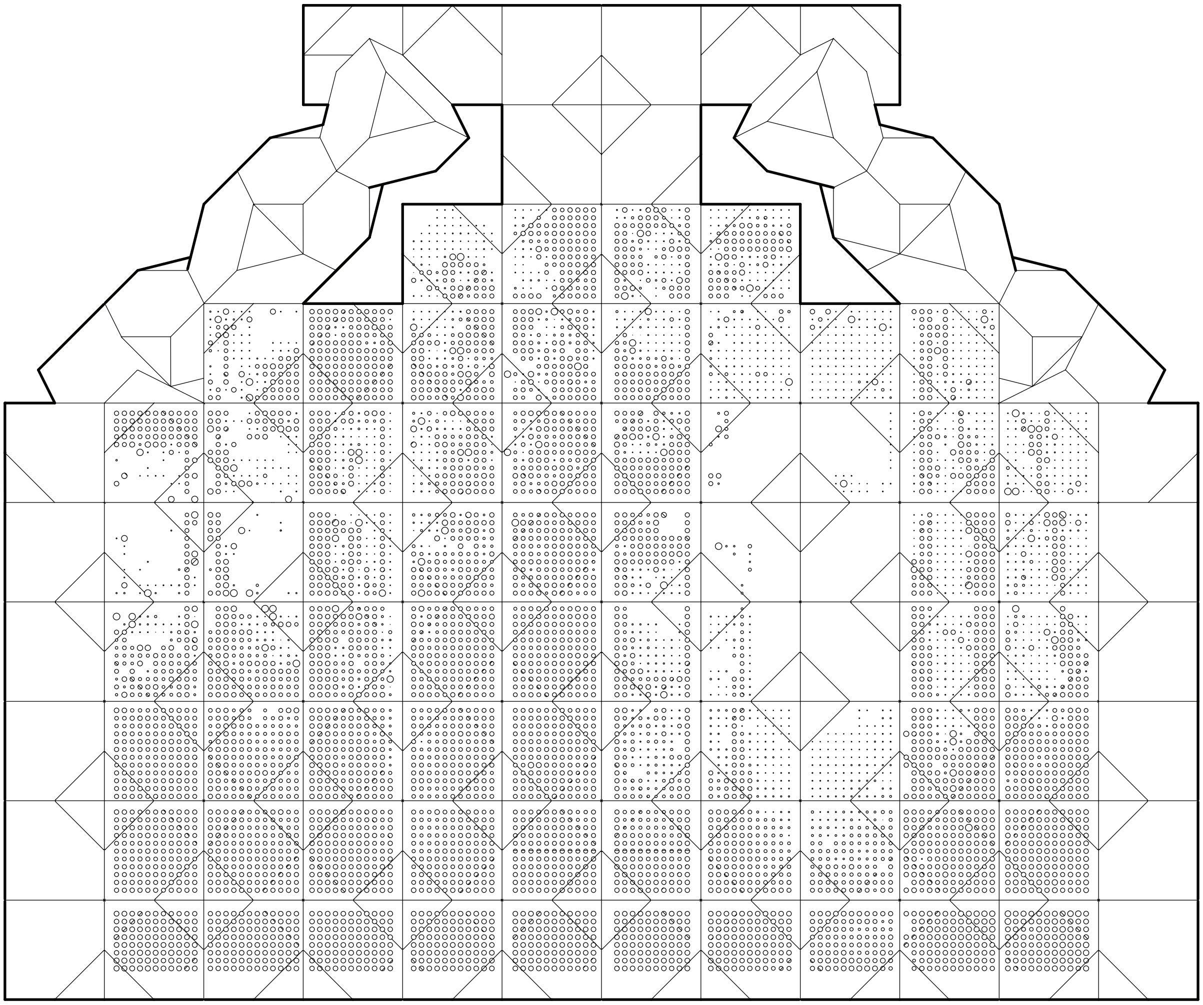
The Image sampler control in grasshopper is set up to recognize a number of image components whether it is the alpha channels, colours or a greyscale as shown to the left, however it assumes lighter areas to be more dense with perforations which is not necessarily our intent as our panels are white. By inverting and posterizing the source image we were able to manipulate the variance and displacement of perforations to create a parametric image that better represents the initial design.

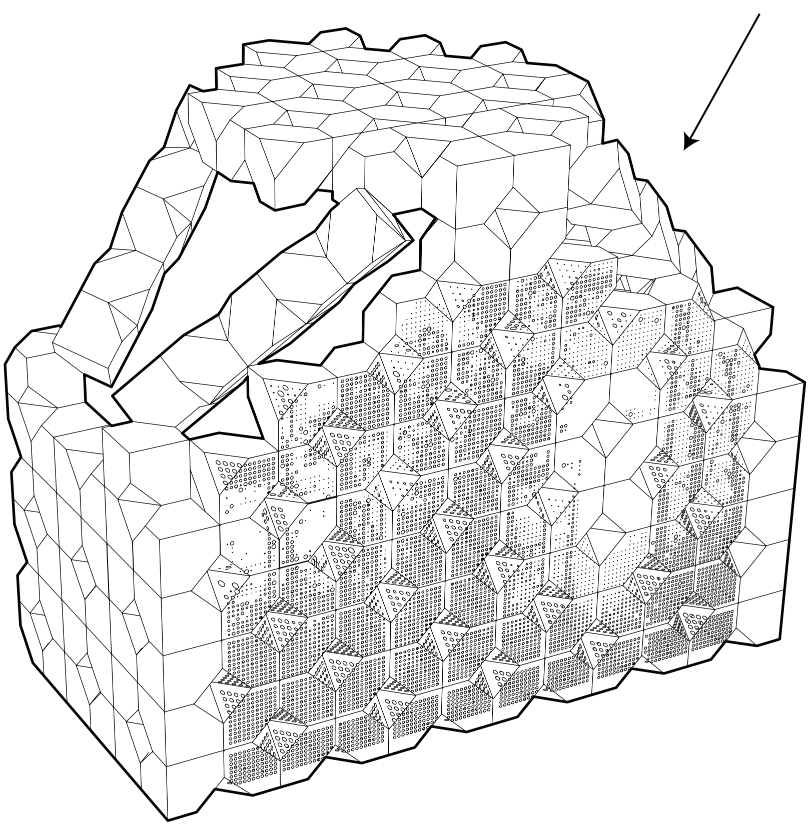
Keeping with the nature themed perforation pattern, the tree-line image was more legible across numerous panels than the wolf.



After a design better suited to the shape of the structure was developed projecting the appropriate perforations on the desired units would be the next challenge. By flattening the structures elevation we were left with a grid to isolate the areas where perforations would not interfere with the folds or connections of the structure.







The design on the rear of the shelter facing the student lounge would add interest from the normally less visible side of the installation.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