

ARCH 696

200 Lines of Code

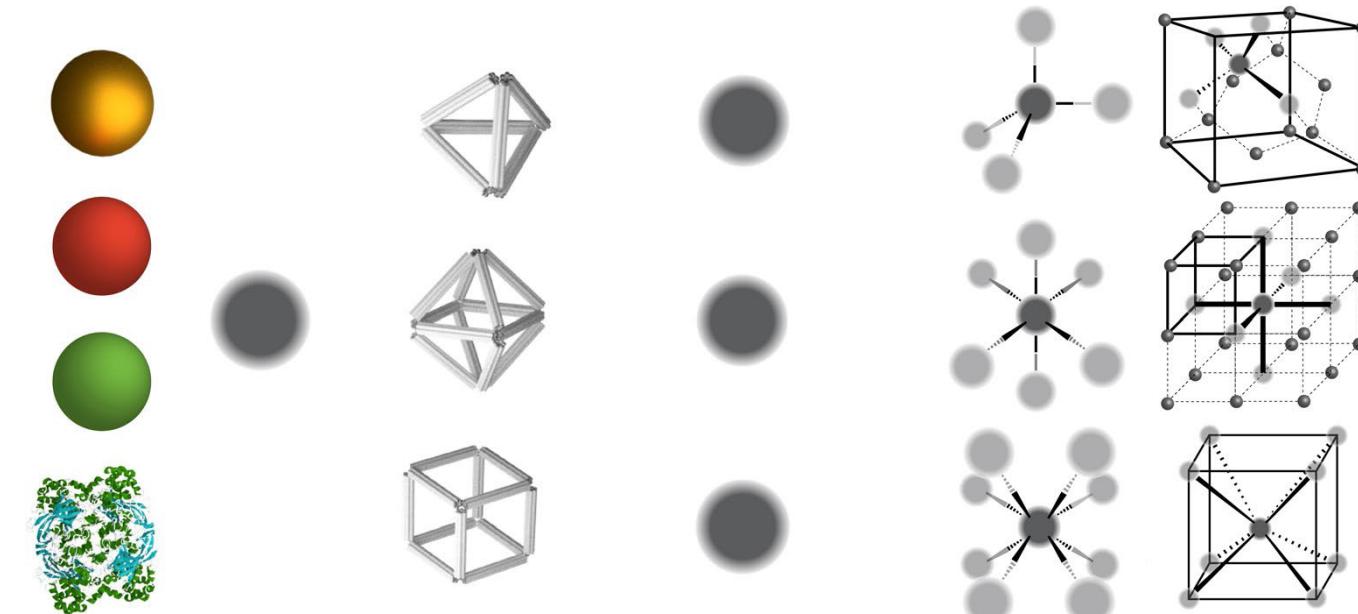
Noordeep Kalsi / Lourdes Narciso / PJ Sandberg / Sukhneer Sidhu / Jo-Lynn Yen

Somerville Design Charrette | Winter 2022

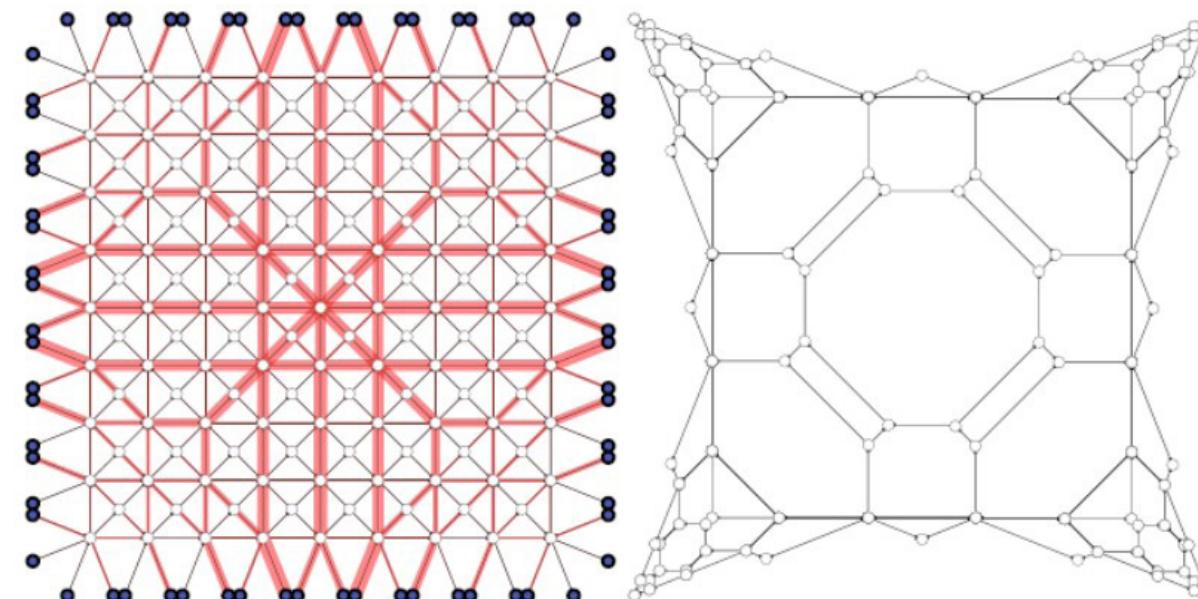
Functionally Graded Material

Developing from the concepts of geometry and physics (i.e., motion), the workshop explored how computer design and programming can be integrated in a feedback loop to inform the structure, fabrication and manufacturing process. Using an experimental toolchain setup, relatively simple initial motions and conditions developed in a modeling environment are then repeated and aggregated through code to develop varying complex emergent outcomes. Geometric features explored through these outcomes can then be used to investigate the mechanical properties and strength of the form and material.

In this rapid additive CAD-CAM prototyping and manufacturing process, the voxel is integrated in the process for unitary modules to base its location in relation to other voxels (and their respective module). As a result of having control in manipulating the structure of the composite aggregation through a gradient, such as the scale, material structural properties can emerge through the form.



DNA material voxels for assembly of 3D lattices (Tian, Lhermitte, Vo & Xin (2020). Ordered three-dimensional nanomaterials using DNA-prescribed and valence-controlled material voxels).

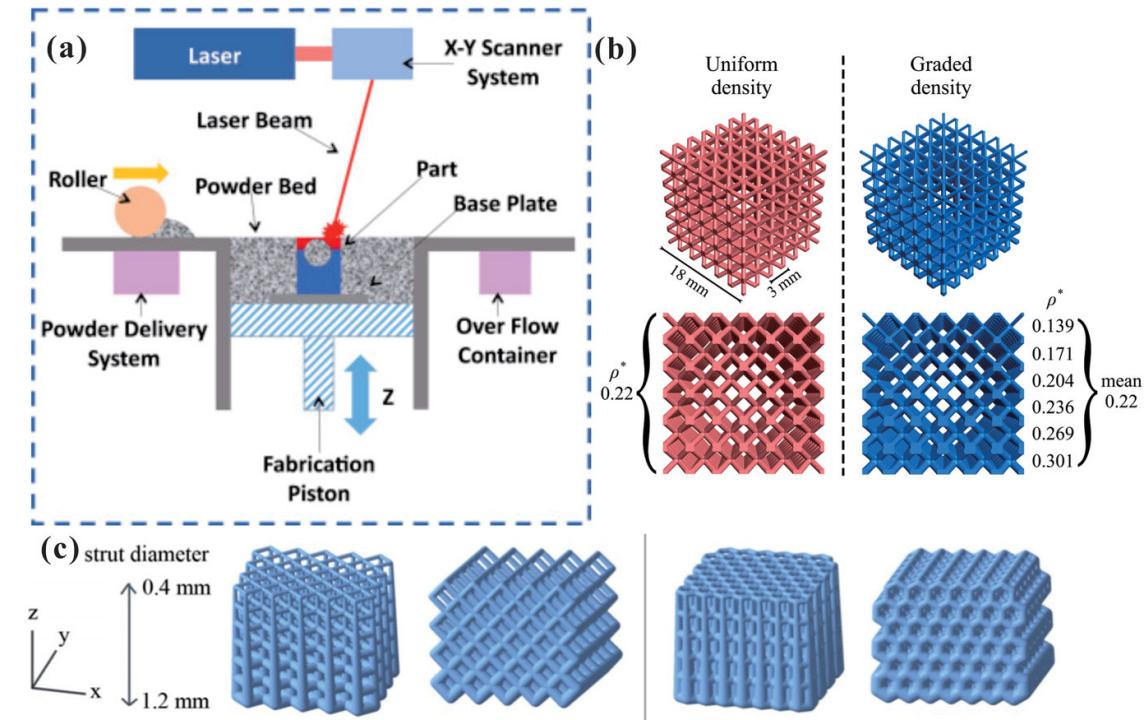


V-shaped grid with general load reactions: load path = 445.4, k = 118 (Liew, Pagonakis, Van Mele & Block (2017). Load-path optimisation of funicular networks).

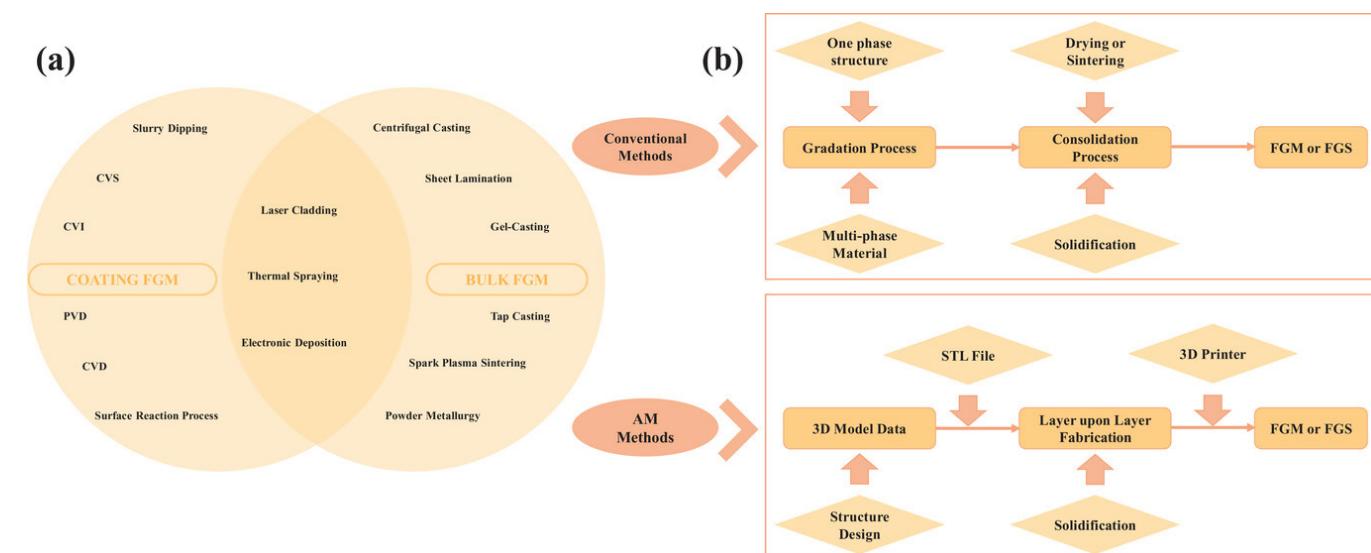
Genotype Phenotype Logic

Borrowing from biological concepts of genotype (gene) and phenotype (traits that come with those genes); the process of mutating genes to create new phenotypes in the logic behind the methodology in varying the structure through the manipulation of vertex scale and translation. Driven by the genotype-phenotype logic, the following questions were developed as a framework for our explorations: how can the basic “cross” be mutated in the generation of a structural lattice, and can this prototype be designed for manufacturing and assembly (DFMA) of a structure at a larger scale?

By working in a toolchain workflow, it enables the designer to interact with the computer to make new networks to generate novel outcomes. Through interactive and architectural geometry, the interaction between designer and computer can produce greater control of shapes that meet a certain objective.



a) principle powder bed fusion process; b) uniform and graded lattice structures looking at density (Li, Feng, Hao, & Huang (2020). A Review on Functionally Graded Materials and Structures via Additive Manufacturing: From Multi-Scale Design to Versatile Functional Properties).

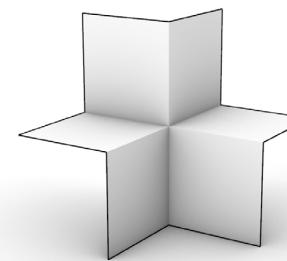


a) conventional FGM manufacturing methods; b) differences between CM and AM methods (Li, Feng, Hao, & Huang (2020). A Review on Functionally Graded Materials and Structures via Additive Manufacturing: From Multi-Scale Design to Versatile Functional Properties).

Toolchain Workflow

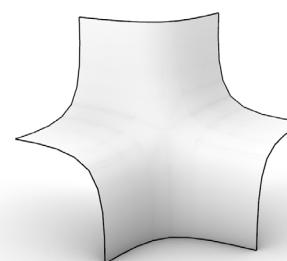
MAYA
Interactive Geometry
User Shape Input (A) +
Computer Adjustments (B)

INPUT



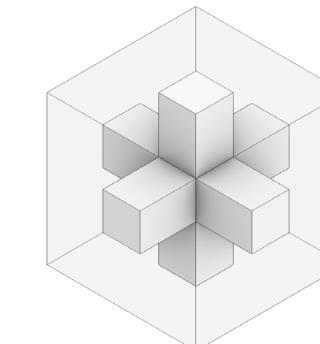
Catmull-Clark
Algorithm (Smooth)

OUTPUT



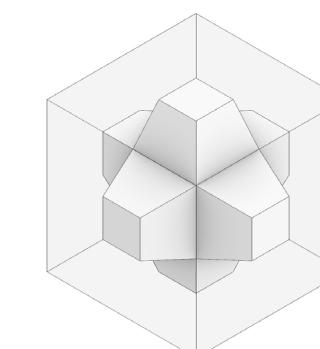
VISUAL STUDIO (C++)
Mutation: Transformation Matrices

IMPORT



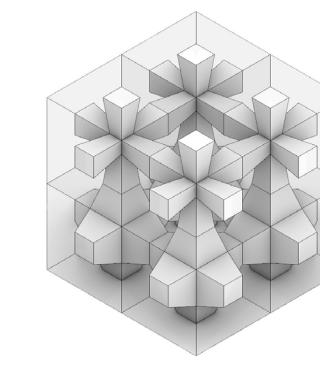
unitary module

SCALE



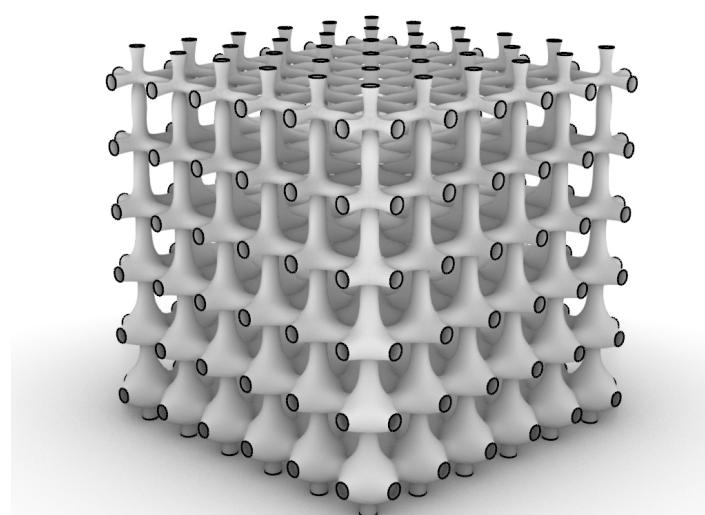
scale selected vertices

MOVE

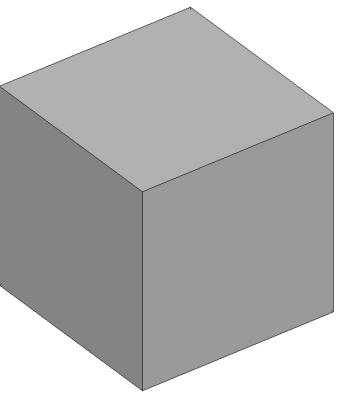


move to correct location on
grid of voxels

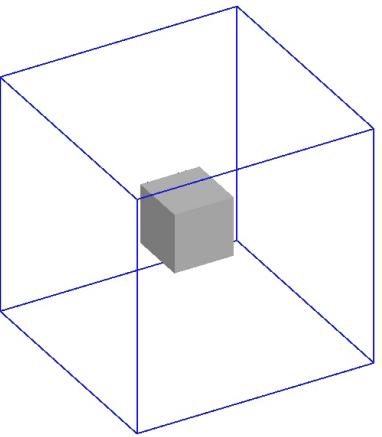
CHITUBOX (3D Print)
Digital Fabrication



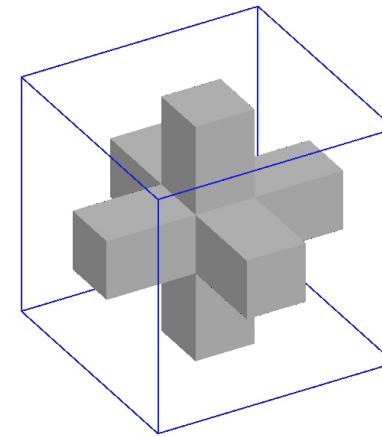
MAYA Procedure



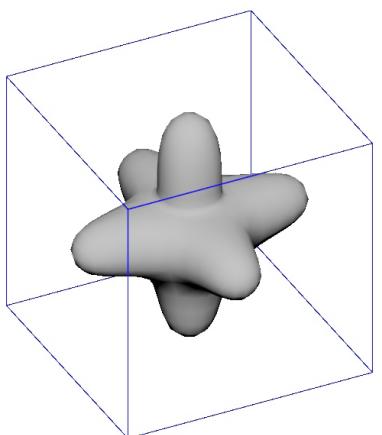
1 Voxel Base (1x1x1)



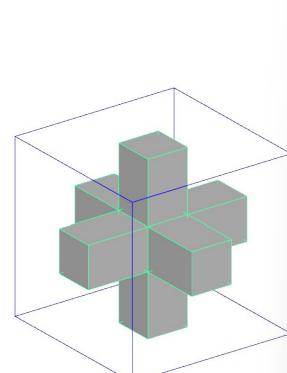
2 Scaled Centre



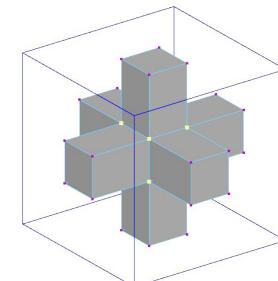
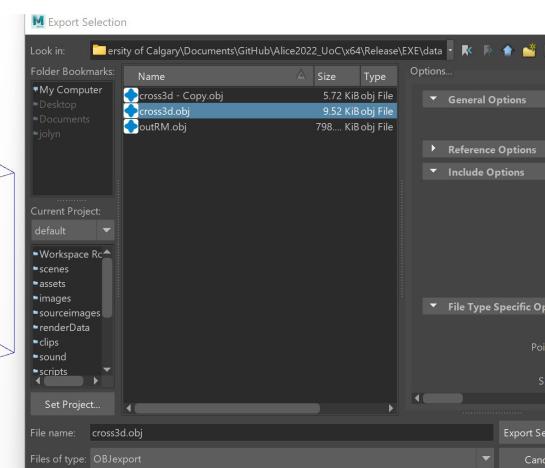
3 Base Cross Node*



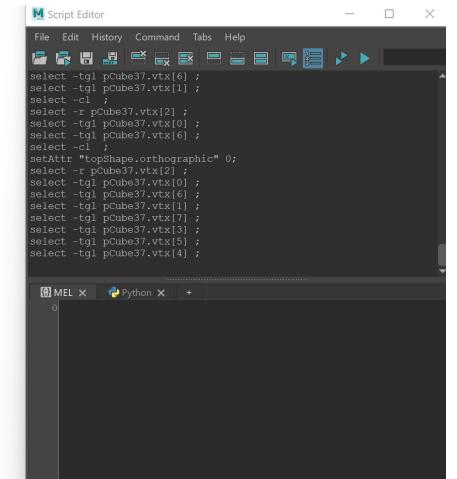
4 Computer Adjustment



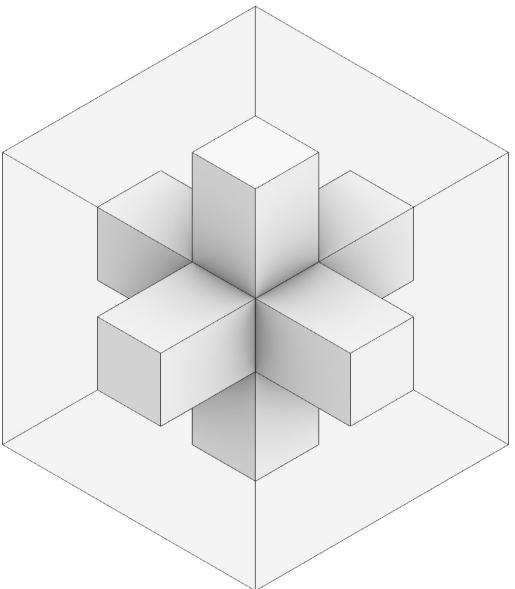
OUTPUT data/cross3d.obj



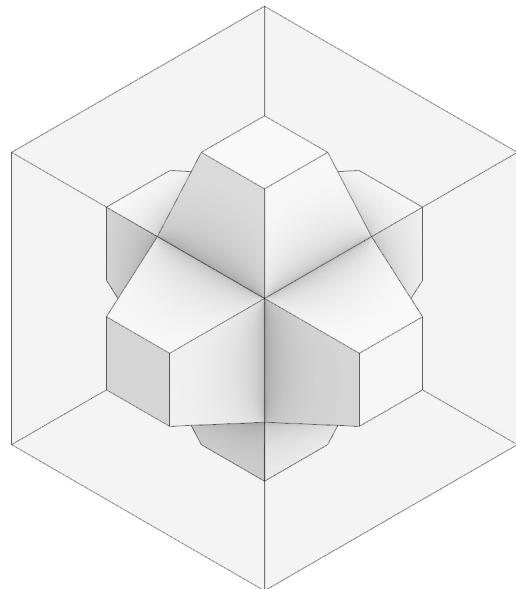
*NOTE Vertices Selection



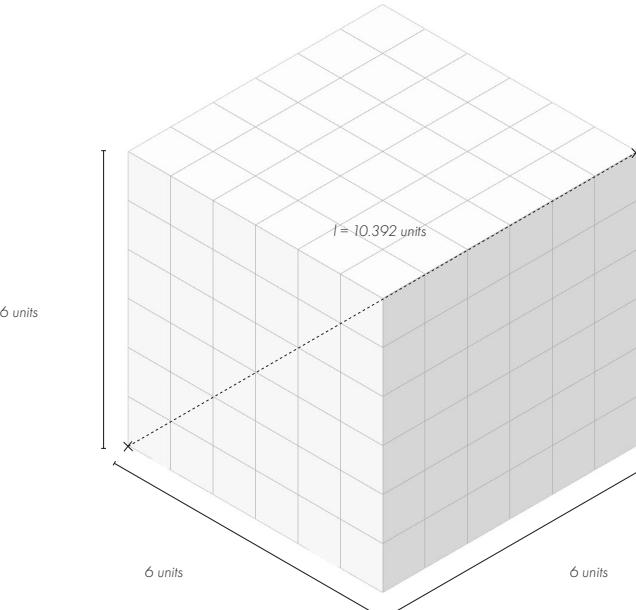
Visual Studio (C++) Procedure



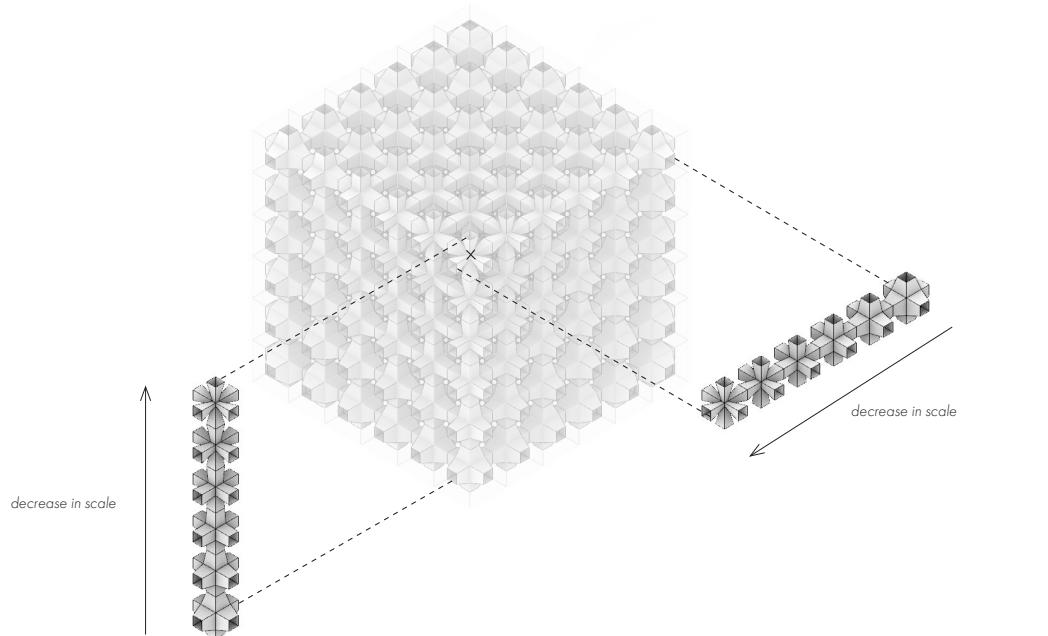
1 Import Mesh (0,0,0)



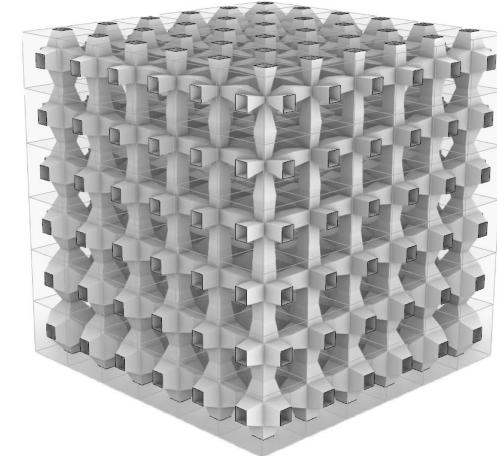
2 Update Select Vertices



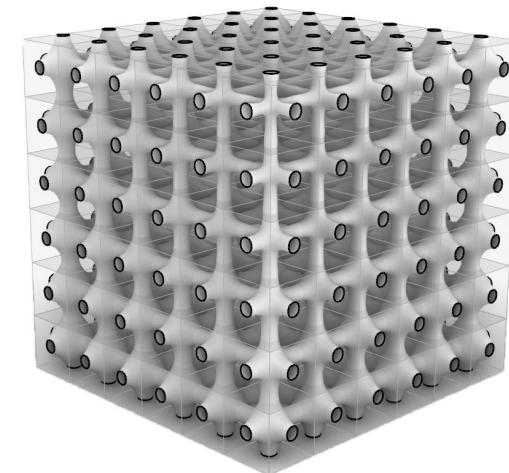
NOTE Grid Dimensions



3 Mutation

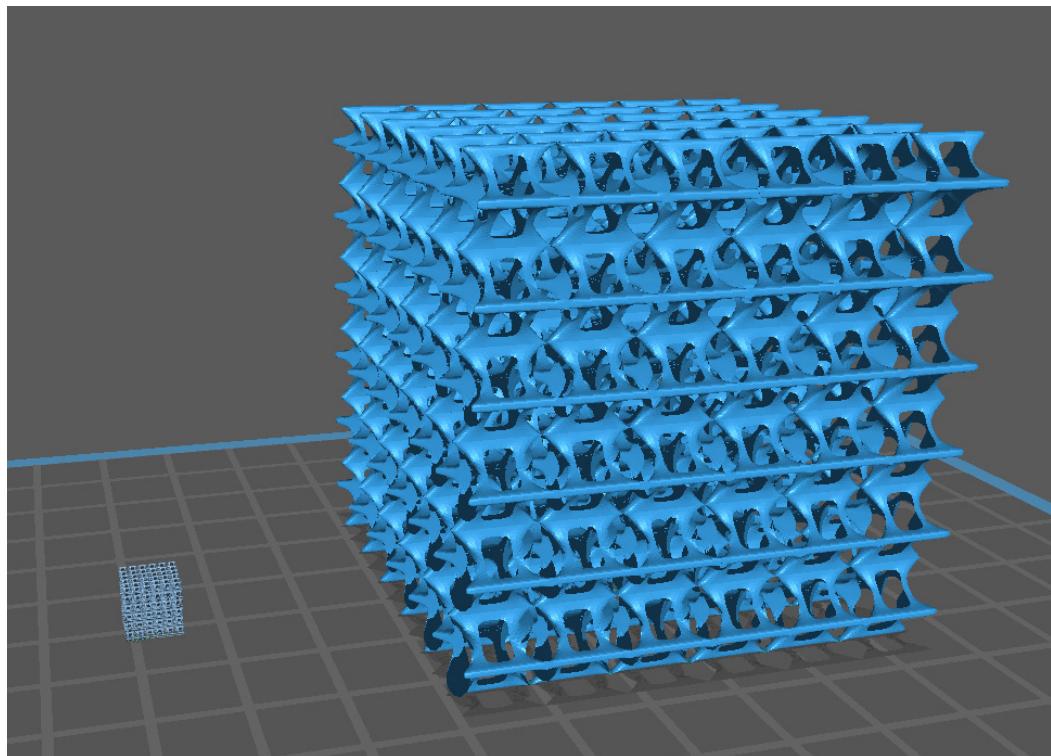


OUTPUT data/outRM.obj

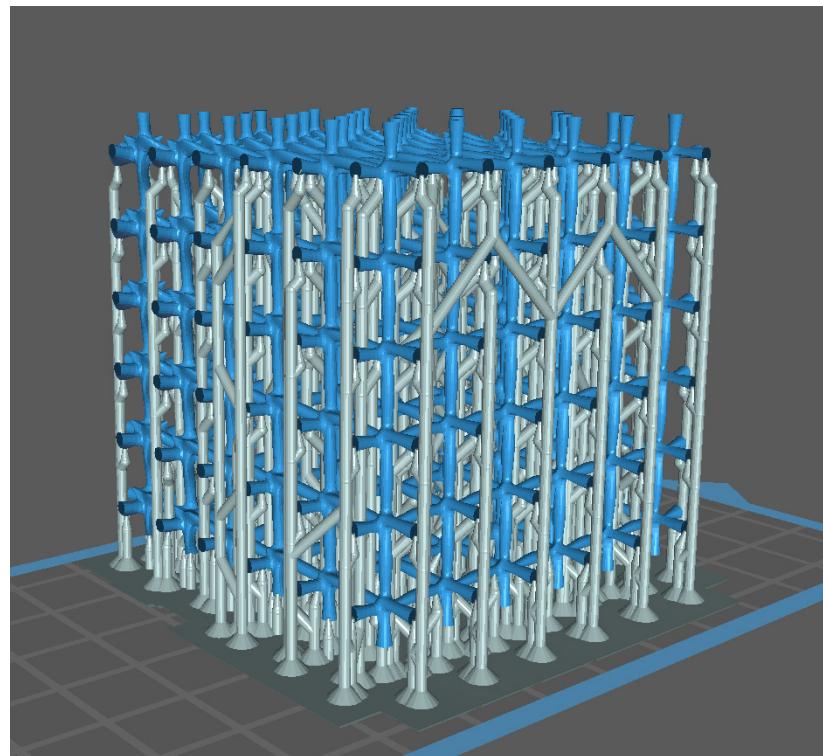


MAYA Adjustments

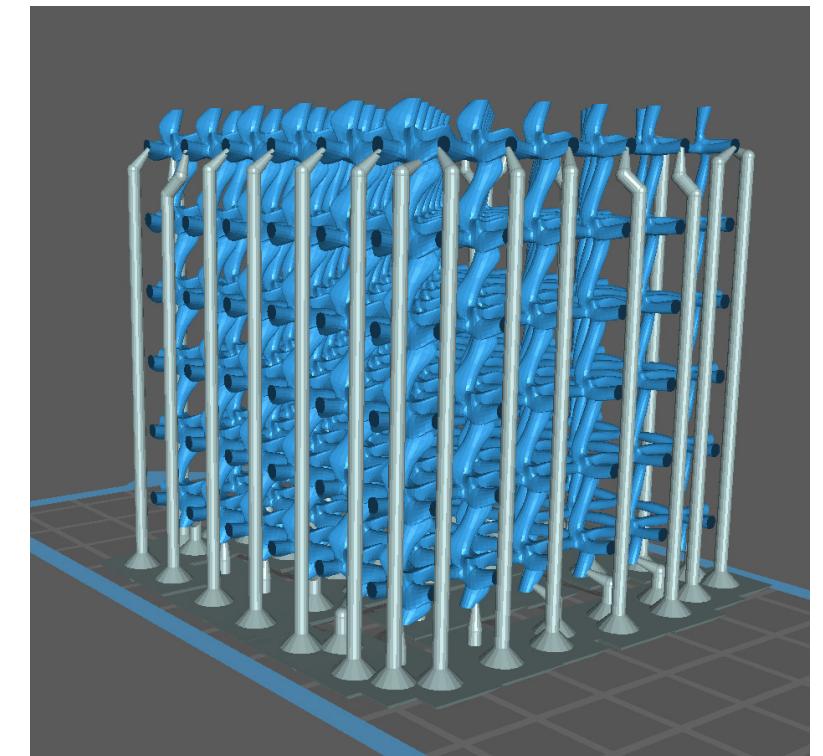
ChituBox Procedure



1 Importing and Scaling

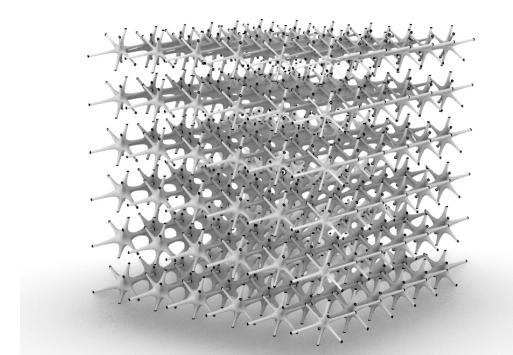
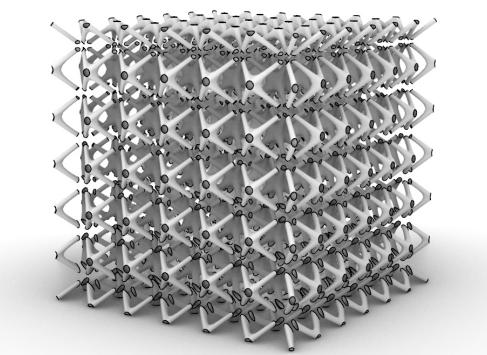
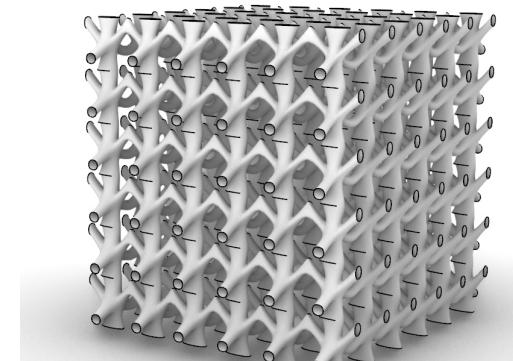
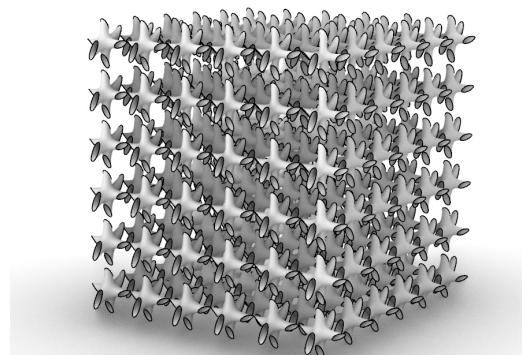
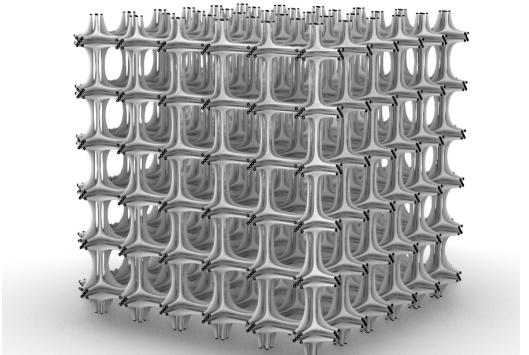
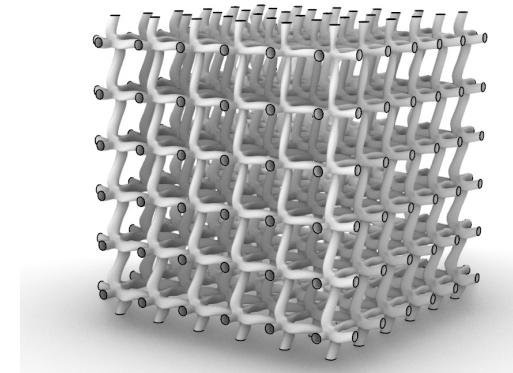
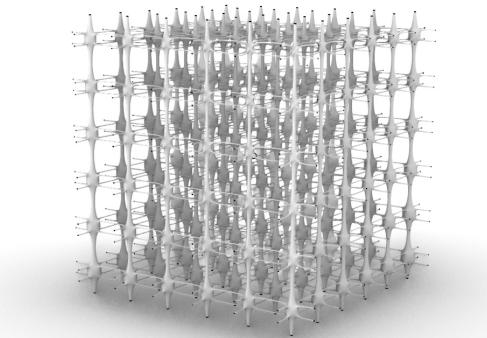
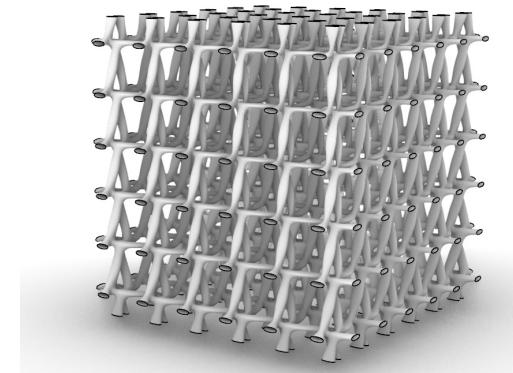
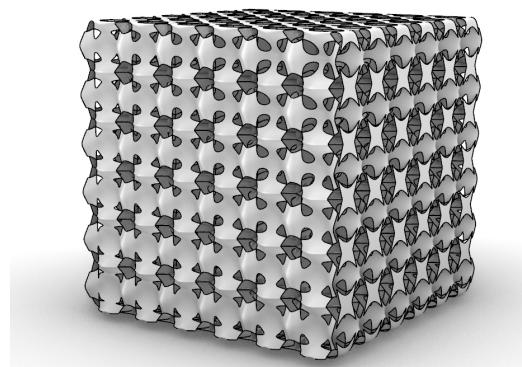
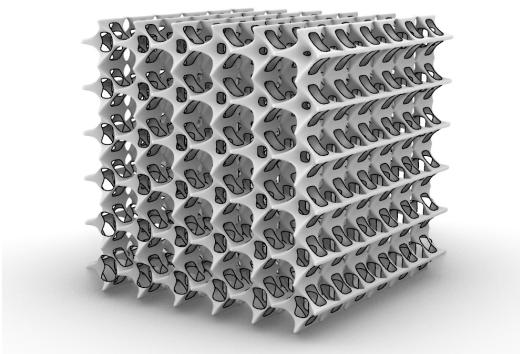


2 Generated Supports

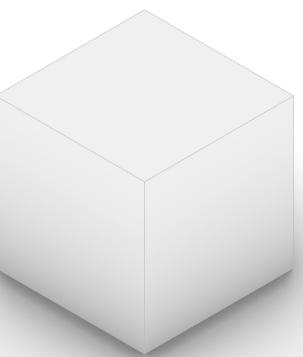


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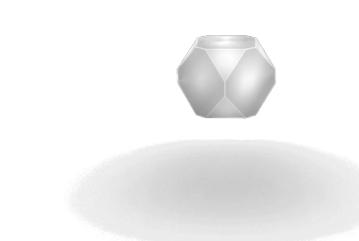
Design
Iteration/Exploration
Catalogue
(MAYA)



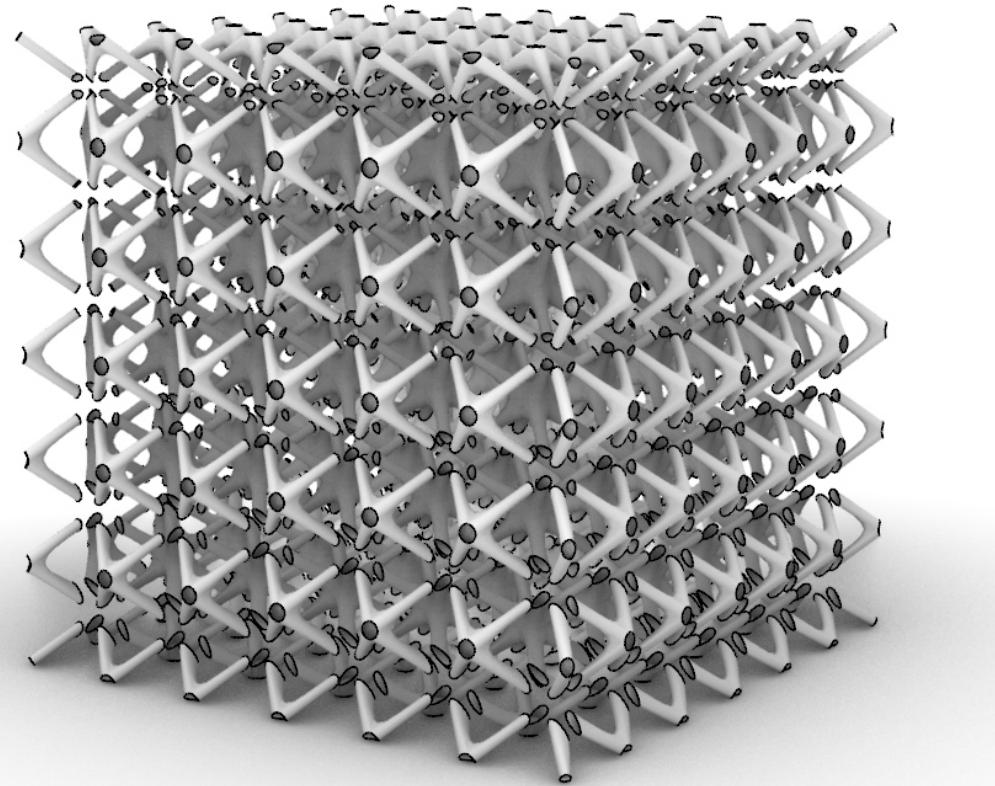
DESIGN ITERATION 1



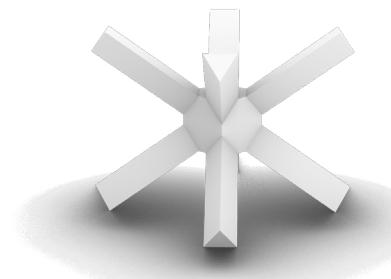
STEP 1



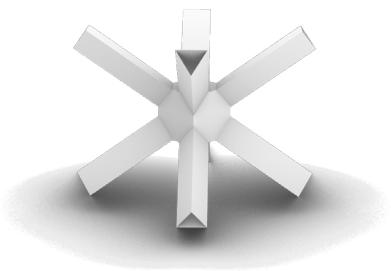
STEP 2



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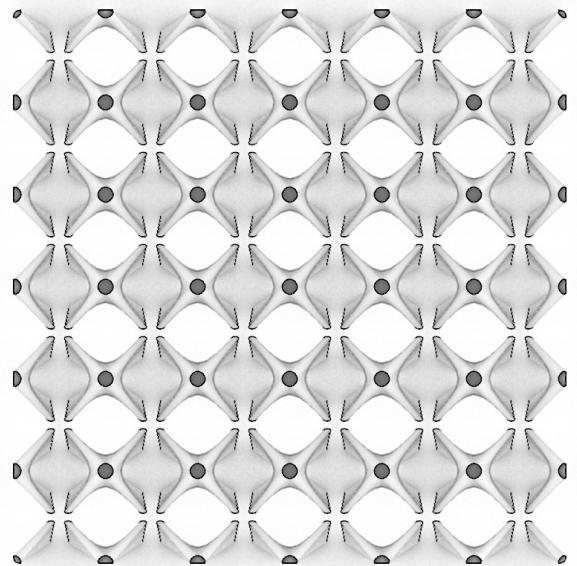


STEP 3

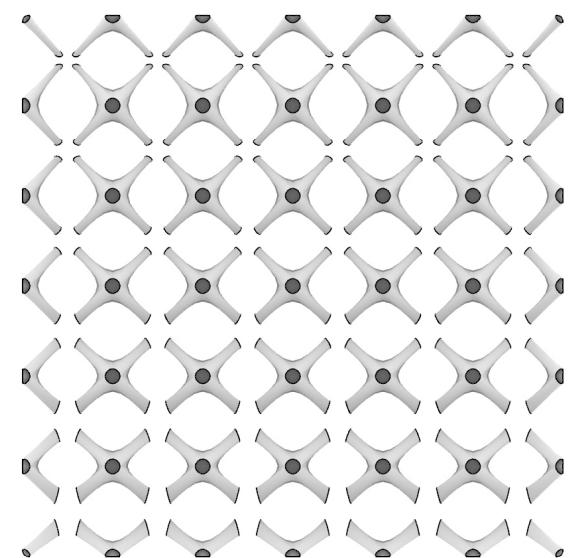


STEP 4

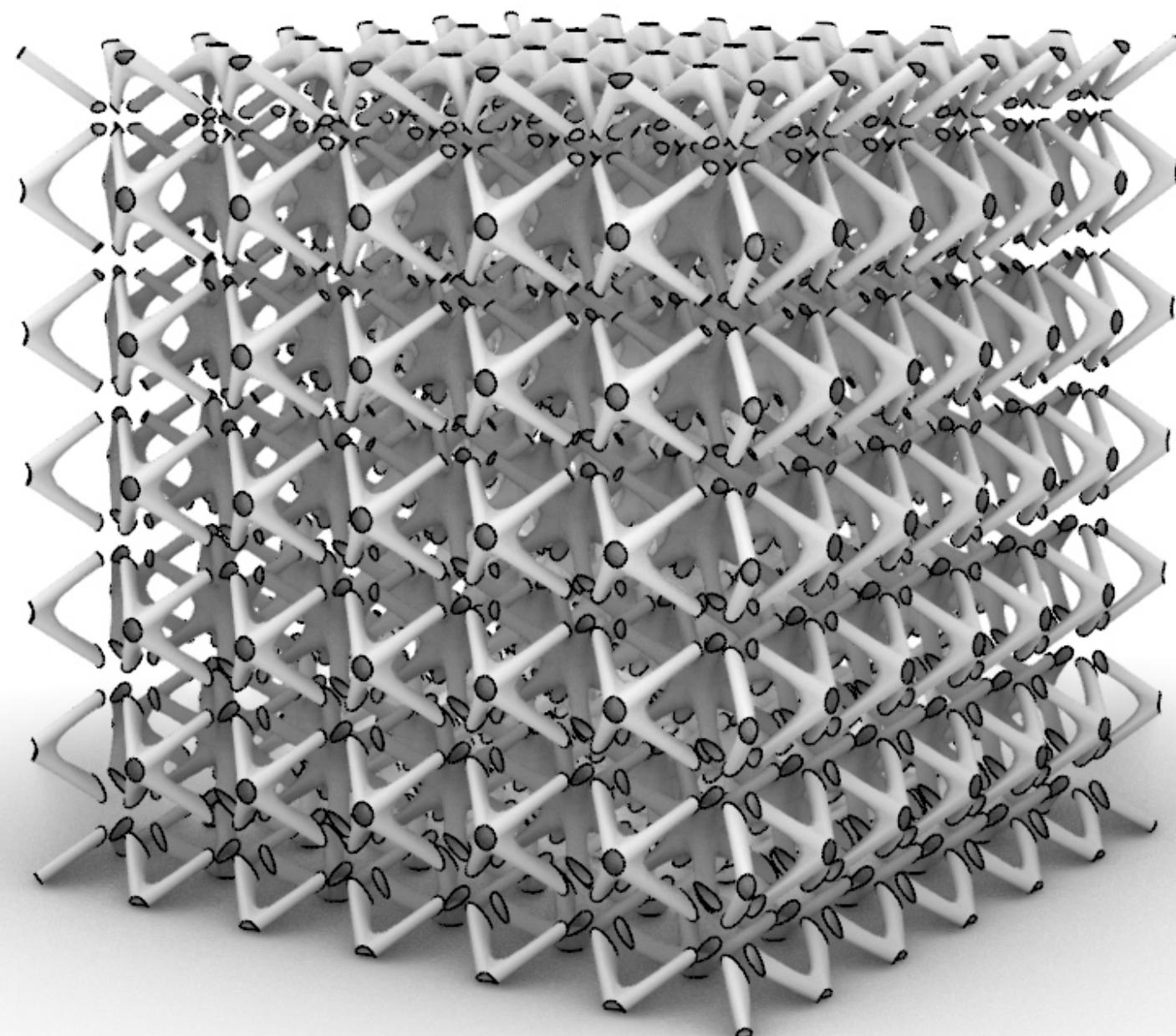
DESIGN ITERATION 1



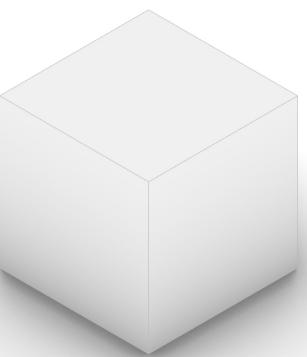
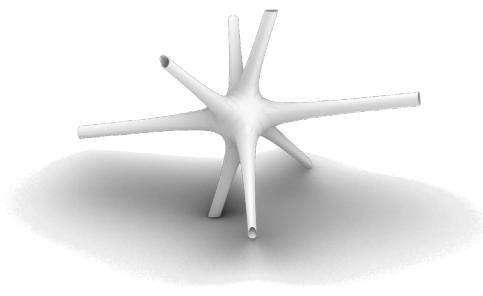
Top View



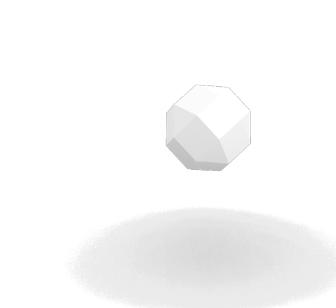
Elevation



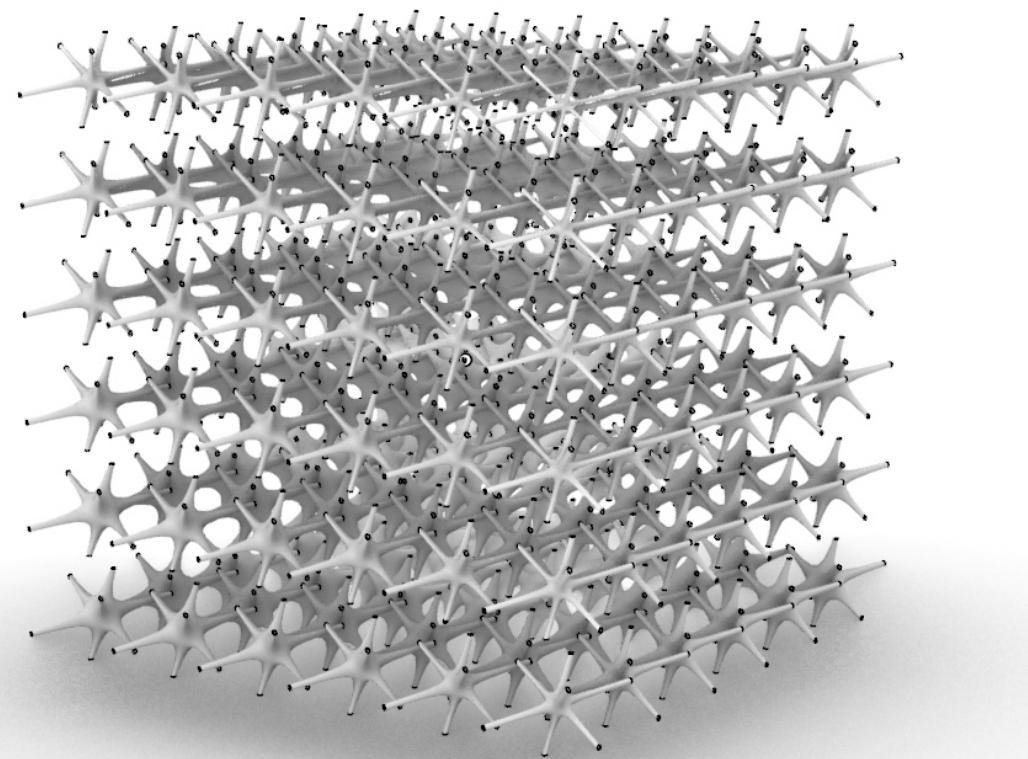
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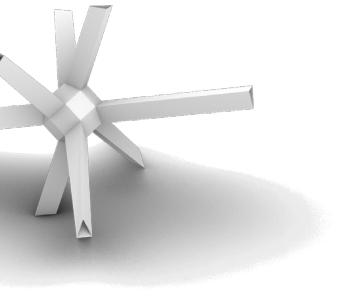
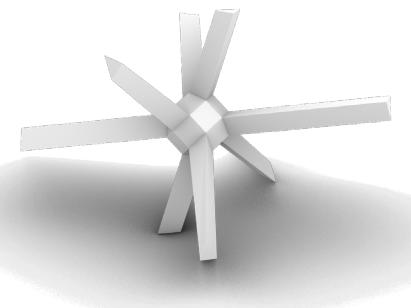
STEP 1



STEP 2



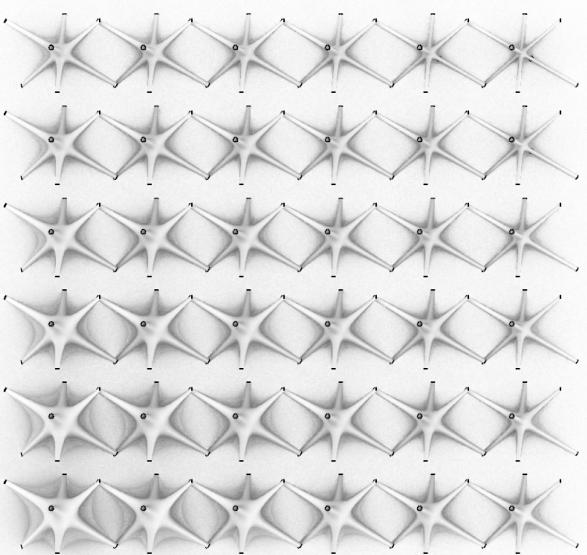
STEP 3



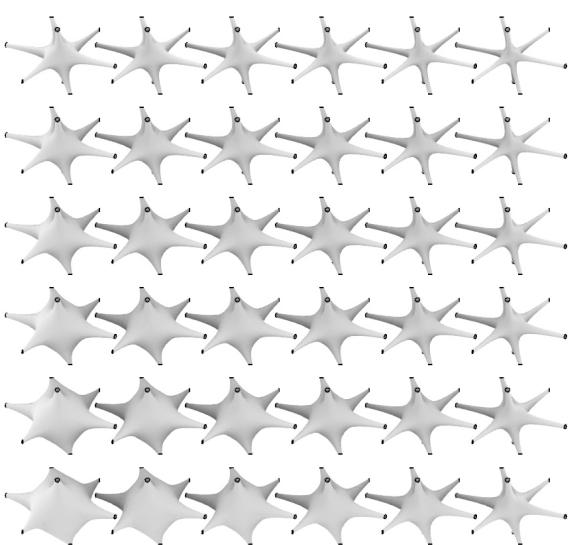
STEP 4

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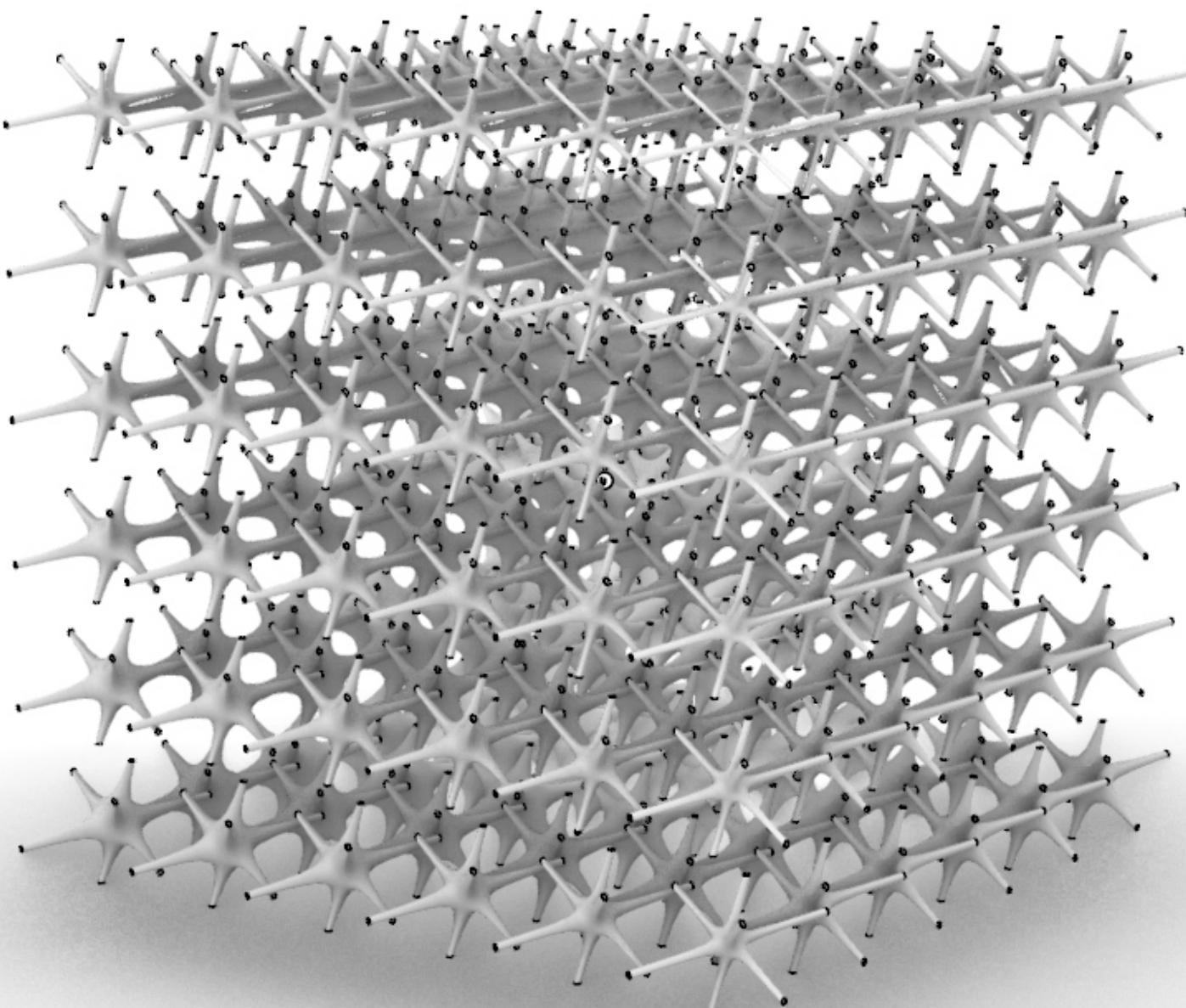
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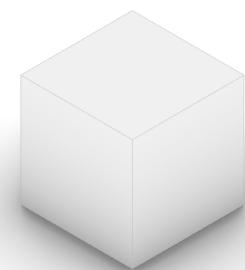
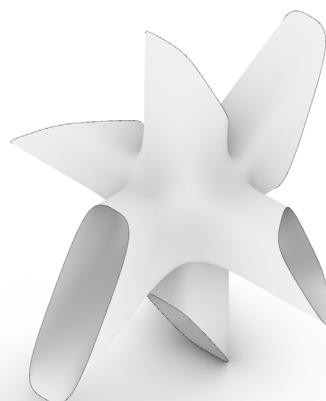
Top View



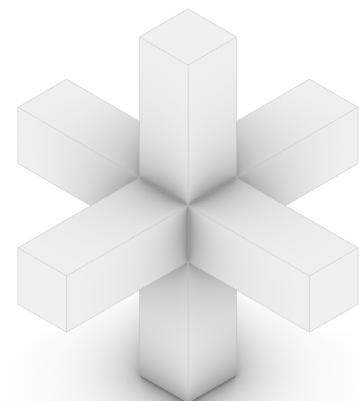
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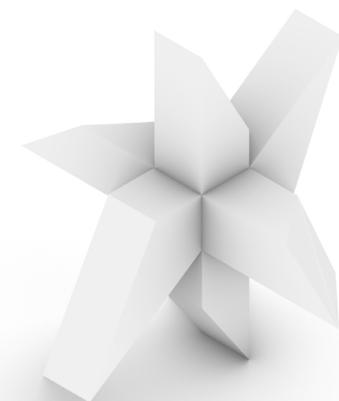
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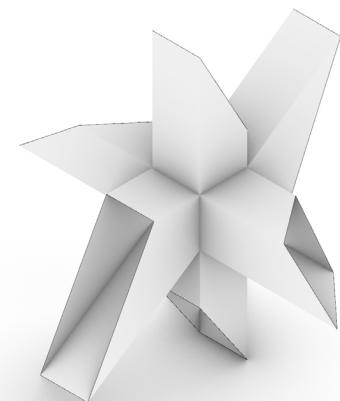
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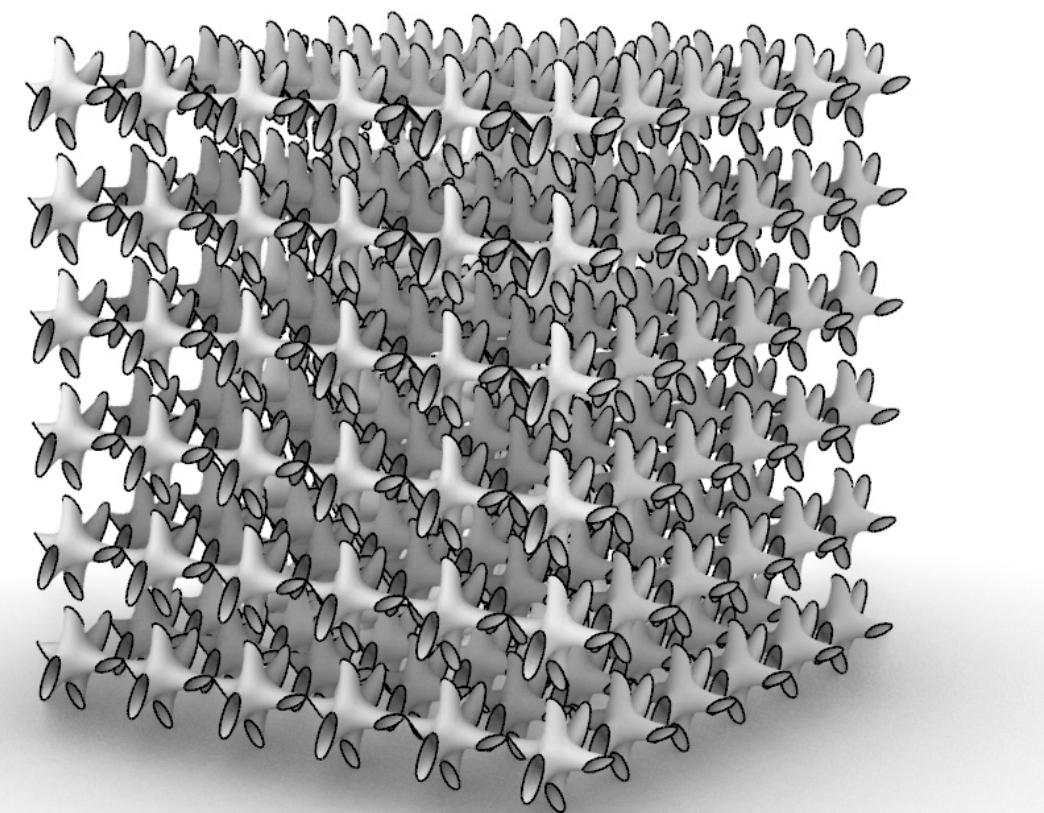
STEP 2



STEP 3

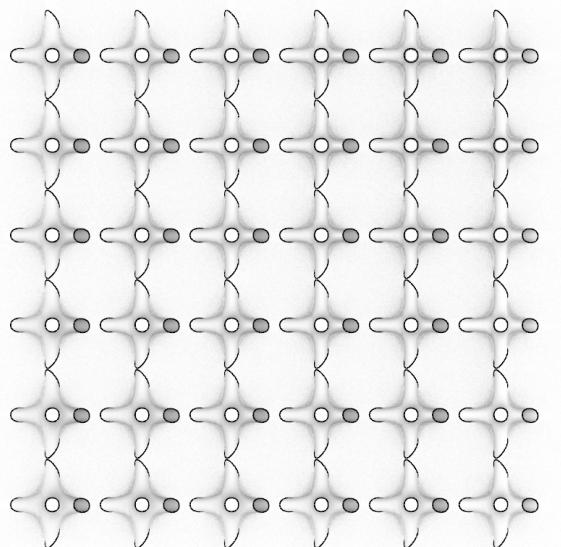


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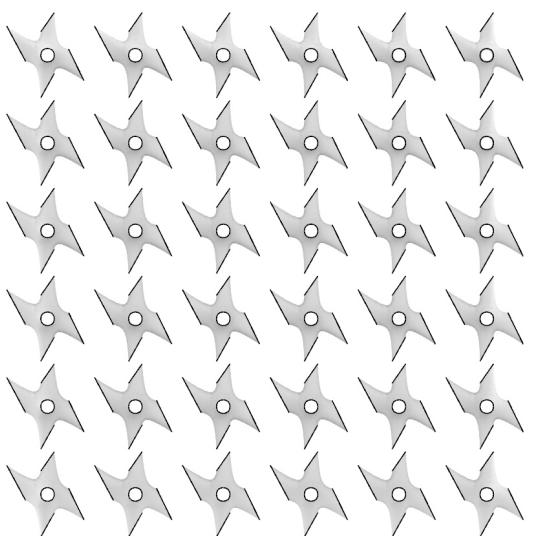


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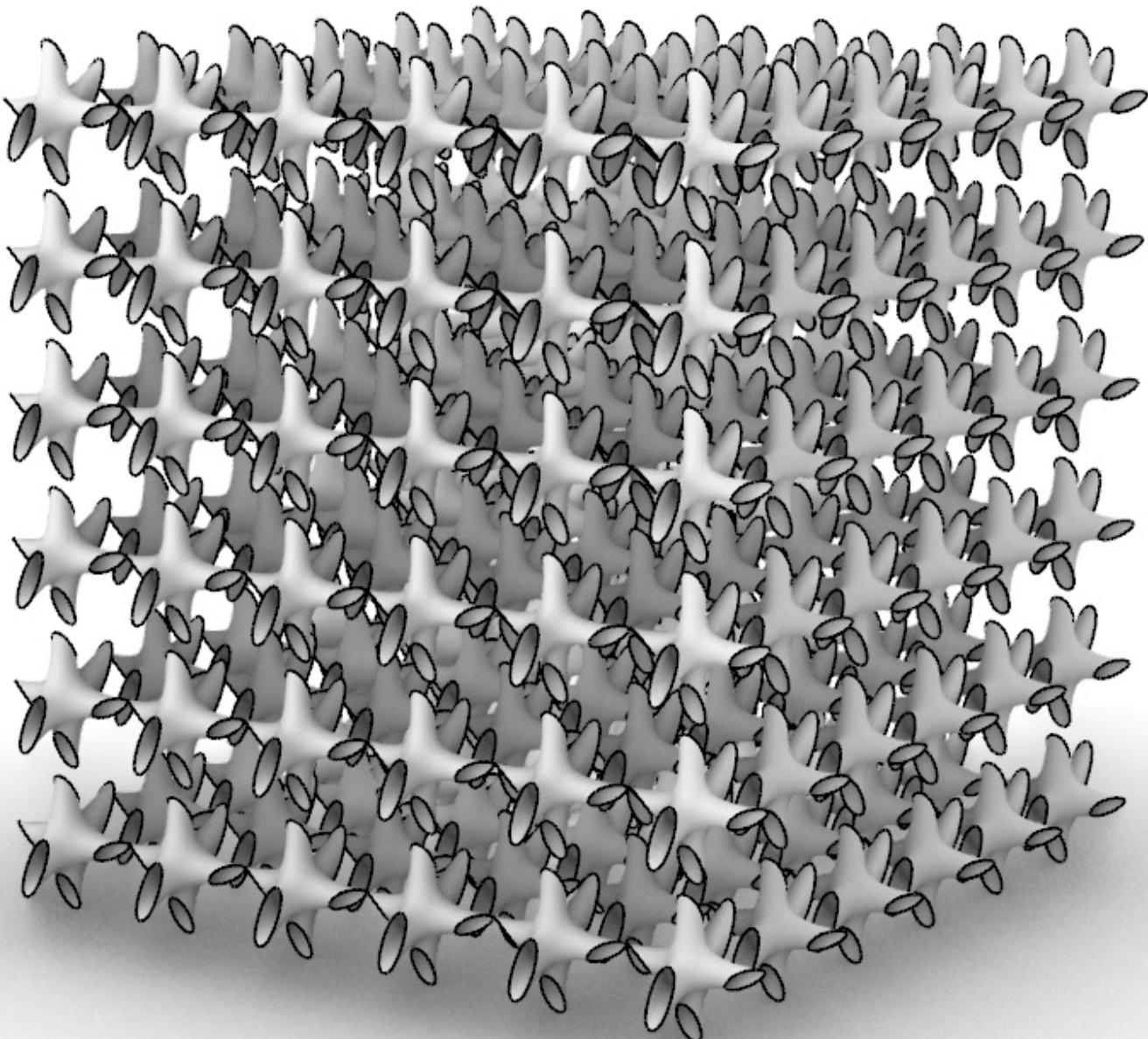
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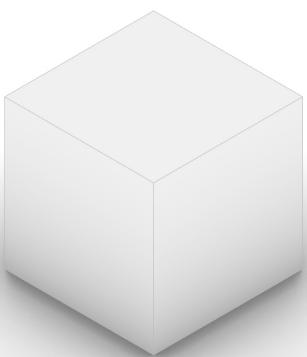
Top View



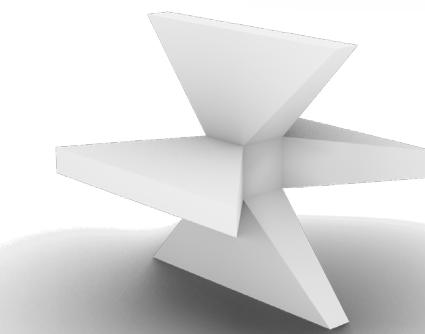
Elevation



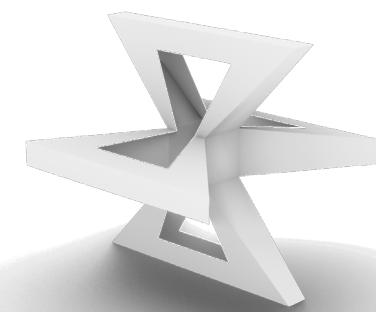
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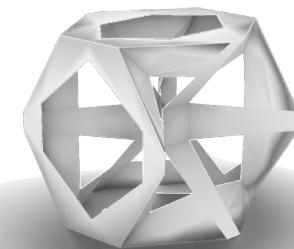
STEP 1



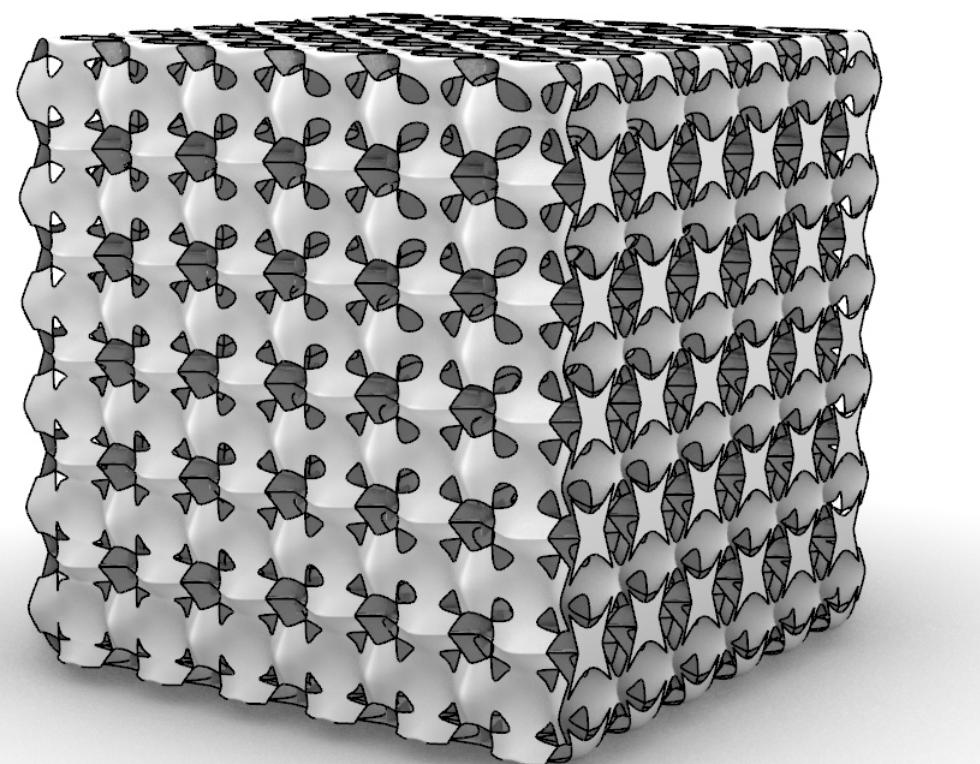
STEP 2



STEP 3

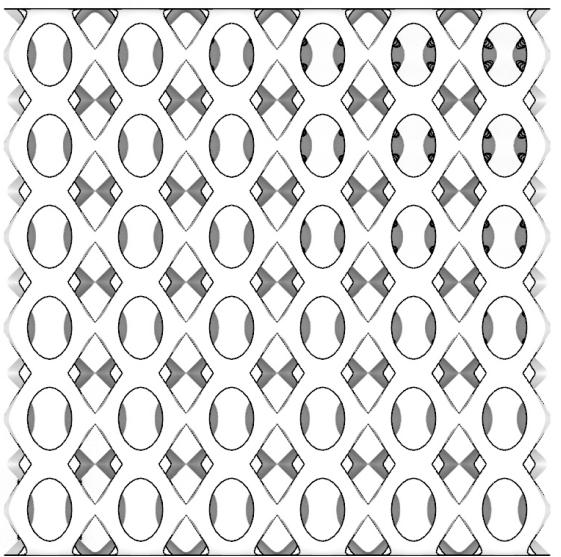


STEP 4

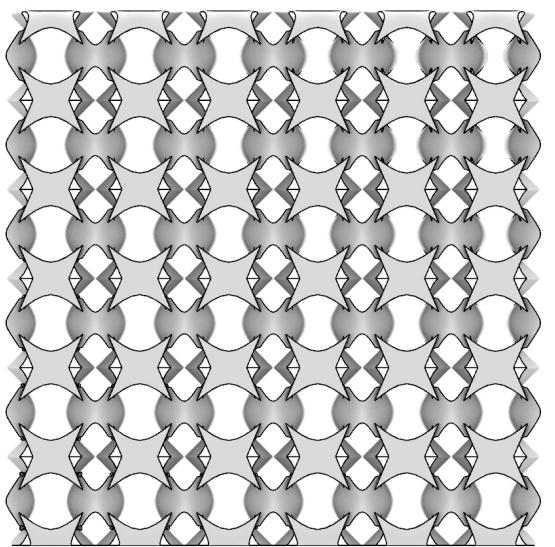


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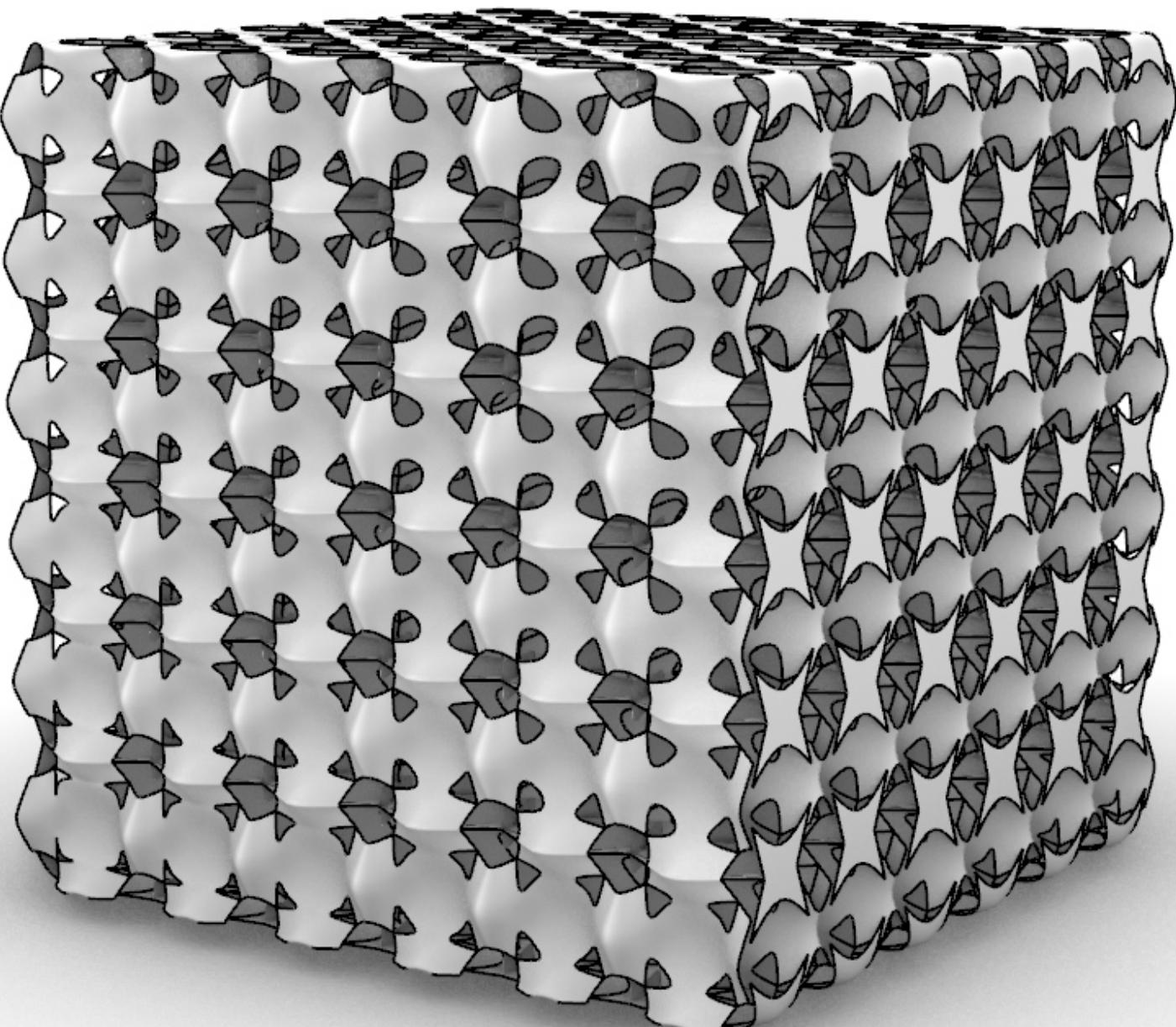
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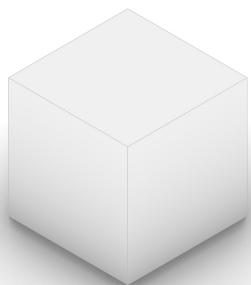
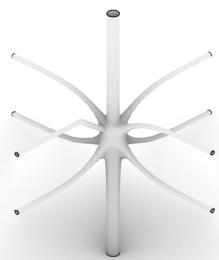
Top View



Elevation



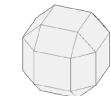
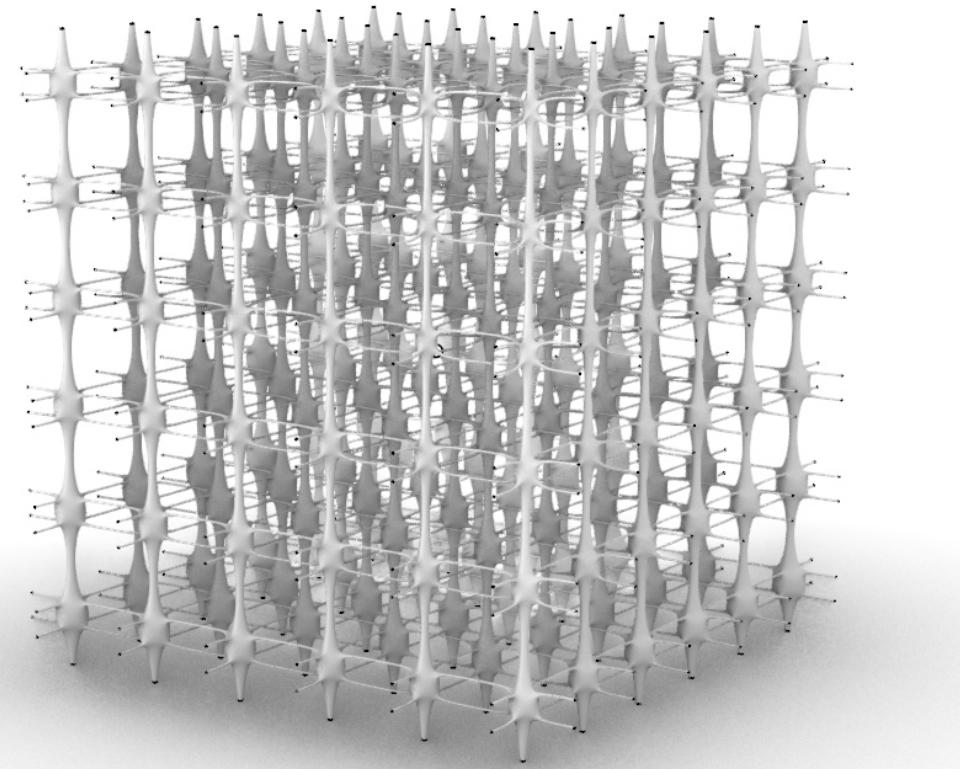
DESIGN ITERATION 5



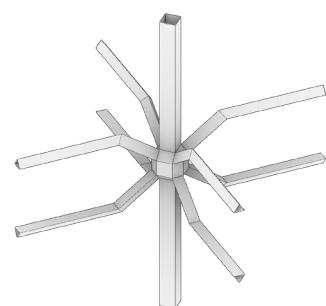
STEP 1



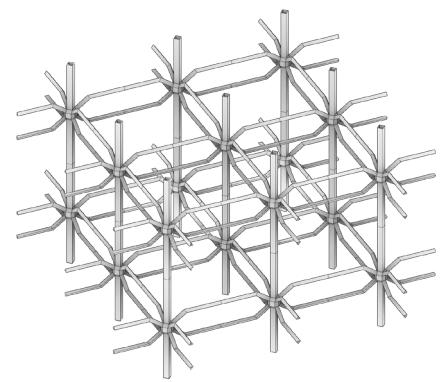
STEP 2



STEP 3



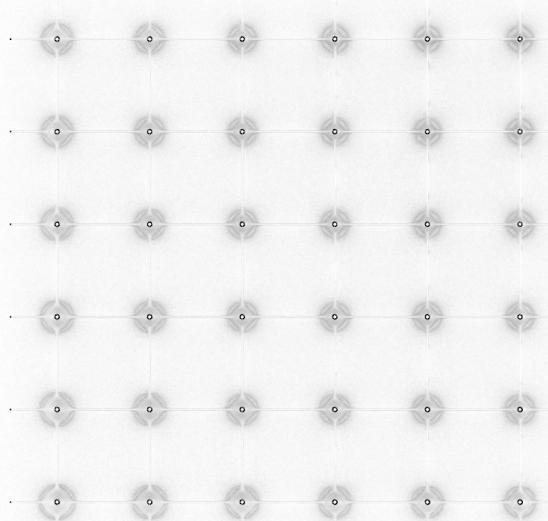
STEP 4



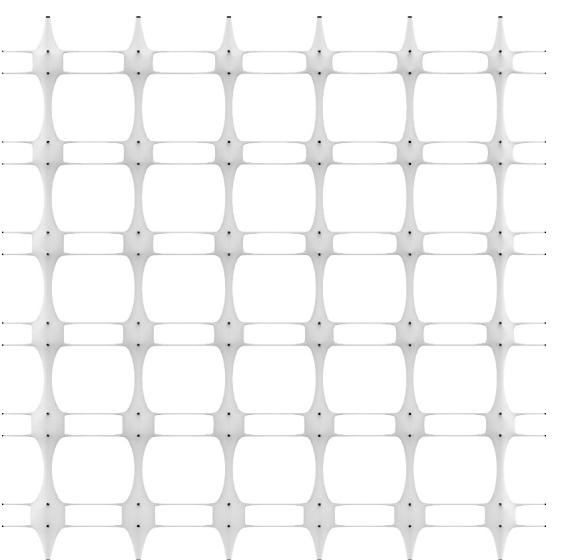
STEP 4

Coded Aggregation

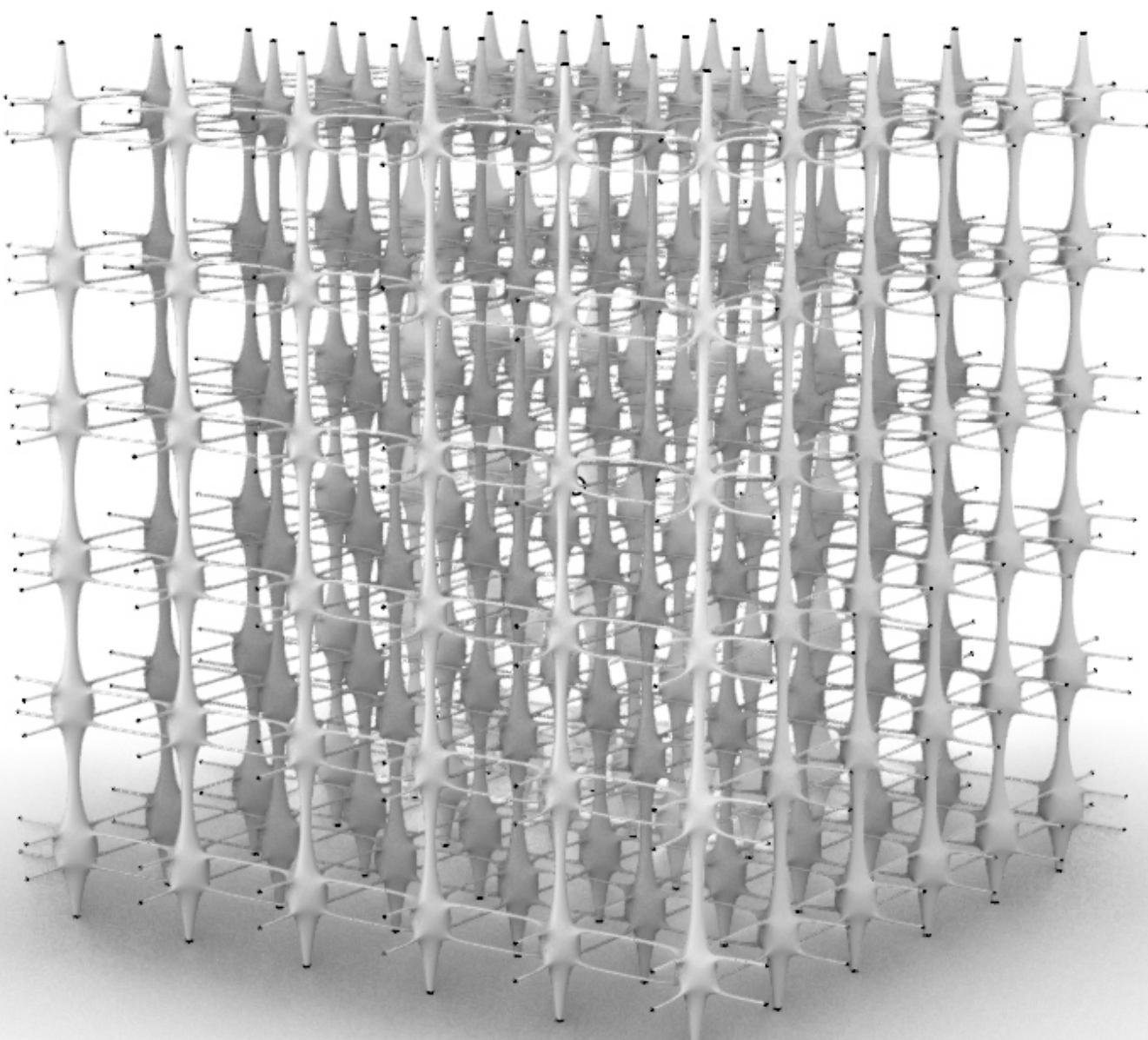
DESIGN ITERATION 5



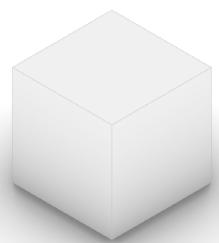
Top View



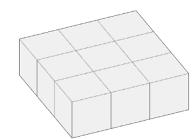
Elevation



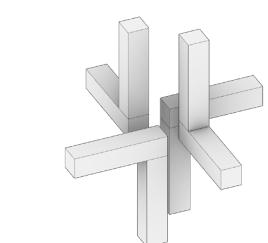
DESIGN ITERATION 6



STEP 1



STEP 2



STEP 3

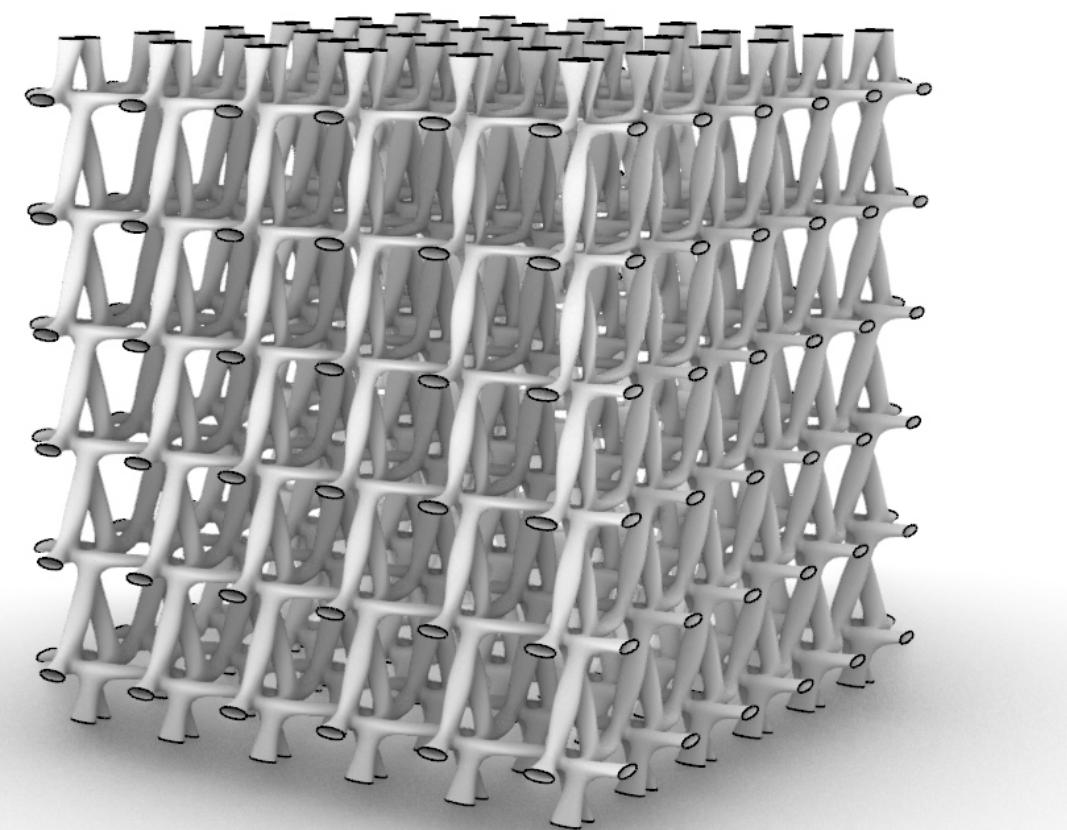


STEP 4



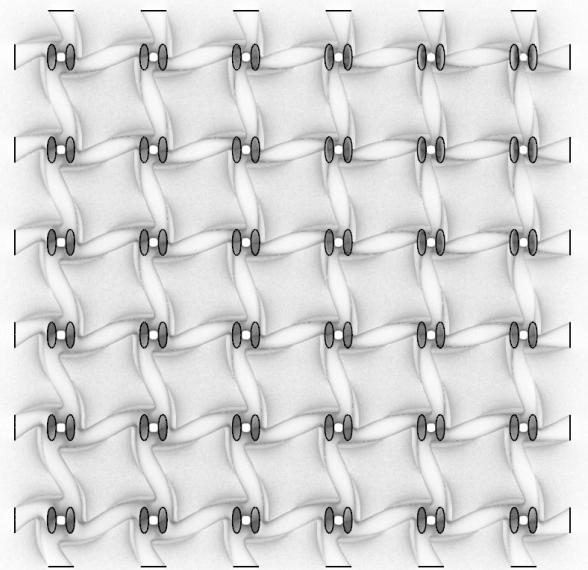
STEP 5

Coded Aggregation

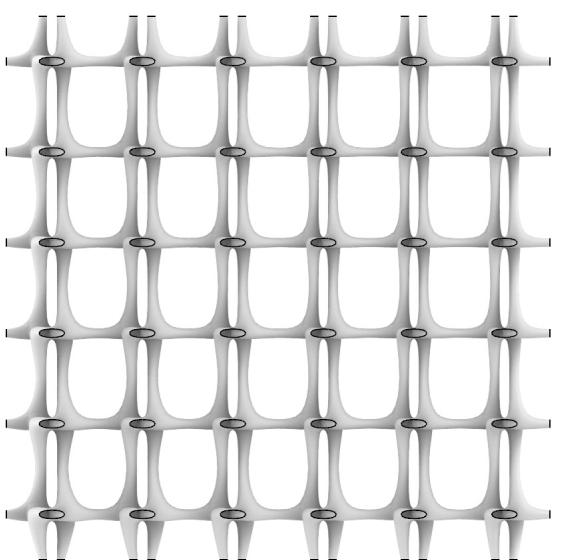


STEP 5

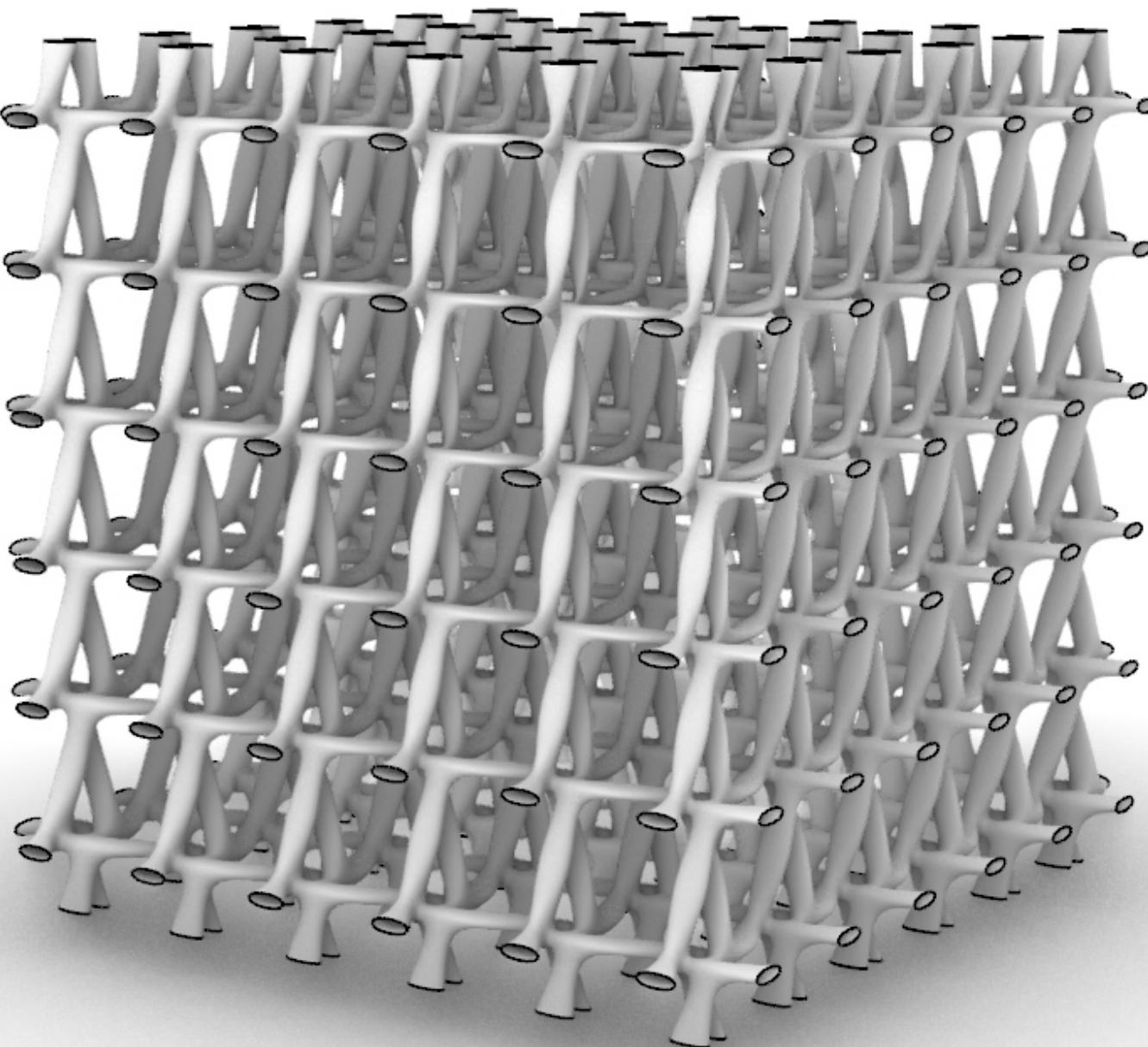
DESIGN ITERATION 6



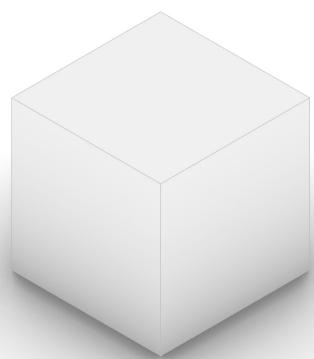
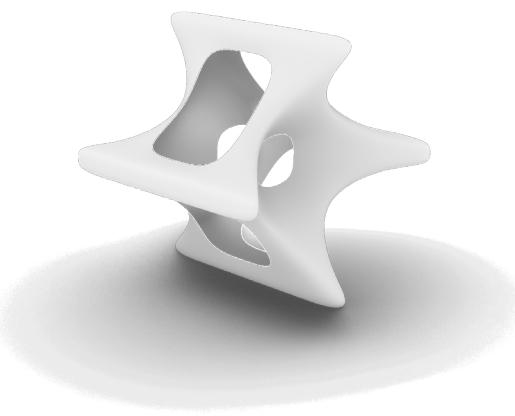
Top View



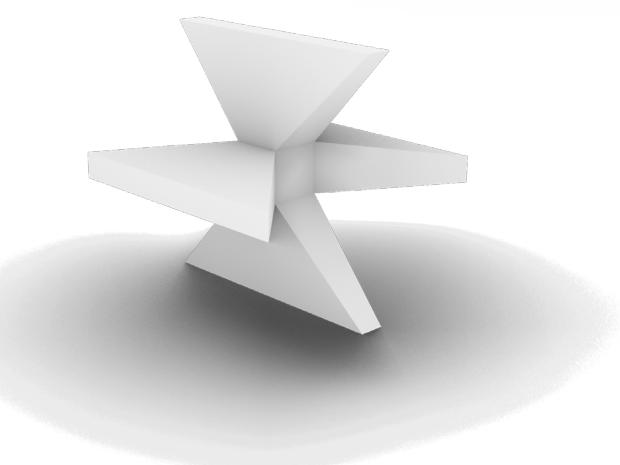
Elevation



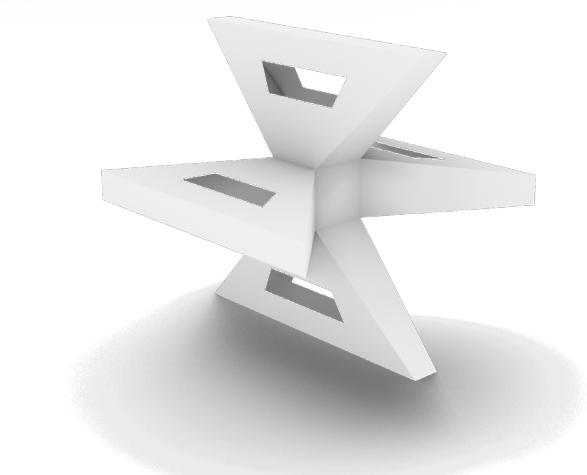
DESIGN ITERATION 7



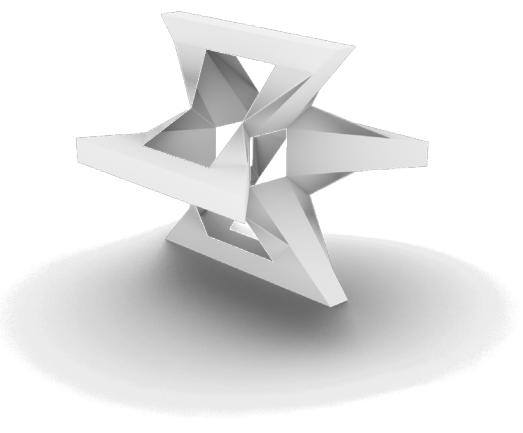
STEP 1



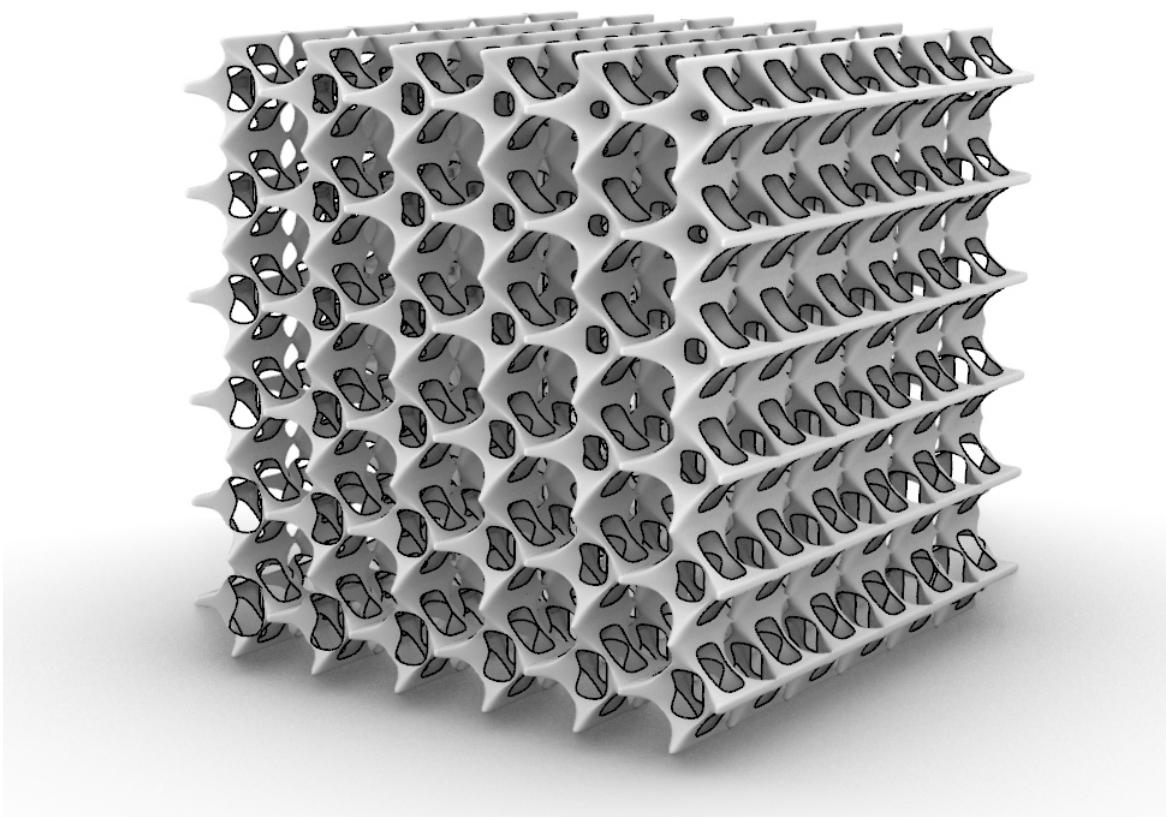
STEP 2



STEP 3

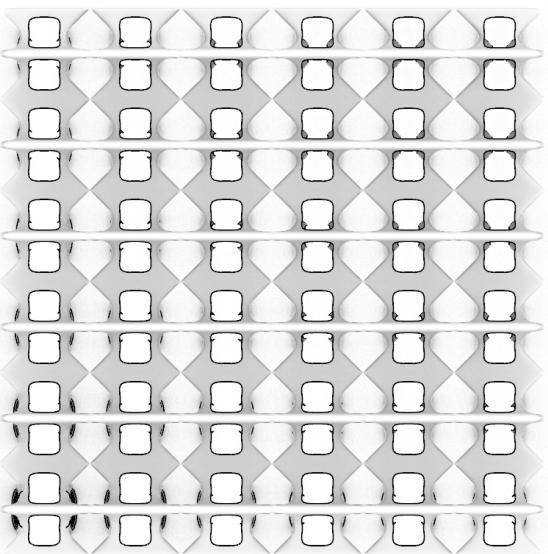


STEP 4

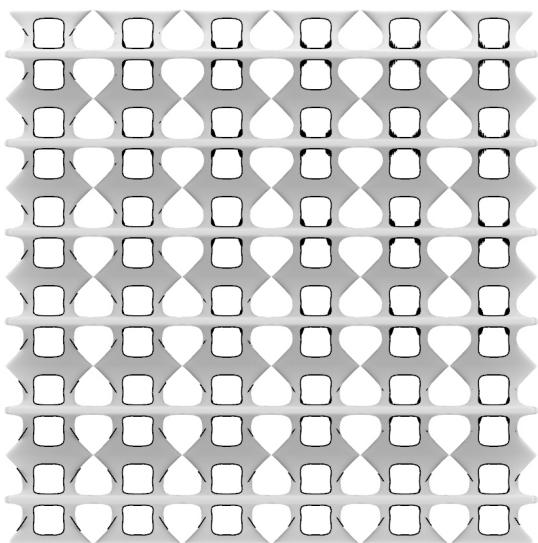


Coded Aggregation

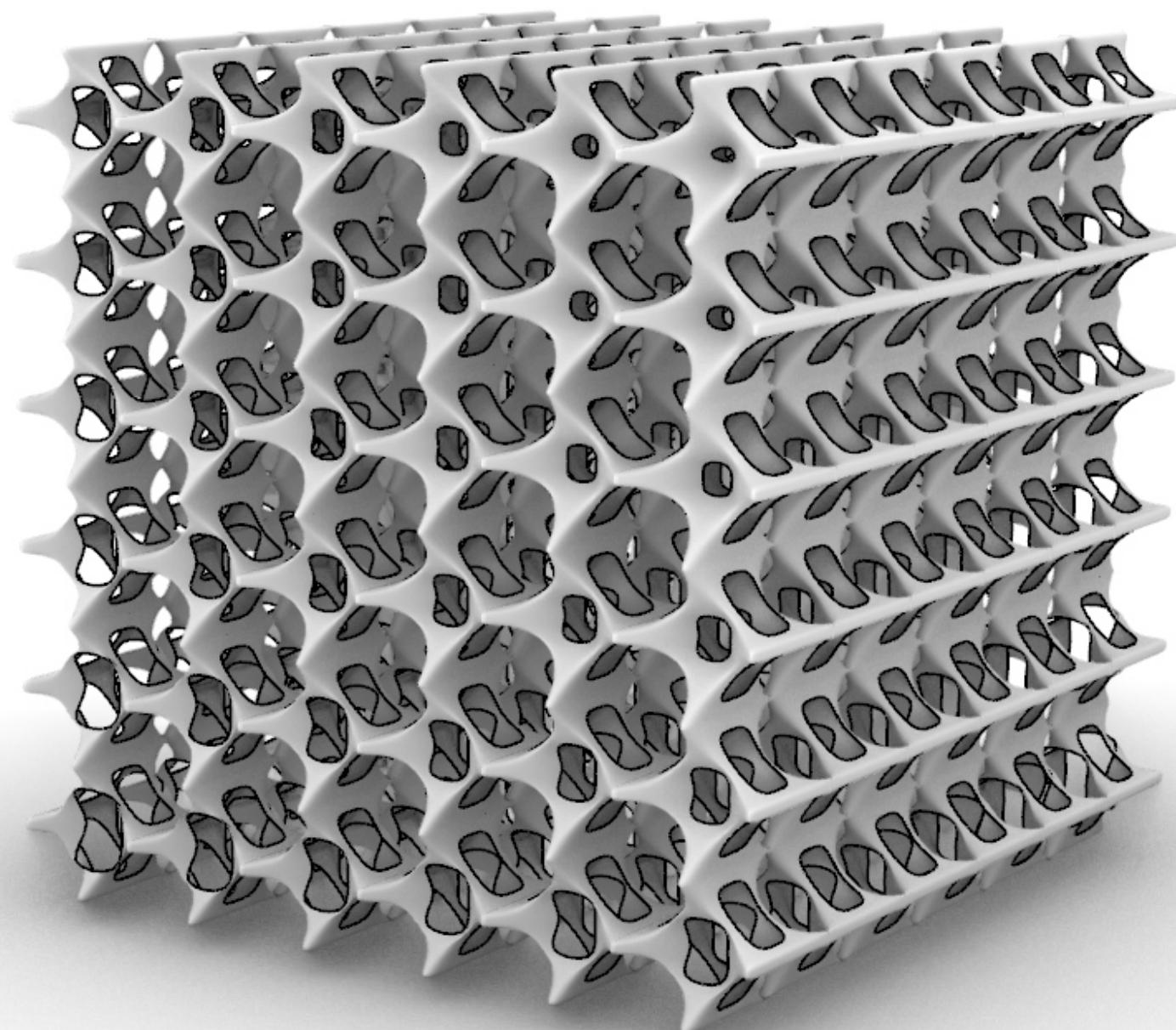
DESIGN ITERATION 7



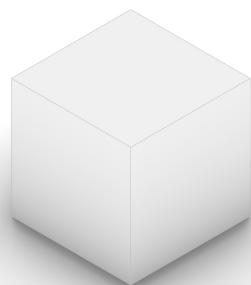
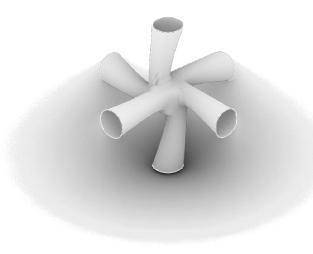
Top View



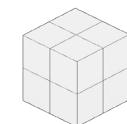
Elevation



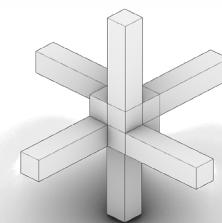
DESIGN ITERATION 8



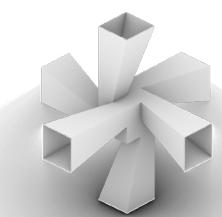
STEP 1



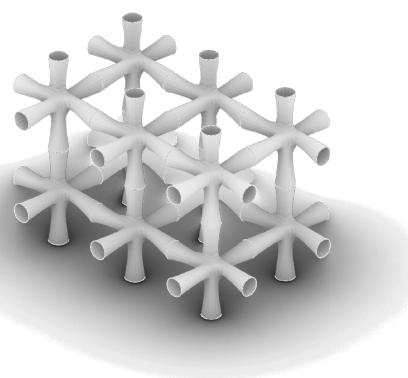
STEP 2



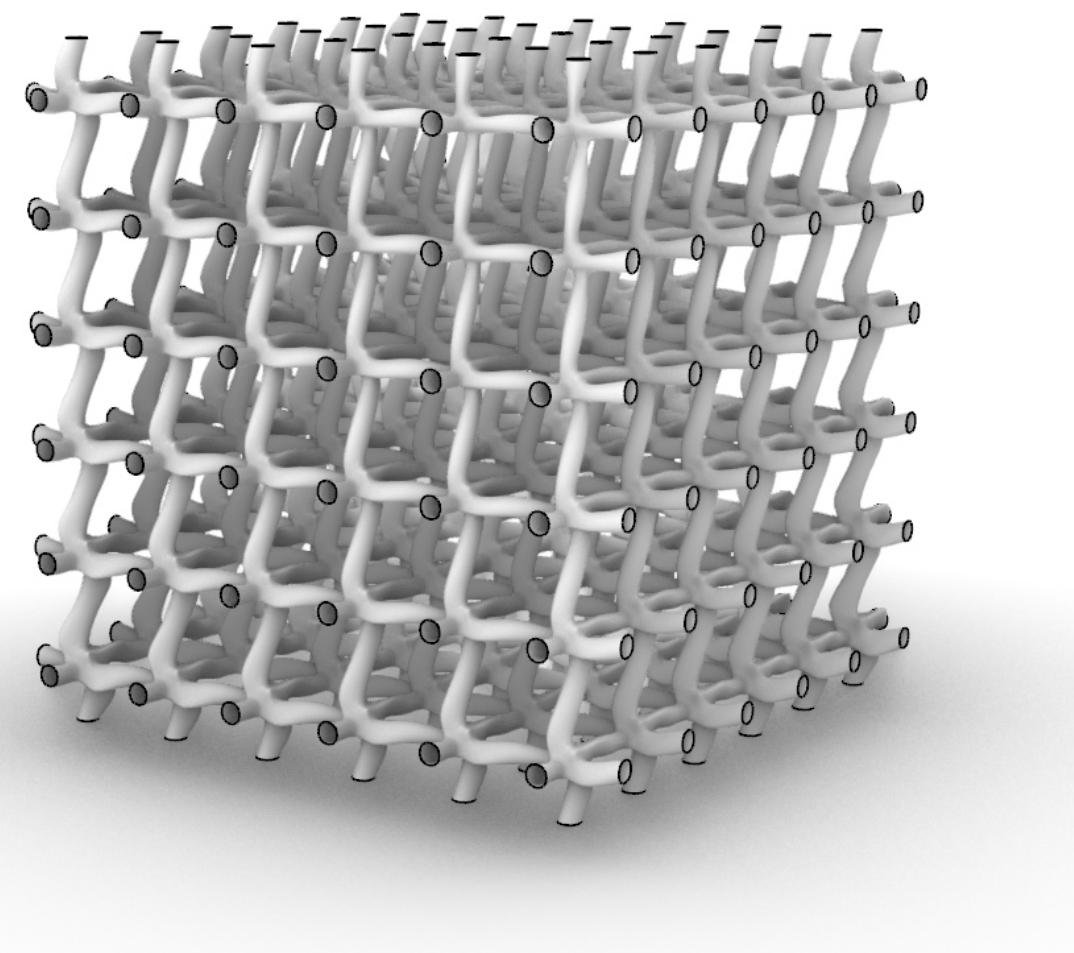
STEP 3



STEP 4

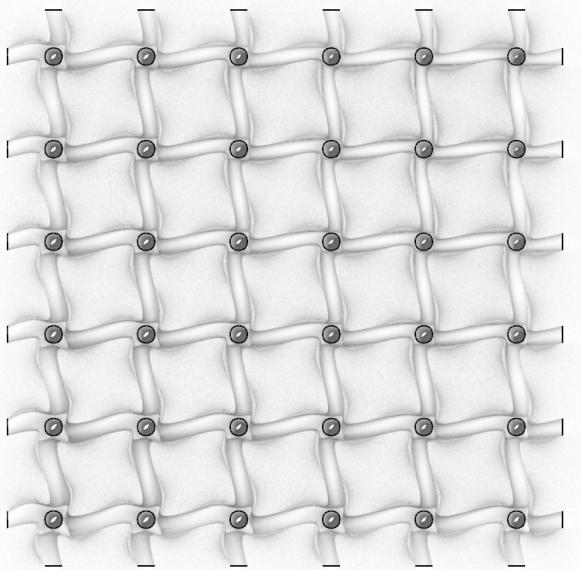


STEP 5

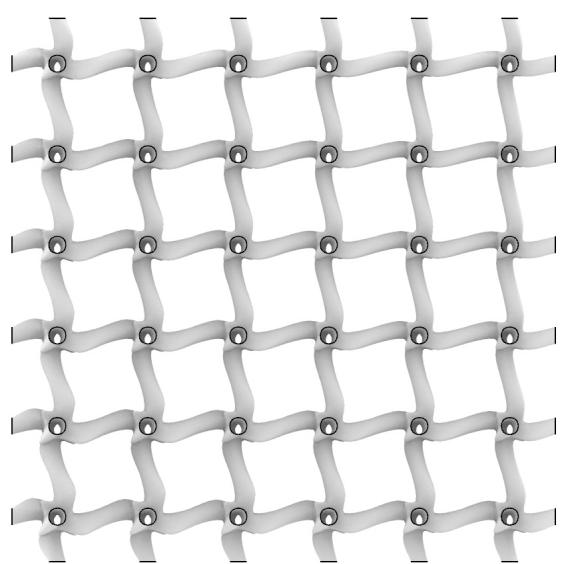


Coded Aggregation

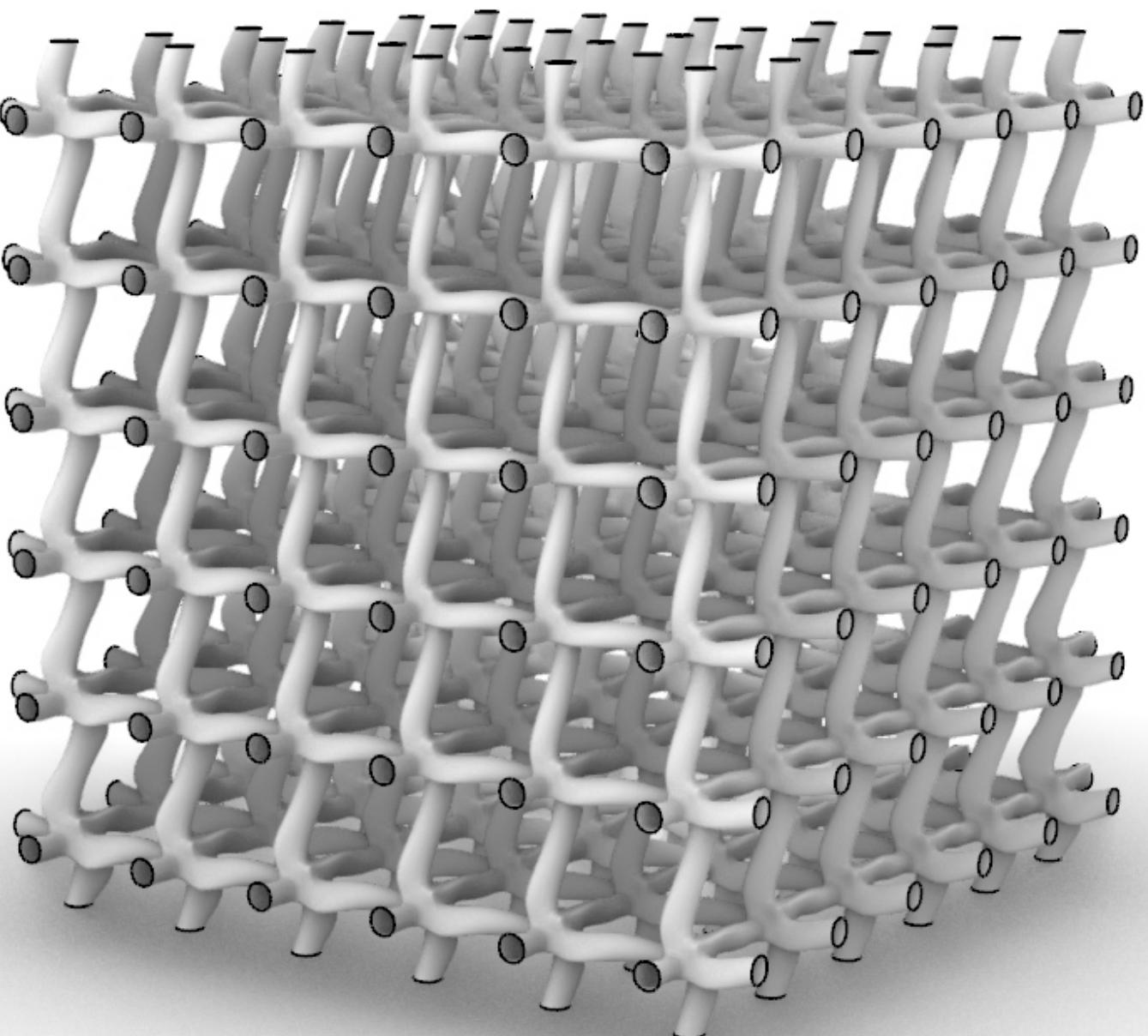
DESIGN ITERATION 8



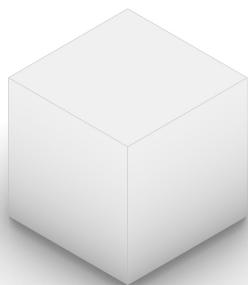
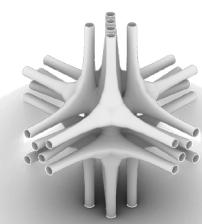
Top View



Elevation



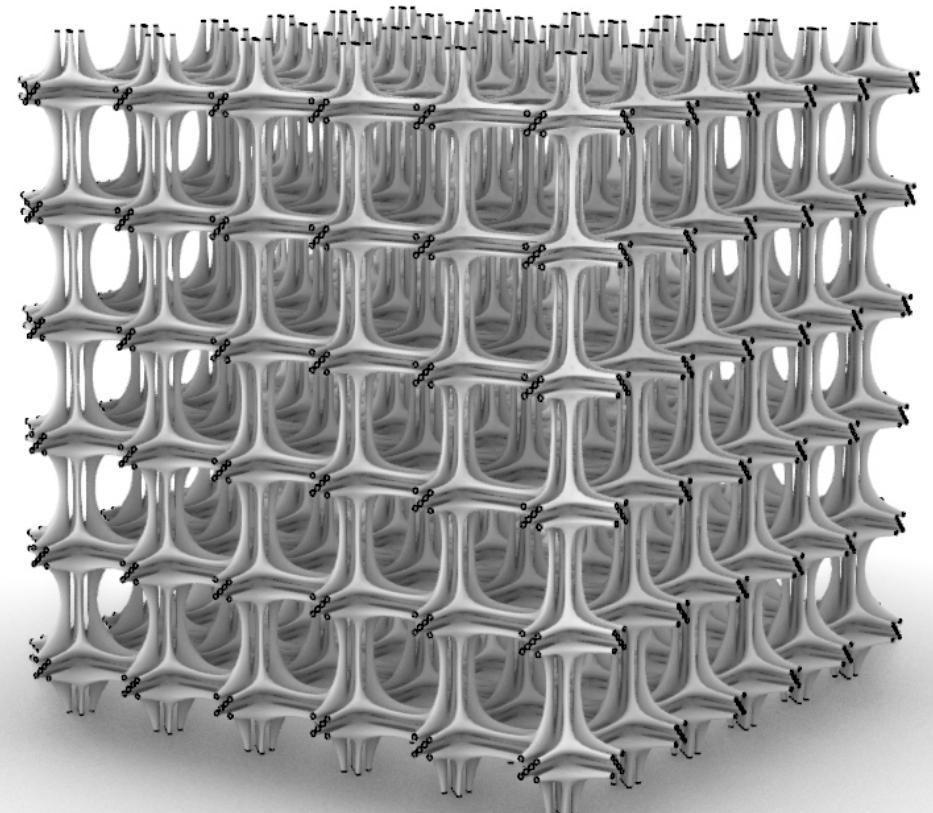
DESIGN ITERATION 9



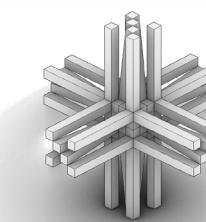
STEP 1



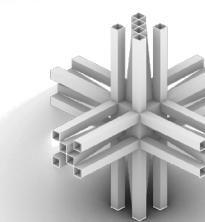
STEP 2



STEP 3



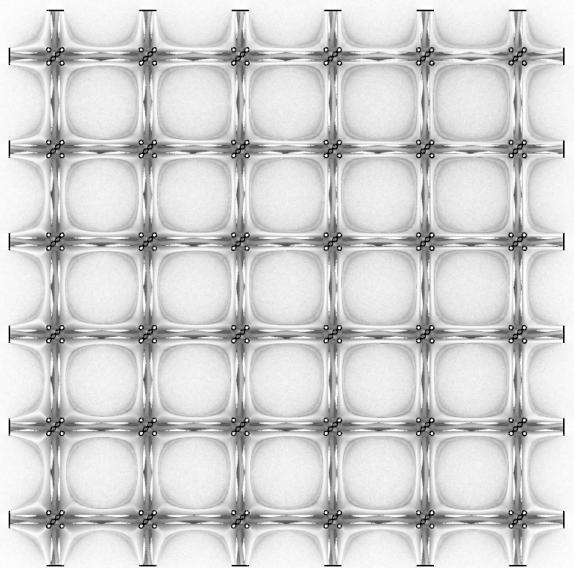
STEP 4



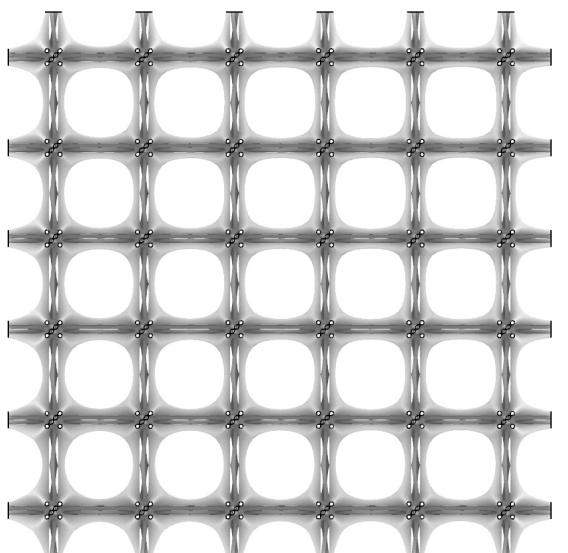
STEP 5

Coded Aggregation

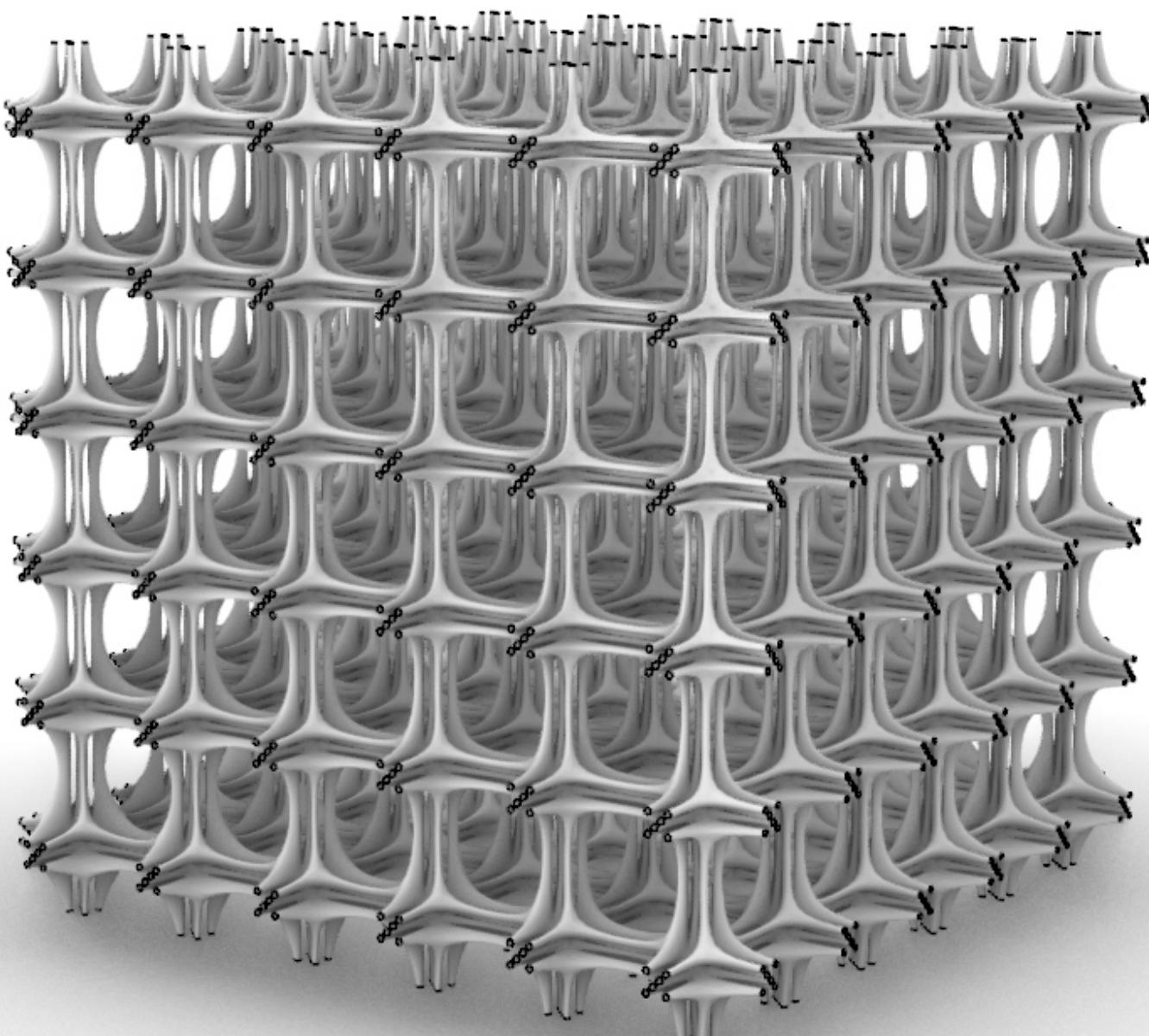
DESIGN ITERATION 9



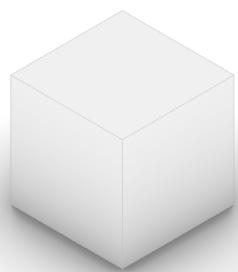
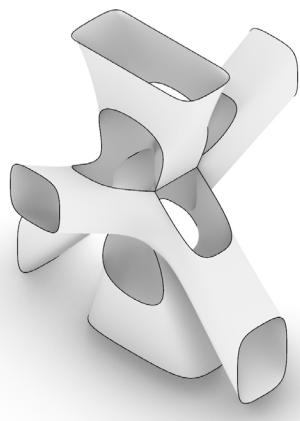
Top View



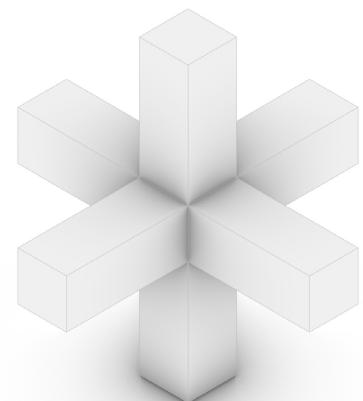
Elevation



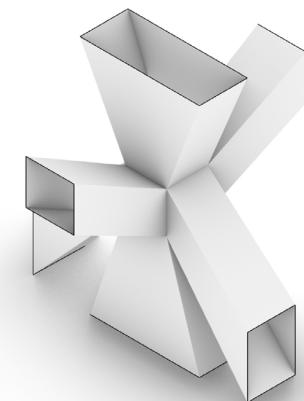
DESIGN ITERATION 10



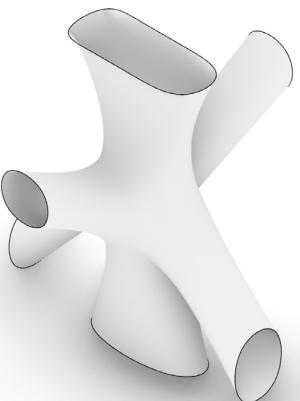
STEP 1



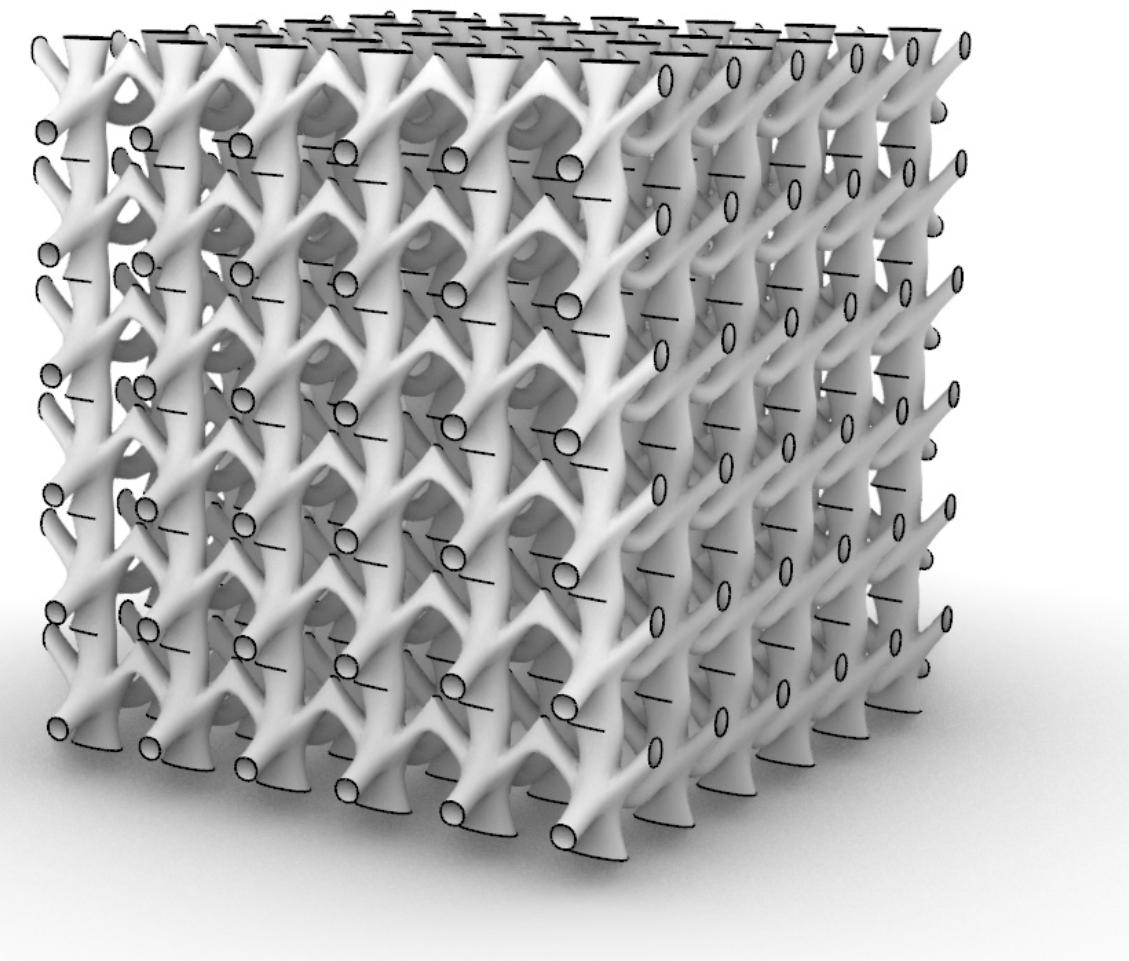
STEP 2



STEP 3

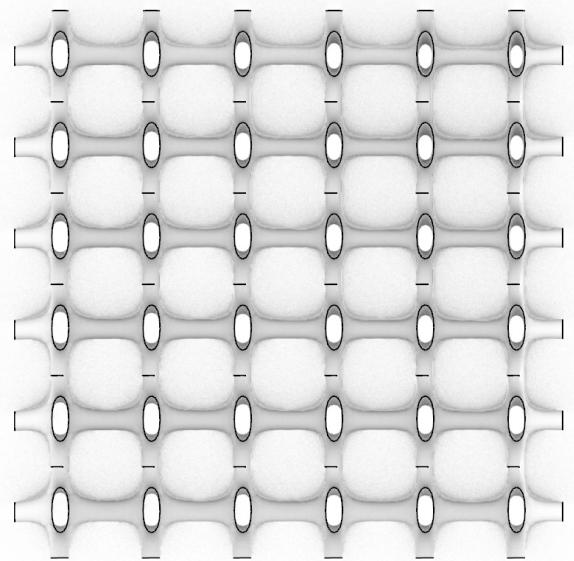


STEP 4

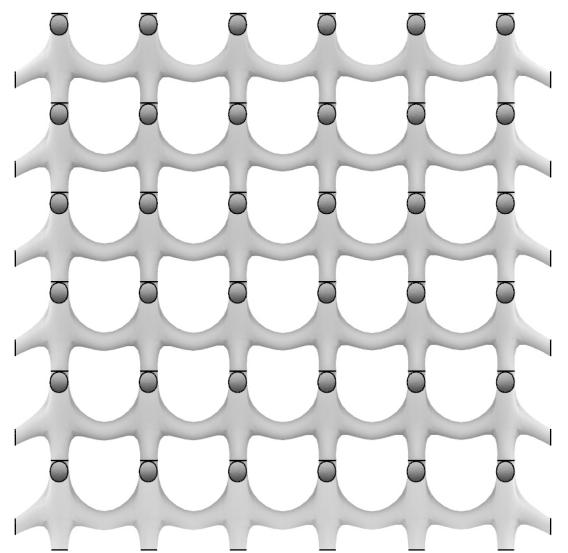


Coded Aggregation

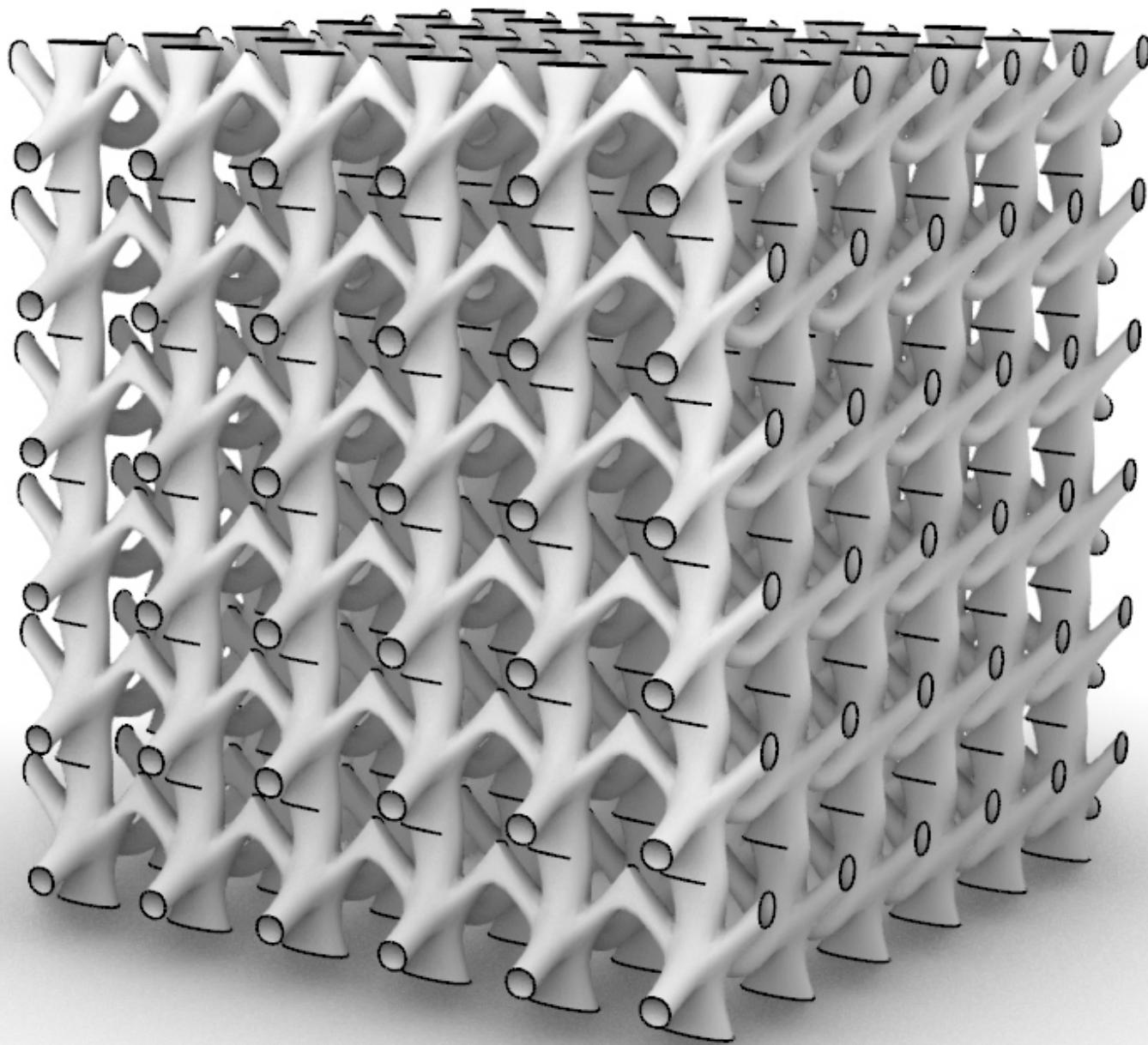
DESIGN ITERATION 10



Top View



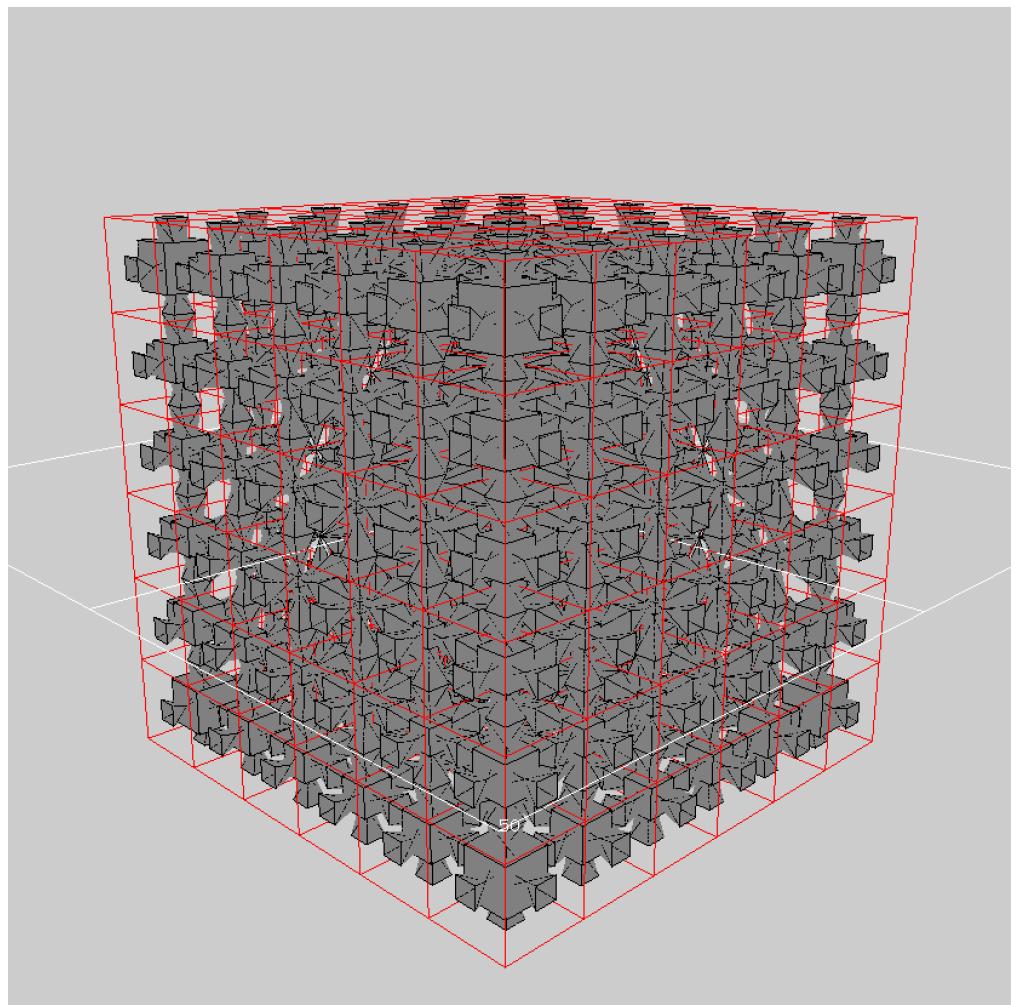
Elevation



Matrix Explorations

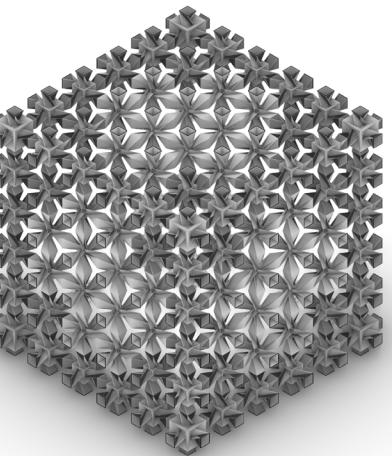
(Visual Studio C++)

TRANSFORMATION ITERATION A1

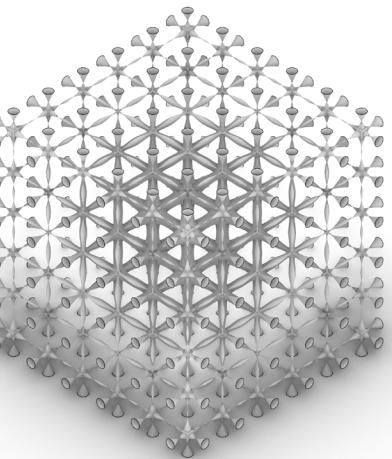


Attractor $(0, 0, 0)$
Range $(0, 2)$
Scale $(2, 0.1)$

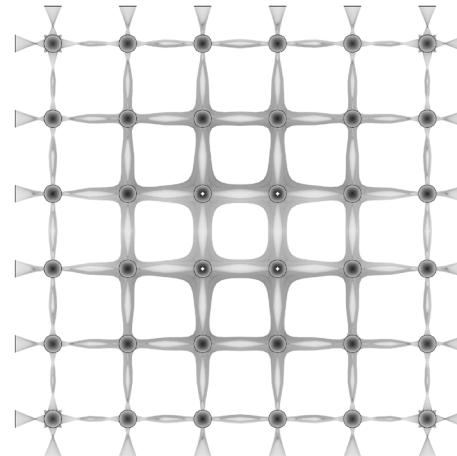
unsuccessful



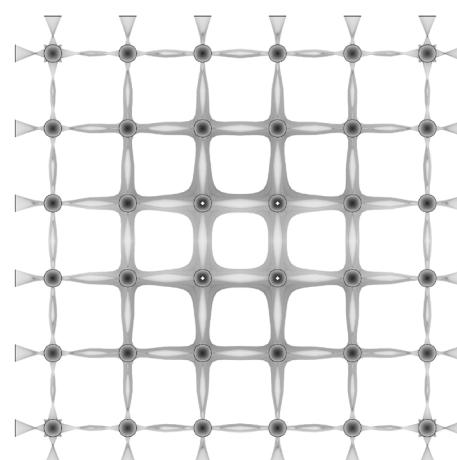
Low Polygon Geometry



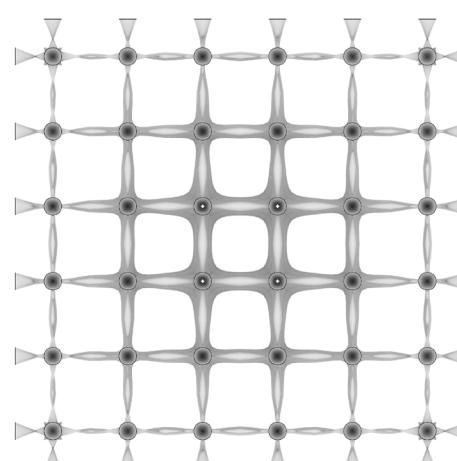
Smooth Geometry



Smooth Front View

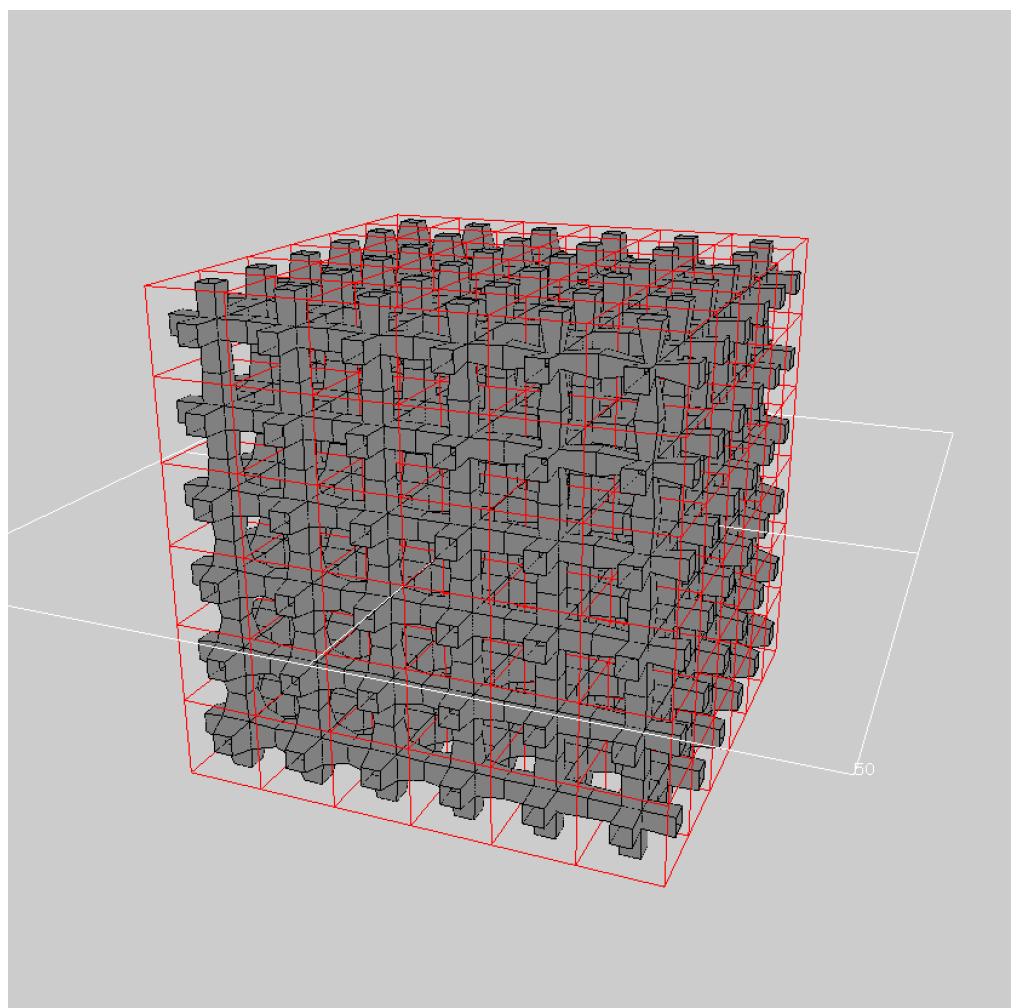


Smooth Right View



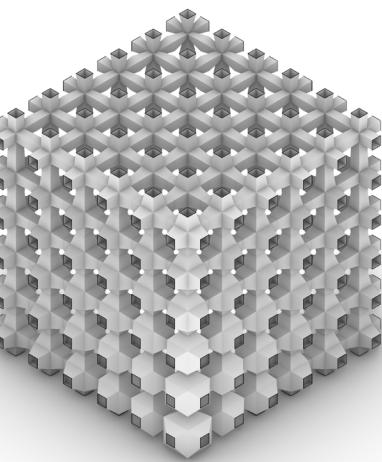
Smooth Top View

TRANSFORMATION ITERATION A2

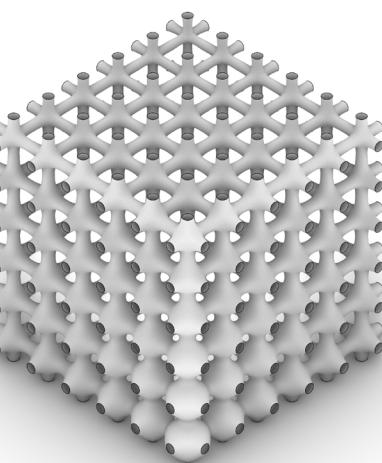


Attractor (-3, -3, -3)
Range (2, 10.392)
Scale 2.5, 0.2)

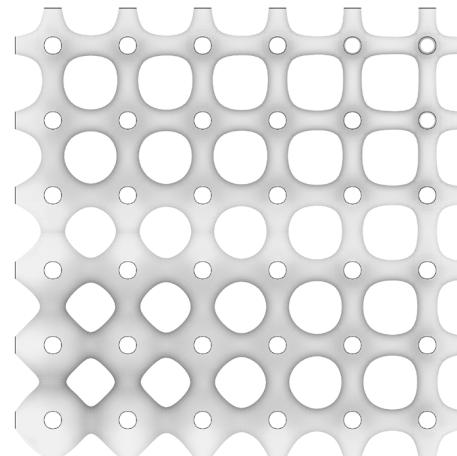
unsuccessful



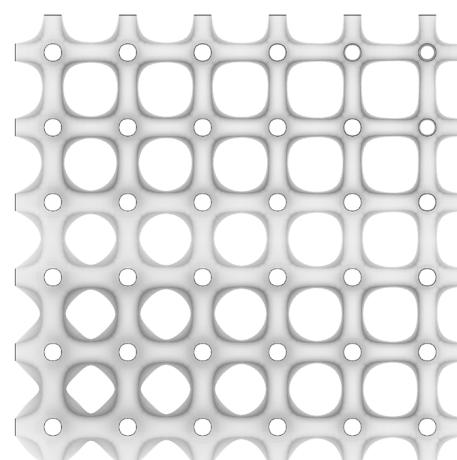
Low Polygon Geometry



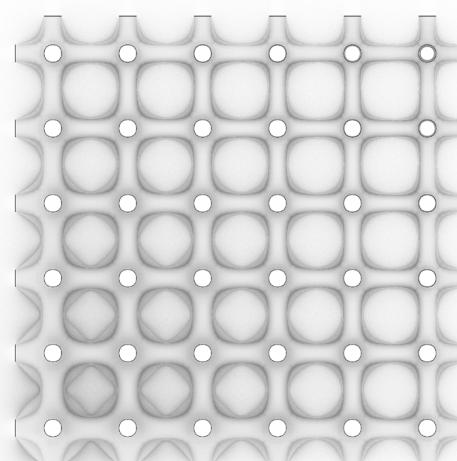
Smooth Geometry



Smooth Front View

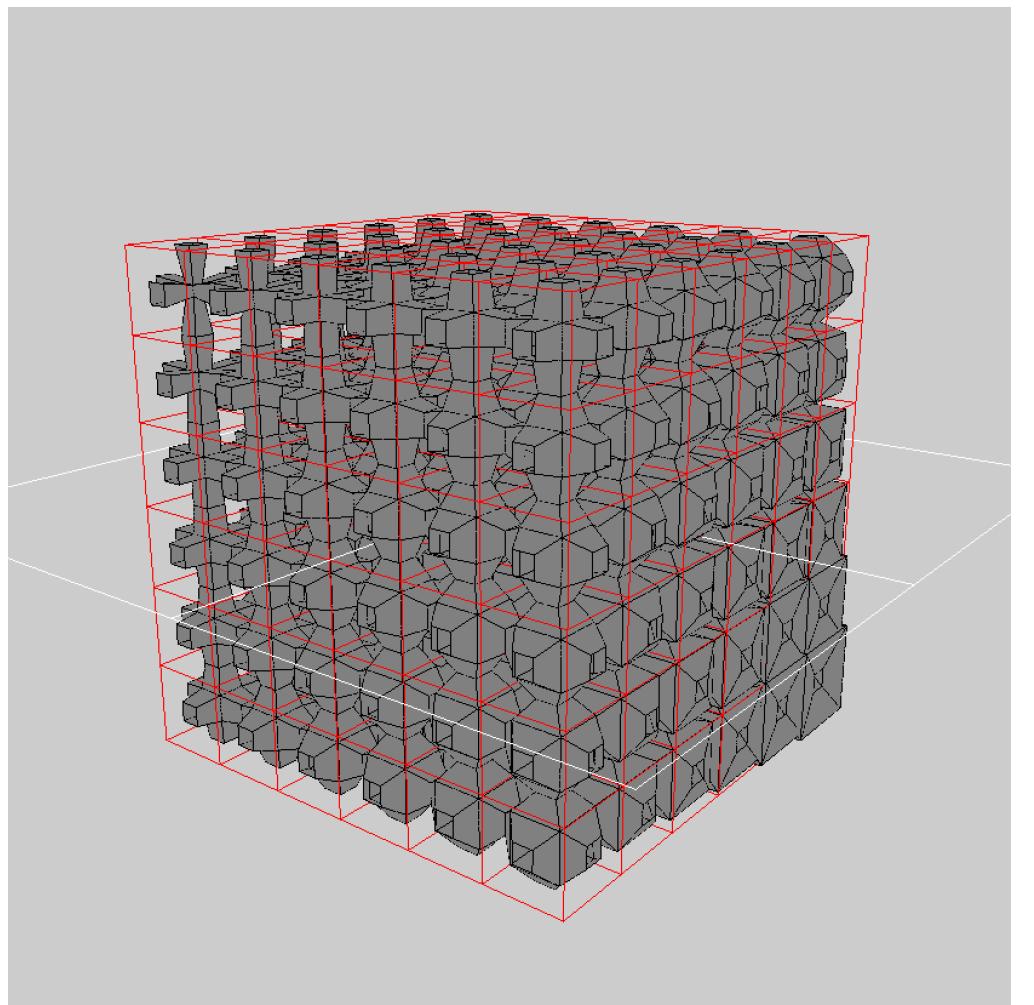


Smooth Right View



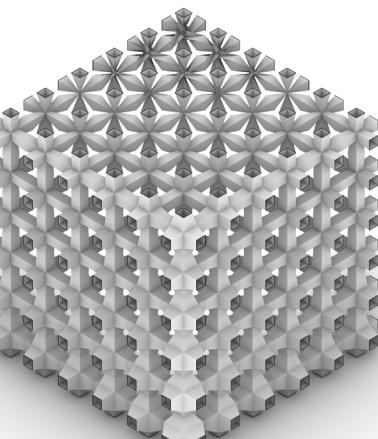
Smooth Top View

TRANSFORMATION ITERATION A3

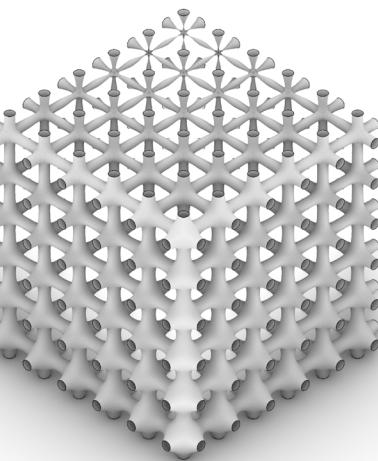


Attractor $(3, 3, 3)$
Range $(4, 10.392)$
Scale $(0.2, 2.5)$

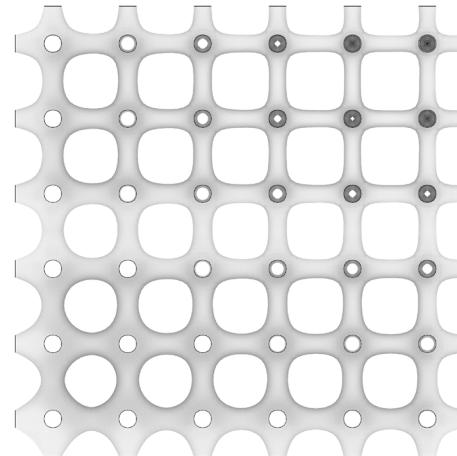
unsuccessful



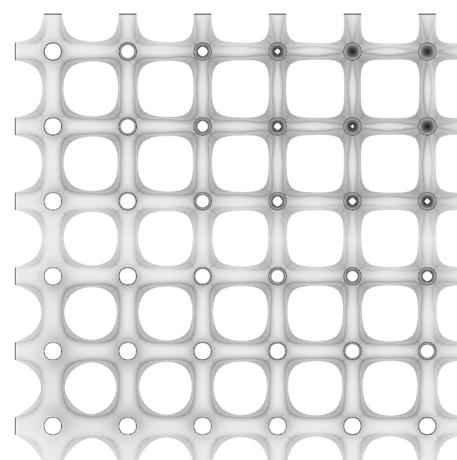
Low Polygon Geometry



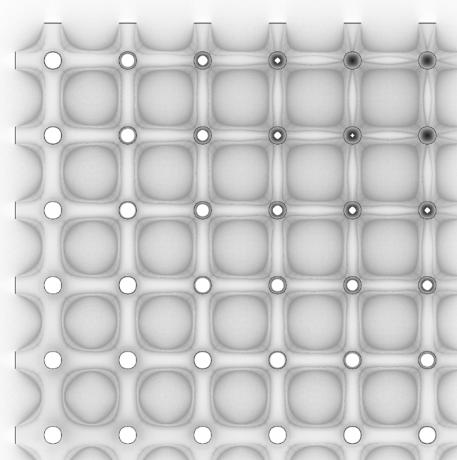
Smooth Geometry



Smooth Front View

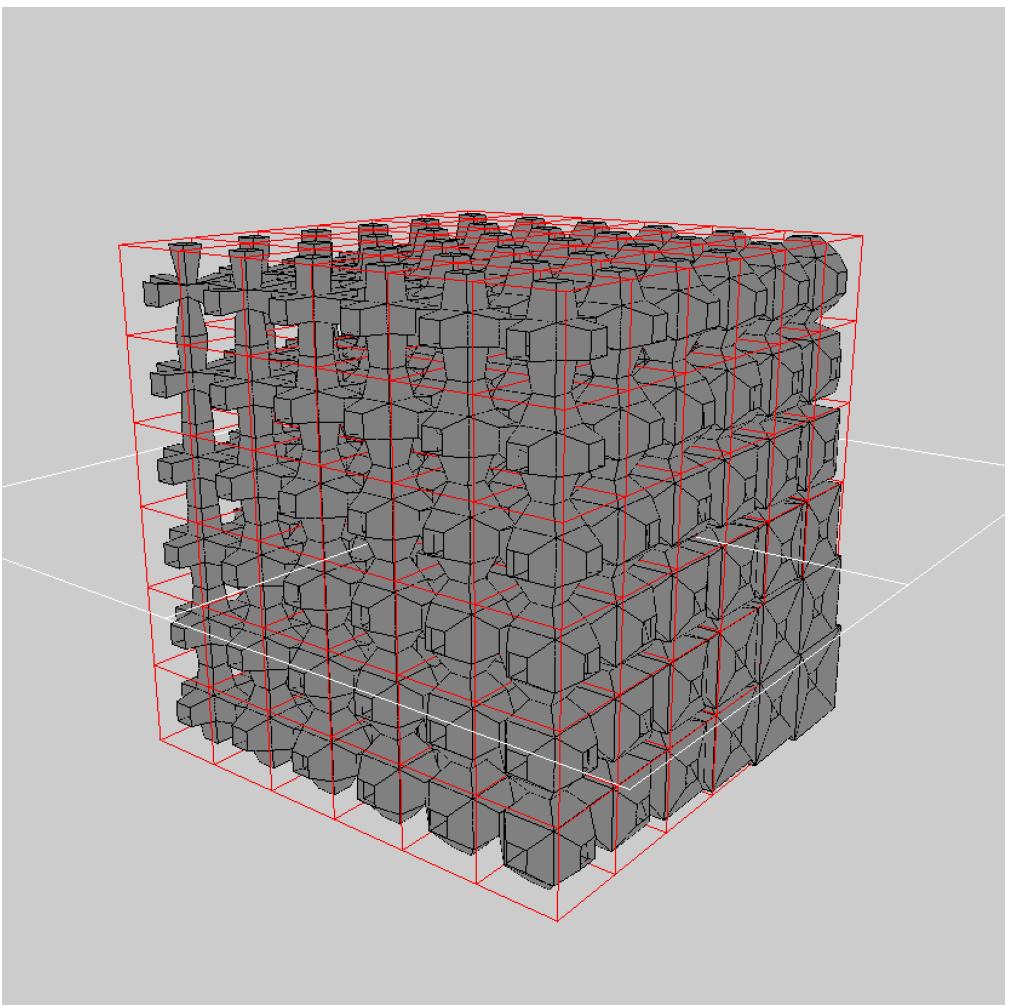


Smooth Right View



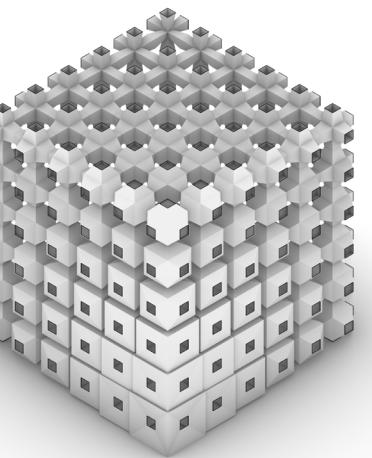
Smooth Top View

TRANSFORMATION ITERATION B1

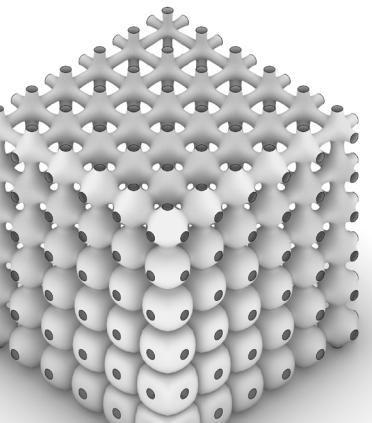


Attractor (3, 3, 3)
Range (0.1, 10.392)
Scale (5, 0.1)

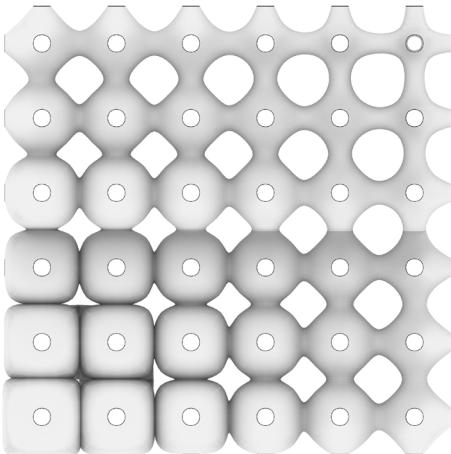
successful



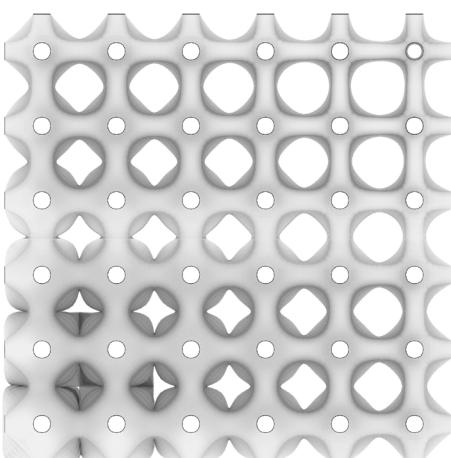
Low Polygon Geometry



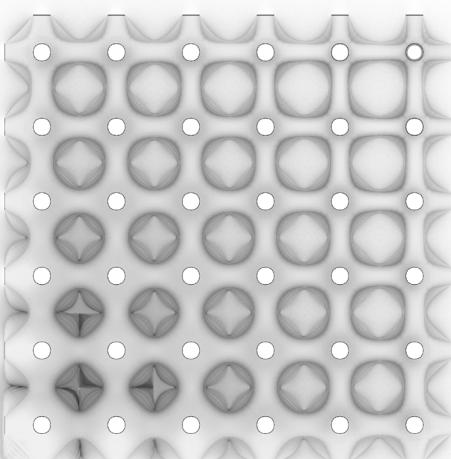
Smooth Geometry



Smooth Front View



Smooth Right View

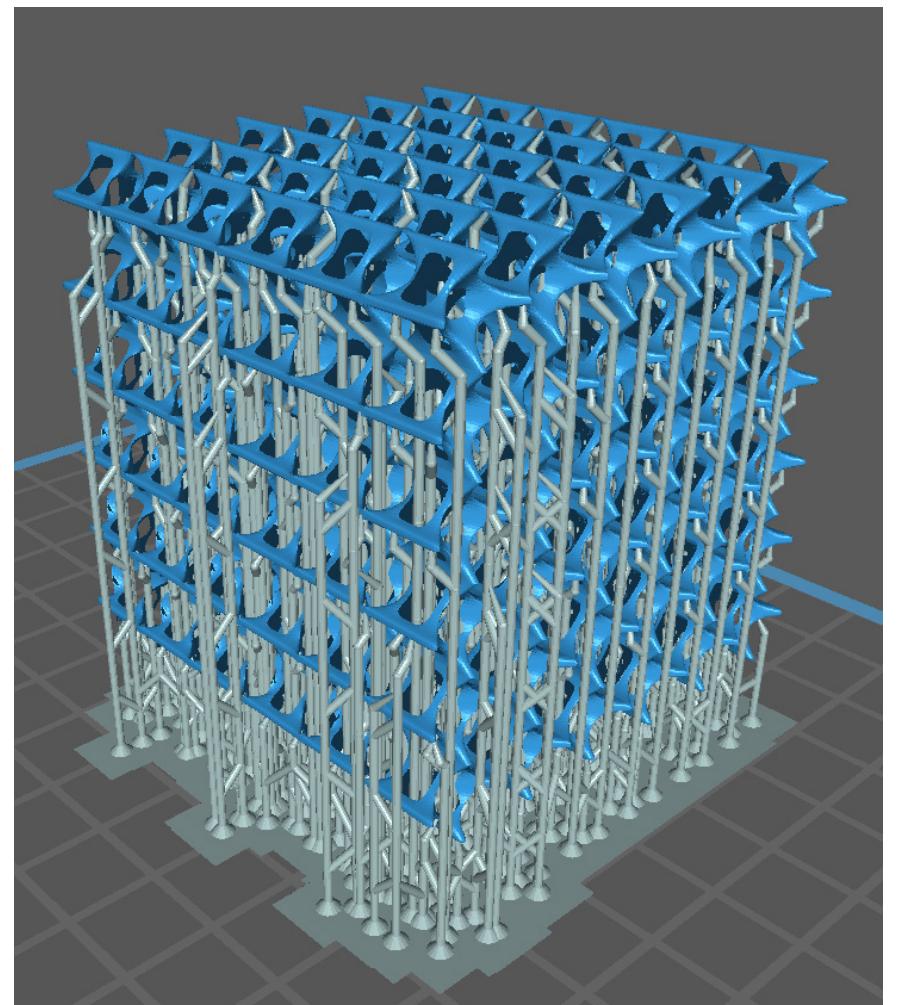


Smooth Top View

3D Print Iterations

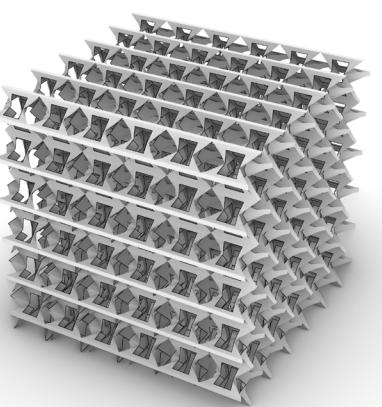
(ChituBox)

DESIGN ITERATION 1

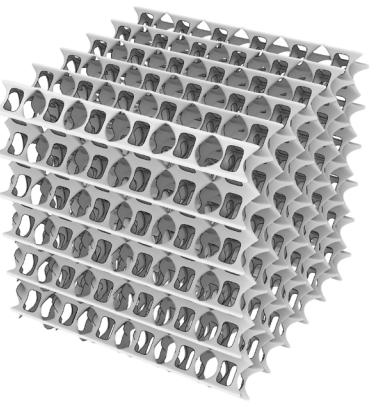


Attractor (3, 3, 3)
Range (0.1, 10.392)
Scale (5, 0.1)

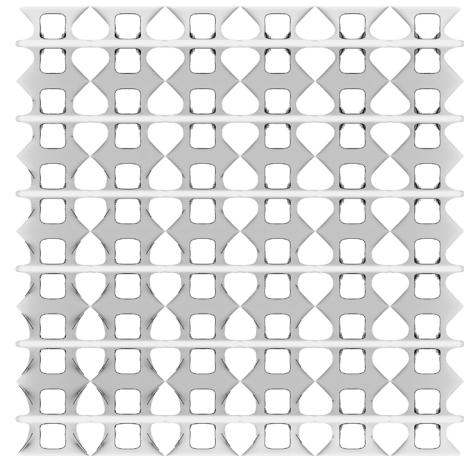
Volume 30.98 ml
Weight 34.1 g
Est Time 4hr 3min 7s



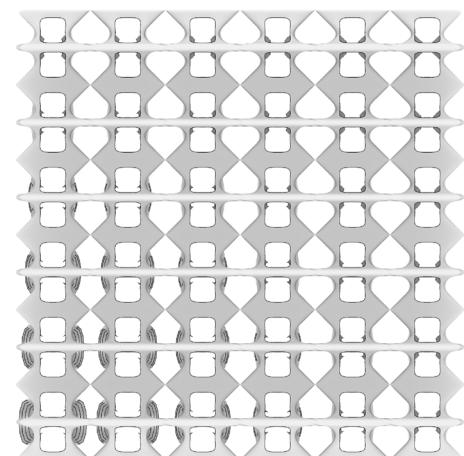
Smooth Front View



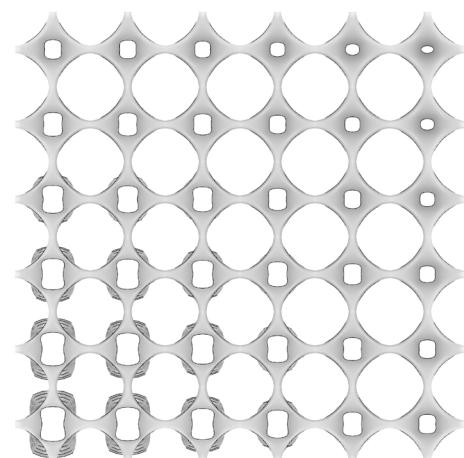
Smooth Right View



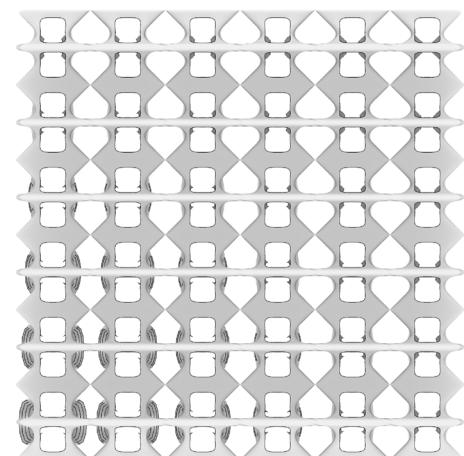
Smooth Top View



Low Polygon Geometry

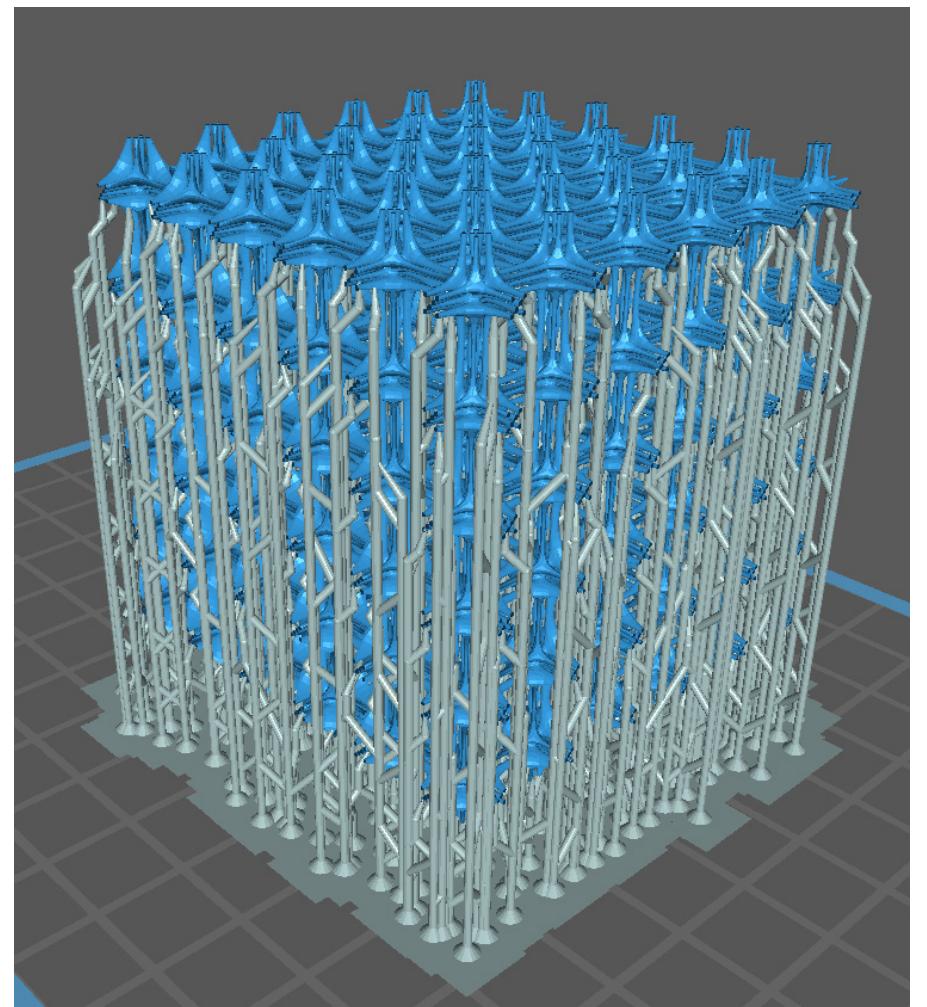


Smooth Geometry



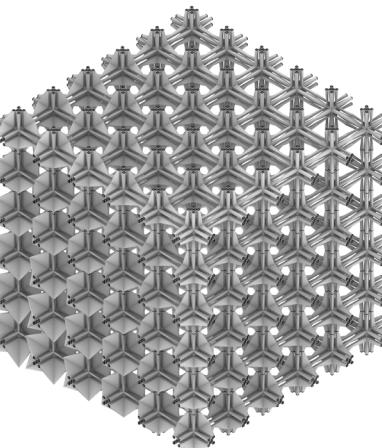
Smooth Top View

DESIGN ITERATION 2

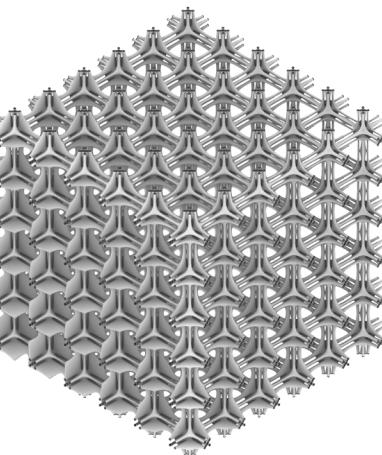


Attractor (3, 3, 3)
Range (0.1, 10.392)
Scale (5, 0.1)

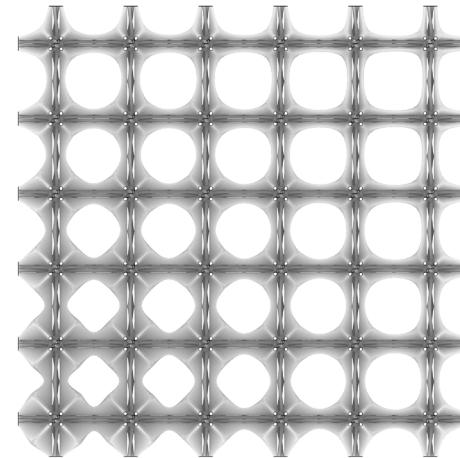
Volume 29.05 ml
Weight 32.0 g
Est Time 4hr 3min 7s



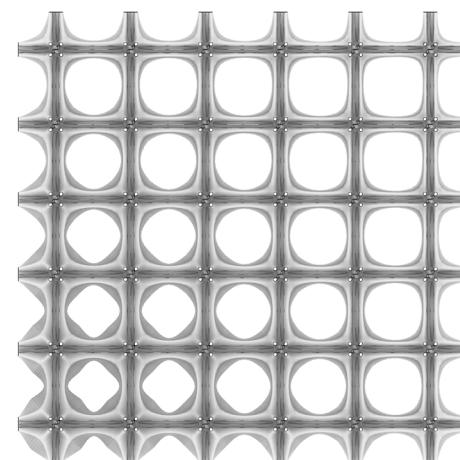
Low Polygon Geometry



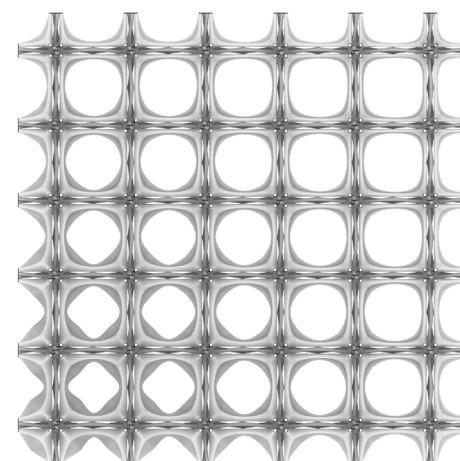
Smooth Geometry



Smooth Front View

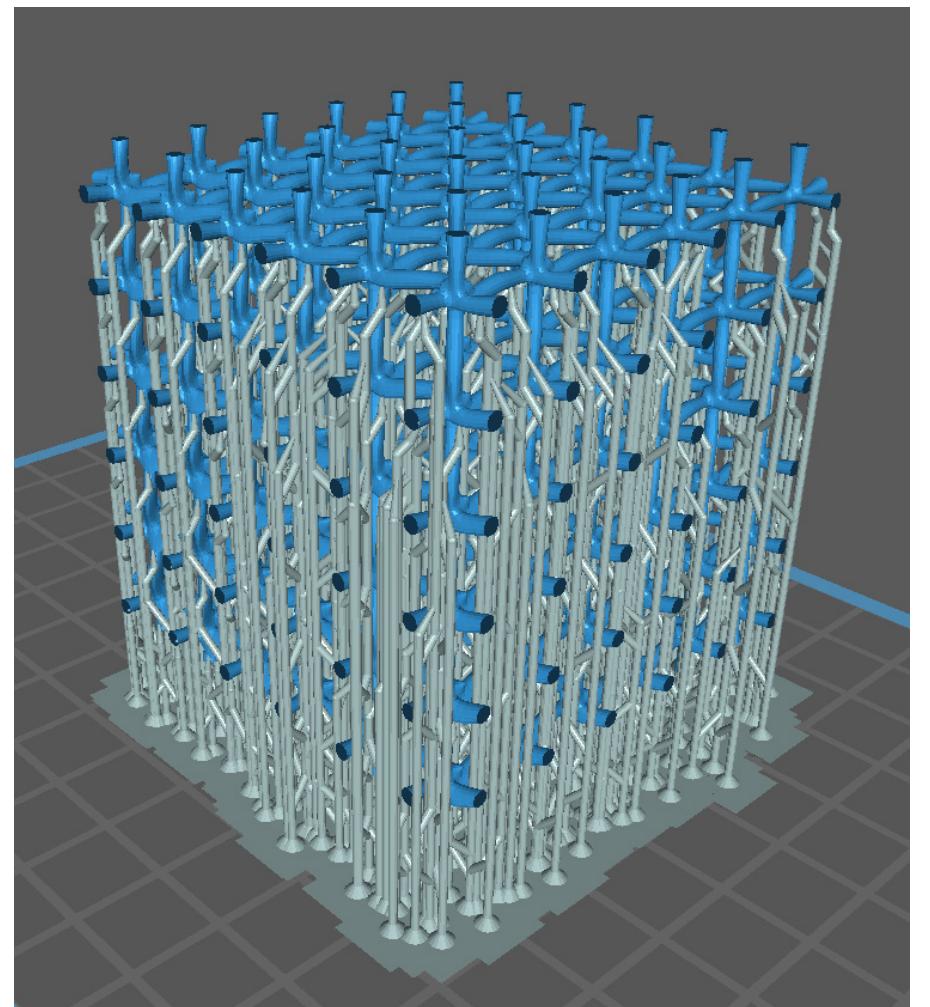


Smooth Right View



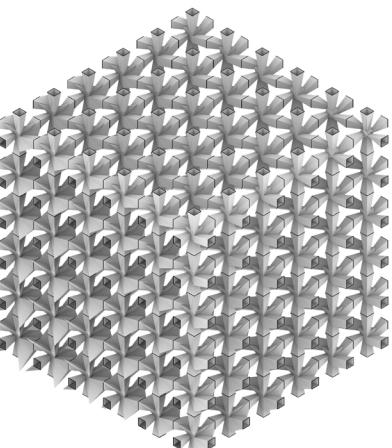
Smooth Top View

DESIGN ITERATION 3

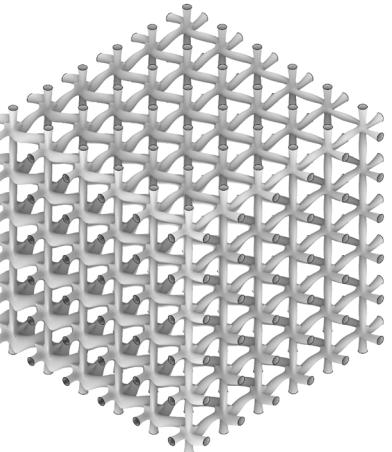


Attractor (3, 3, 3)
Range (0.1, 10.392)
Scale (5, 0.1)

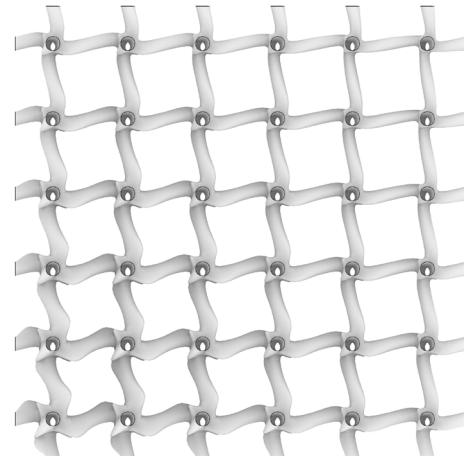
Volume 25.78 ml
Weight 28.4 g
Est Time 4hr 3min 7s



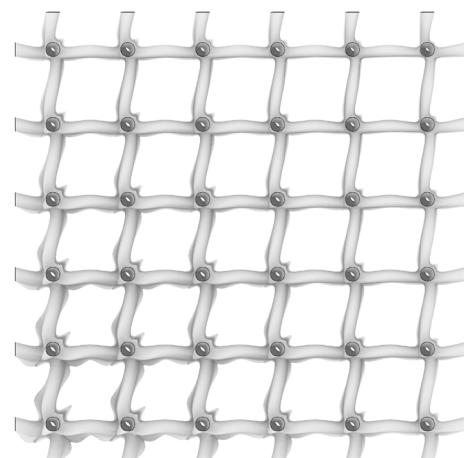
Low Polygon Geometry



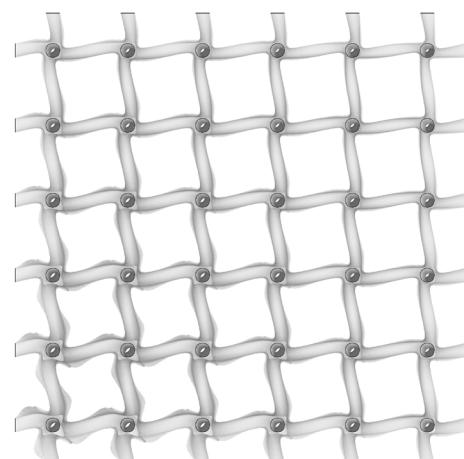
Smooth Geometry



Smooth Front View

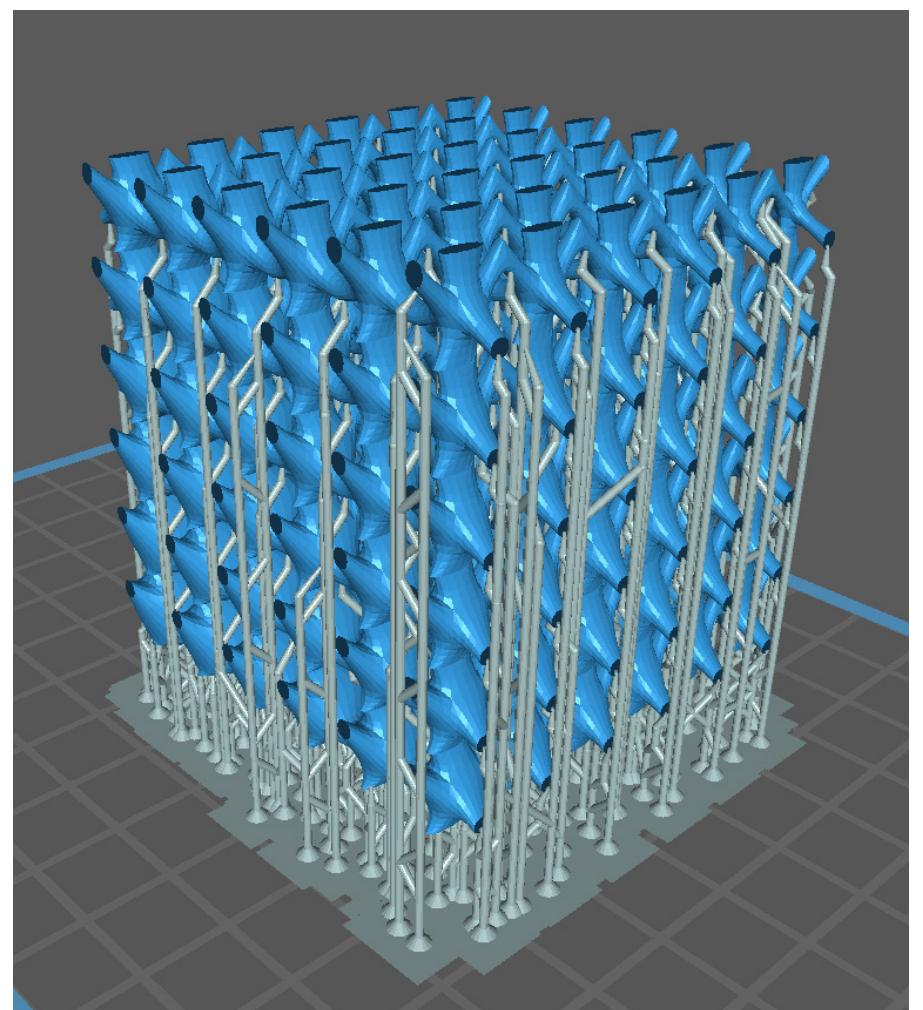


Smooth Right View



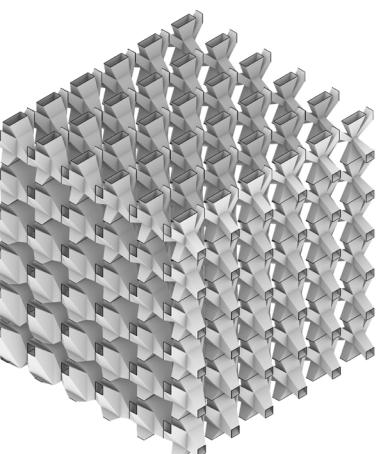
Smooth Top View

DESIGN ITERATION 4

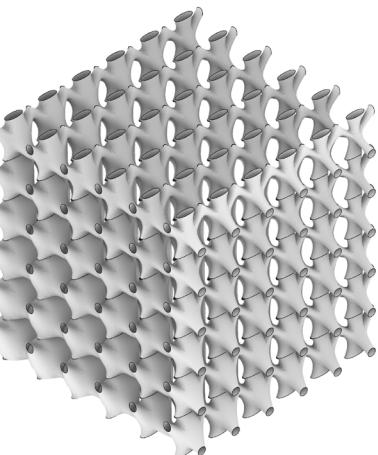


Attractor (3, 3, 3)
Range (0.1, 10.392)
Scale (5, 0.1)

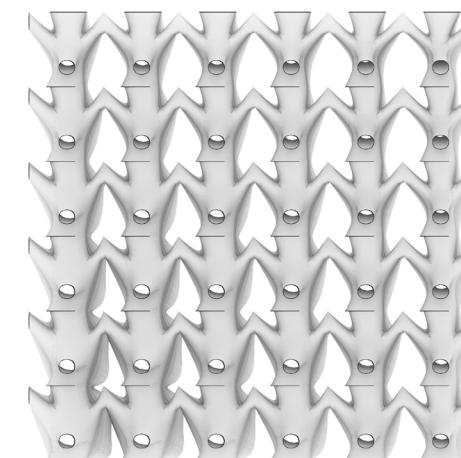
Volume 42.39 ml
Weight 46.6 g
Est Time 4hr 3min 31s



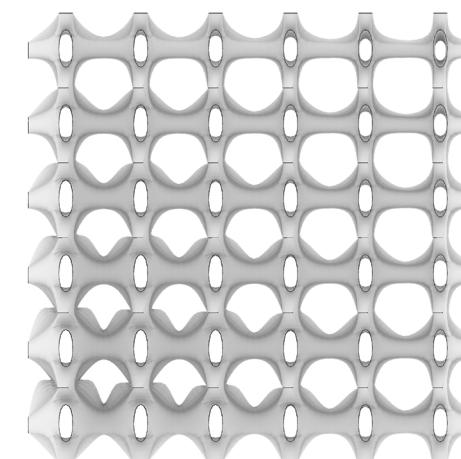
Smooth Front View



Low Polygon Geometry

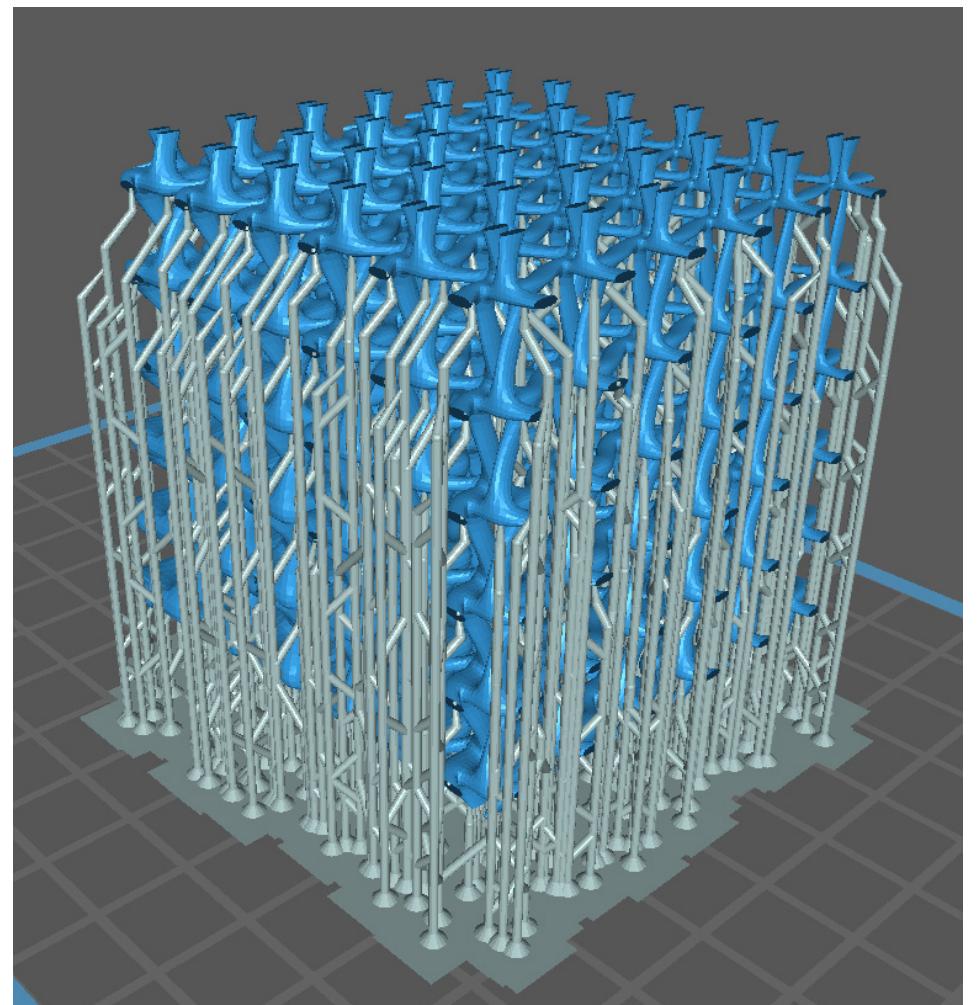


Smooth Right View



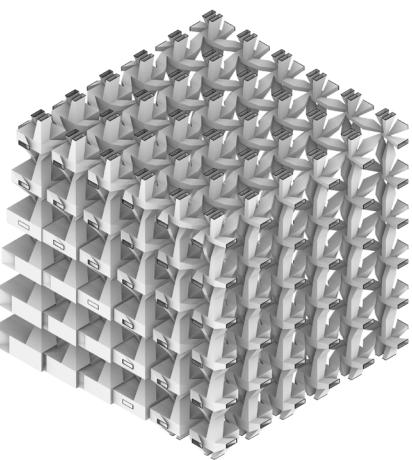
Smooth Top View

DESIGN ITERATION 5

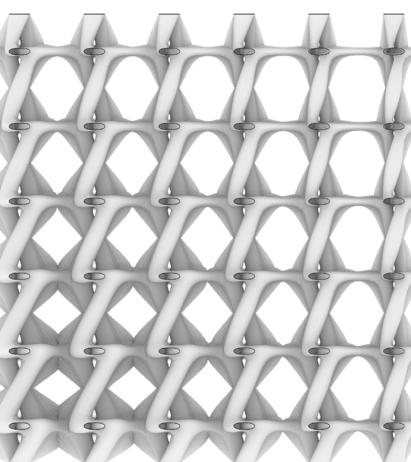
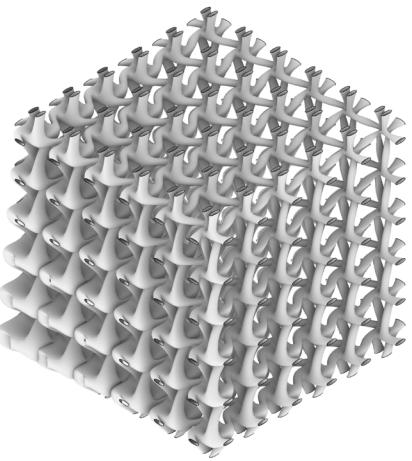


Attractor (3, 3, 3)
Range (0.1, 10.392)
Scale 5, 0.1)

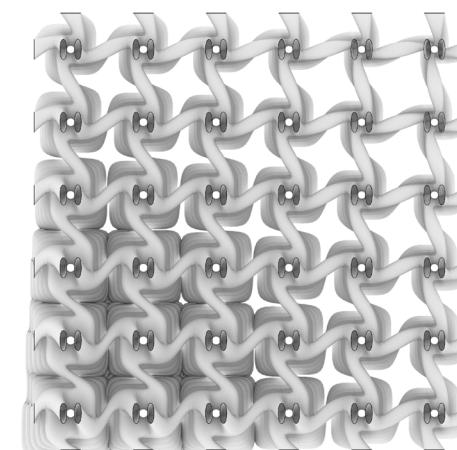
Volume 33.64 ml
Weight 37 g
Est Time 3hr 57min 20s



Smooth Front View



Smooth Right View



Smooth Top View

Design Discoveries

General Learnings:

Workflow

- Every step in the workflow between programs resulted in different learnings about how a geometry reacts to changes
- Giving up complete control, where we learn/discover from different degrees of success, failures and/or novel findings through each aggregate iteration

Back and Forth with Tools

- In this toolchain setup, one part can inform another part in a feedback loop (i.e., after putting some unitary modules through the code, we realize the errors in some, so it can inform new conditions for the modules).

Geometry Discoveries:

Best Practices

- Shapes that extend to the edge on all sides connect better in the matrix, resulting in a more uniform, aggregated whole ---- quads vs. ngons

Handling Complexity

- Divisions in the base geometry can increase the complexity of the geometry, as it allows for more faces to be subjected to manipulation. Vice Versa, a simple geometry can result in clearer outputs.
- In short, relatively simple motions and conditions can result in complex outcomes through emergence.
- Any breaks in conformity and uniformity result in a more complex, but less integrated whole.

3D Printing Discoveries:

- Changes made in the first two stages (maya exploration and coding) of the exercise can greatly affect the 3D printing process.
- If the design has 45 degree angled members, support in those areas won't be needed.
- If the design is less porous, supports within the interior won't be needed.
- This however can vary results as the object will be more solid, meaning more material is needed to be printed.

Failures

- The designs that failed generally features large gaps within the aggregate, resulting in an object that is consisting of an array of smaller objects, rather than a single connected object.