

200 LINES OF CODE

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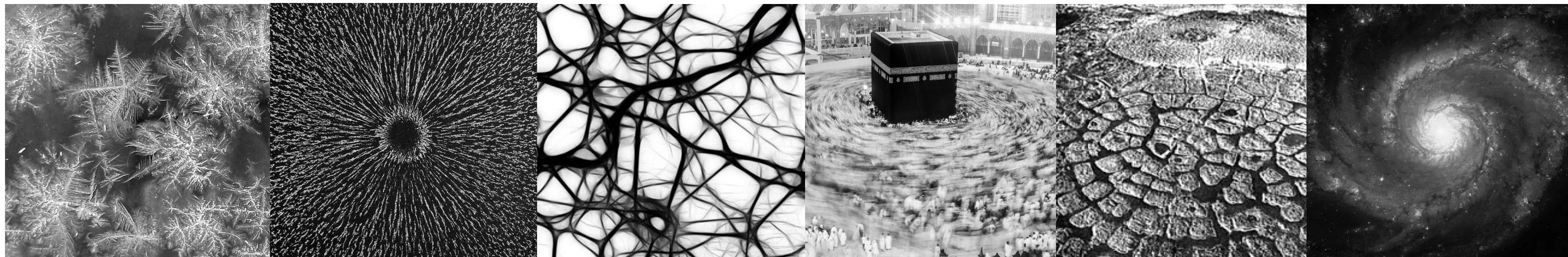
Functionally graded materials (FGMs) are known within the larger design discipline as an emergent form of composite materials in which the properties of the overall form are consistent and continuous as the surfaces of an aggregated material vary "smoothly and continuously from one surface to another" [1].

Through the explorations over the course of our 200-lines of code class, we found that a functionally graded material is one that can be repeated and changed over time and distance. Taking a typology and inserting it into a mixed or aggregated matrix where an emergent form evolves from the constraints of the code and base mesh geometries.

The core base constraints of forming an FGM we identified as alignment and simplicity of a base form. Cubes are composed of a typology, and the requirements of the typology are that each of the smaller components come together to form a larger system. Each of the smaller components requires thoughtful and rigorous planning, so they act as structural integrity as part of this system. 2 large parameters of this 3D-printed exploration were that: 1. the components connect to each other, and 2. that the components act as a structure together as well.

The aggregations our team has been working on this week are an emergent process that fractals its own patterns within itself. By using smoothing, aggregating, attractors, scaling, and rotation transformations the FGM we created is a unique form that would be impossible to model with a NURBS modelling method. By giving up some of the direct control associated with typical CAD methods, our FGM is an emergent and self-reinforcing form that is unique and applicable at various scales of design applications.

[1]. Yoshihisa Uchida, Jun Yamada, Y.P. Kathuria, Niichi Hayashi, Shigeo Watanabe, Shuntaro Higa, Hideo Furuhashi, Yoshiyuki Uchida, Excimer, Laser Processing of Functionally Graded Materials, Functionally Graded Materials 1996, Elsevier Science B.V., 1997, Pages 337-342,



FGM {GEOTYPE-PHENOTYPE}

PROCESS OVERVIEW

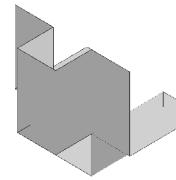
MAYA

TRANSFORM
REFLECT
AUGMENT

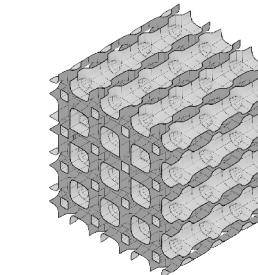
①



②



③



C++ OPERATIONS

ATTRACTOR
SCALE
ROTATE
TRANSLATE

④

```
// construct a gradient parameter
zVector u, v, w, c, move, origin, attractor;
attractor = zVector(0, 0, 3);
c = cen;
float disAttractor = cen.distanceTo(attractor);
float maxL = diagLength;
float mult = ofMap(disAttractor, 0, 4, 5, 1);
```

⑤

```
TM.col(0) << cos_theta, sin_theta, u.z, 1;
TM.col(1) << -sin_theta, cos_theta, v.z, 1;
TM.col(2) << w.x, w.y, 1, 0;
TM.col(3) << 0, 0, 0, 1;
```

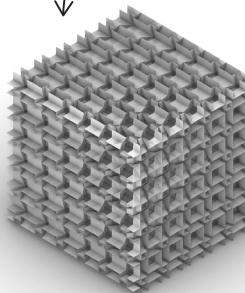
⑥

```
//construct the transformation matrix
zTransform TM;
TM.setIdentity();
u = zVector(1, 0, 0);
v = zVector(0, 1, 0);
w = zVector(0, 0, 1);
u.normalize(); v.normalize(); w.normalize();
u *= mult; v *= mult; w *= mult;
```

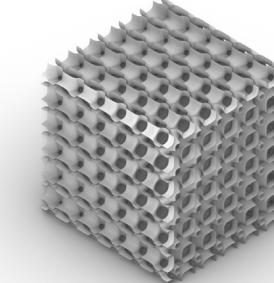
MAYA

MERGE
SMOOTH
CAP

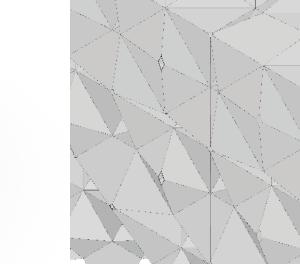
⑦



⑧



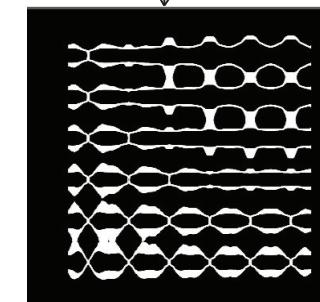
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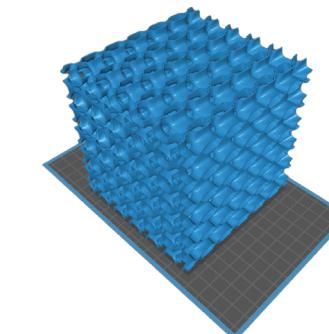
CHITUBOX

EVALUATE
PRINT

⑩



⑪

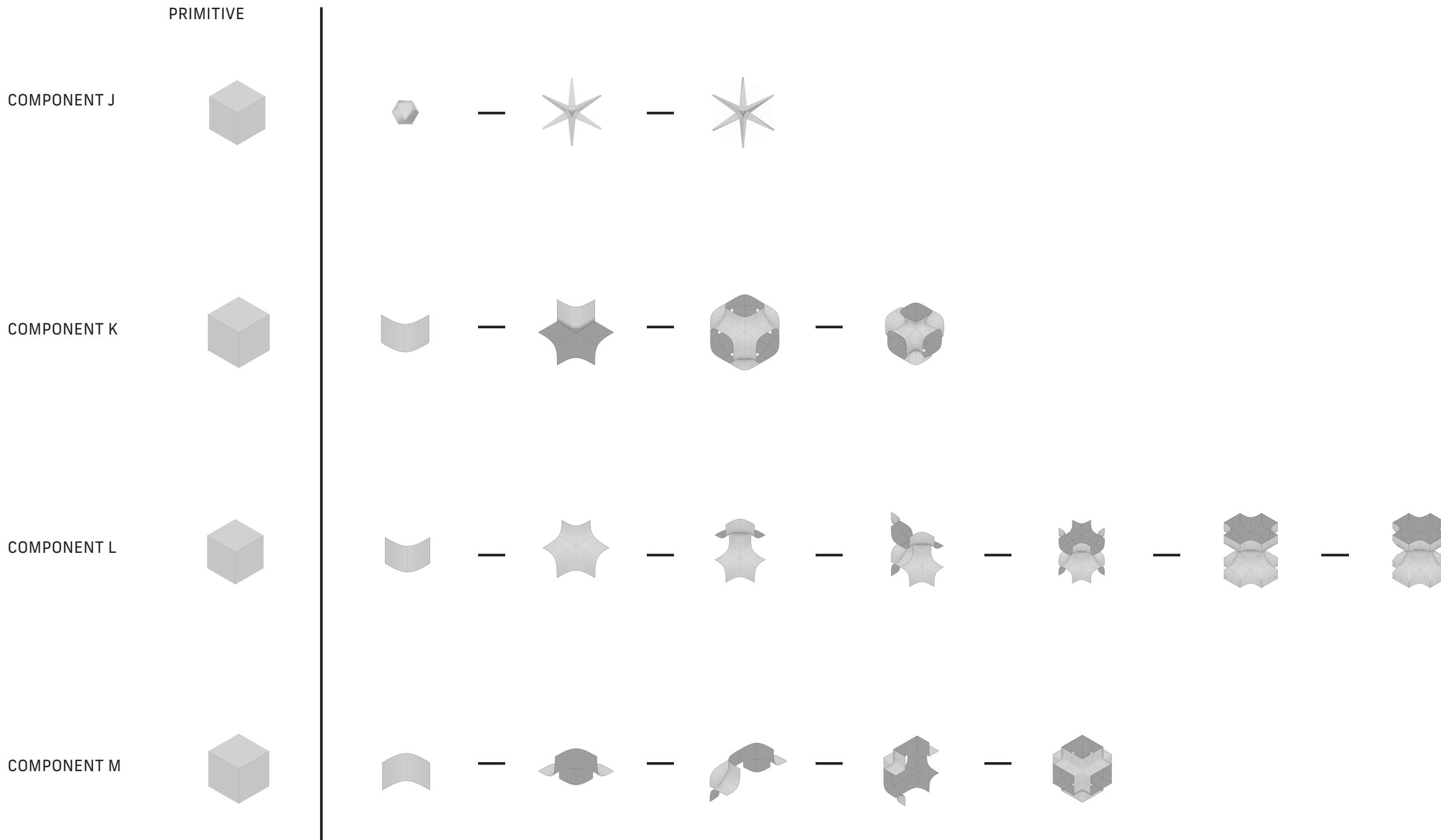


MATRIX I

PRIMITIVE					
COMPONENT F			-		
COMPONENT G			-		-
COMPONENT H			-		-
COMPONENT I			-		-

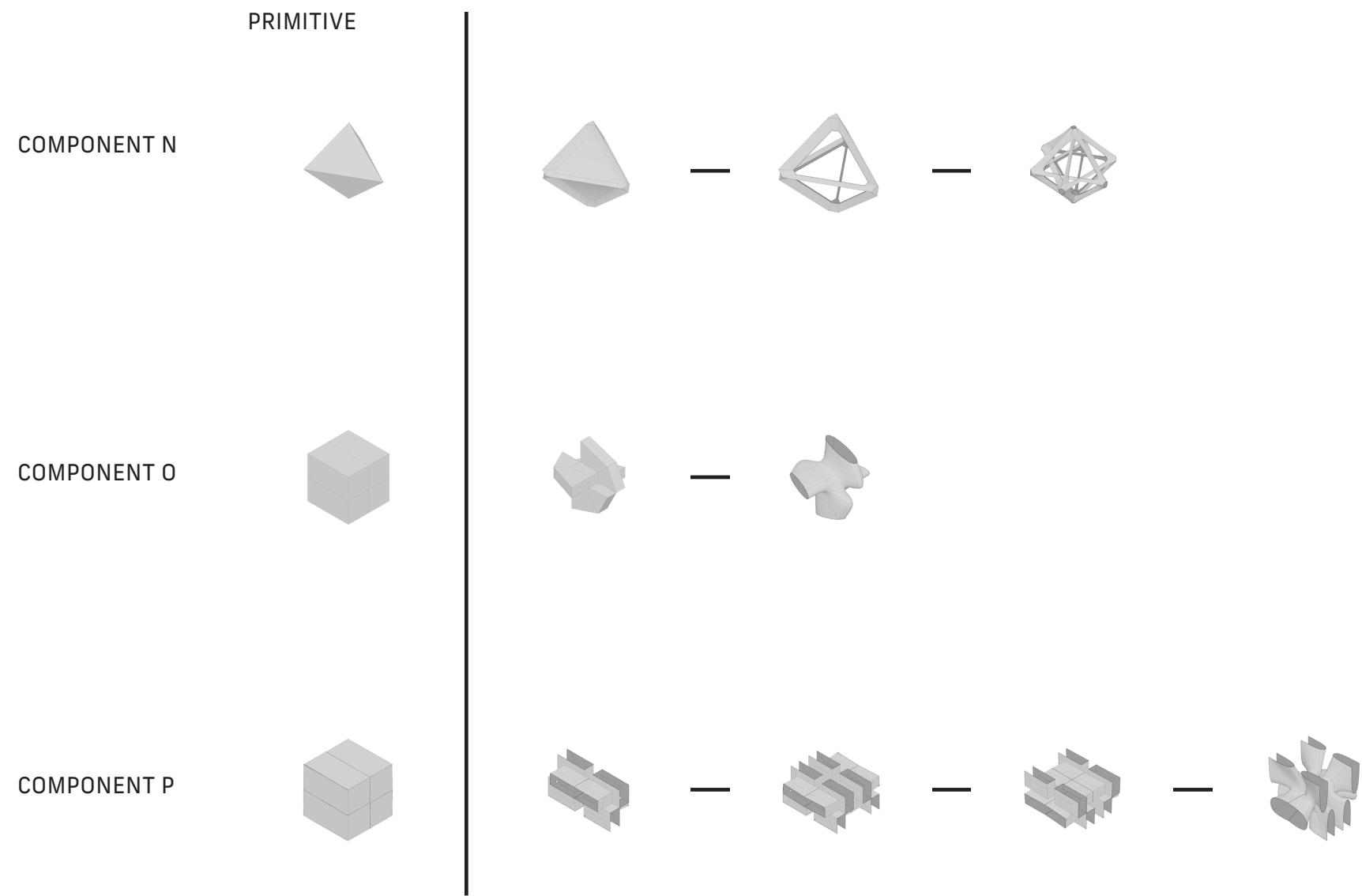
COMPONENT ITERATION MATRIX

MATRIX II

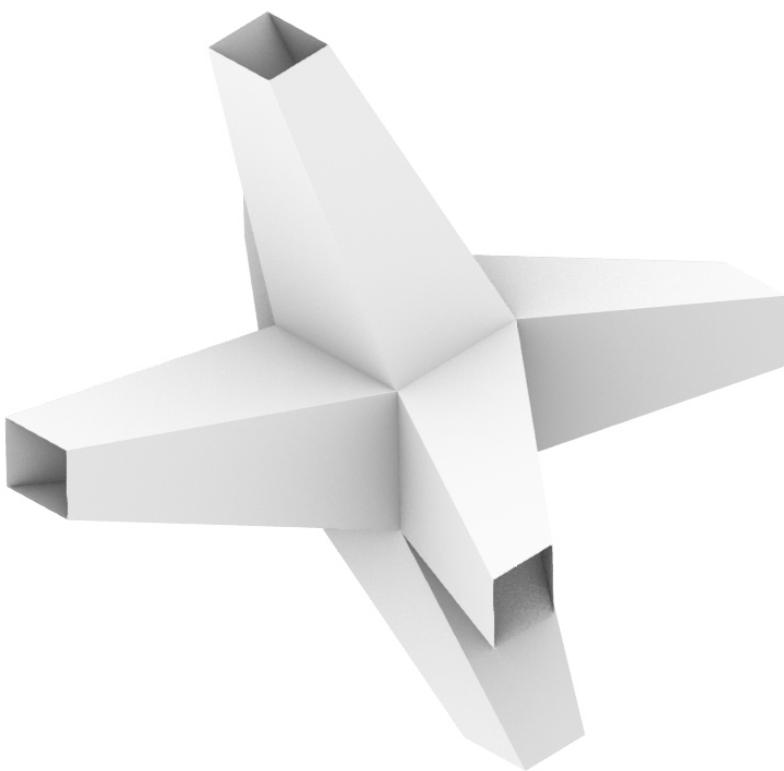
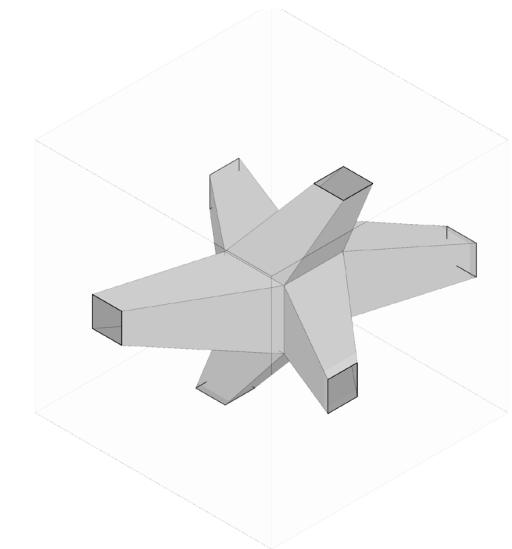
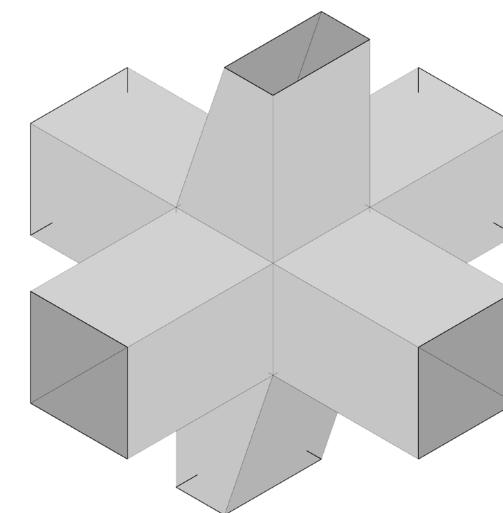
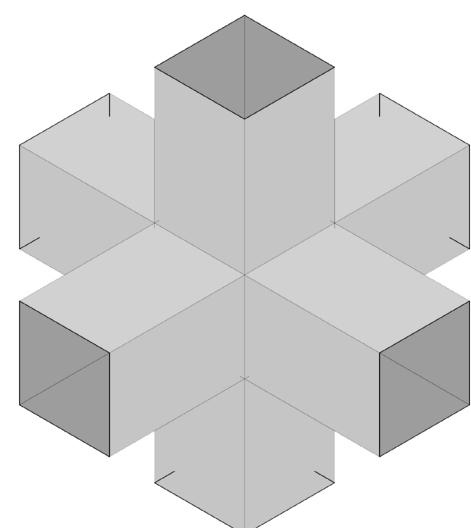
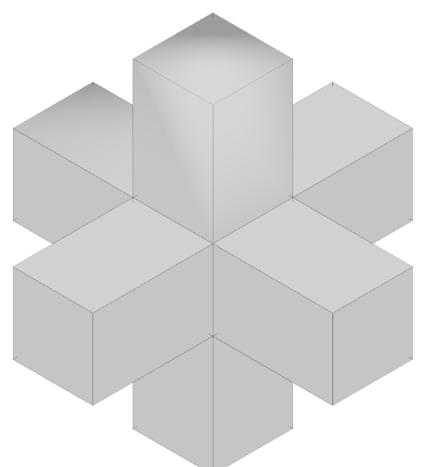
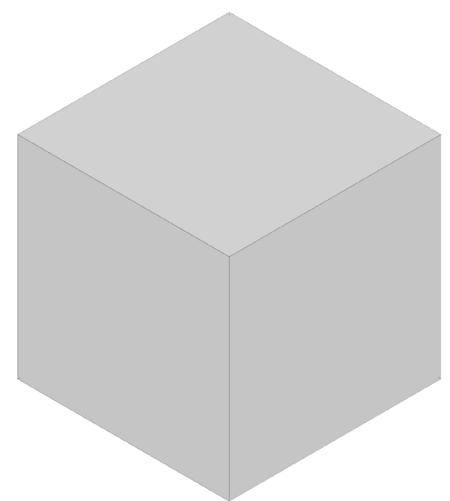
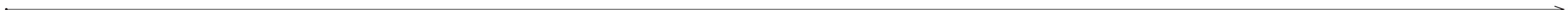


COMPONENT ITERATION MATRIX

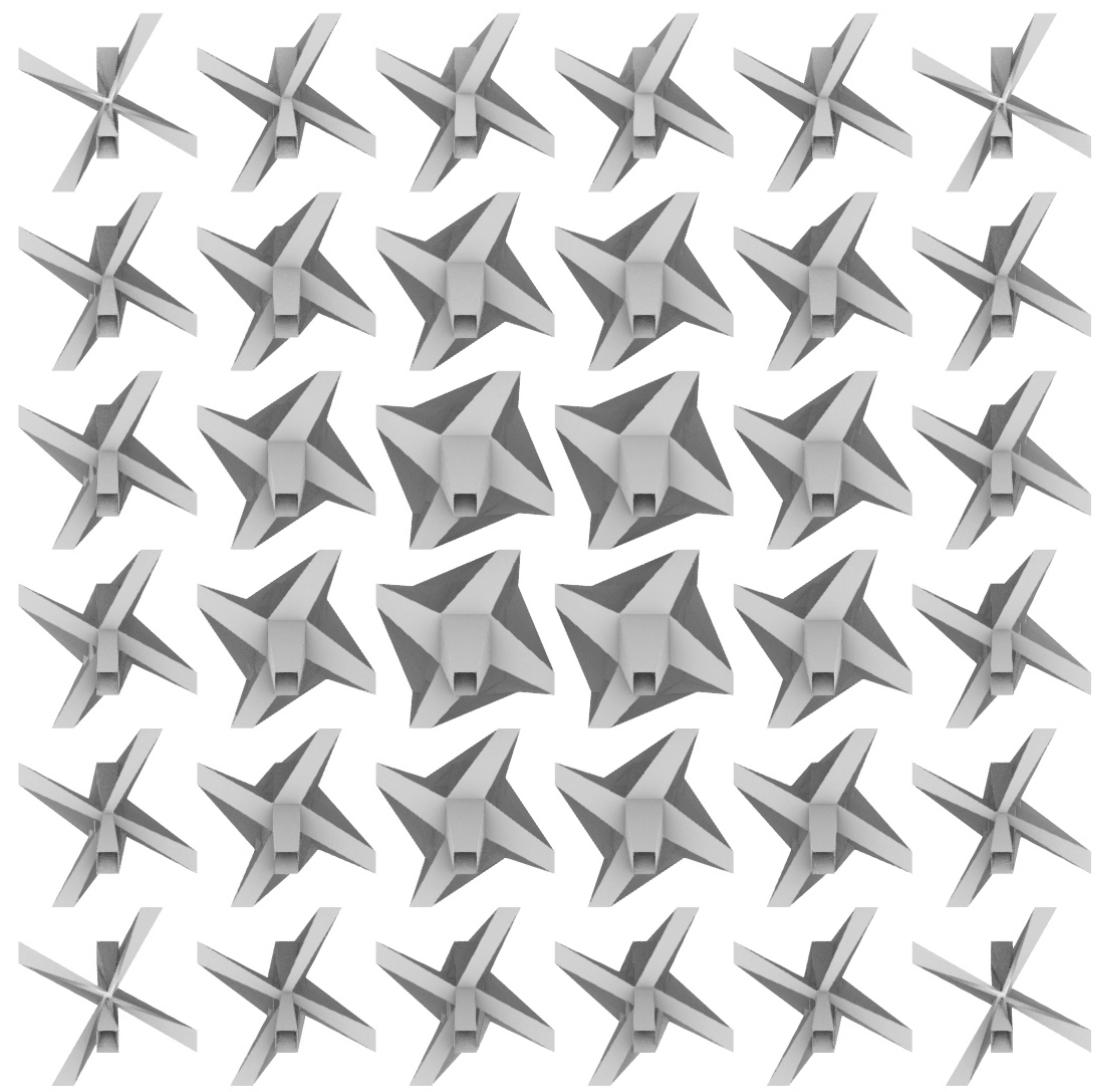
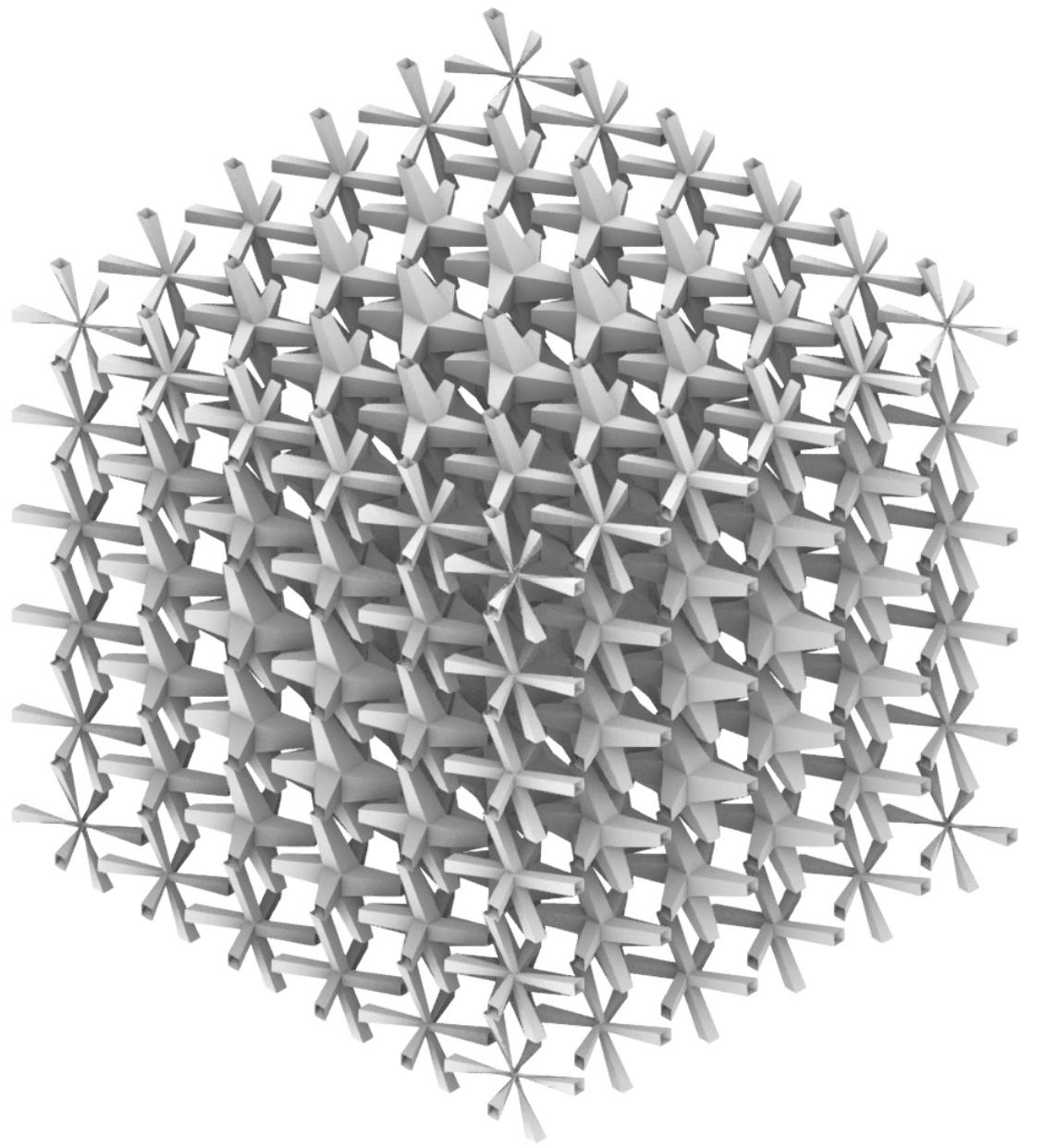
MATRIX III



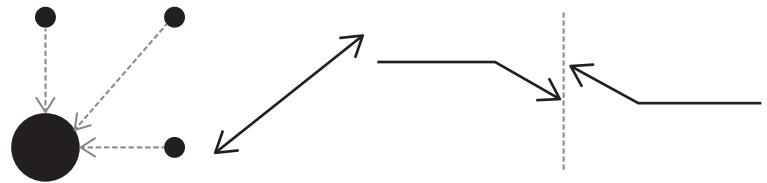
COMPONENT ITERATION MATRIX

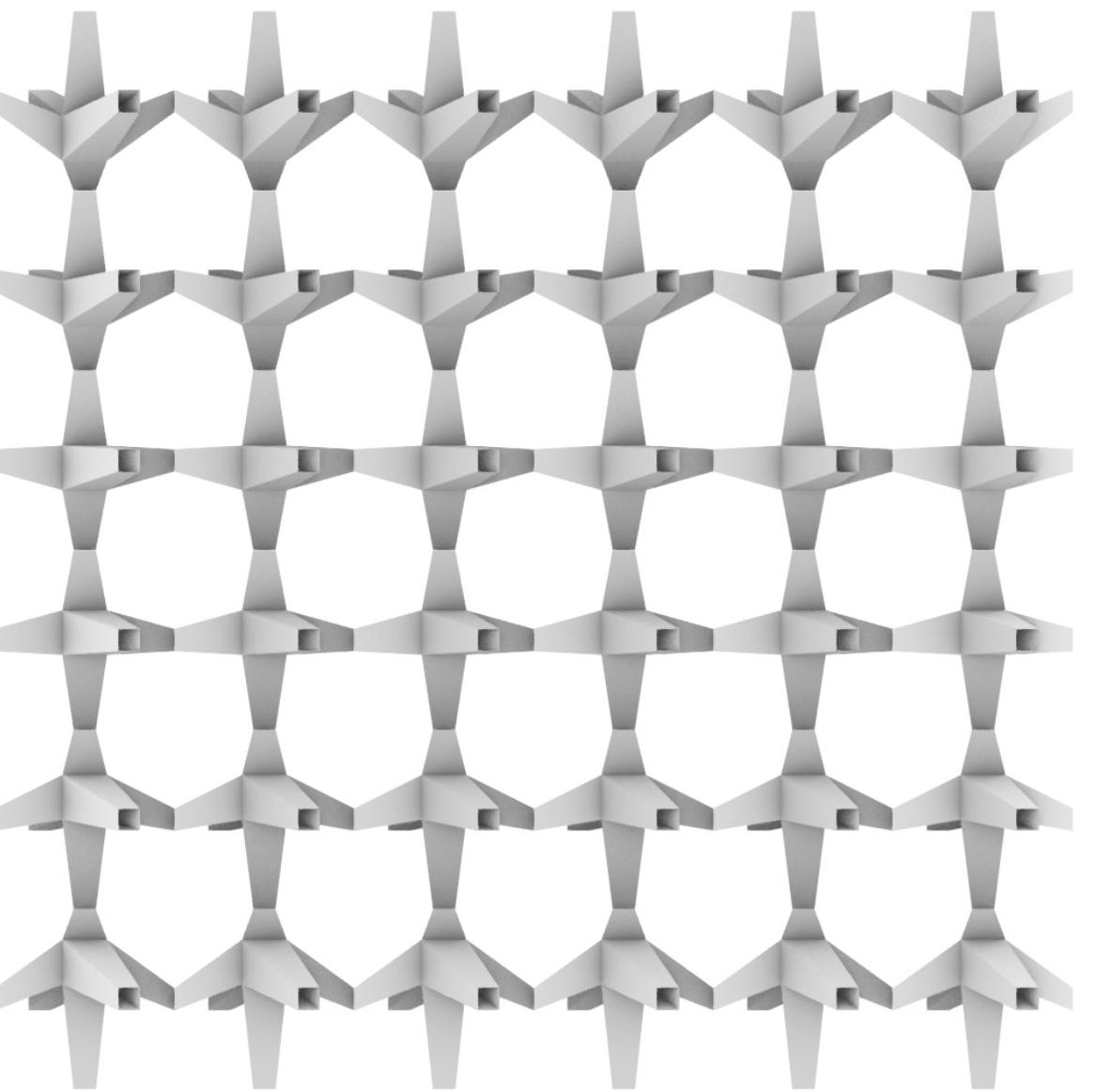
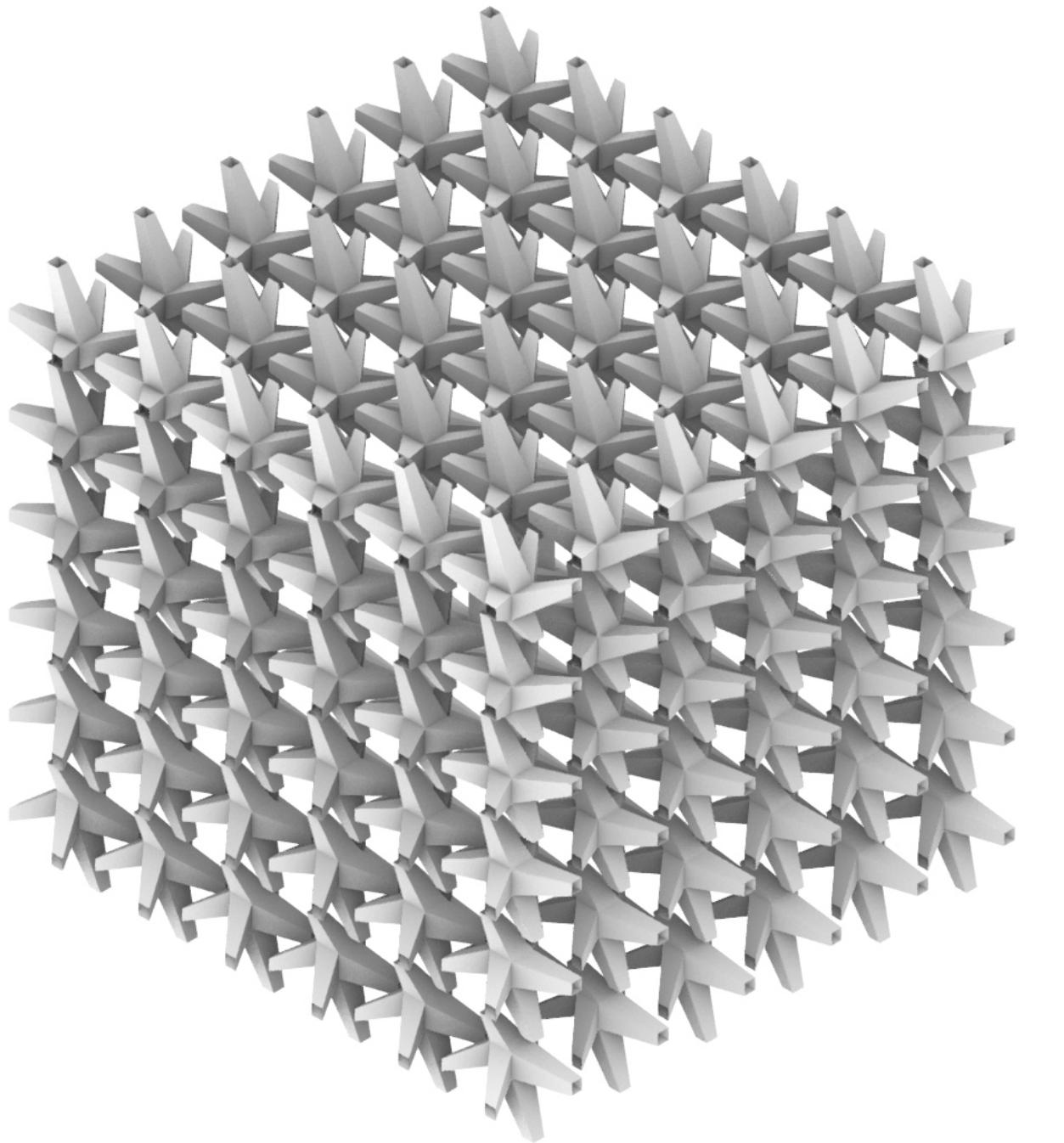


COMPONENT A

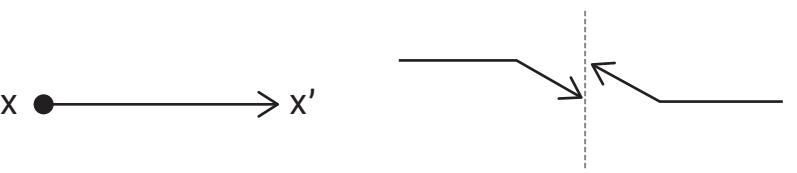


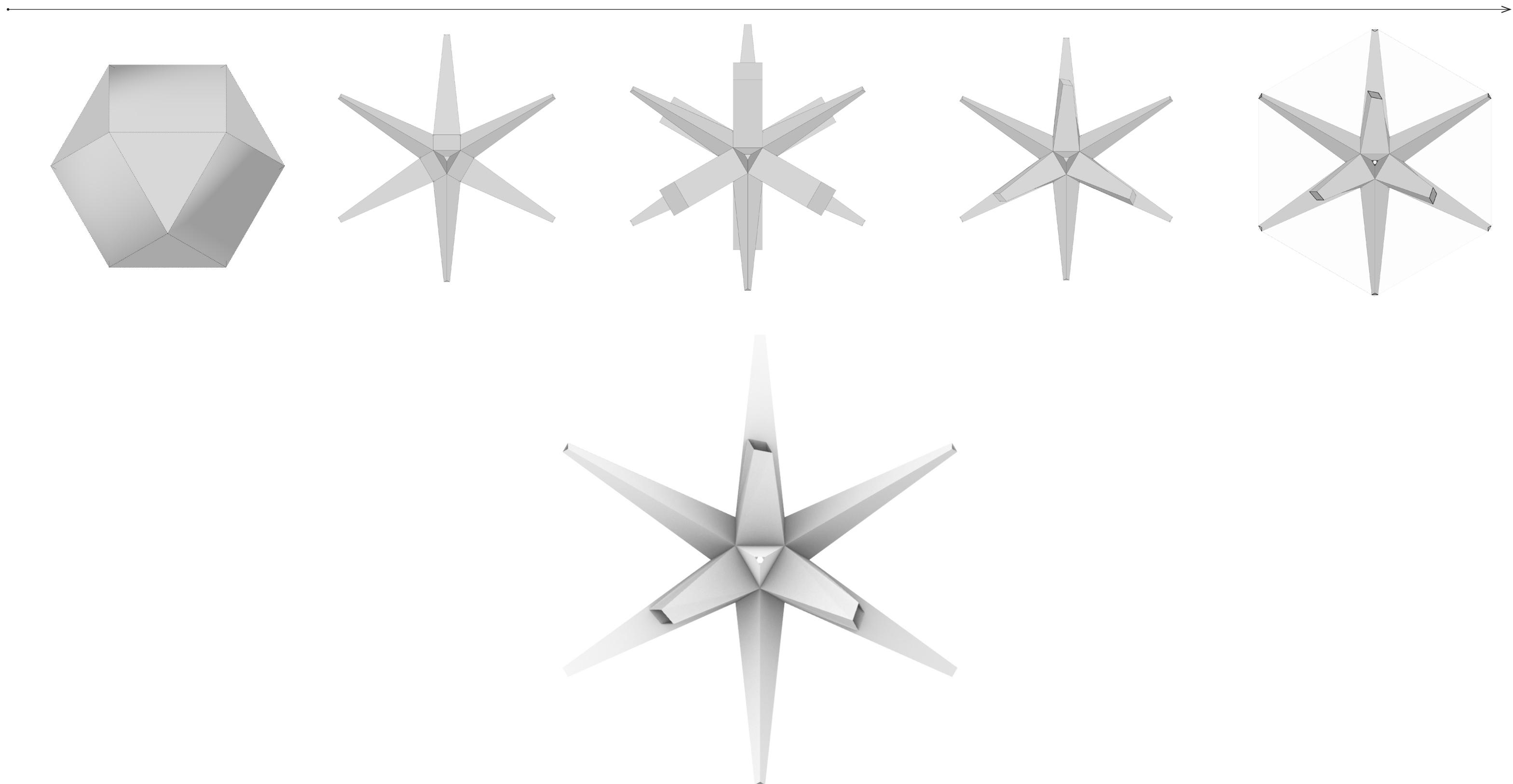
COMPONENT A - AGGREGATION 1



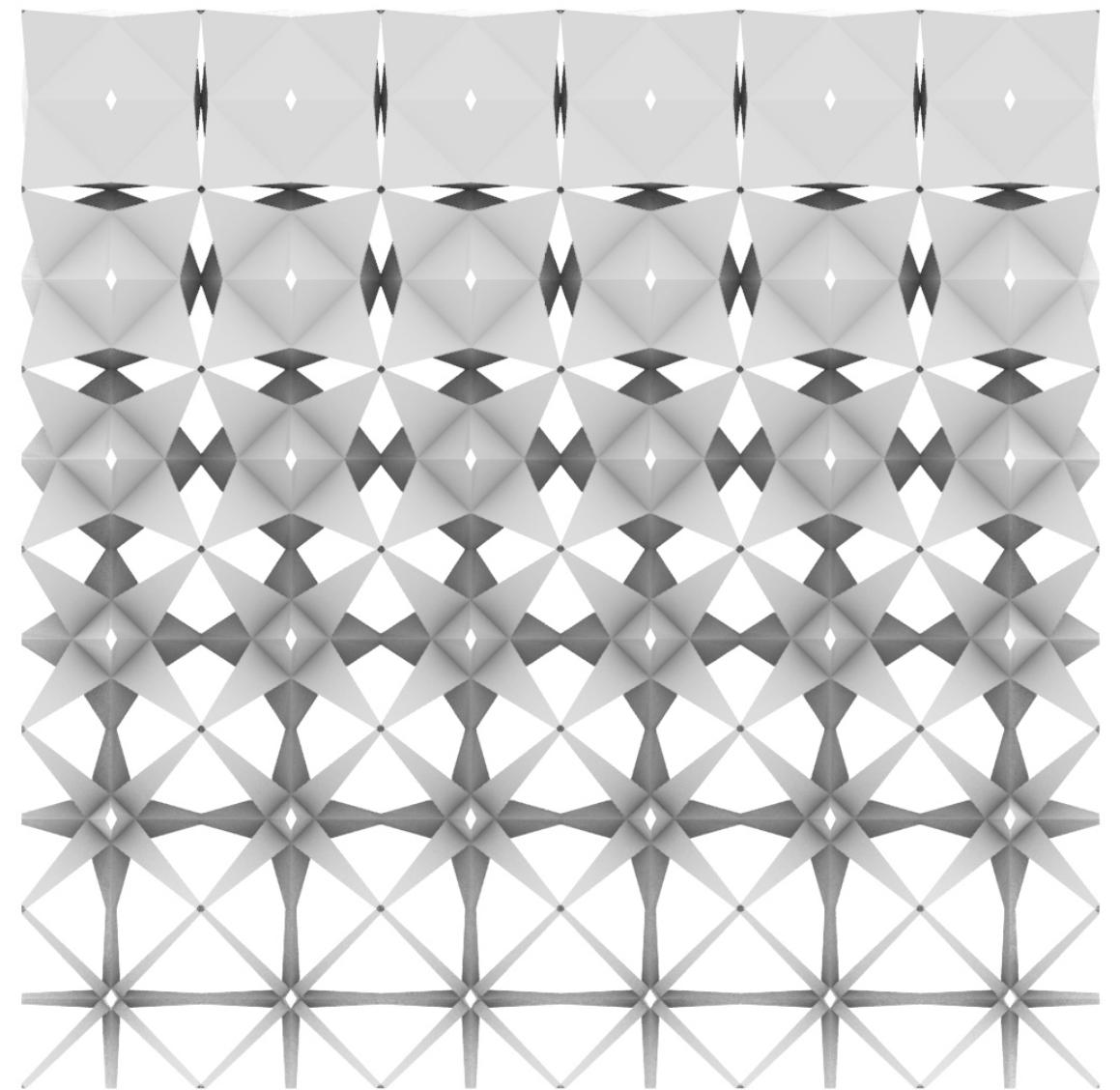
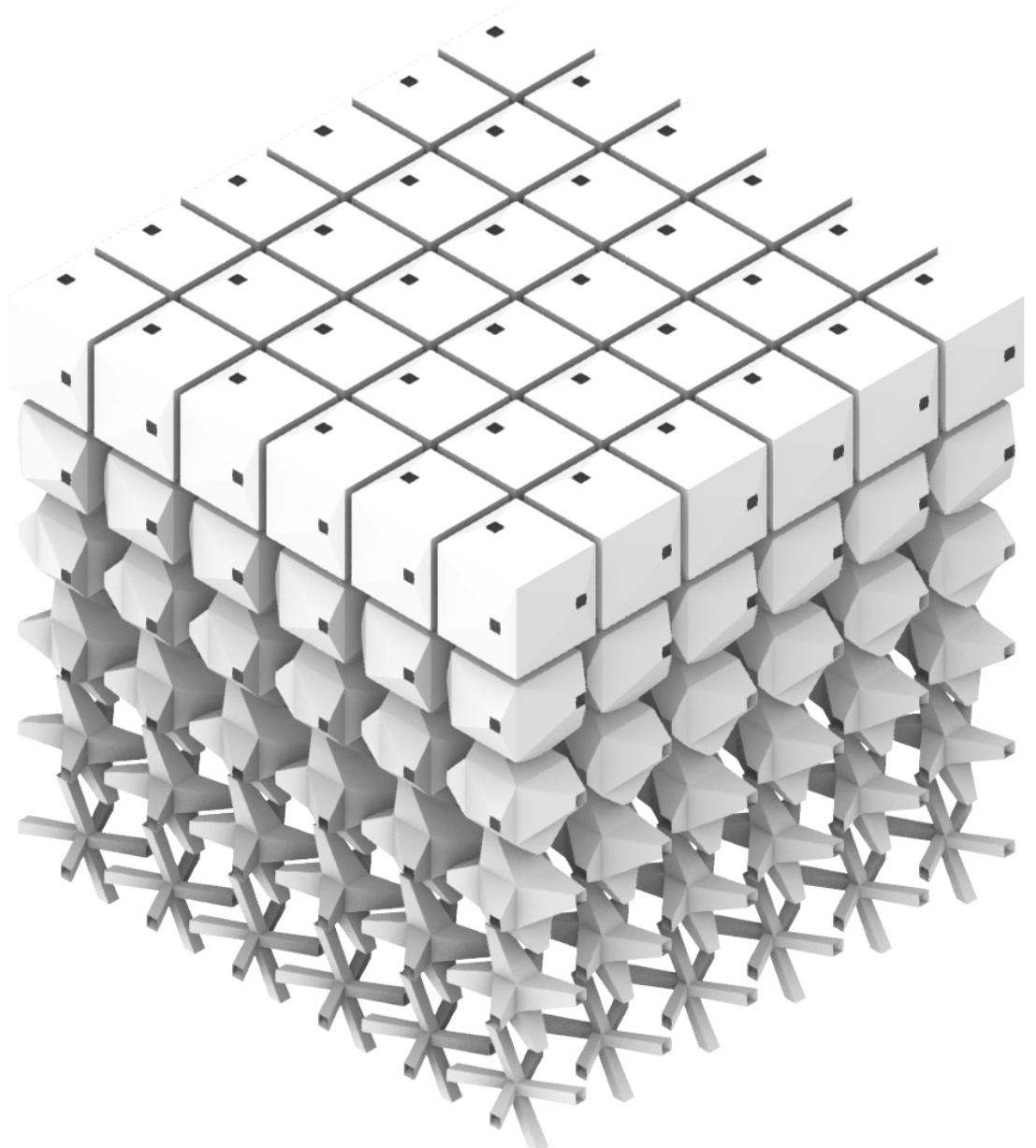


COMPONENT A - AGGREGATION 2

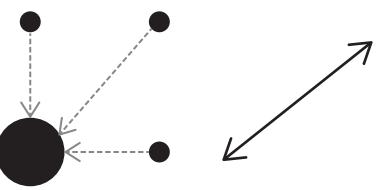


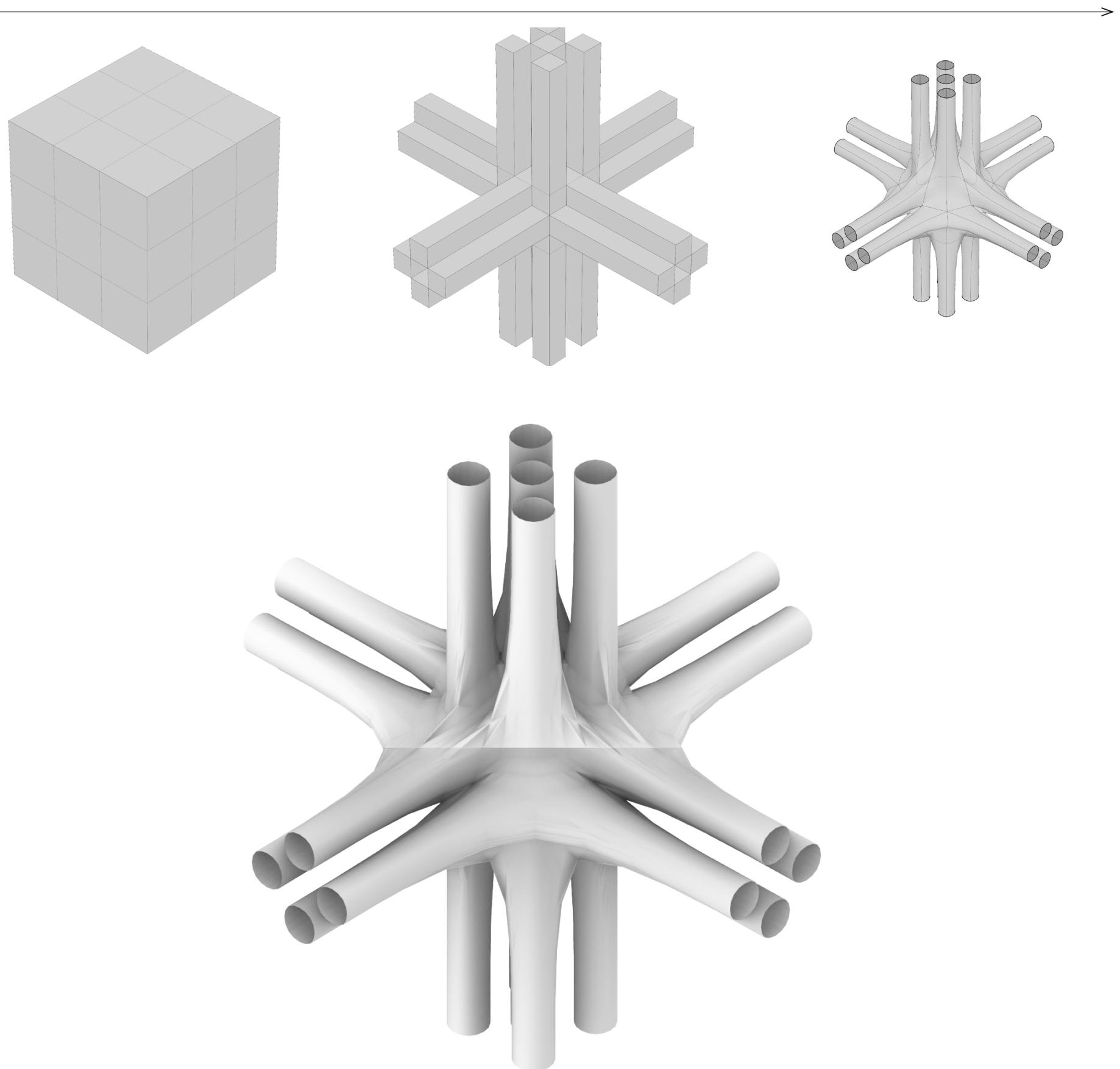


COMPONENT B

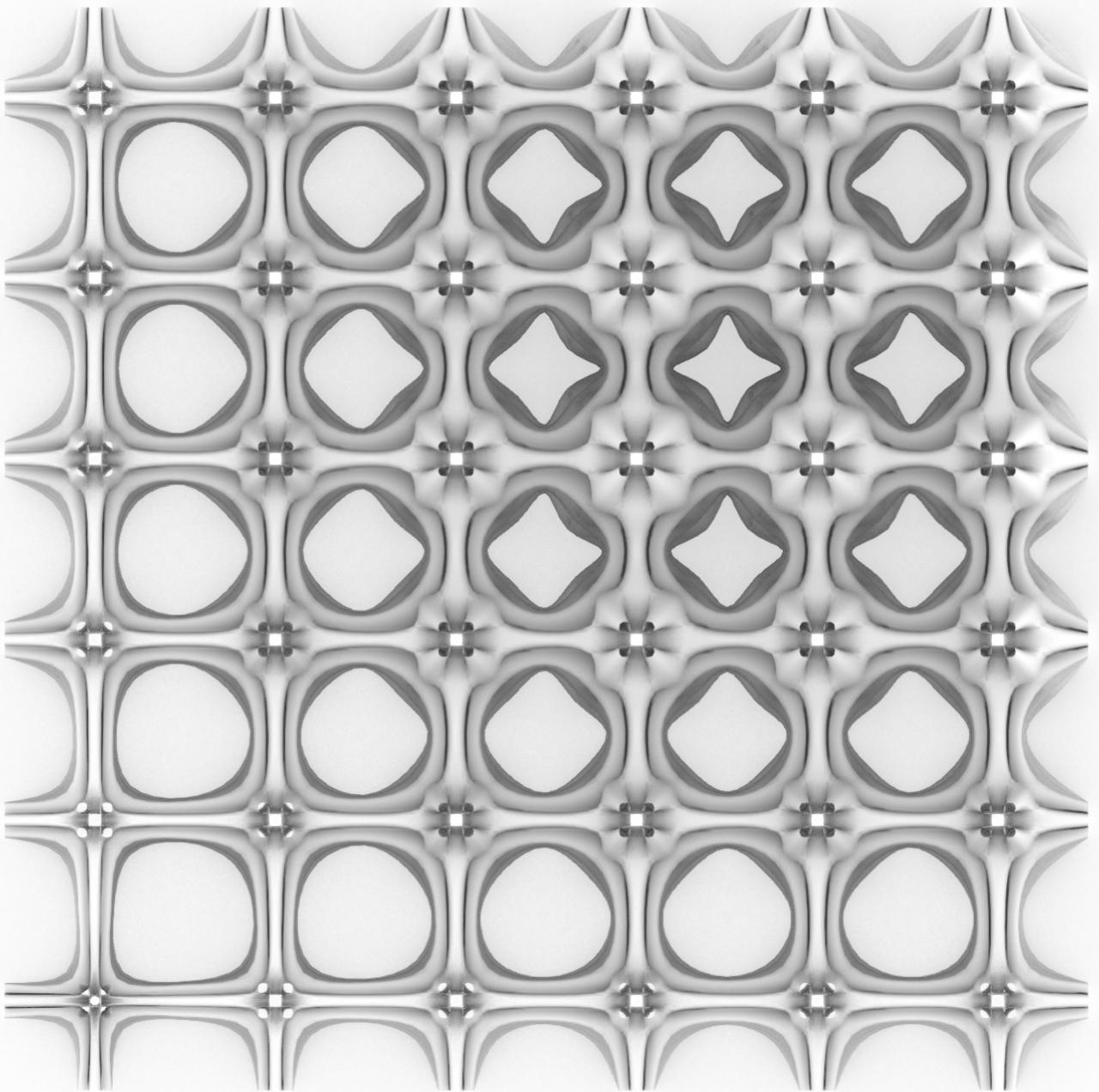
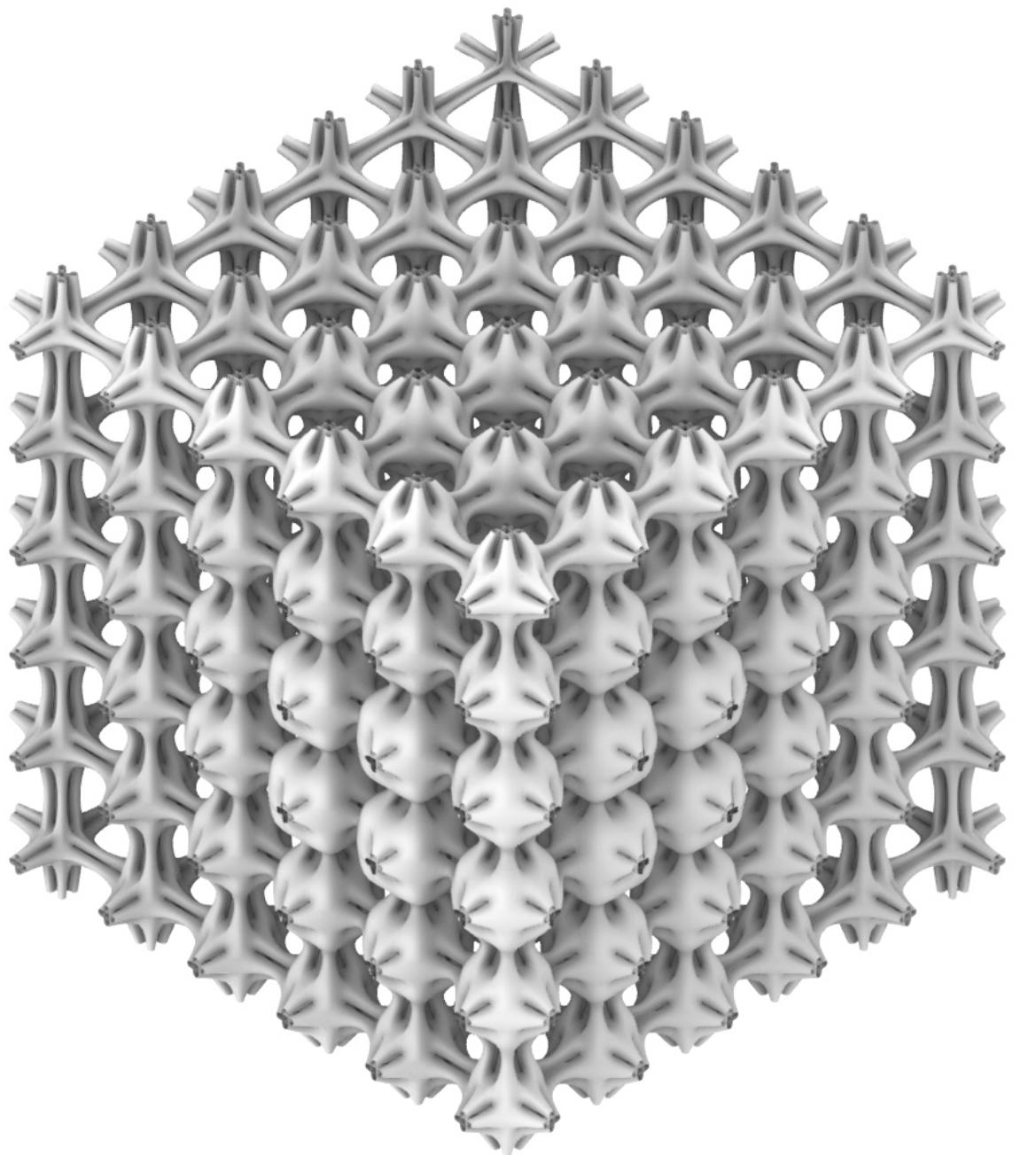


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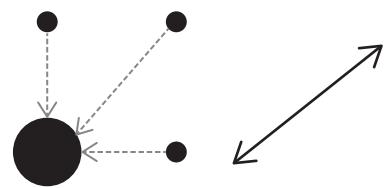


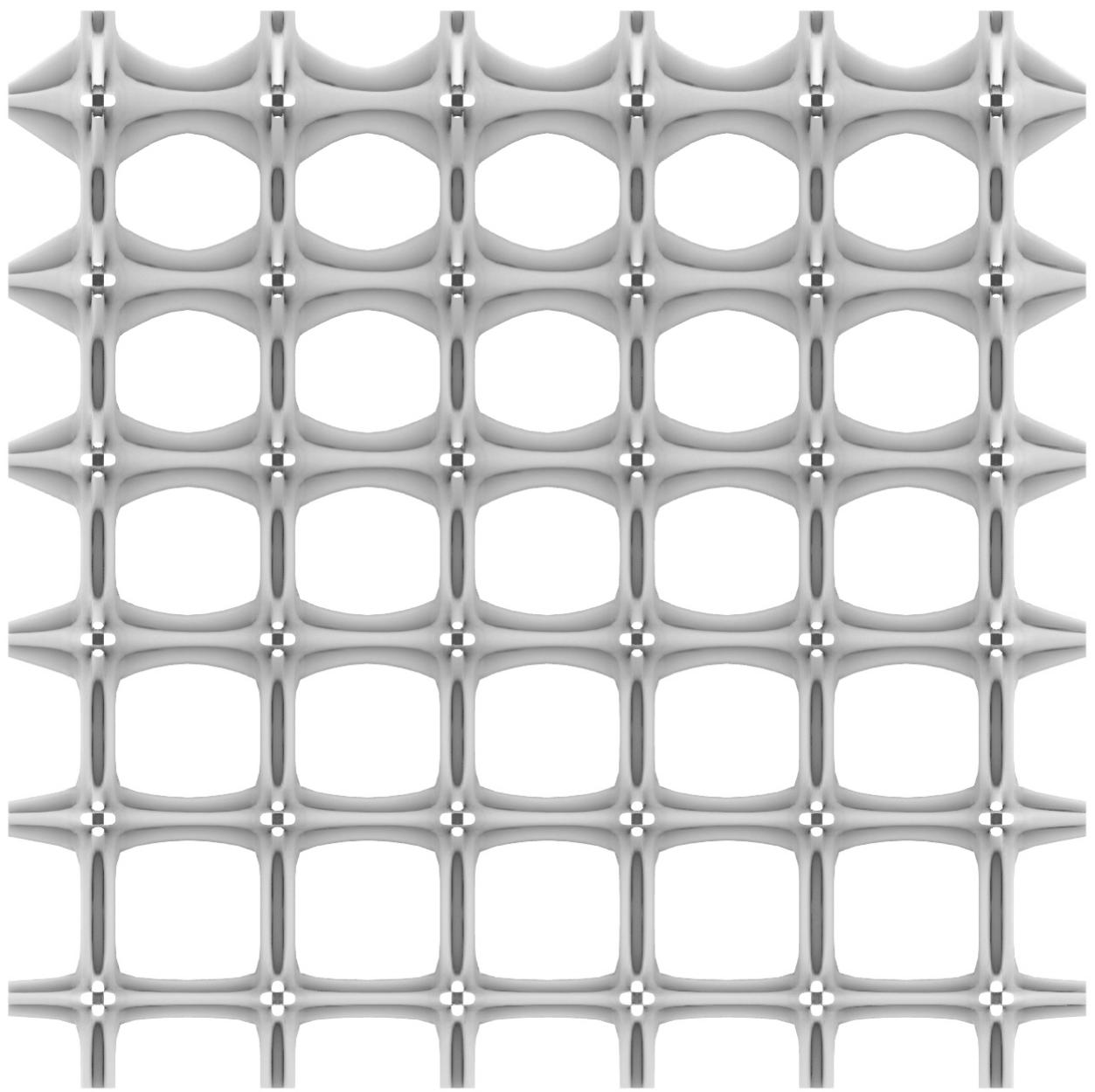
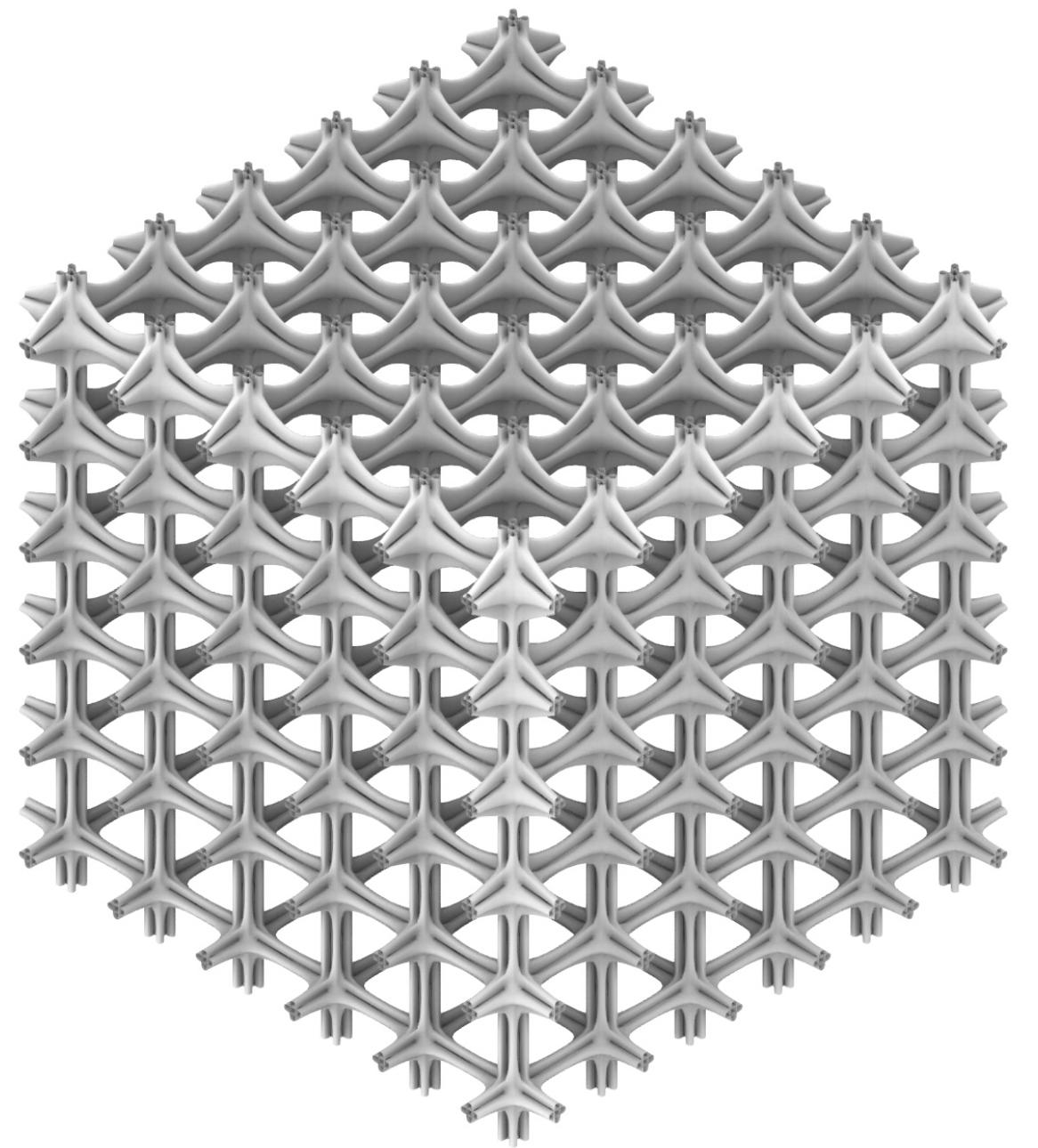


COMPONENT C

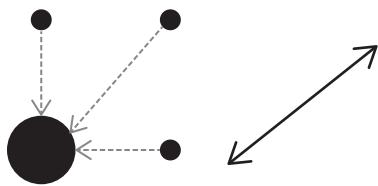


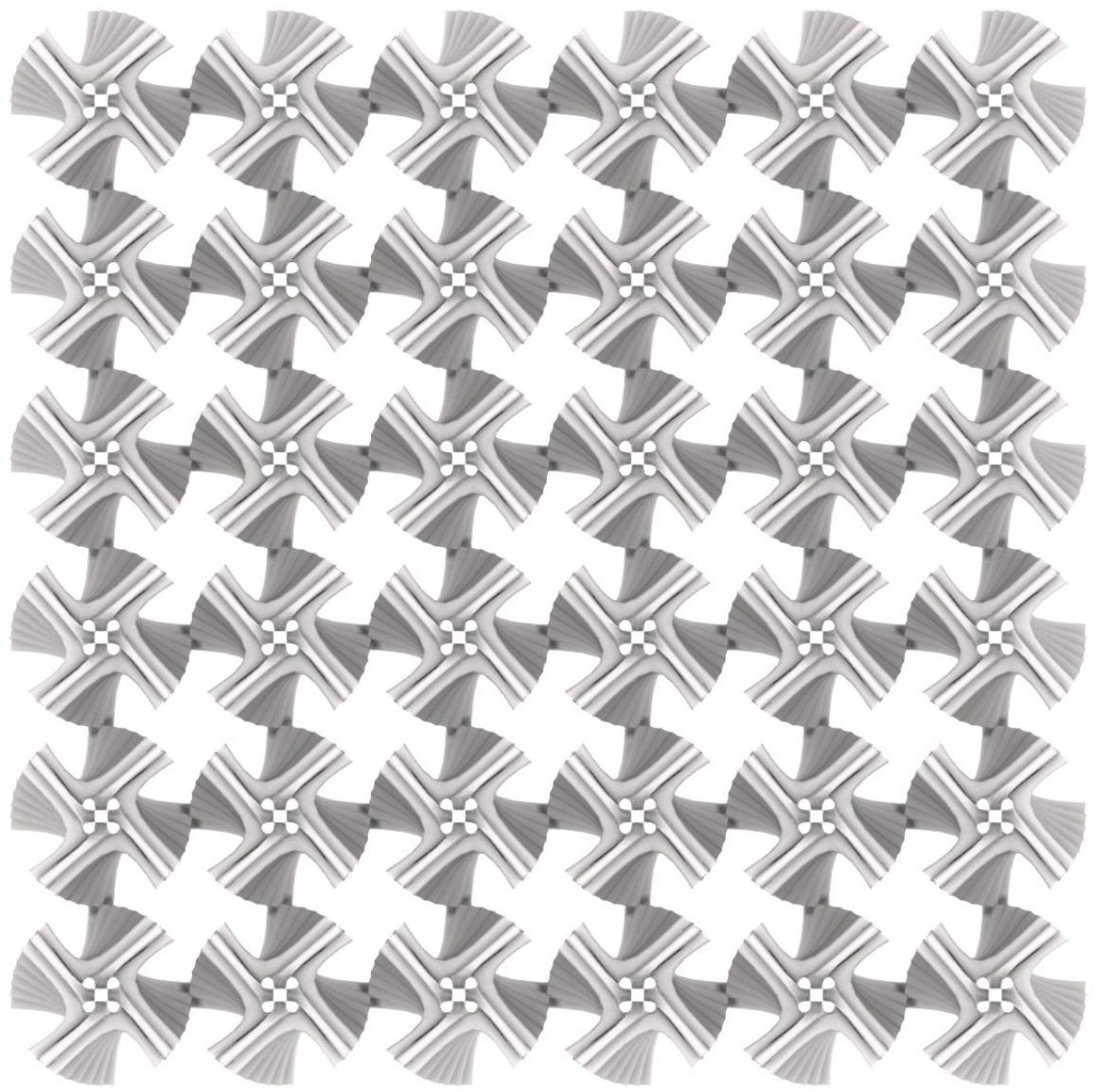
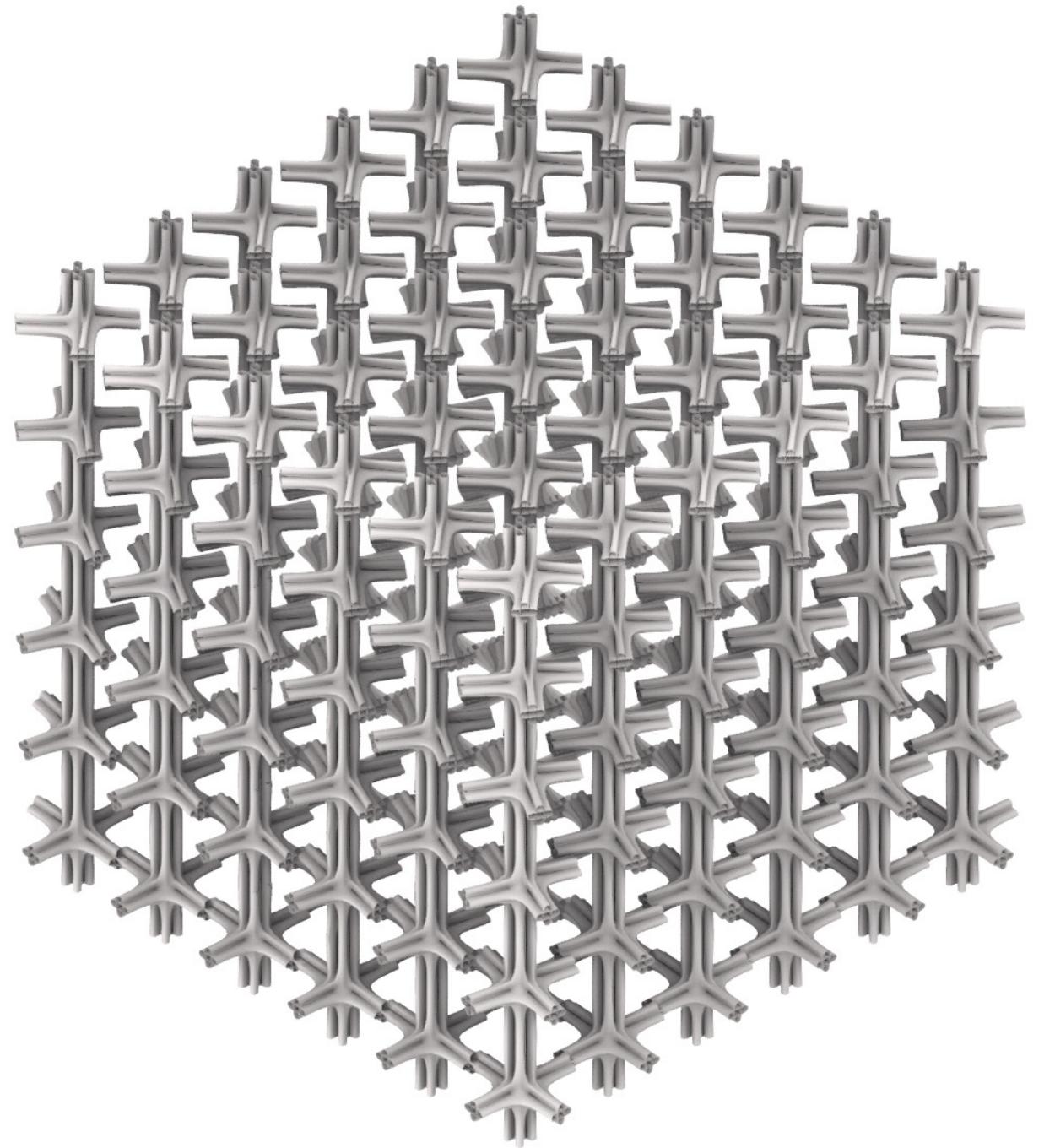
COMPONENT C - AGGREGATION 1*





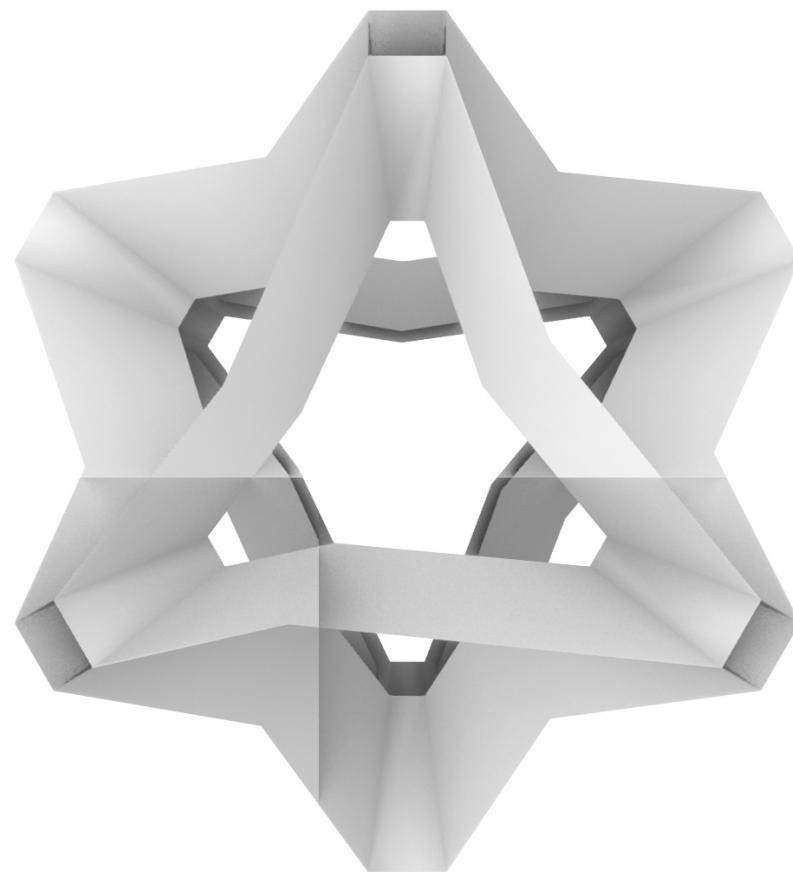
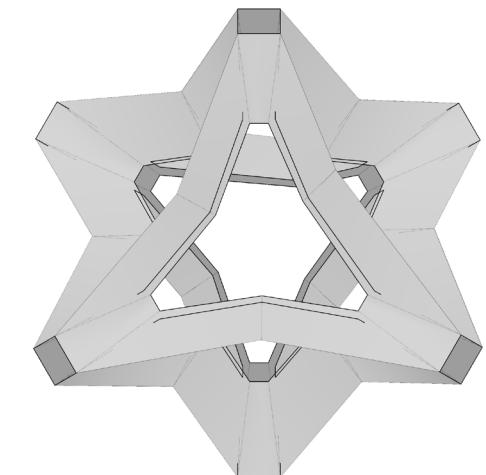
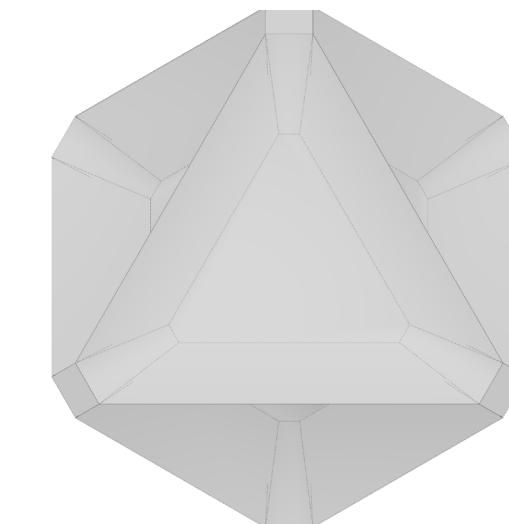
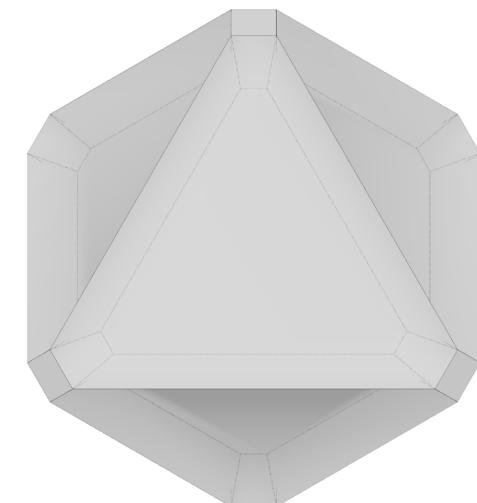
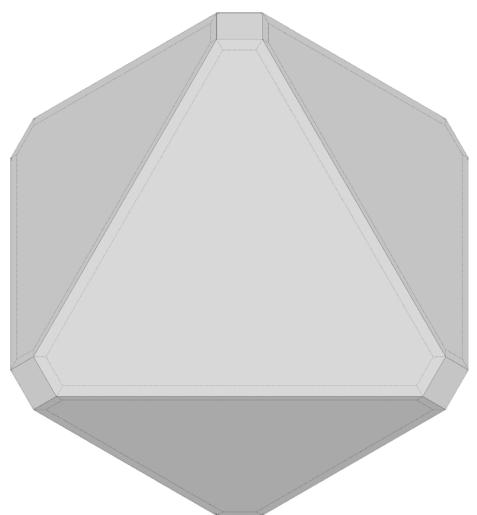
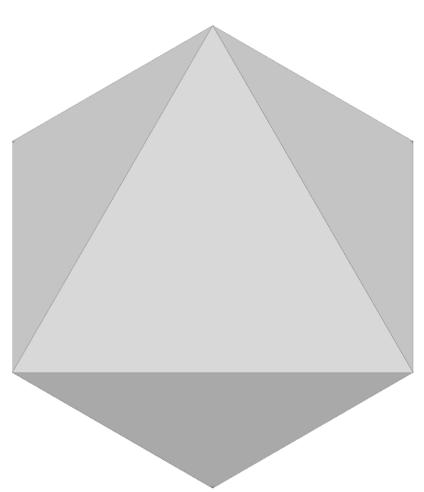
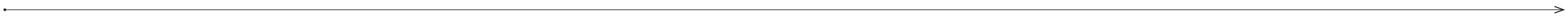
COMPONENT C - AGGREGATION 2



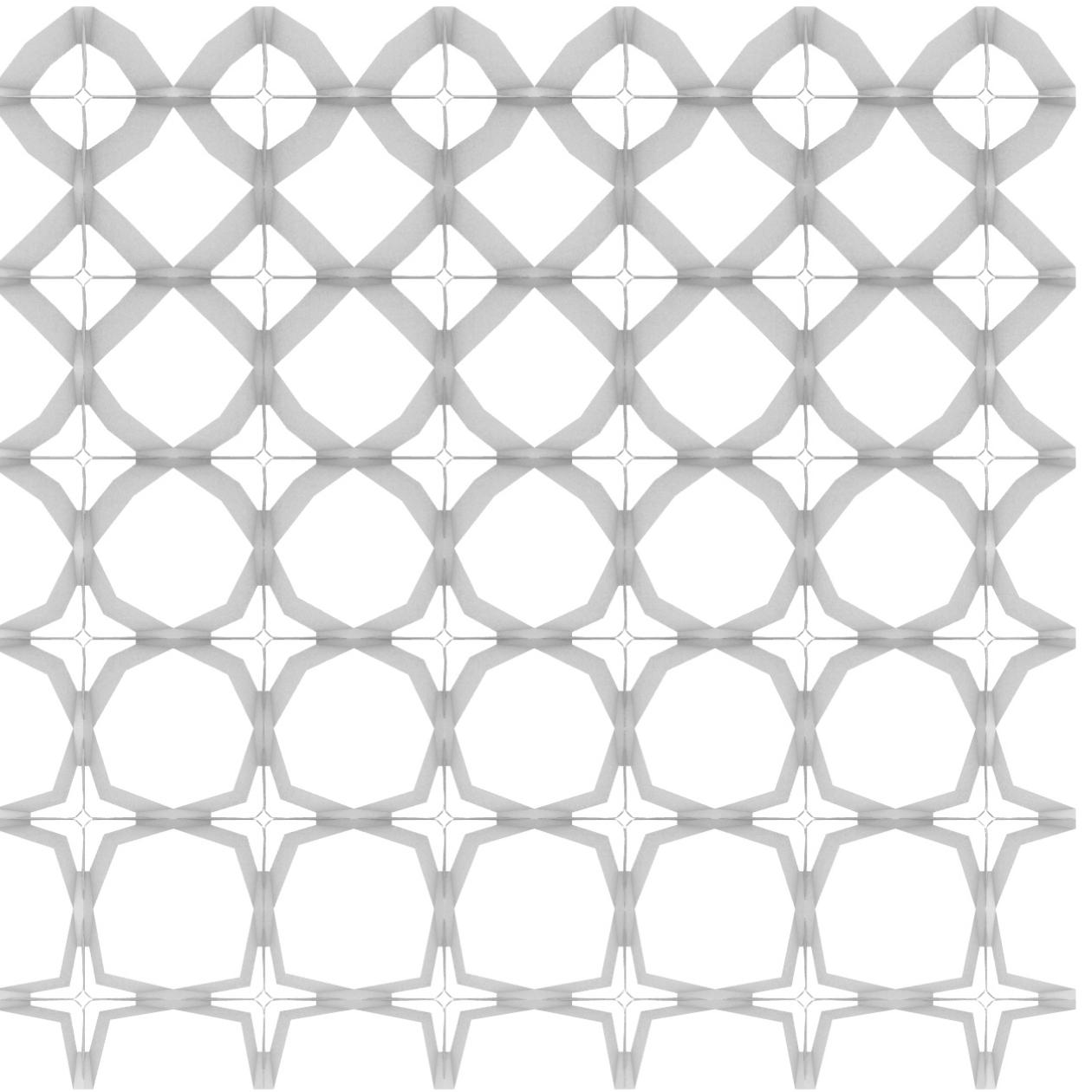
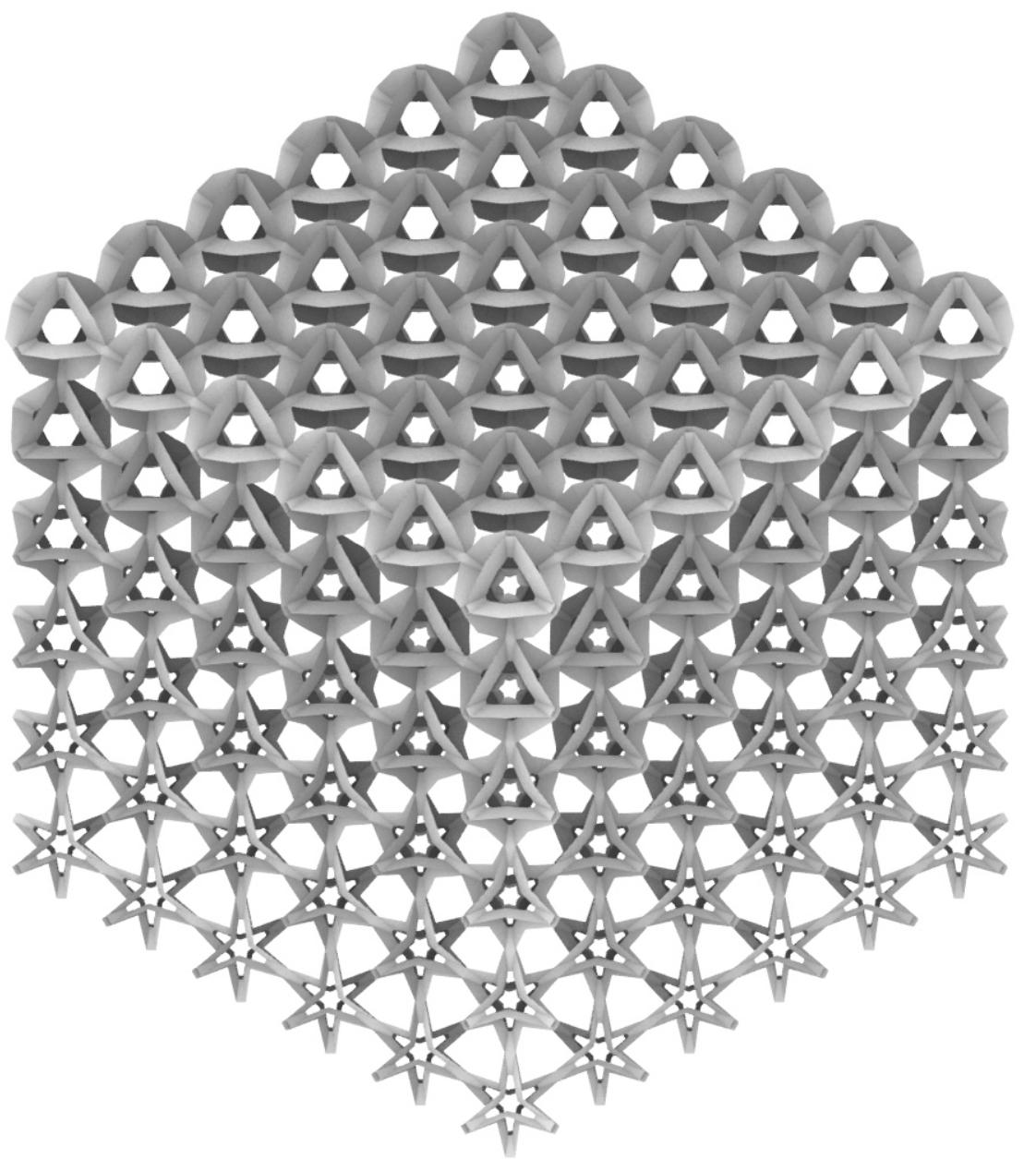


COMPONENT C - AGGREGATION 3

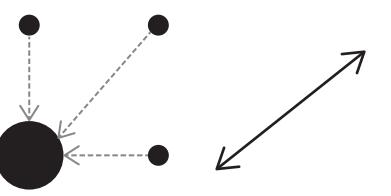


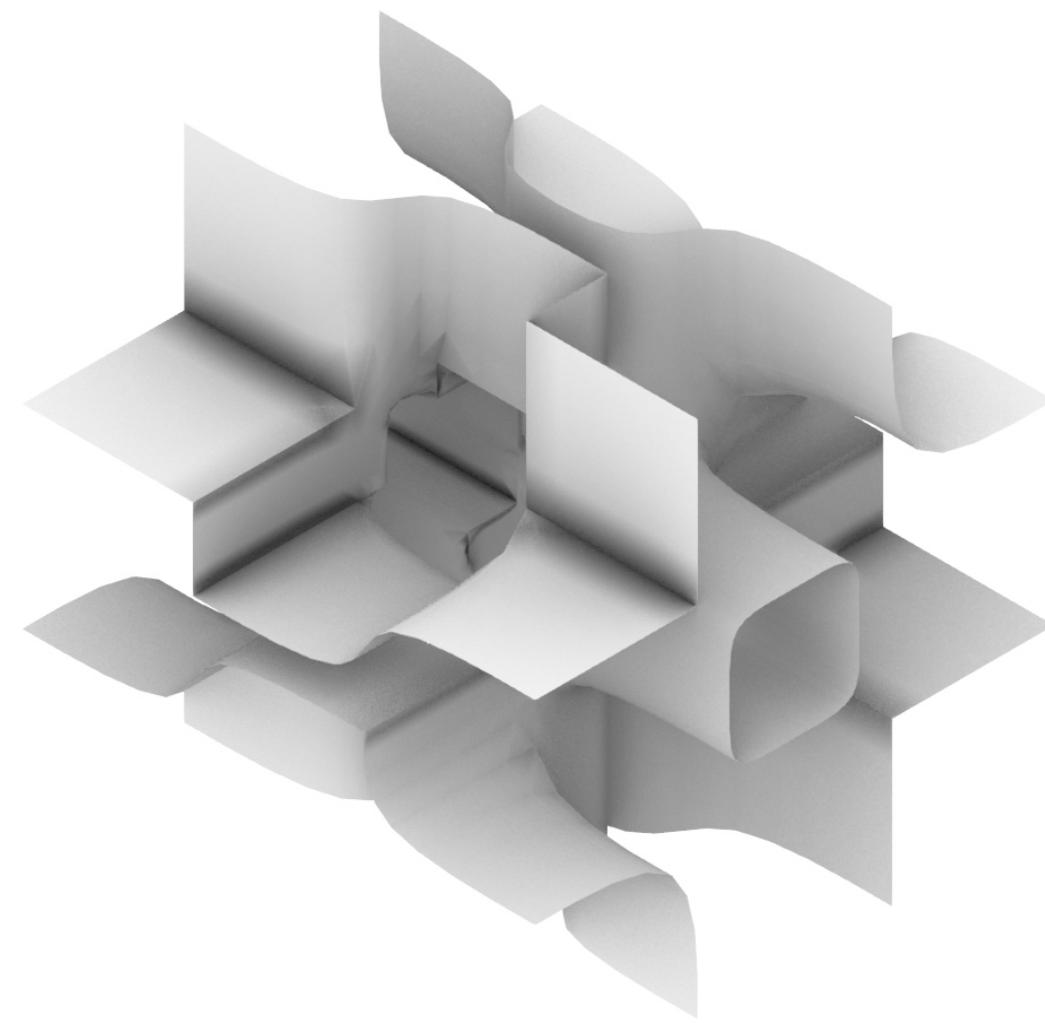
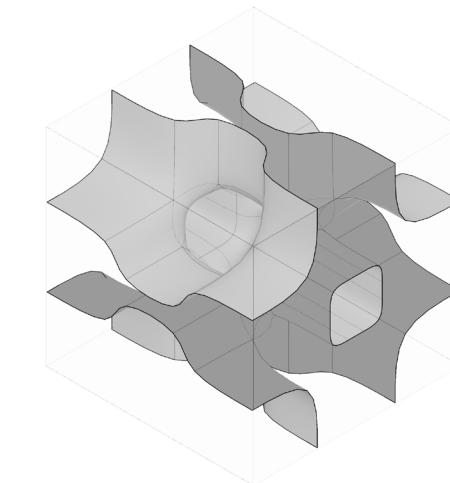
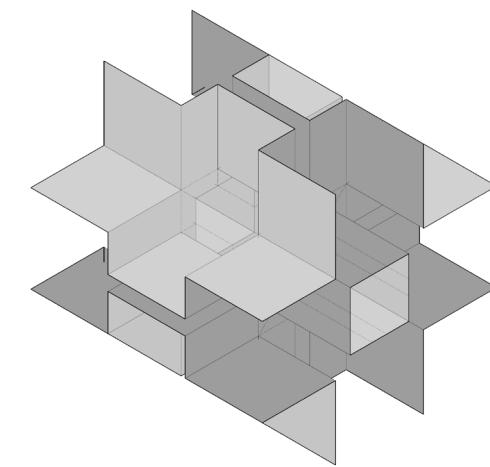
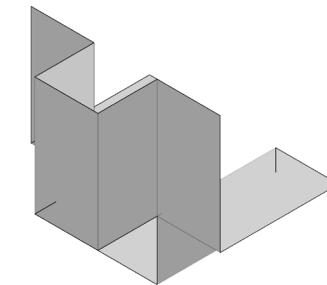
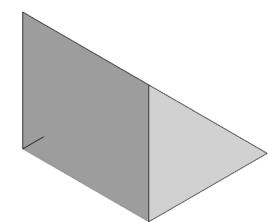
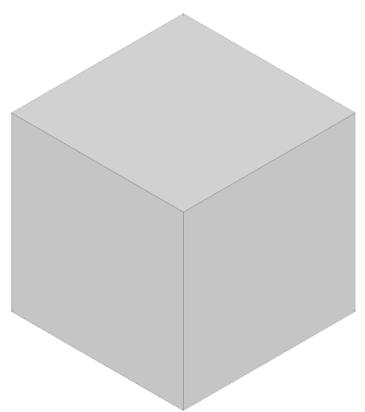


COMPONENT D

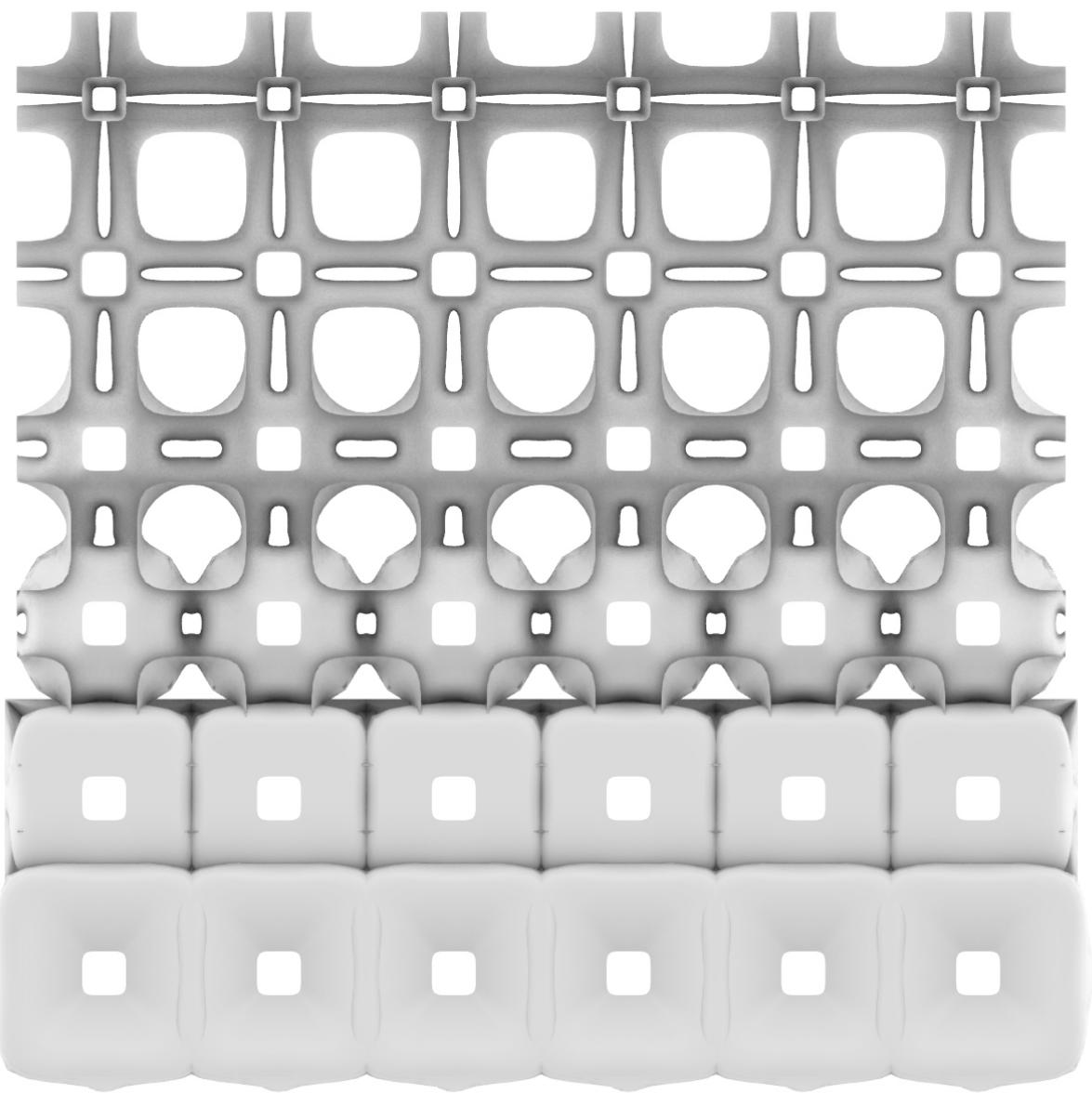
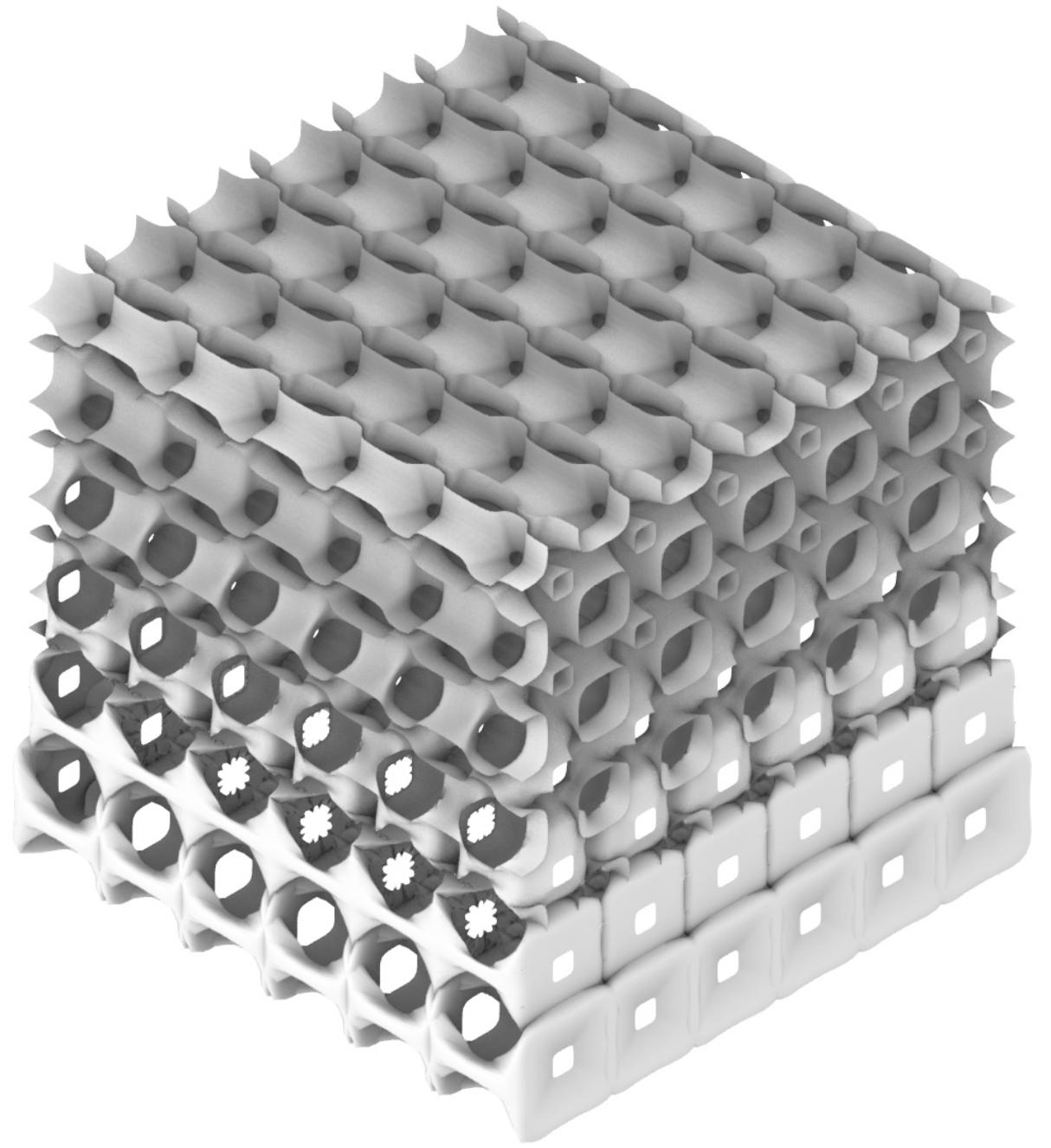


COMPONENT D - ITERATION 1

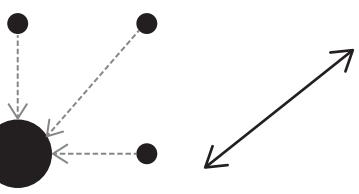


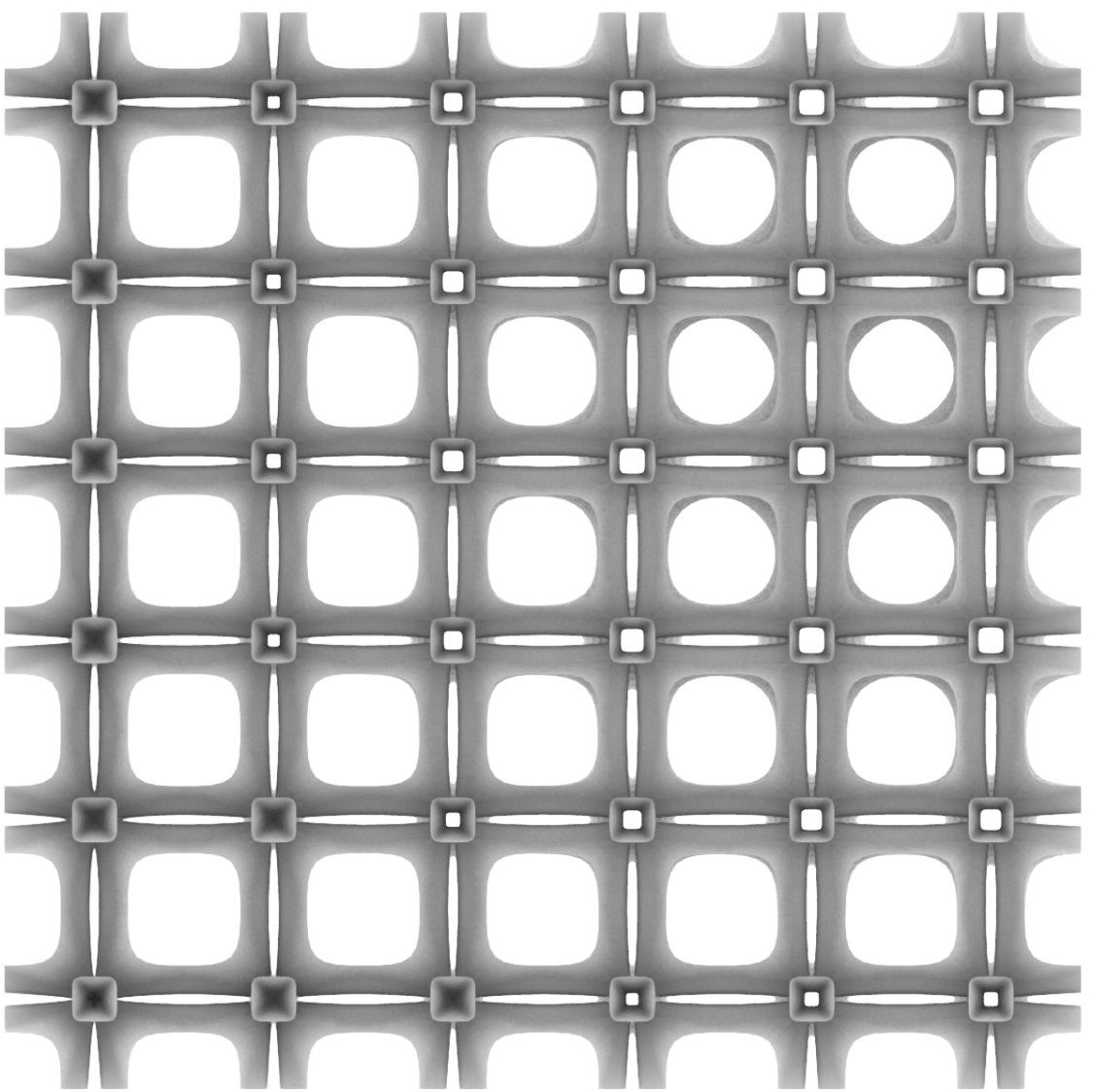
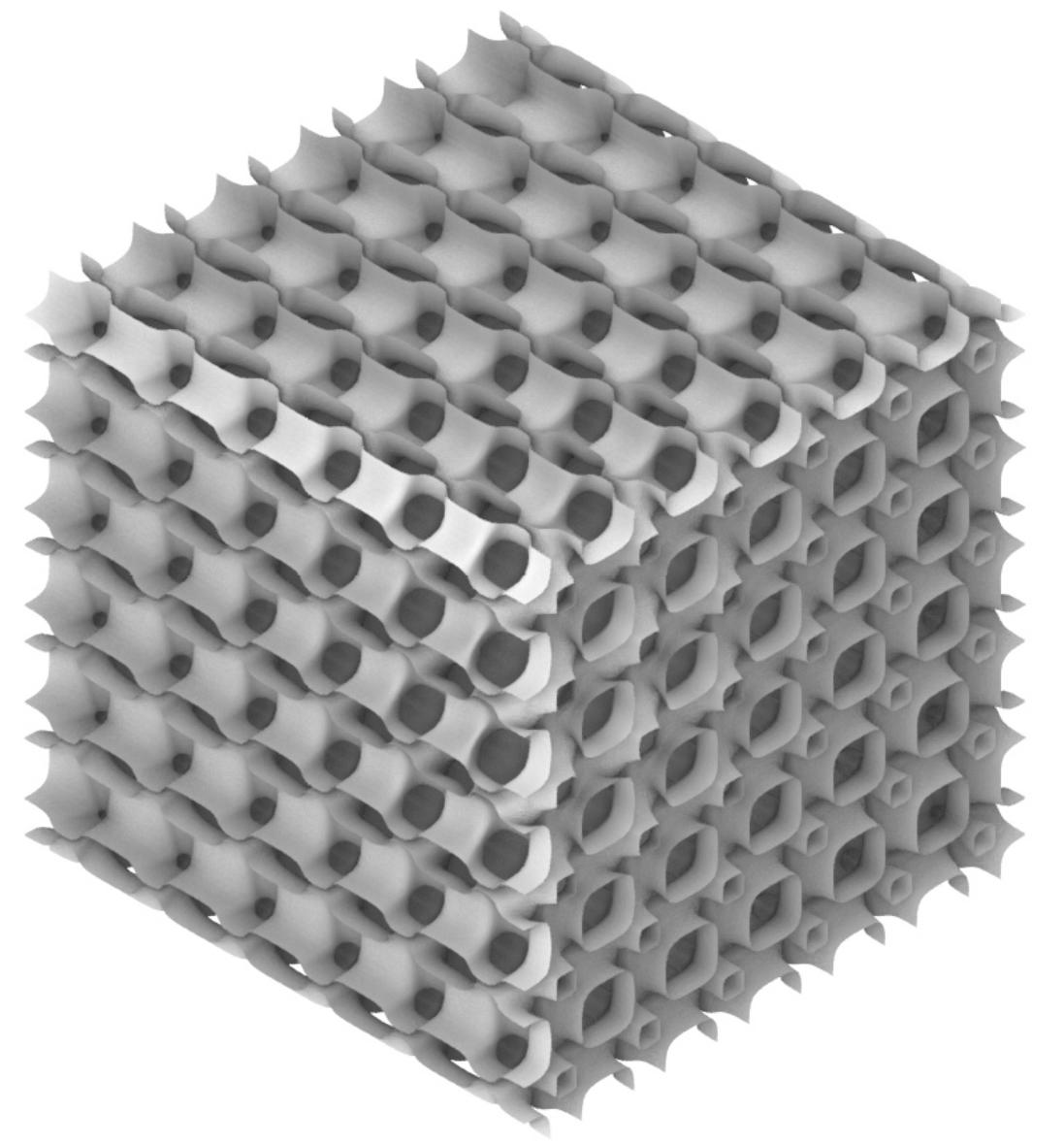


COMPONENT E

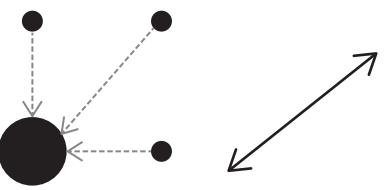


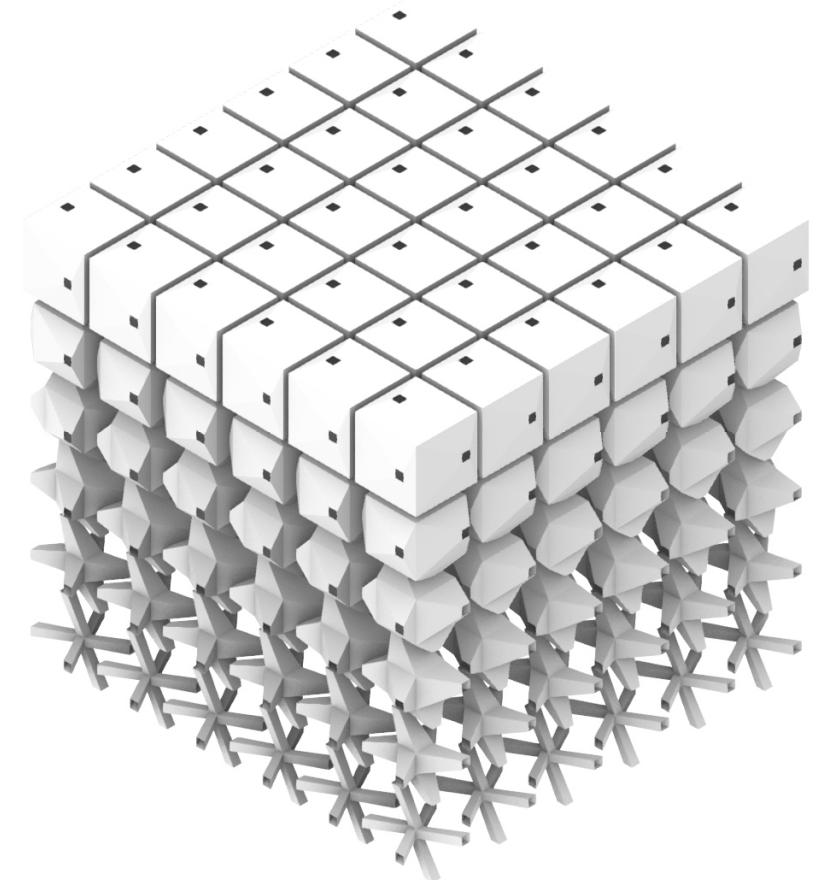
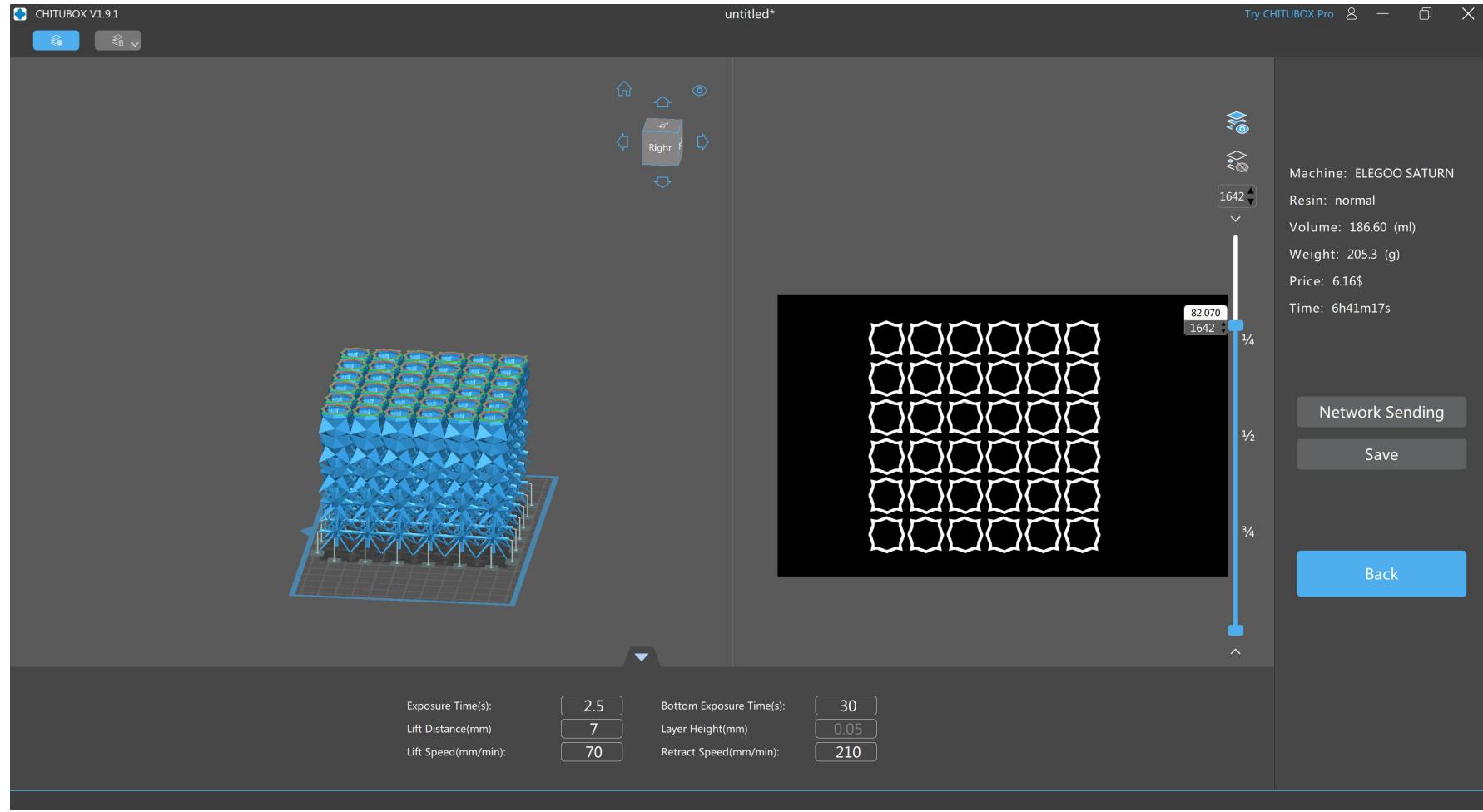
COMPONENT E - AGGREGATION 1





COMPONENT E - AGGREGATION 2

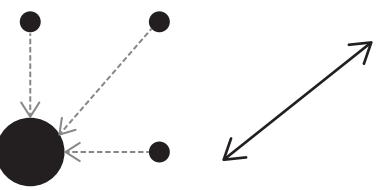


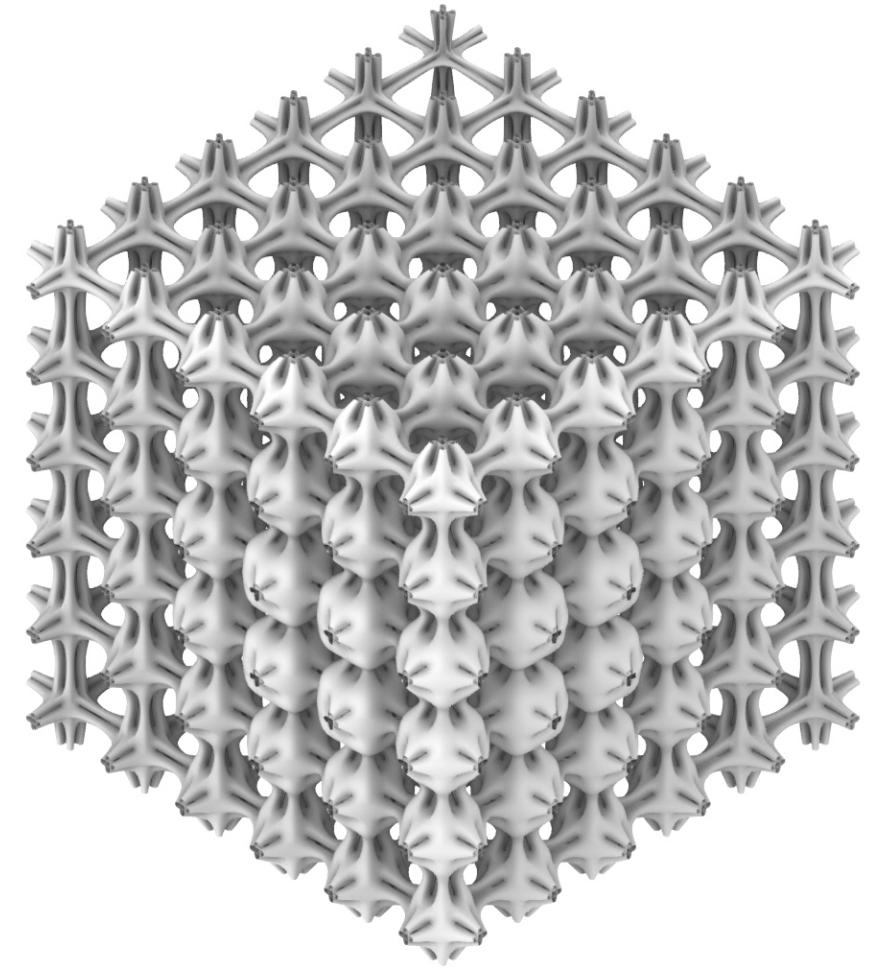
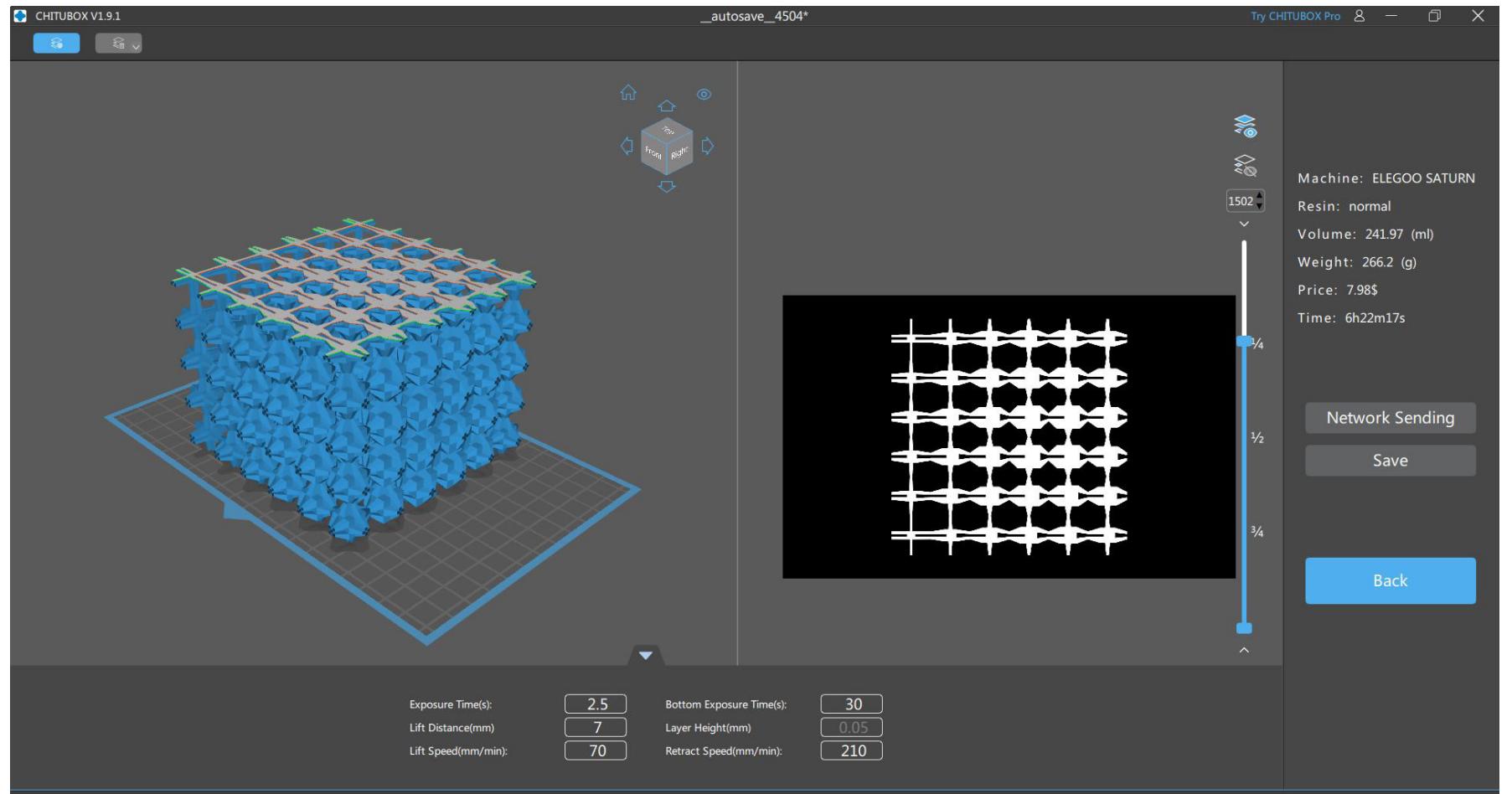


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3D PRINT

COMPONENT B - AGGREGATION 1

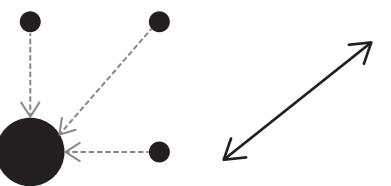


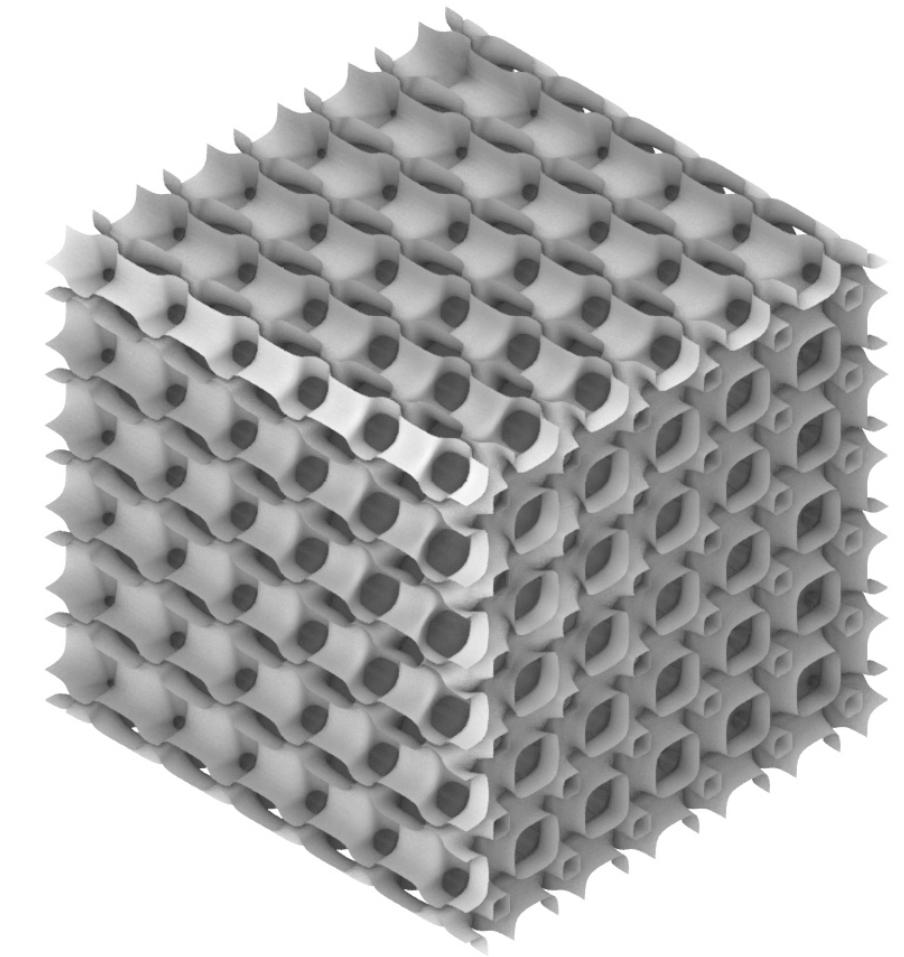
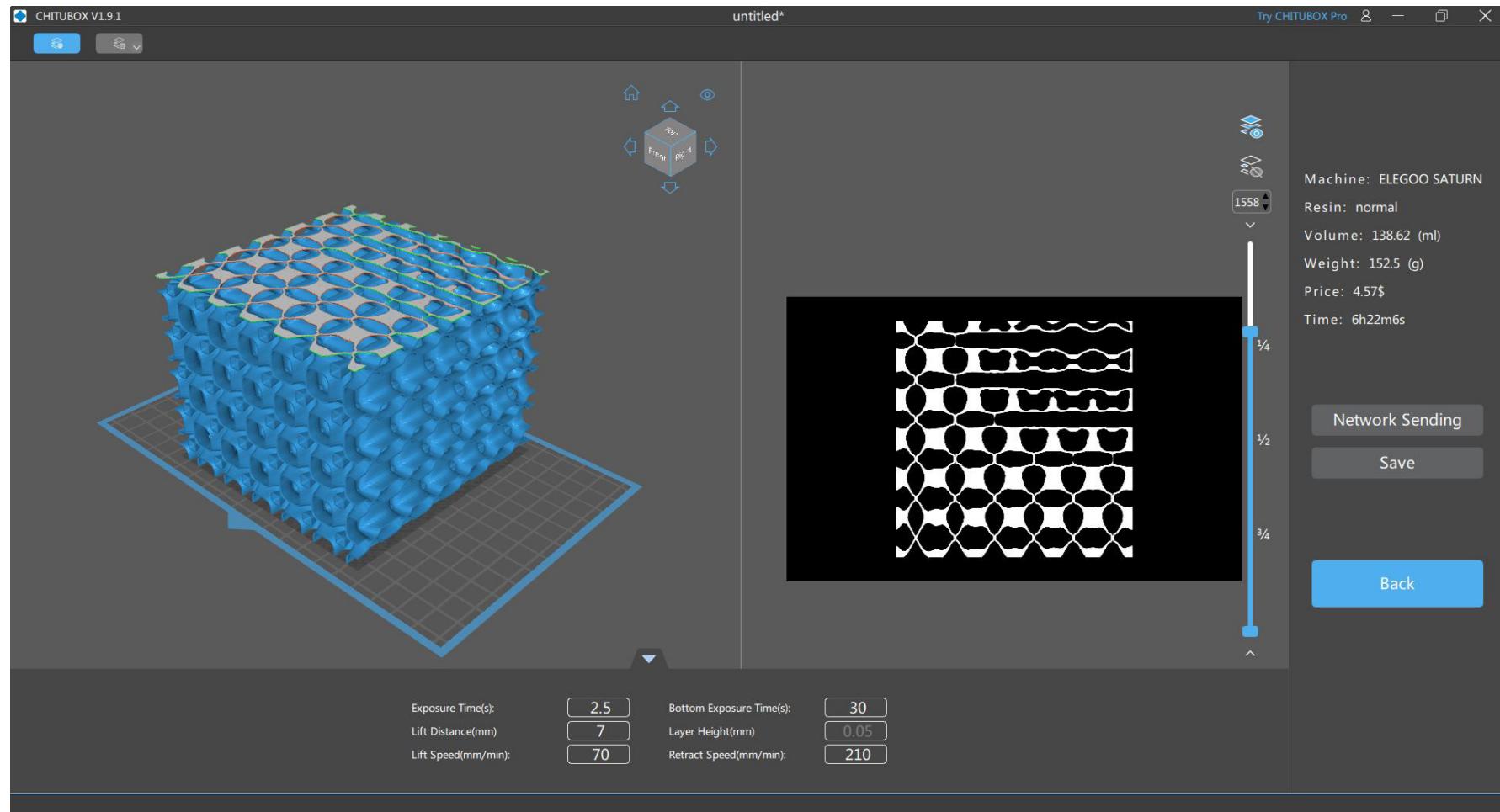


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3D PRINT

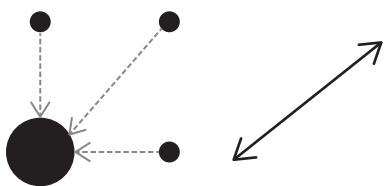
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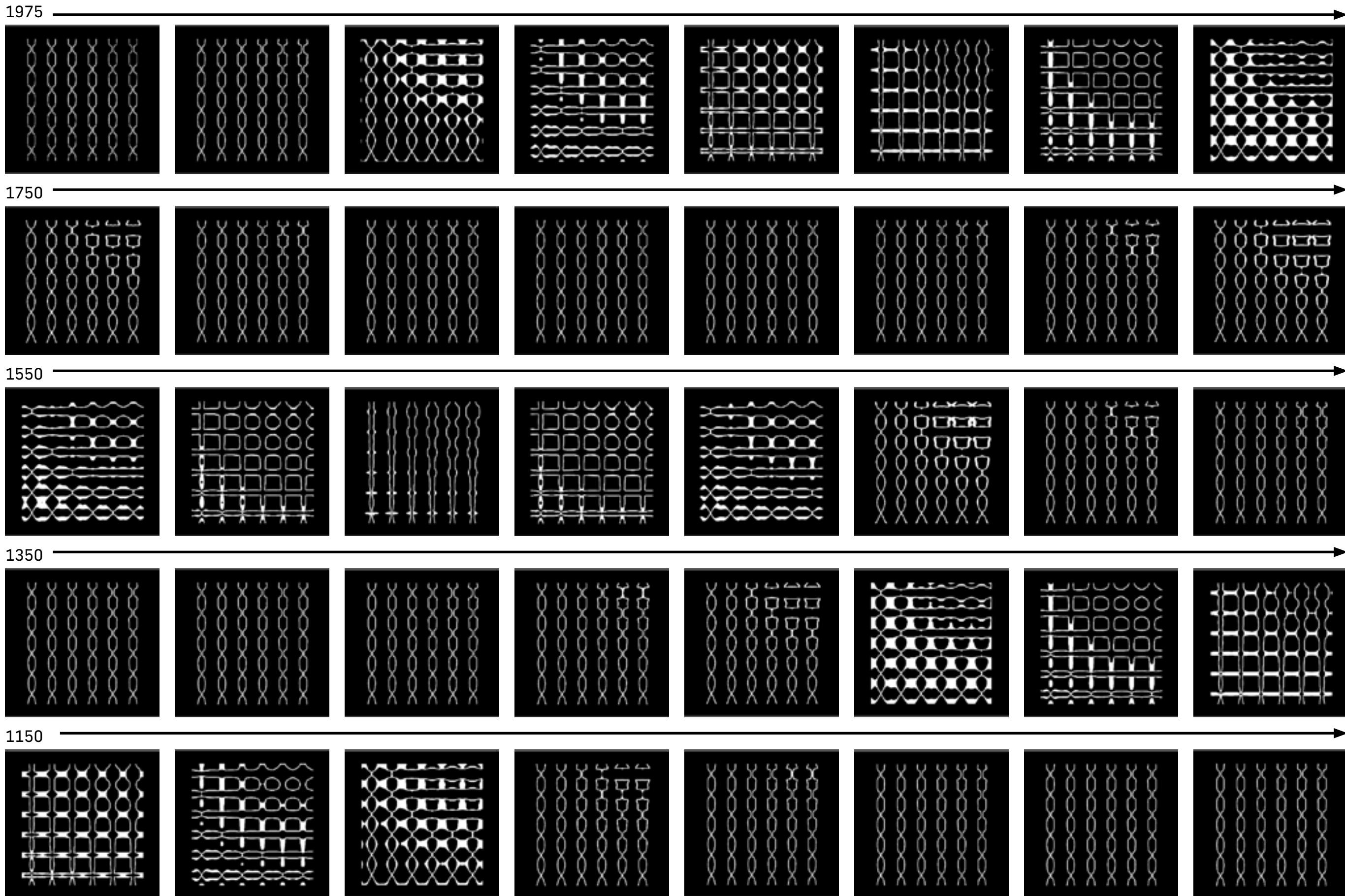




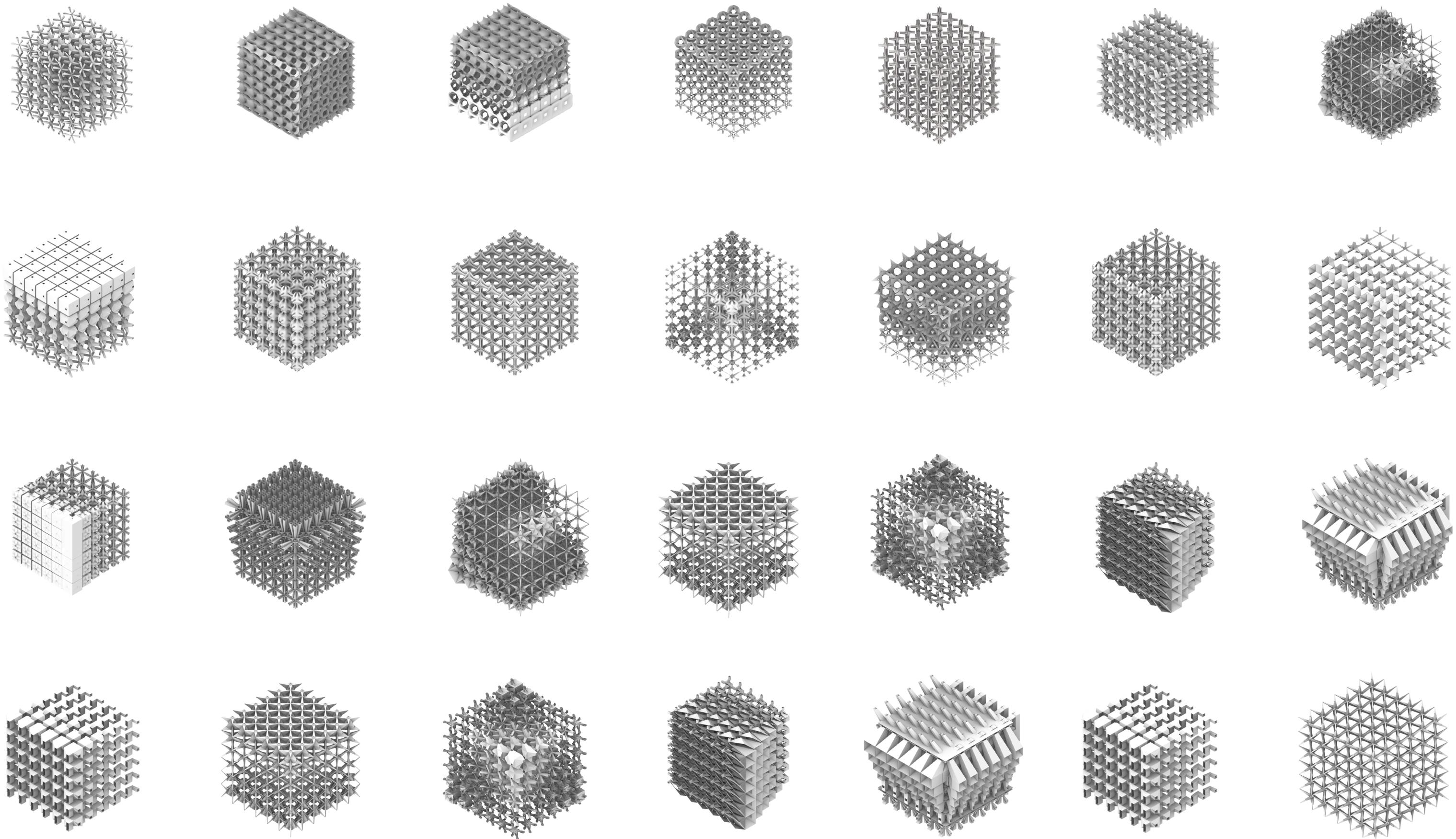
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3D PRINT COMPONENT E - AGGREGATION 2

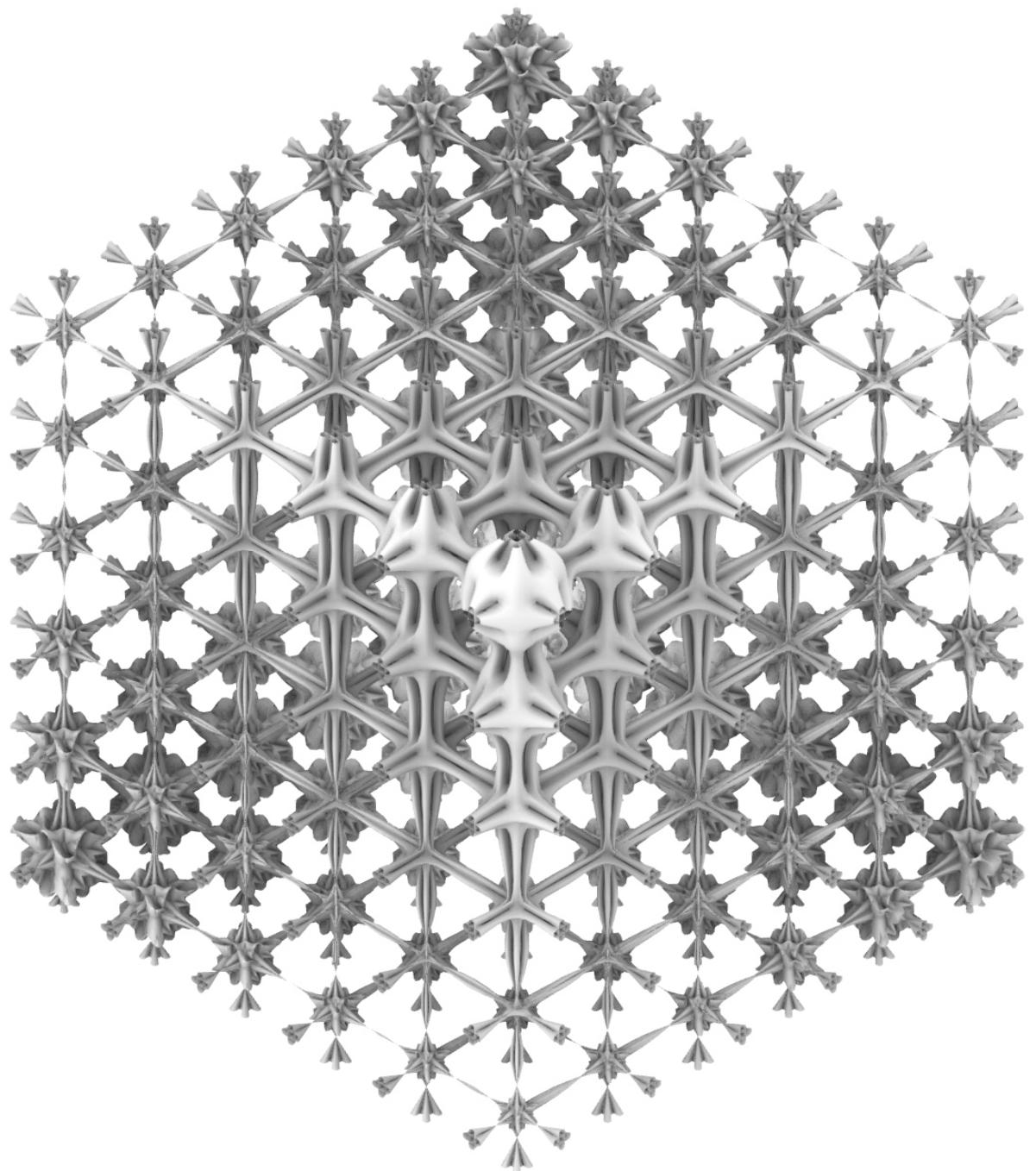




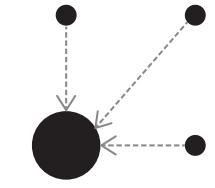
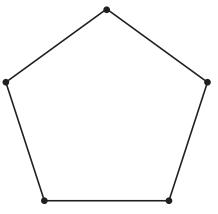
PRINT SLICES MATRIX



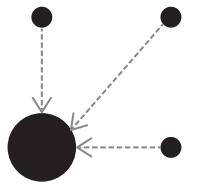
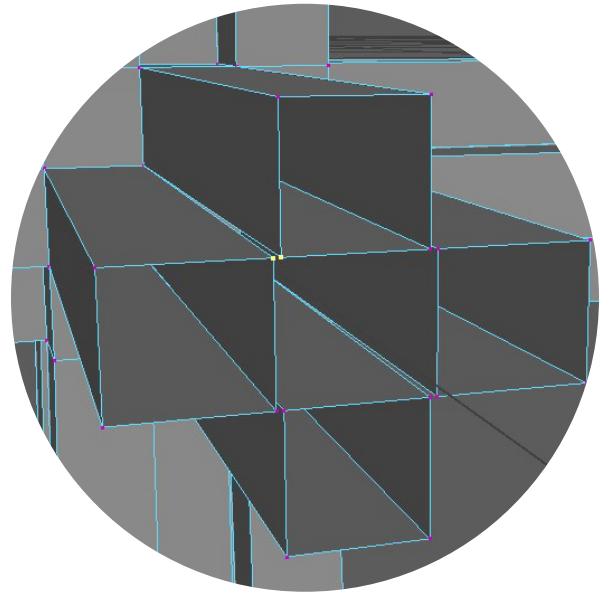
AGGREGATION MATRIX



FAILED ATTEMPTS

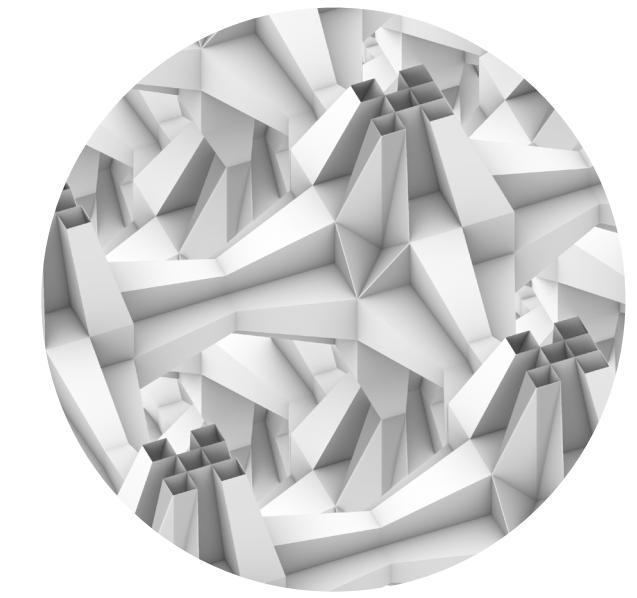
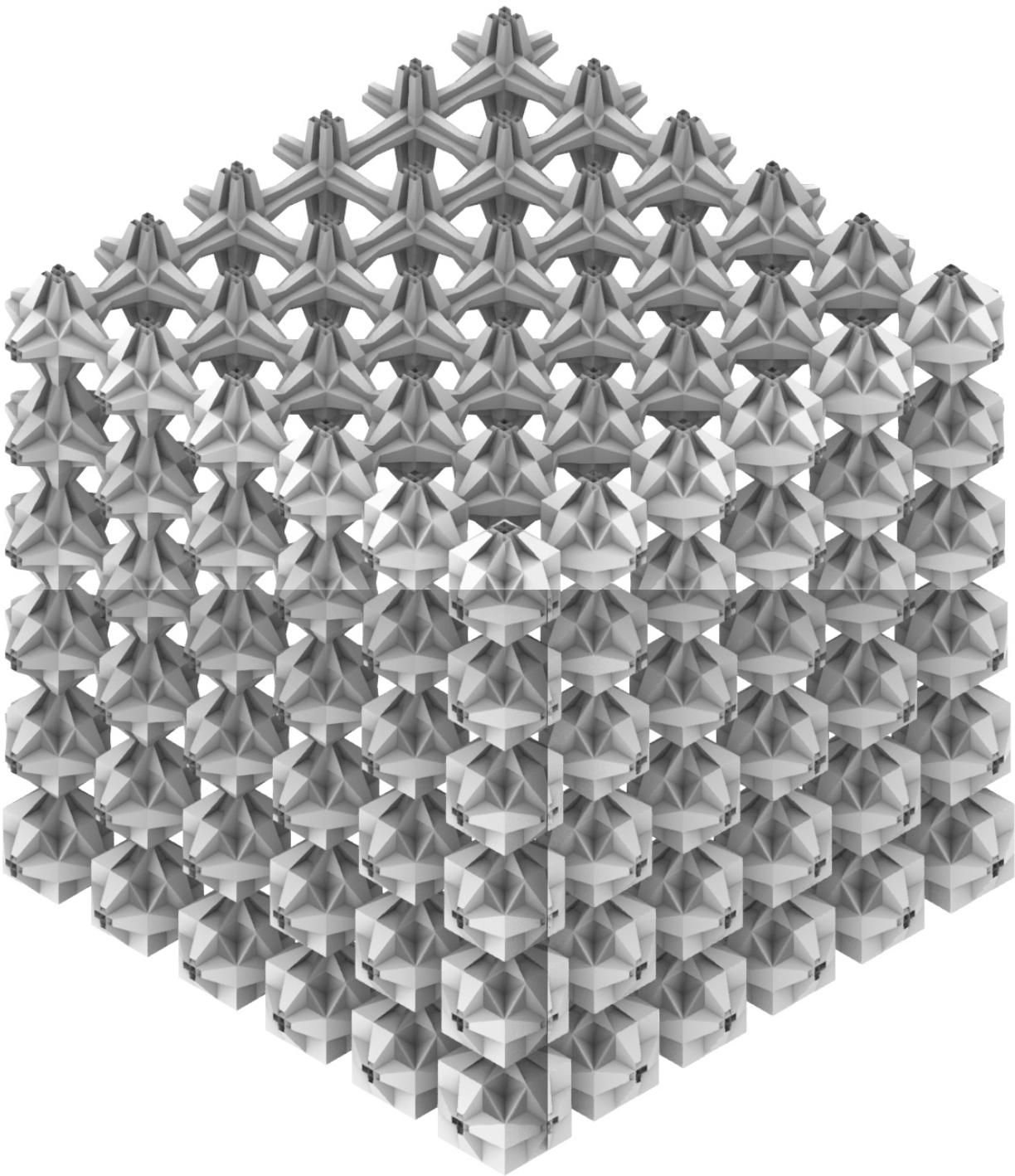


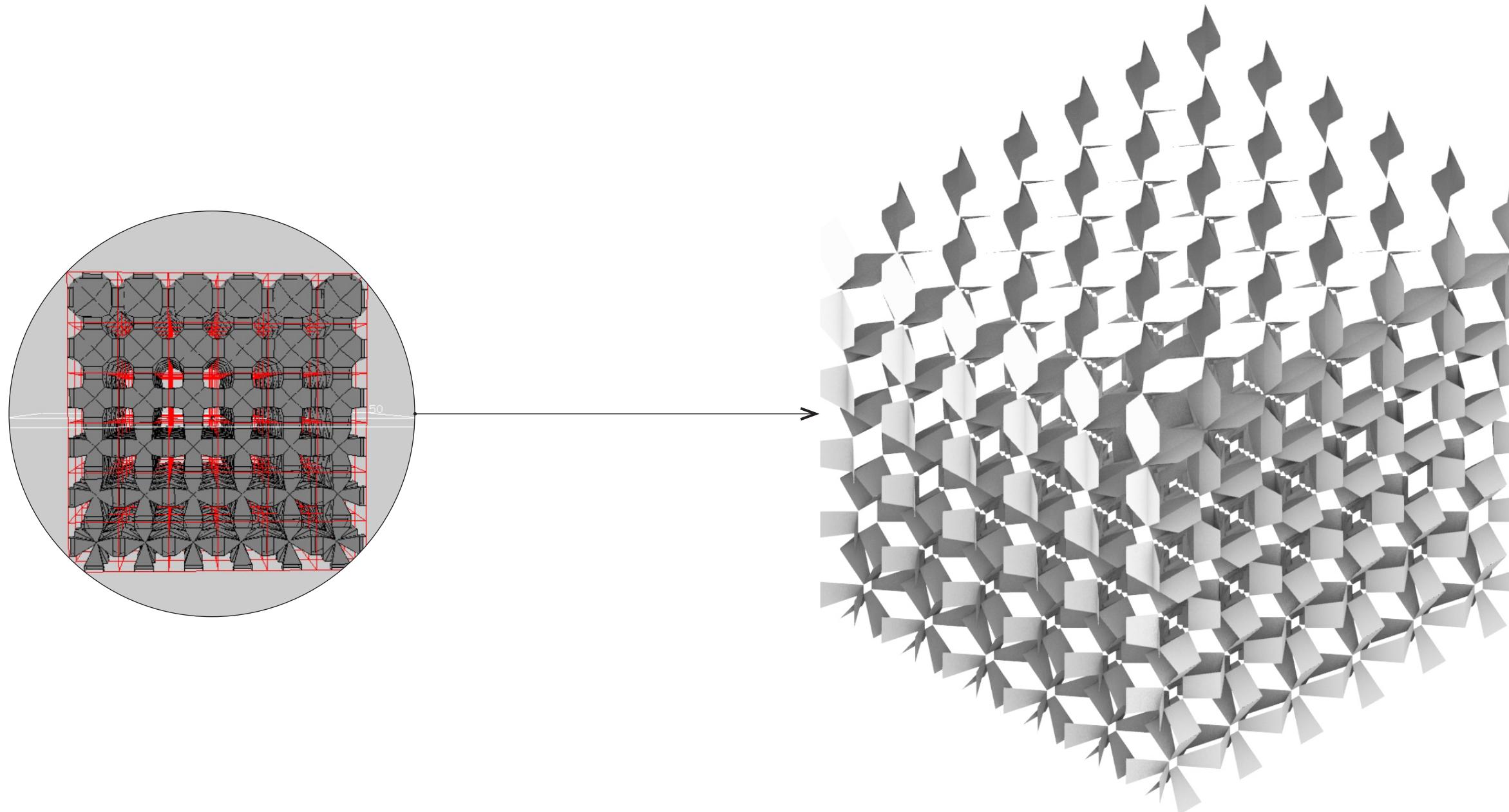
*N-POLY
FAILED ATTRACTOR RANGE*



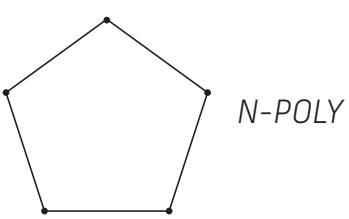
MERGING OF VERTICES

FAILED ATTEMPTS

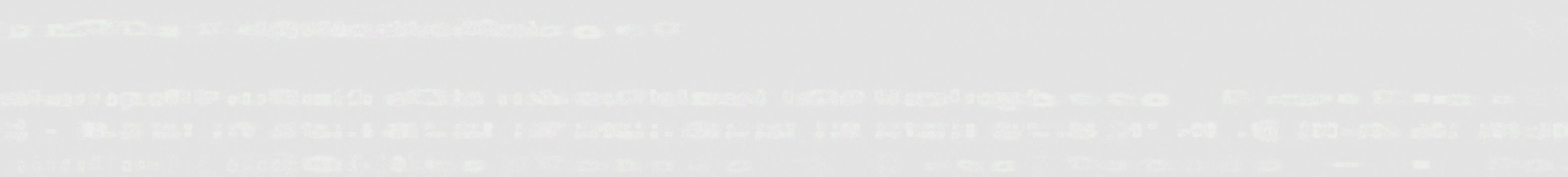




FAILED ATTEMPTS



Design Iterations

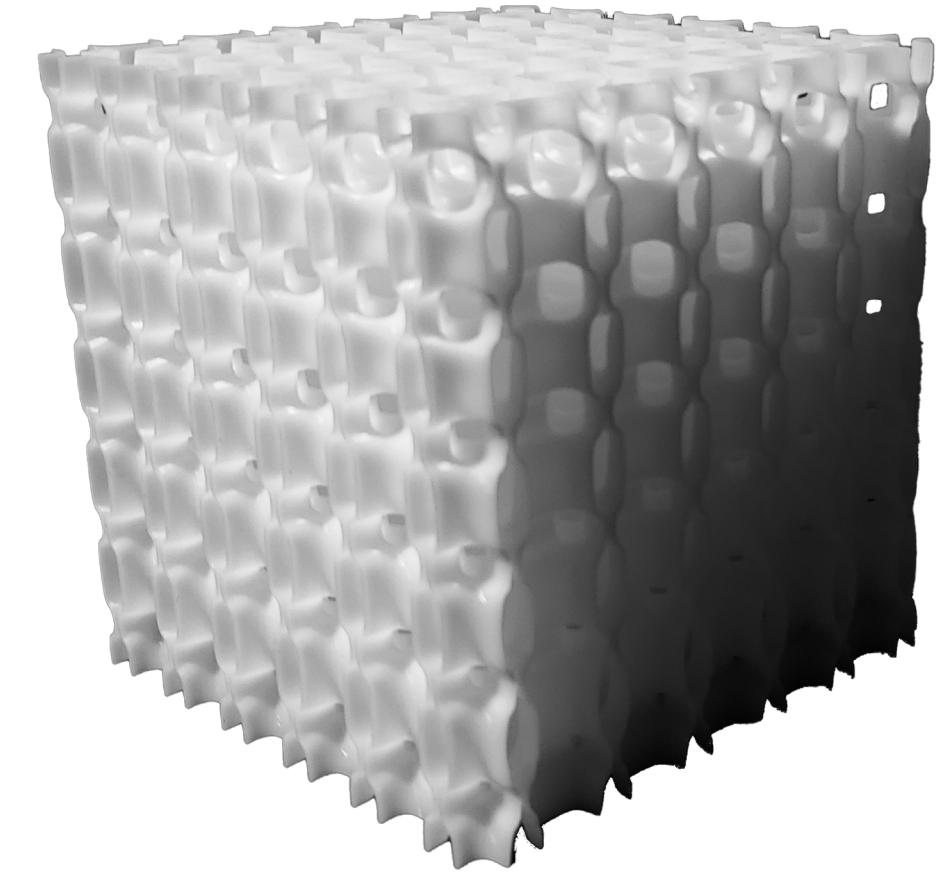


During our explorations we discovered that simple geometries with a low-poly count worked best for the FGM applications we undertook in our matrix operations. Tools such as boolean operations created complex geometries and meshes that did not work within our matrix.

In creating the iterations our team found that the requirement for all edges to line up to create a lattice structure posed a significant design challenge. To resolve this, as noted above, we chose to stick with simple operations that resulted in clean meshes and mirrored and connected the objects where needed to ensure that they would result in repeatable structures that cleanly lined up in the transformed voxel matrix.

By adhering to the above modelling and design constraints we relinquished some of our design control to enable the creation of an emergent form, taking advantage of both simple mesh objects and leveraging the adaptability and speed of iteration from the 200 lines of code that we used to create our augmented object. The result was a form that would be impossible to model in a fully controlled manner using NURBS, a form that emerged from our methodology rather than a clear vision of the object.

LESSONS LEARNED



PREP/PRINT/CLEAN TIME: 12Hrs 10 Mins

ECO RESIN PRINT COMPONENT E - AGGREGATION 2

