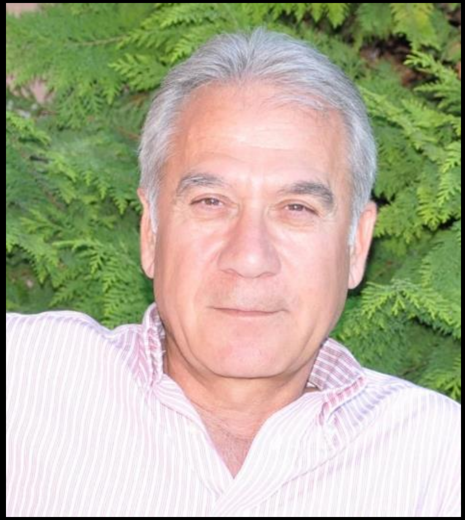
How Virtual Became Real

For me, the most important part of the composition is the structure. What interests me, the most is the expressive potential of structural forms.

Félix Candela

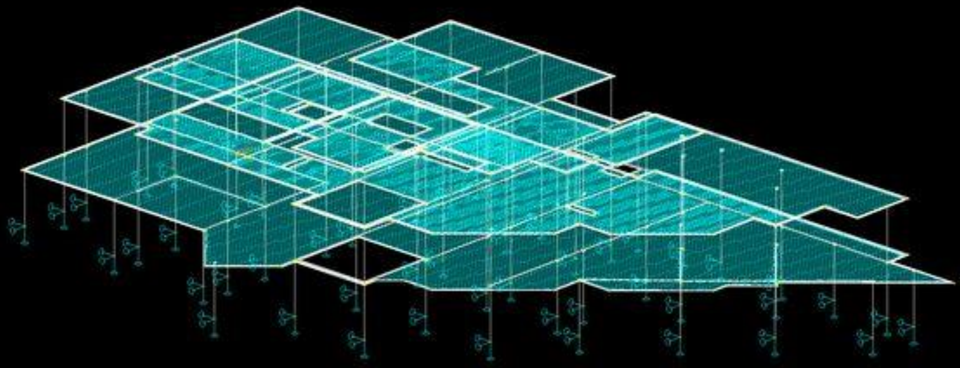


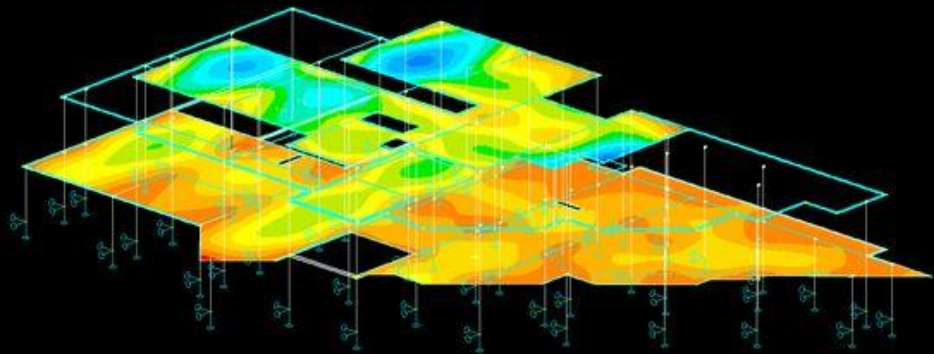
Sabah Shawkat

Physical modelling of structures, Gaudi, Heinz Isler or Frei Otto.

In traditional constructions, the shape is known in advance, the state of stress and deformation is unknown.

Geometry known



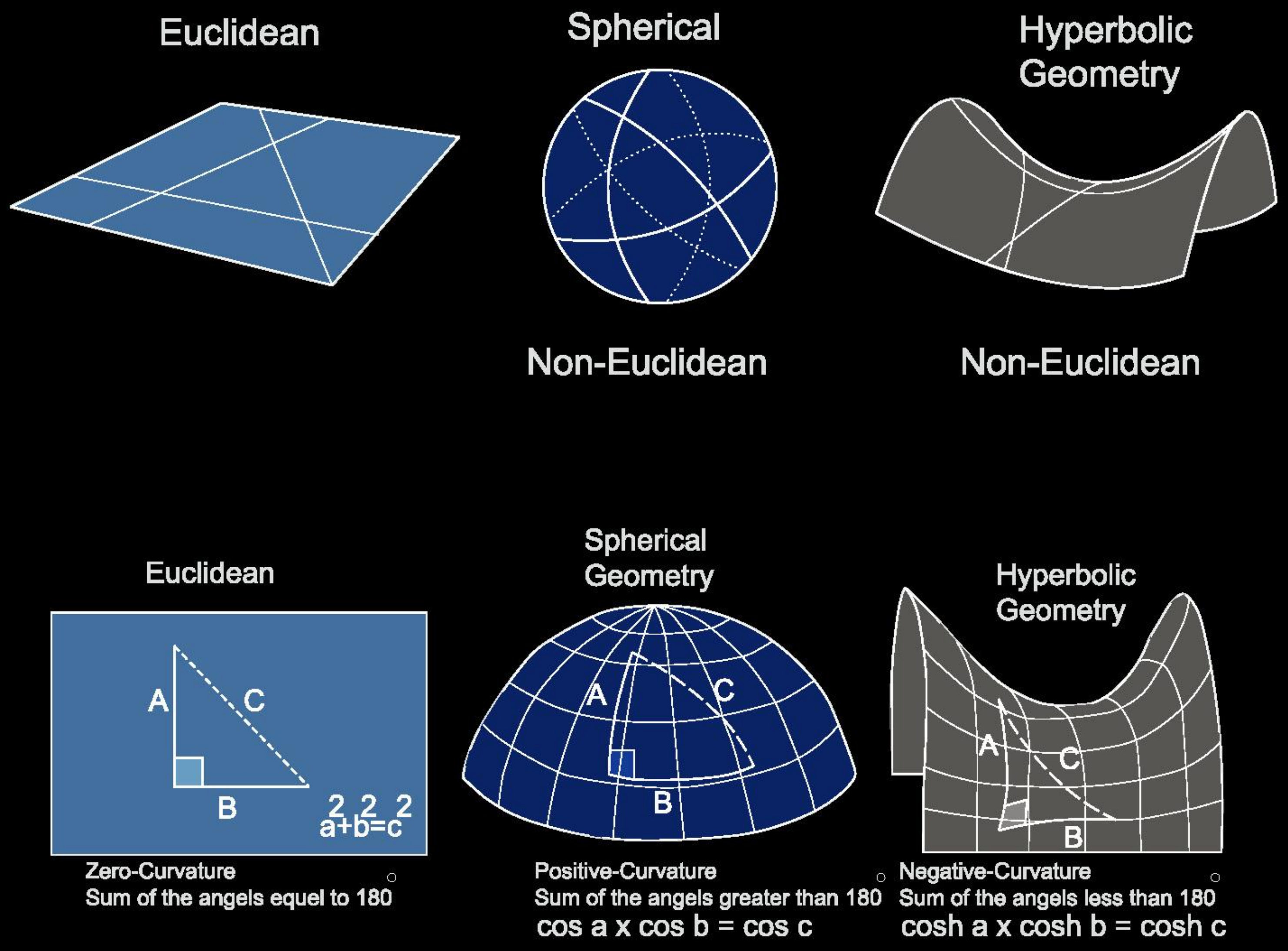


Deformations unknown

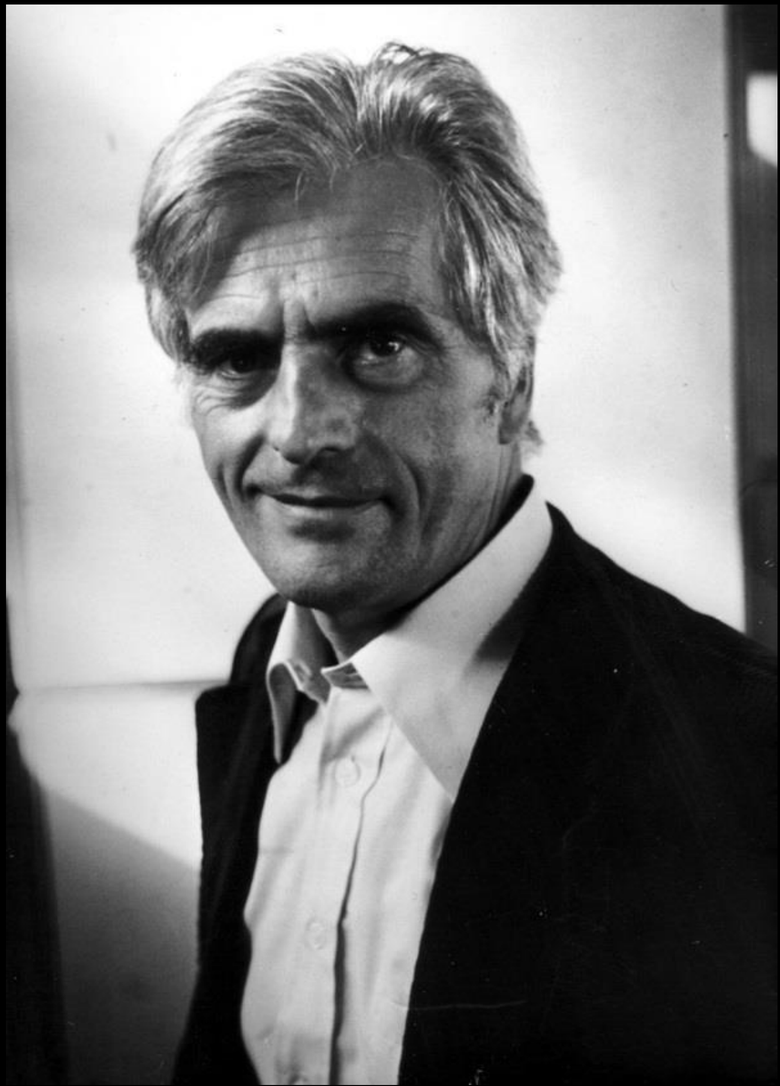
Lightweight structures, Forces and deformation are Known, Geometry unknown

This inverse procedure makes a static analysis and the architectural shape of the structure inseparably linked with the cooperation of the engineer and the architect from the project preparation.

Euclidean and Non-Euclidean Forms



Form Follows Force

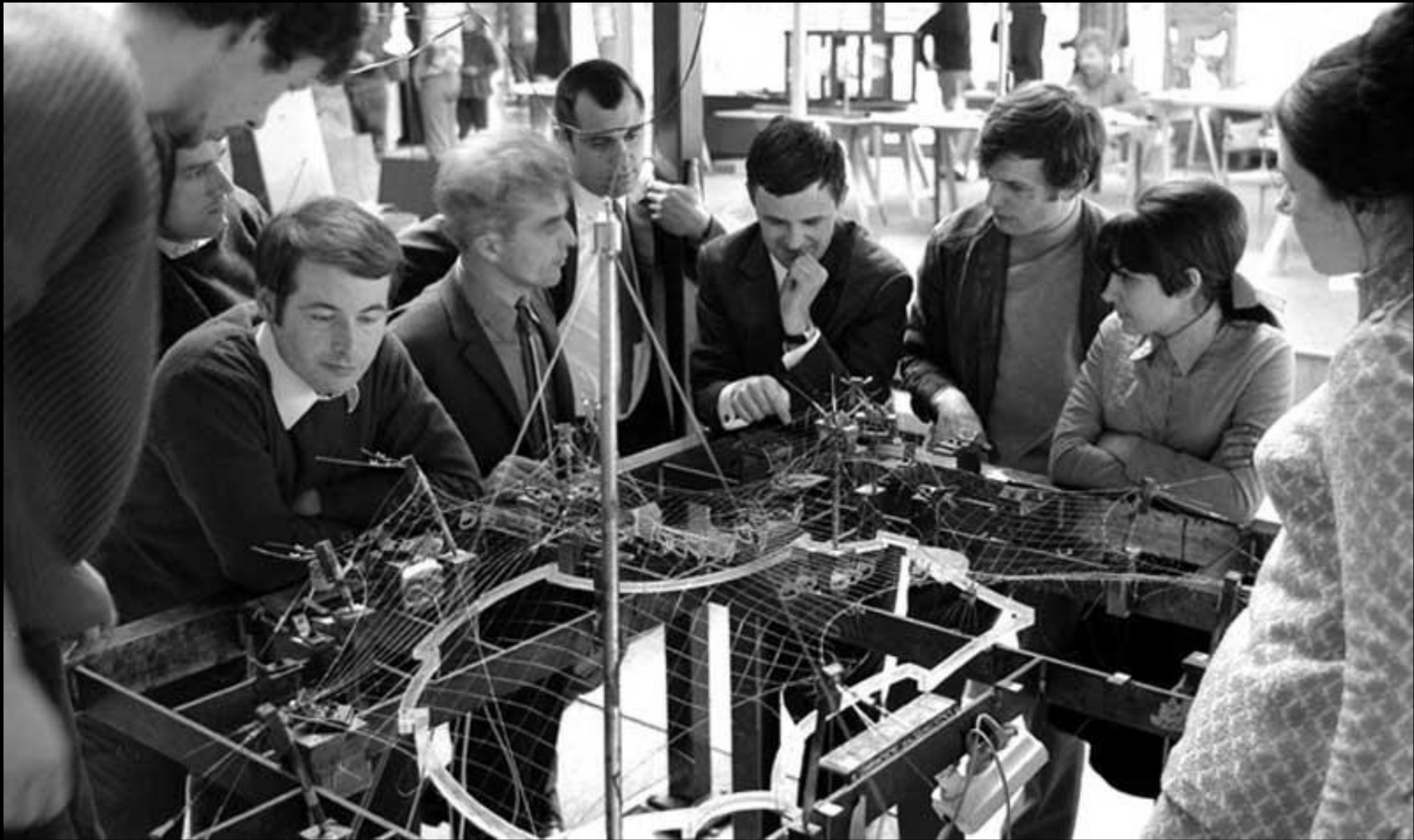


**Hello,
my name is...**

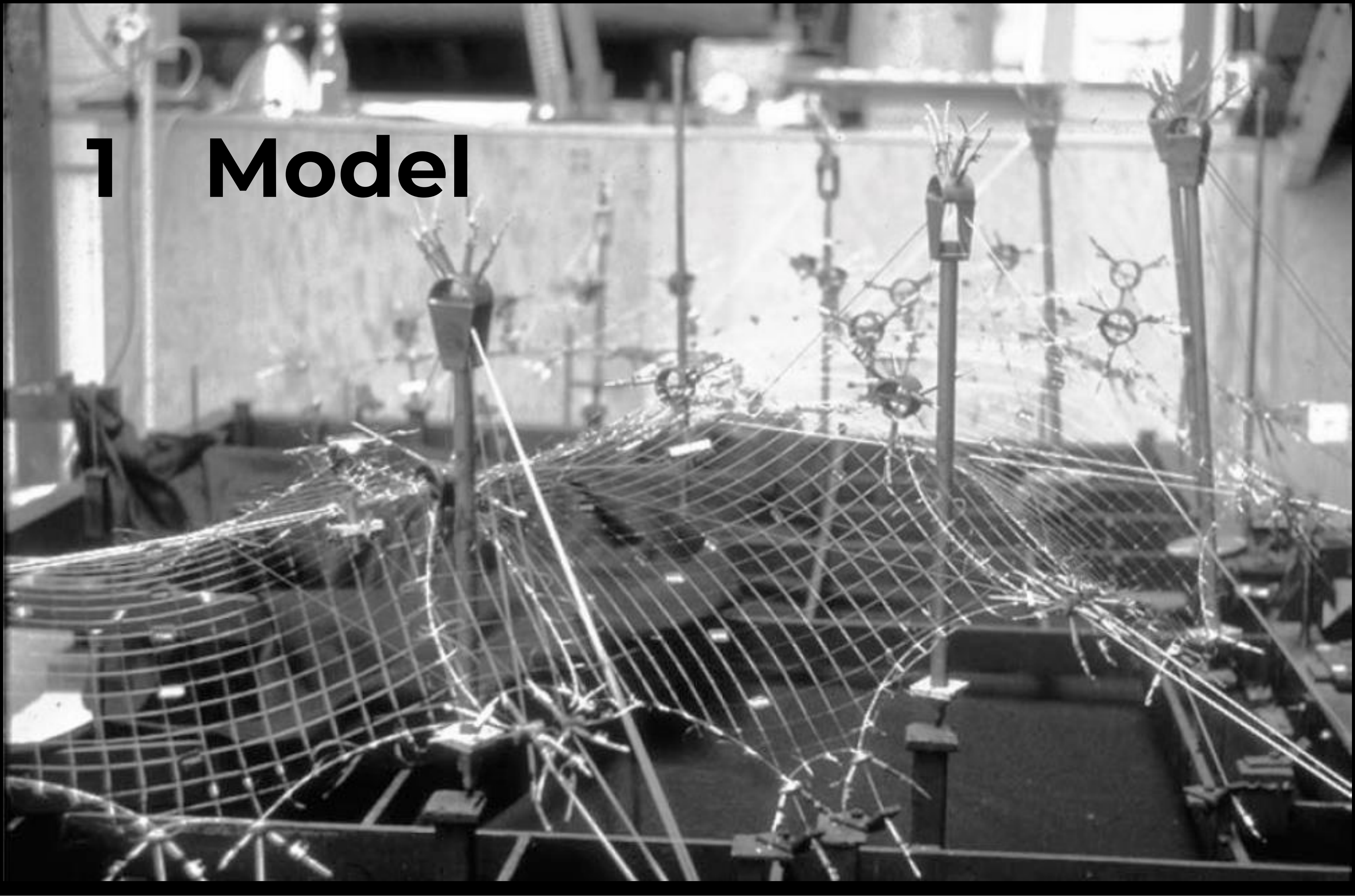
Frei Otto

Munich 1972

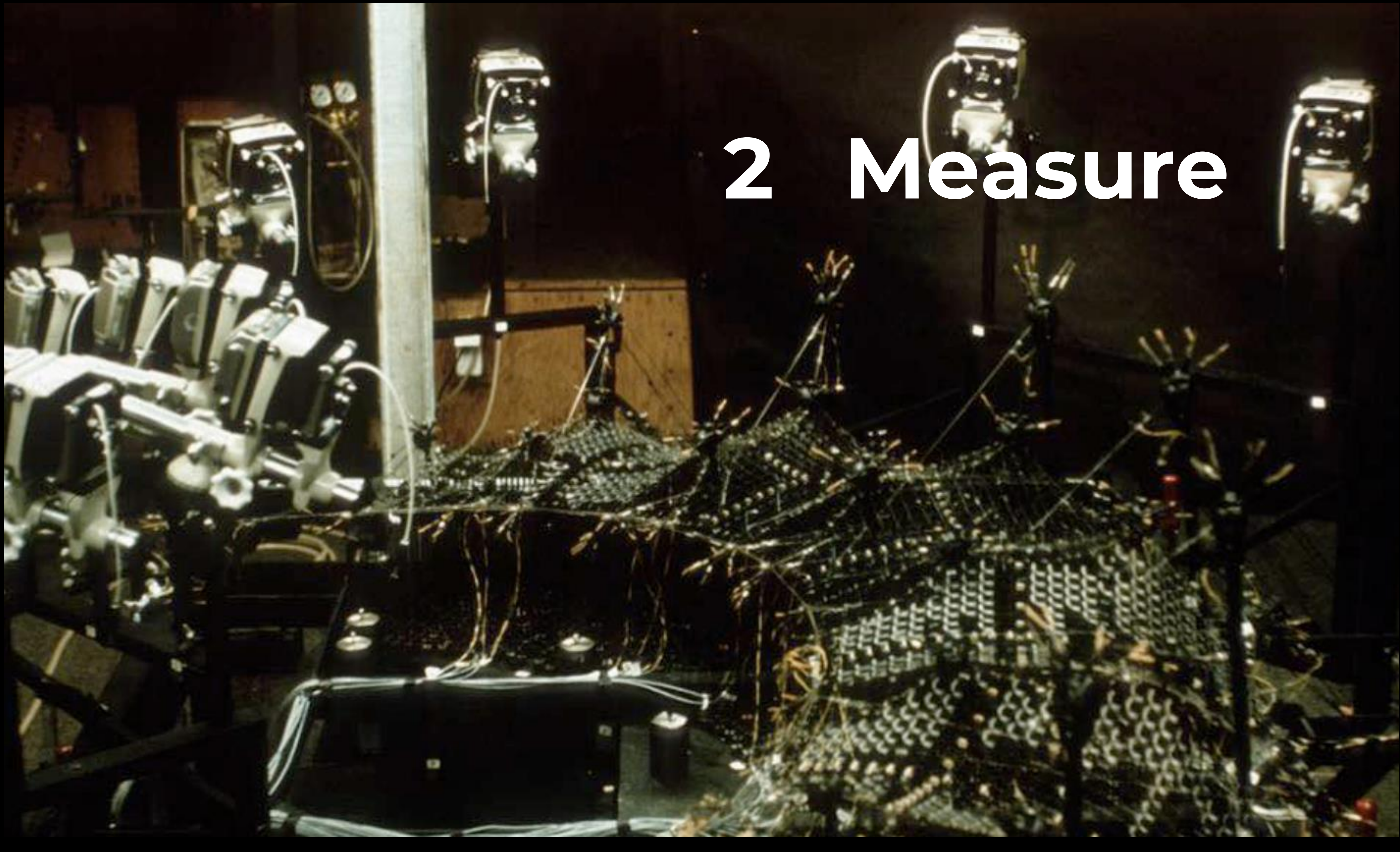
Physical modelling as a design tool



1 Model



2 Measure

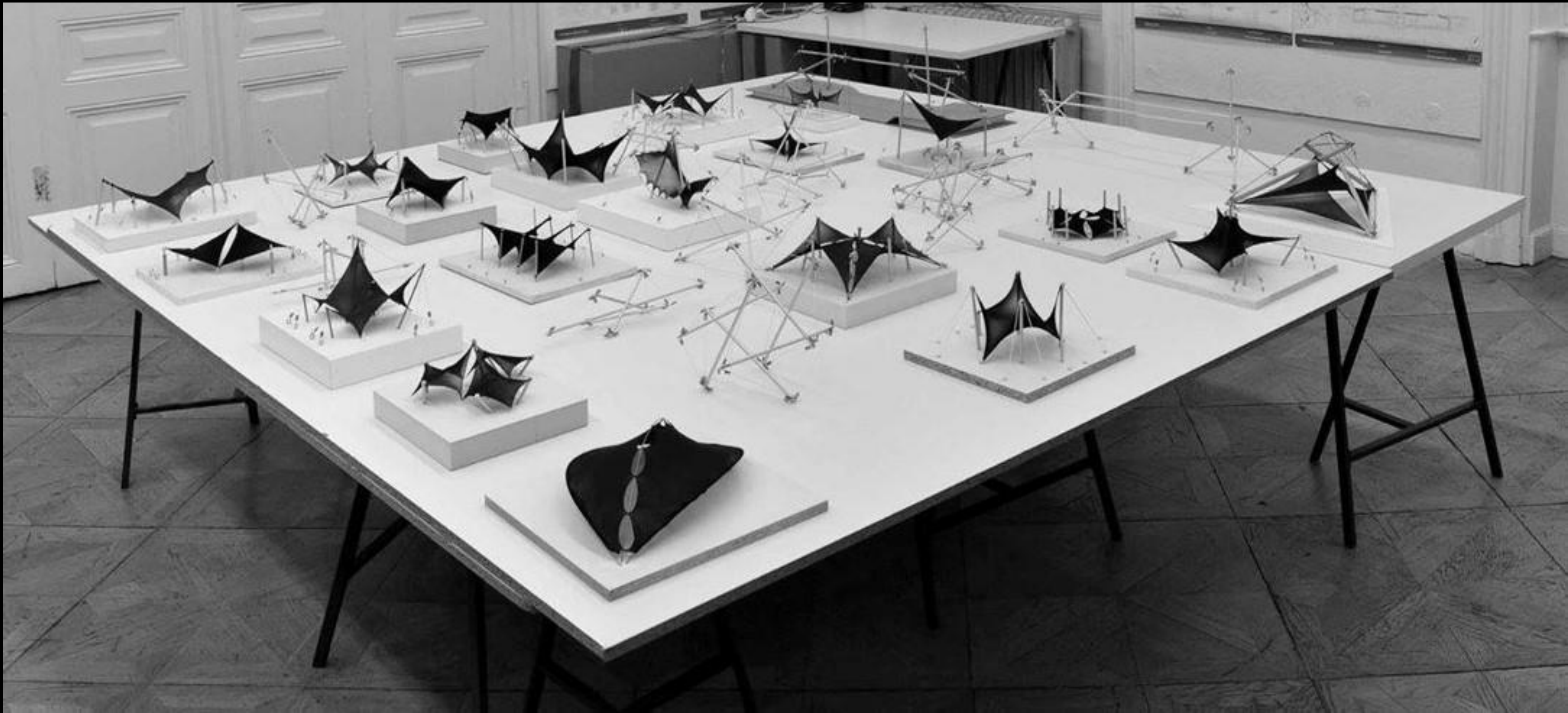


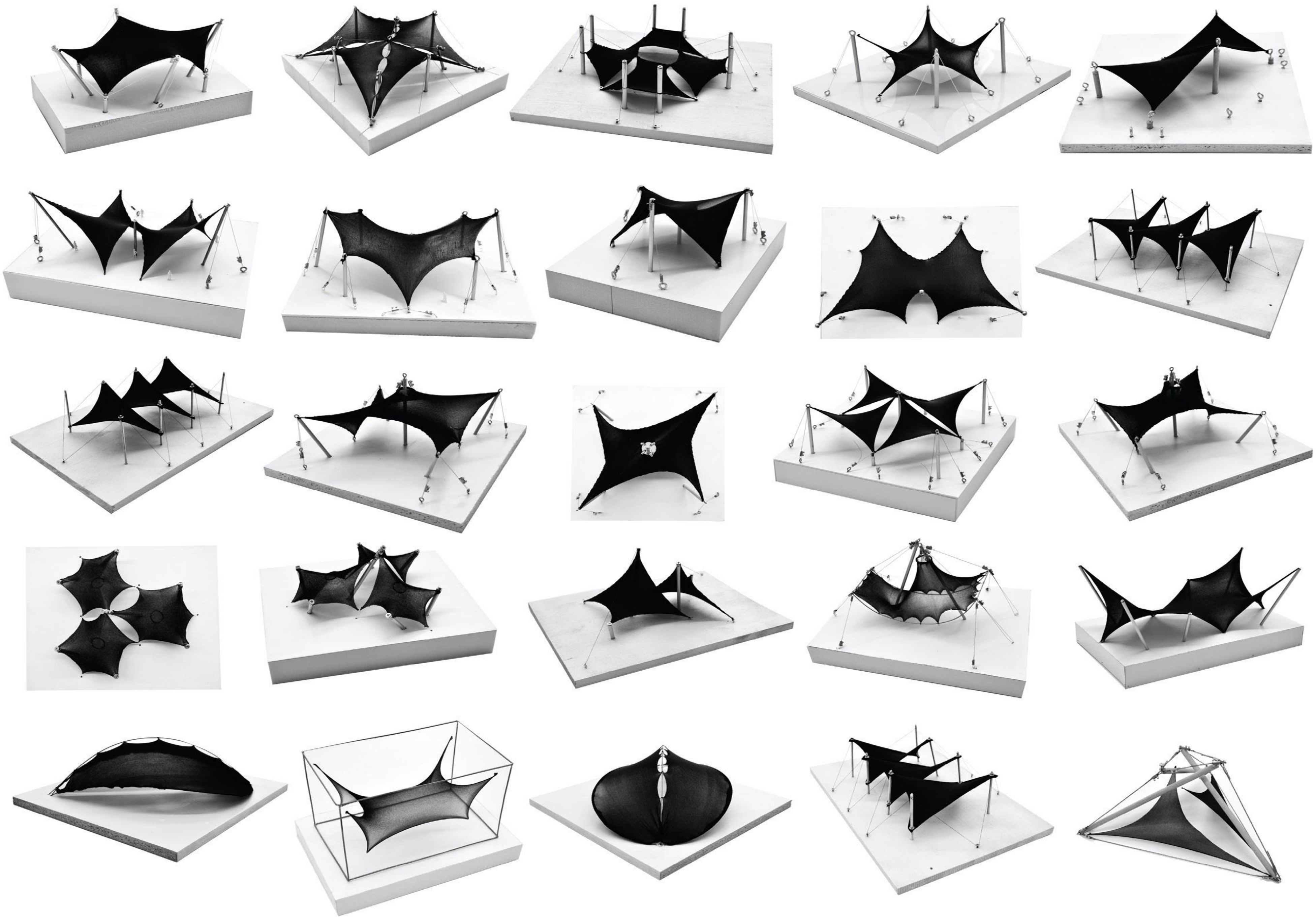
3 Build

Modern Lightweight Constructions

- Tensile Integrity Structures
- Membrane Structures
- Reciprocal Frame
- Grid Shells
- Geodesic Dome
- Tensairity
- Suspension Bridges, Cable Stayed Bridges
- Pneumatic Structures
- Folding Structures

Small Scale Counts



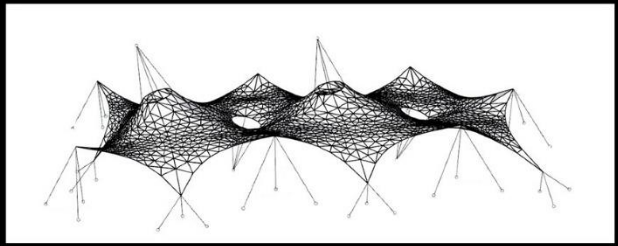


One of the extremely popular architectural forms of contemporary architecture and design represent the membrane structures. They appeal especially with their non-traditional solution, innovative design, unique shape, and great flexibility (Otto, Trostel, 1967 and Bach, 1988). Compared to traditional rigid structures they allow larger spans with minimal number of support members.

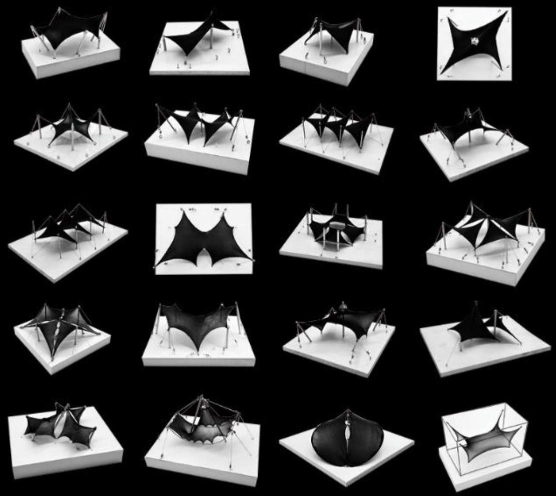
Membrane structure has always enjoyed great interest of students. Many different models of textile structures can be produced as physical miniatures of the static-structural system with large spans.

The advantage of such models versus virtual 3D models is the possibility to directly verify the structural scheme. Instead of the term Membrane Structures, we can also come across designations such as Tensile Structures, Architectural Textile, Fabric Architecture or Textile Membranes. All these names refer to the same concept.

Today, membrane constructions are a common (and at the same time very aesthetic) part of various interior and exterior constructions and are used in every type of design. Exterior membrane constructions made of technical textiles are used as temporary (often mobile) or permanent light roof constructions of stadiums, arenas, cultural stands, shopping centres, exhibition halls, airports, amphitheatres, or as effective dominants of selected spaces. In interiors, textile membranes fulfil an aesthetic function and can also function as thermal or acoustic insulation.



Form Finding of Membrane Structures (Shawkat)



Membrane Models, Small Scale Counts

Membrane Structures

Membranes become protagonist and represents the new trend in design: construction with the minimum amount of material, thanks to many qualities and features that make possible a correct functionality for different architectonic spaces and they can give a particular meaning to places where they are installed. As is well-known, the primary advantage of tensile members over compression members is that they can be as light as the tensile strength permits.

Tensile structures have always fascinated architects and engineers, mainly because of the aesthetic shapes they produce. Despite this, very few tensile structures have been built.

From the works we have described here, we can derive some considerations about special aspects of textiles, in particular about their adaptability and their facility to furnish, as well as their reversibility. So we can say that membranes are very easy to adapt to different spaces and in the same time they are able to modify these spaces because of given needs, for instance expanding or restricting delimited spaces, in height or in depth. Moreover, membranes can be included with lightness in contexts that are yet full of values and strong signs, without any volumetric invasion in consolidated spaces; furthermore, membranes are easily usable so they make places recognizable and perceptible in a direct way, avoiding disorientation like it could happen in places which are not well designed.

The shape of a tensile structure, which very much depends on the internal forces, also governs the load-bearing capacity of the structure. Therefore, the process of determining the initial equilibrium configuration calls for the designer’s ability to find an optimum compromise between shape, load capacity and constructional requirements.

Membranes lend themselves to different kinds of work or adaptation, in fact they often provide different solutions to practical problems that frequently occur on the building site and which must be solved even in phase of realisation.

Fabric reinforced membranes are a class of lightweight materials which are important for many different engineering branches. They can be used to efficiently cover big areas or enclose large volumes with a minimum of structural weight.

Due to the negligible flexural stiffness of cables and membranes, the initial configuration of these structures must be stressed, even if the self-weight is disregarded. Thus, before the analysis of the behaviour of the structure to external loads can be performed; the initial equilibrium configuration must be found.

Confusingly, there are a lot of different names for tensile structures.

You might see them referred to as:

- Tension membrane structures
- Tensile membrane structures
- Tensile fabric structures
- Thin-shell structures
- Tensile facilities
- Tensile buildings

What are Tensile Structures ?

- How Do they Work?
- What Types of Tensile Structures are There?
- What are Possible Applications and Uses for Tensile Structures?

“Assemblage of structural elements working uniquely under tensile stress state“.

- Nowadays, modern architecture is focused the possibility to produce lightweight solutions with maximum elegance in shape.

- There is always an effort to free objects from shapes that are based on straight lines.

The peaks of the era of straight lines and simple geometric shapes in architecture were the period of Cubism architecture 1906, Constructivism 1917 and Functionalism "form follows function" form subordinated to function 1927.

The straight line belongs to men, the curved one to God.

Antonio Gaudí
(Architect)

Frei Otto "form follows forces", evolution in nature, which optimized its own structures, has become a major source of inspiration for the shapes of building structures.

Construction = Architecture

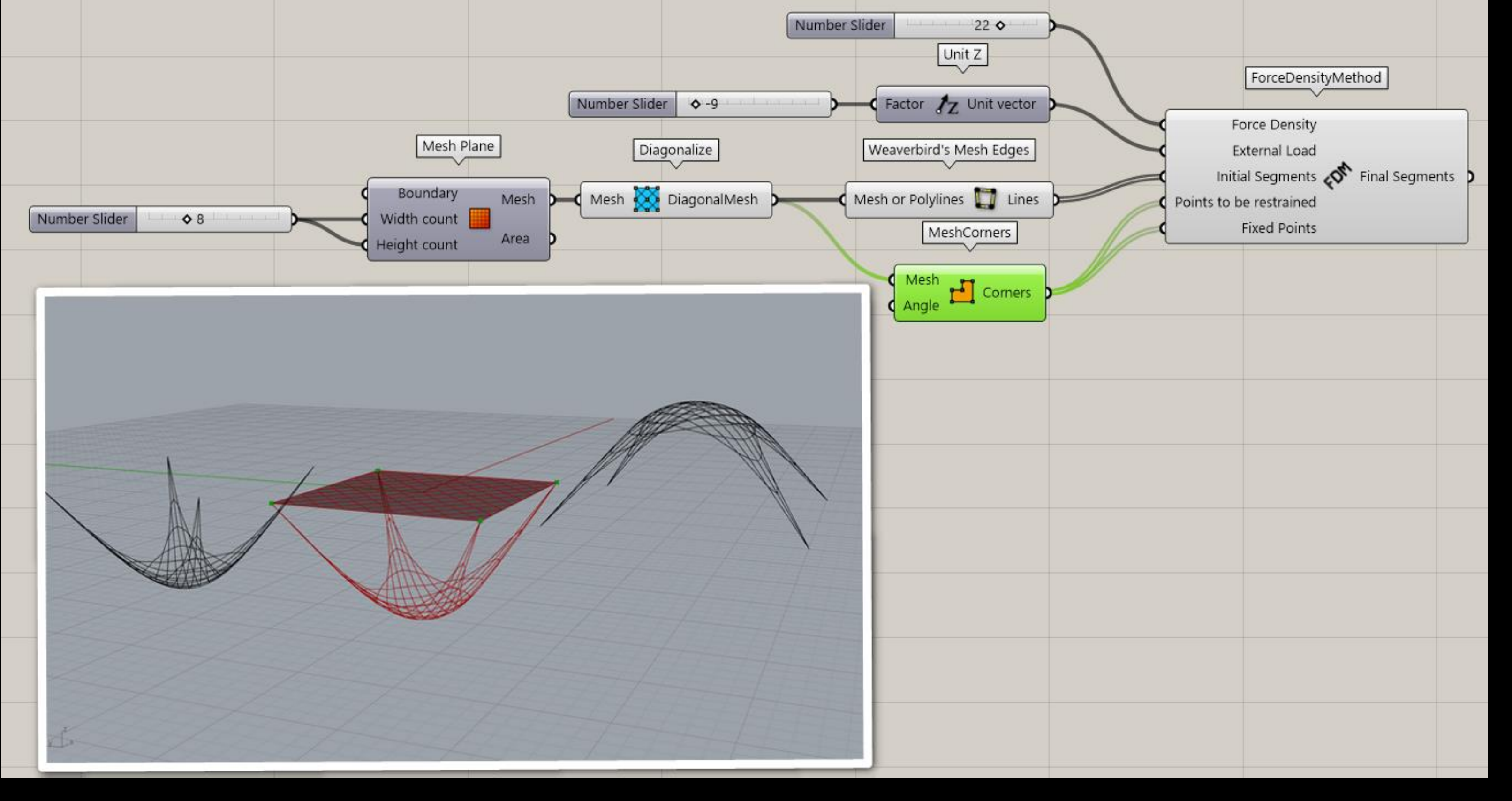
Membrane constructions and grid shells of so-called "free-form" shapes are a manifestation of modern architecture and have the potential to develop in the future.

"Free form" shapes have no analogy in nature, and it is impossible to describe them exactly mathematically.

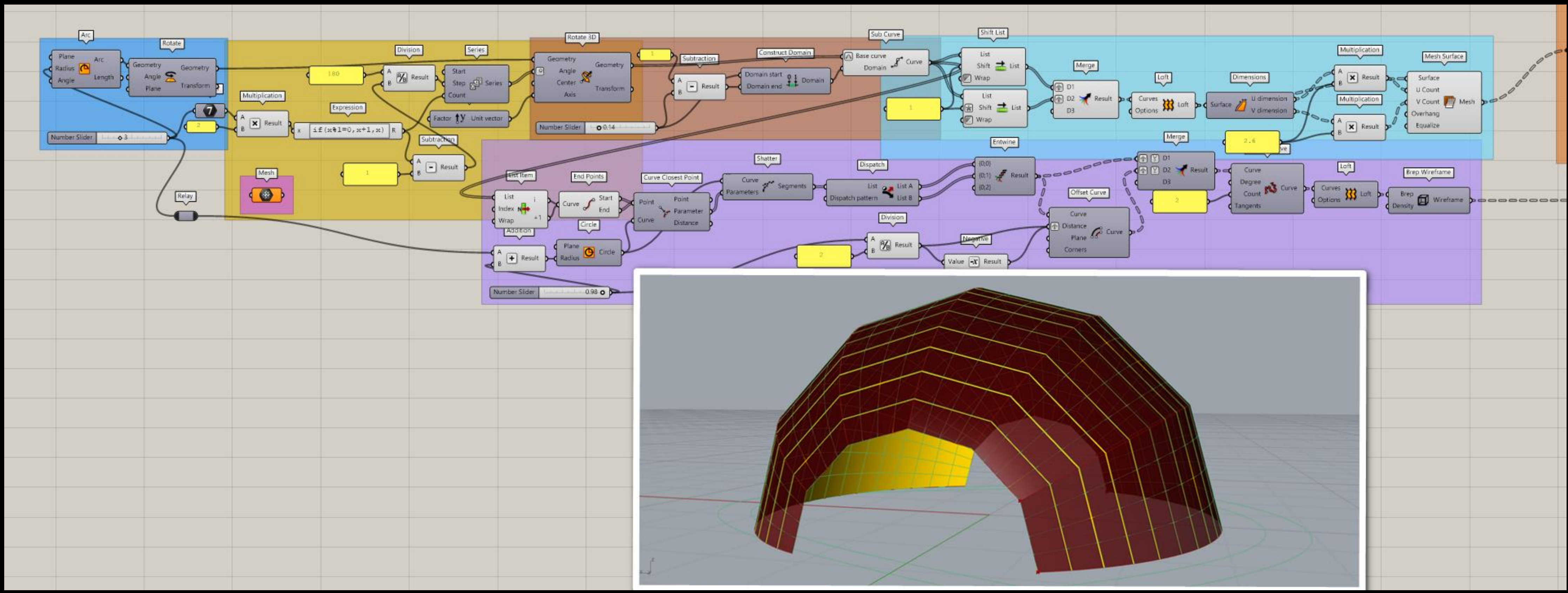
Force Density Method

The Force Density Method can be used to find the equilibrium solution for a cable net or a shell discretized through bar elements. The component requires as input:

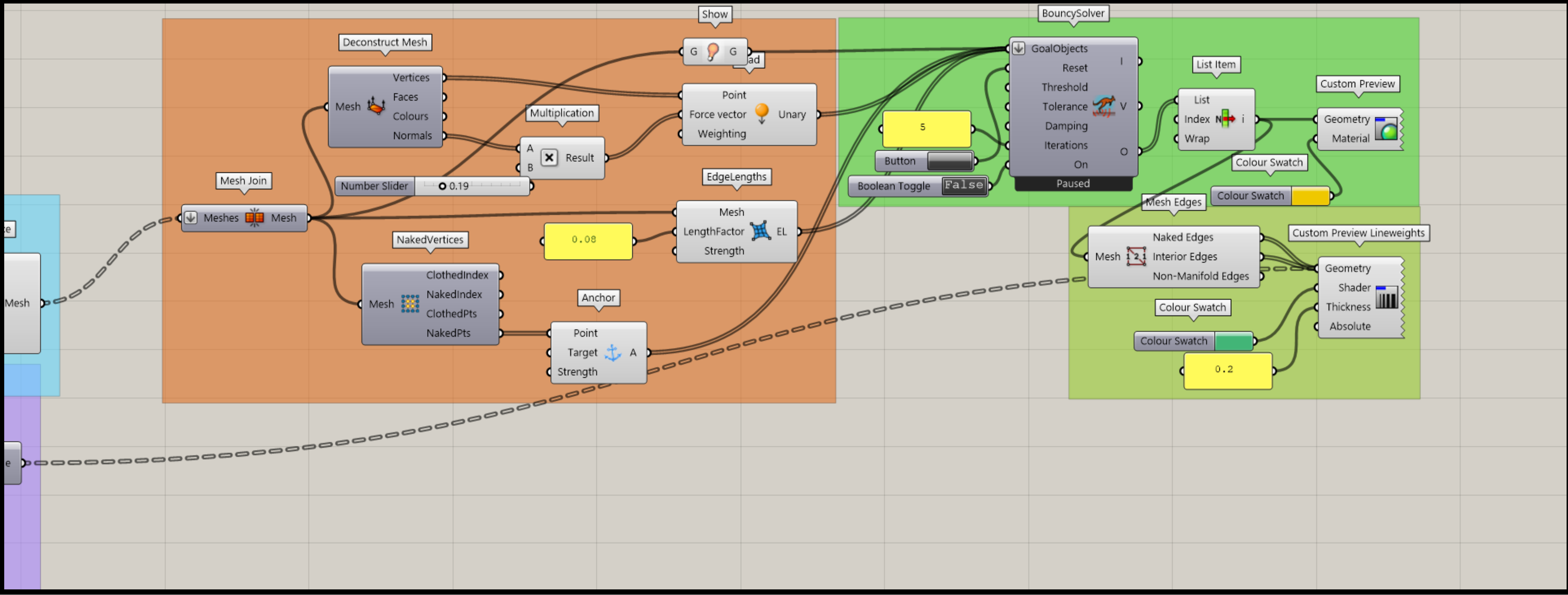
- the initial geometry and the restraints;
- the loads;
- the force densities (the ratios between the tension or compression force in a segment and its lenght).



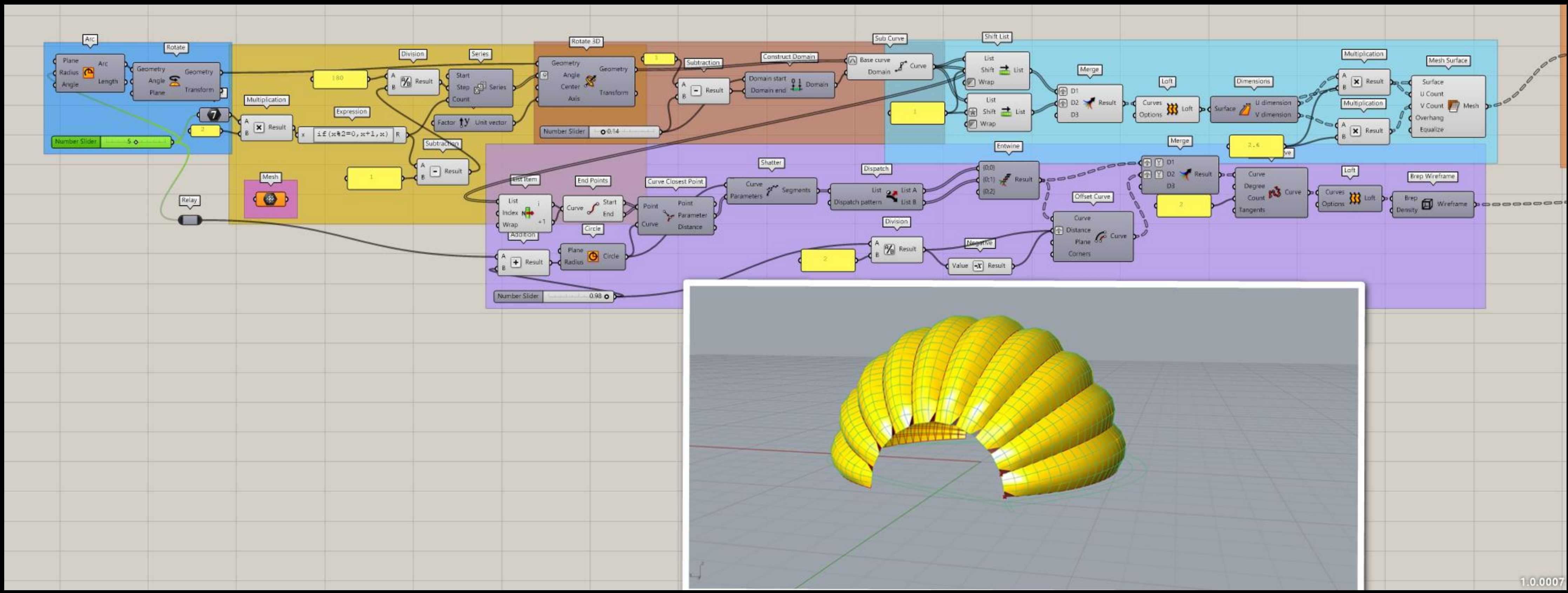
Tensile Structure- Flow Chart of Grasshopper



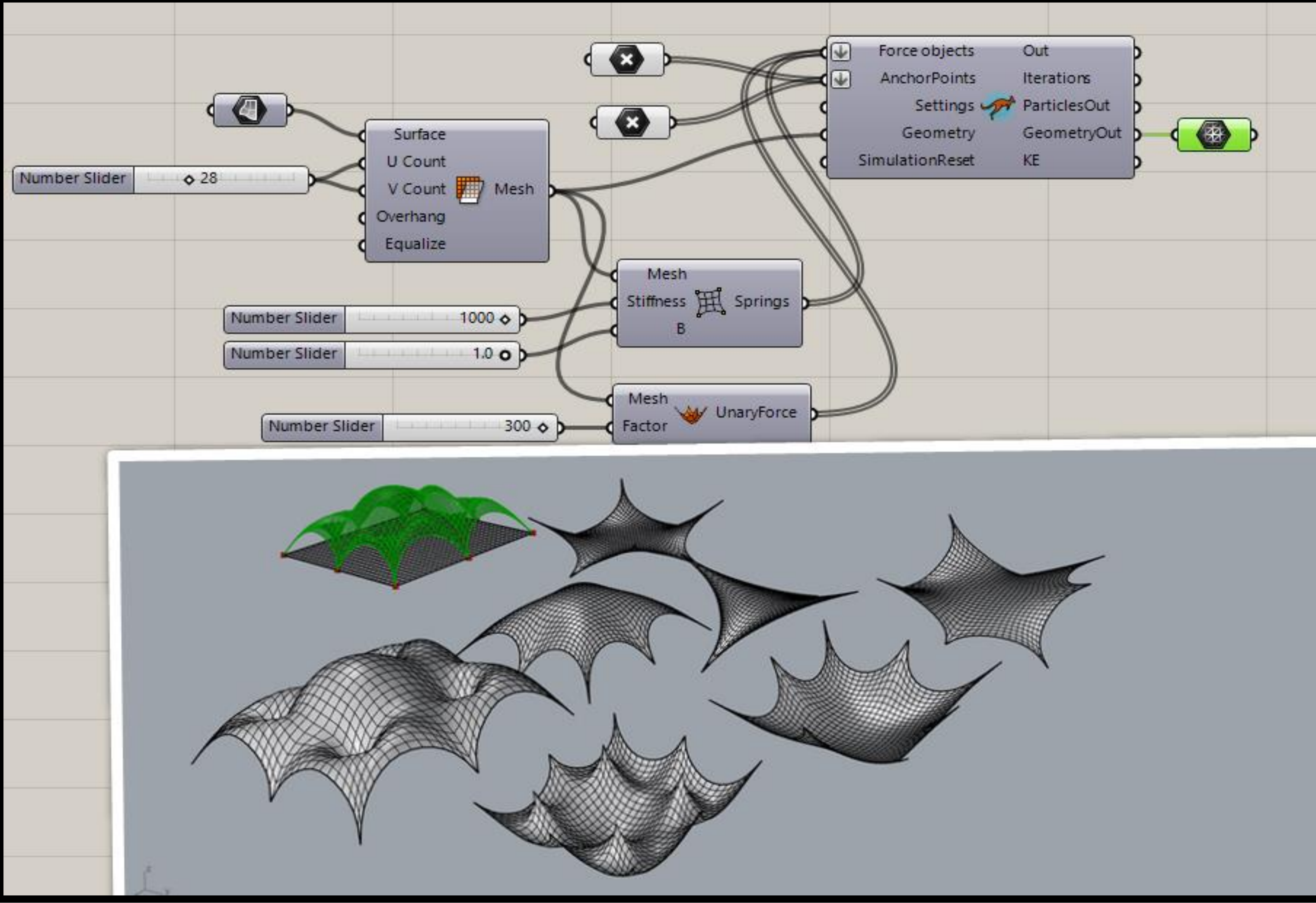
Tensile Structure- Flow Chart of Grasshopper



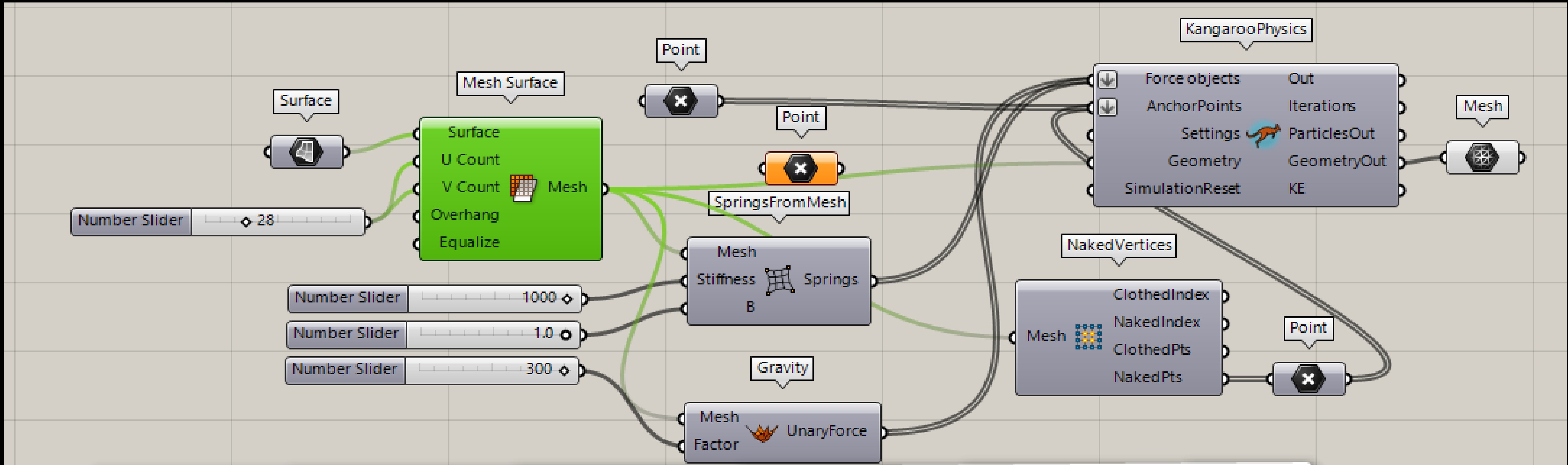
Tensile Structure- Flow Chart of Grasshopper

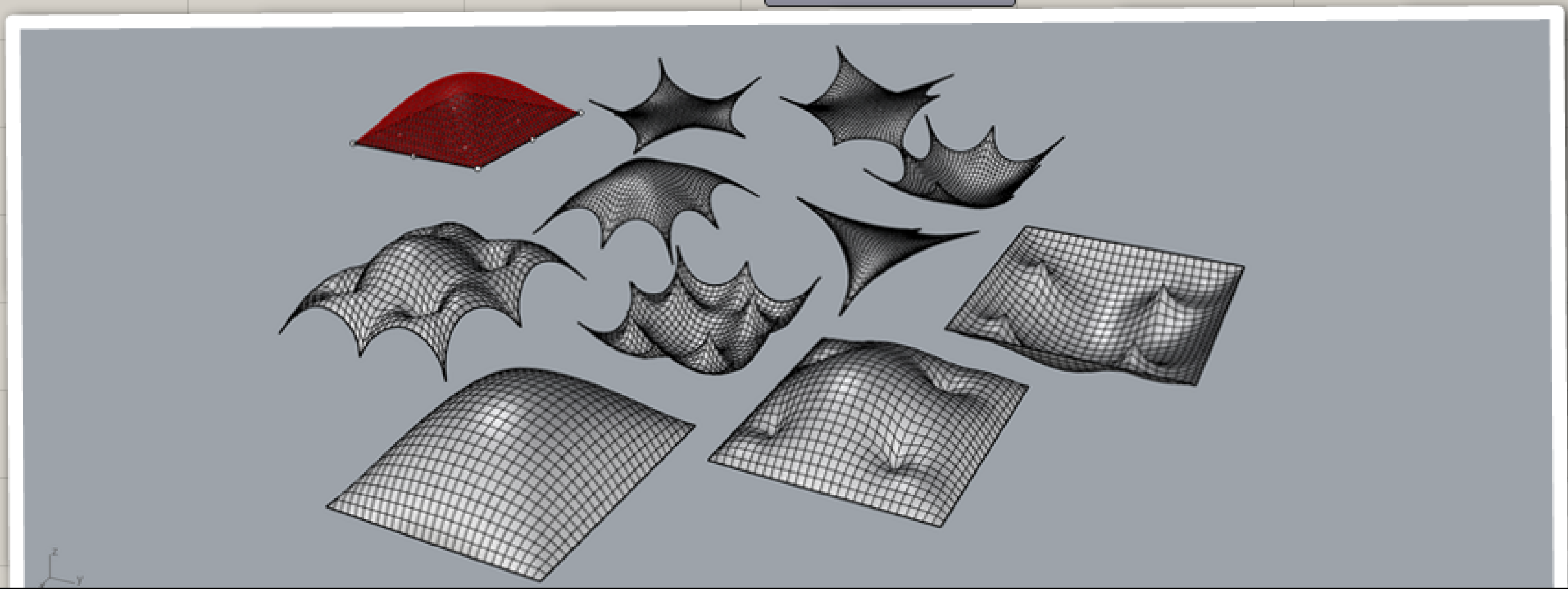


Tensile Structure- Flow Chart of Grasshopper

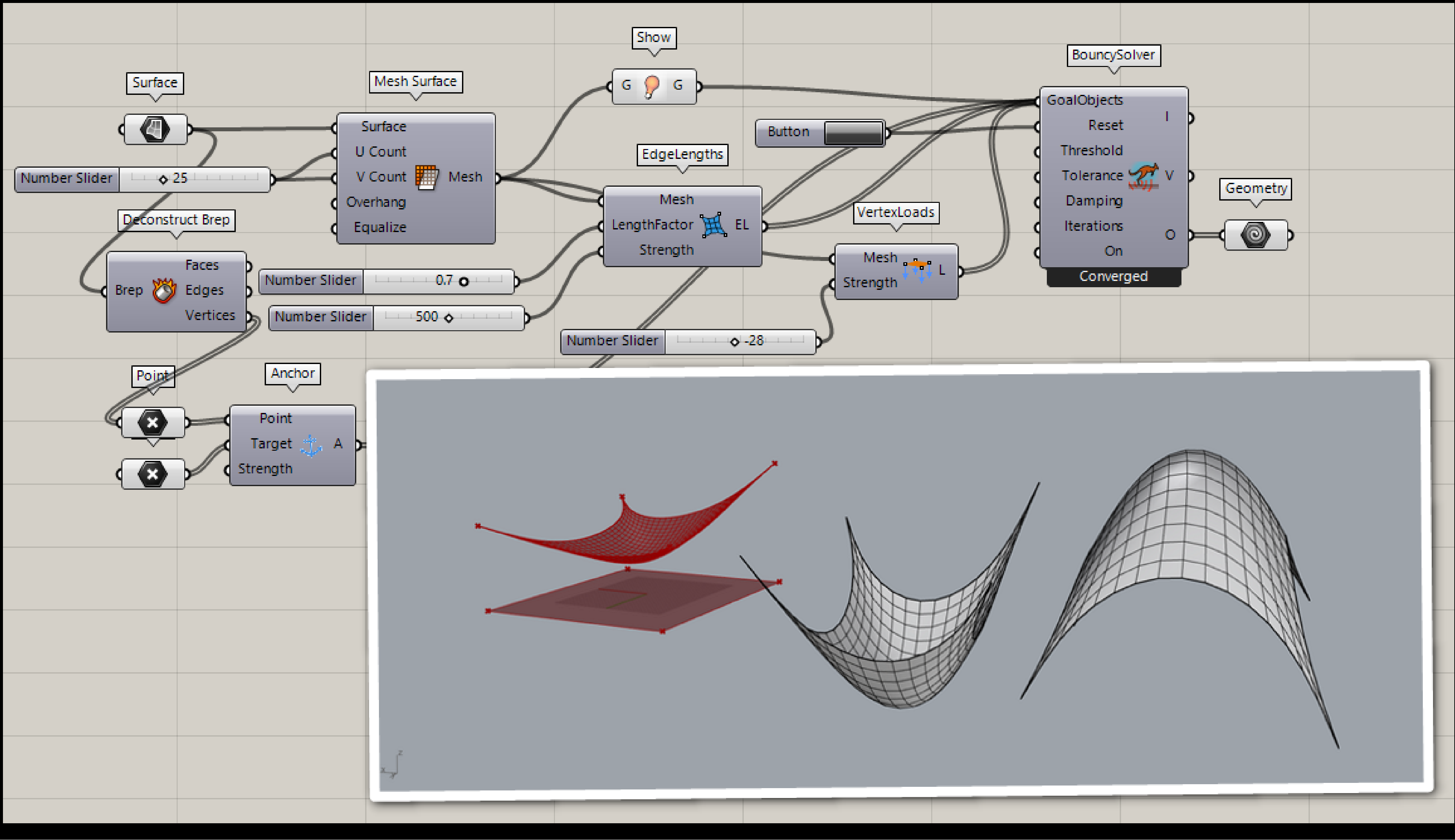


Synclastic-Anticlastic Geometry-Flow Chart of Grasshopper

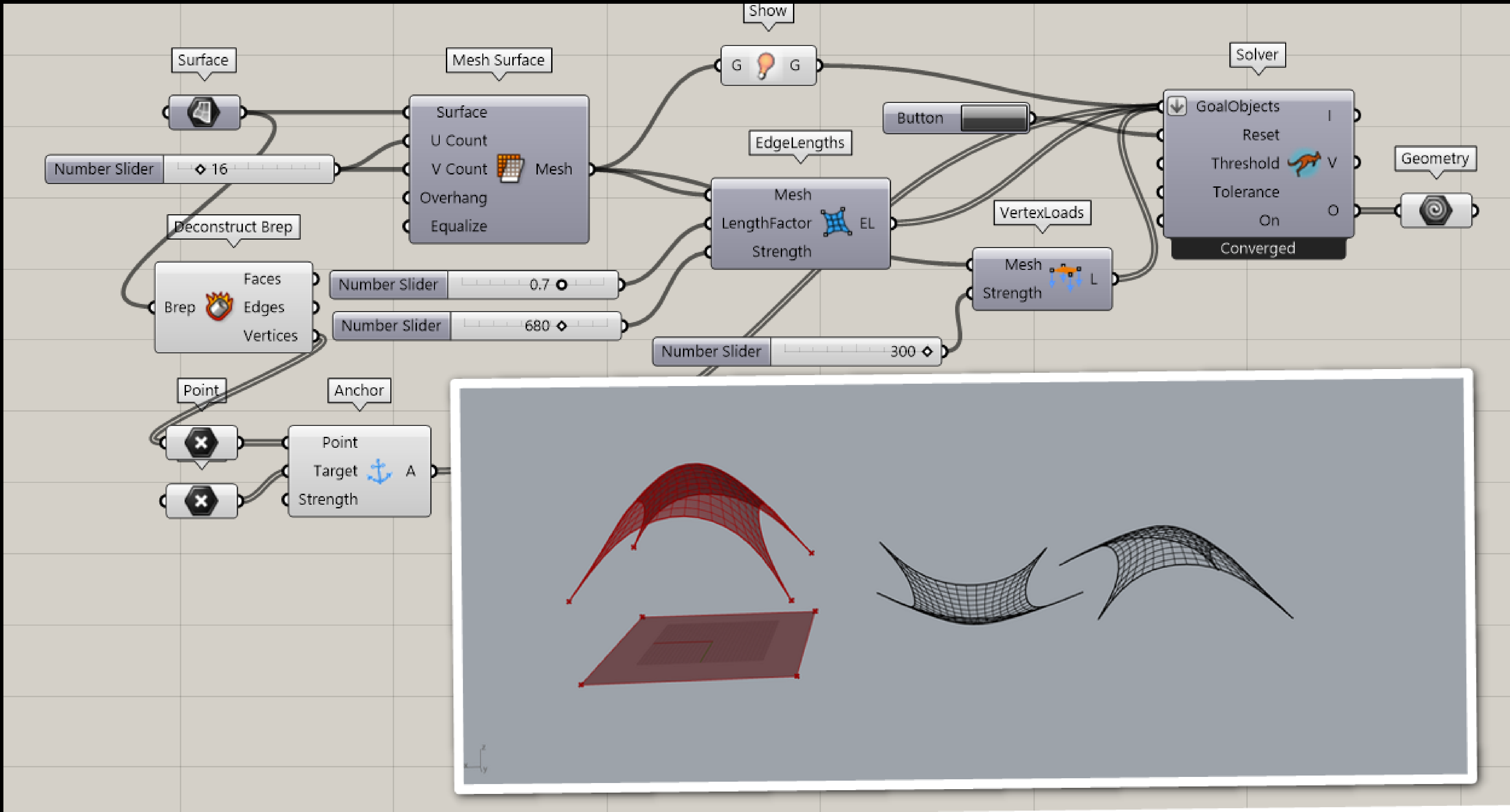




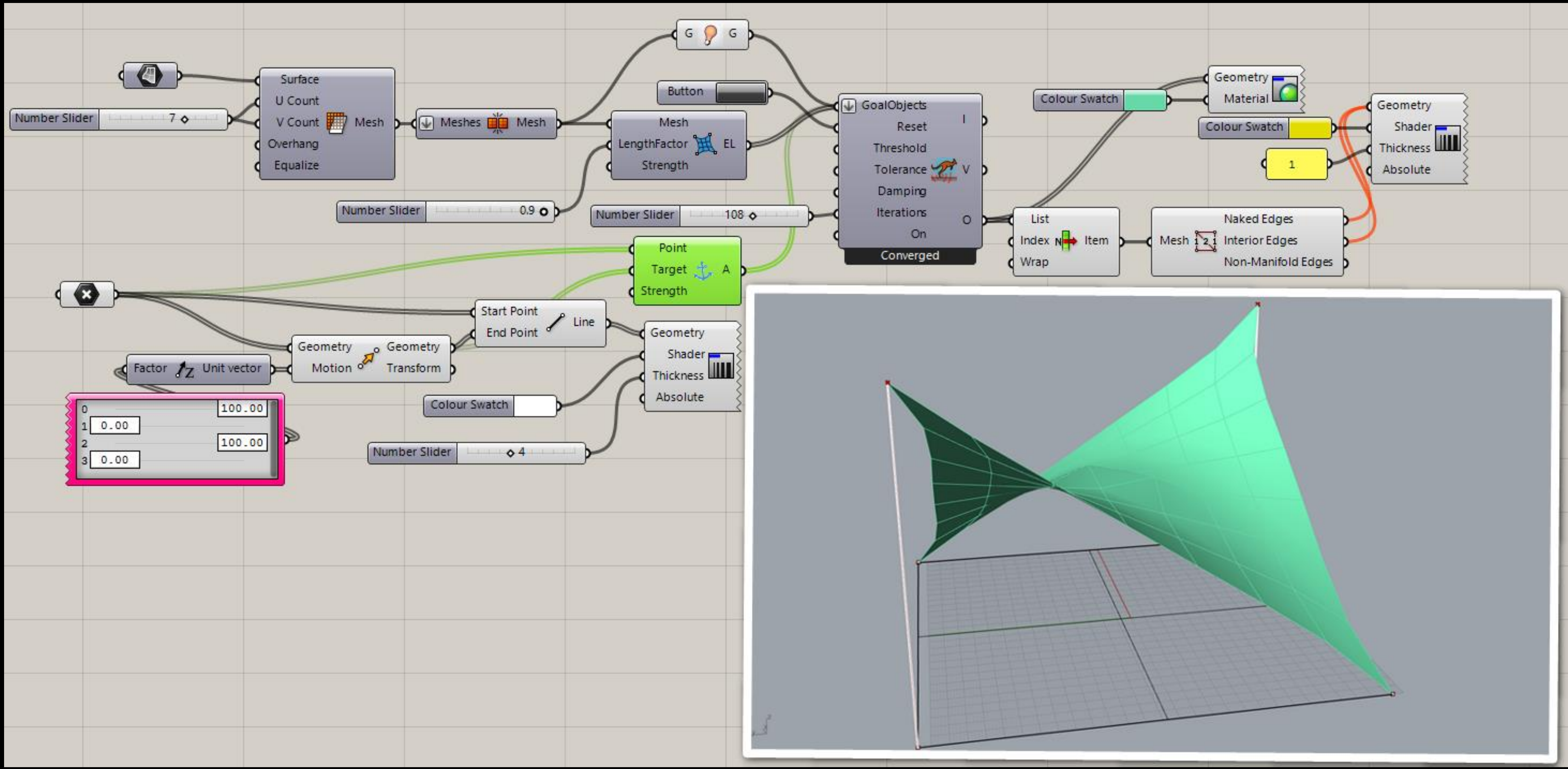
Tensile Structure- Flow Chart of Grasshopper



Tensile Structure- Flow Chart of Grasshopper



Tensile Structure Physical Form-Finding

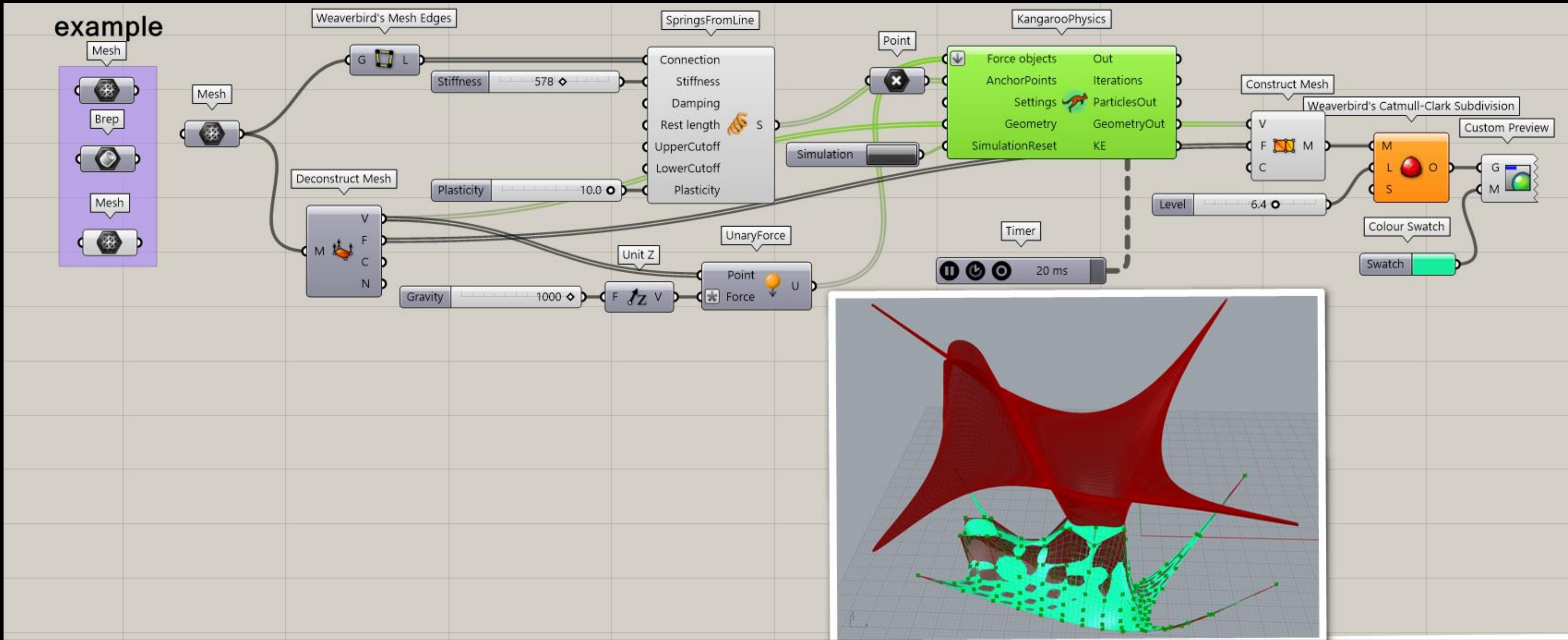


How can use the kangaroo for tensile structures

1. First create a surface in rhino, rebuild the surface to have more segments on the surface, mesh the surface and set it to the mesh component.
2. Put some anchor points on that mesh you have made, make sure the point are exactly attached to the mesh.
3. For the springs component we need the mesh wireframe to make it stretch, it makes a mesh surface like a pantyhose using the law of springs.
4. If you want gravity to make it more real you can add unary force component, the component needs mesh points.
5. You can even use toggle instead of button, do not run the simulation before connecting the anchor points and the mesh, and Kangaroo physics needs a timer
6. If you run the simulation and the surface goes away notice that:

a. The anchor points are not attached on the mesh surface in rhino.
b. You have changed the position of the points and then started the simulation
c. In the situation you’d better right click on the point component and clear value the points, then set the previous multiple points again, and run the simulation

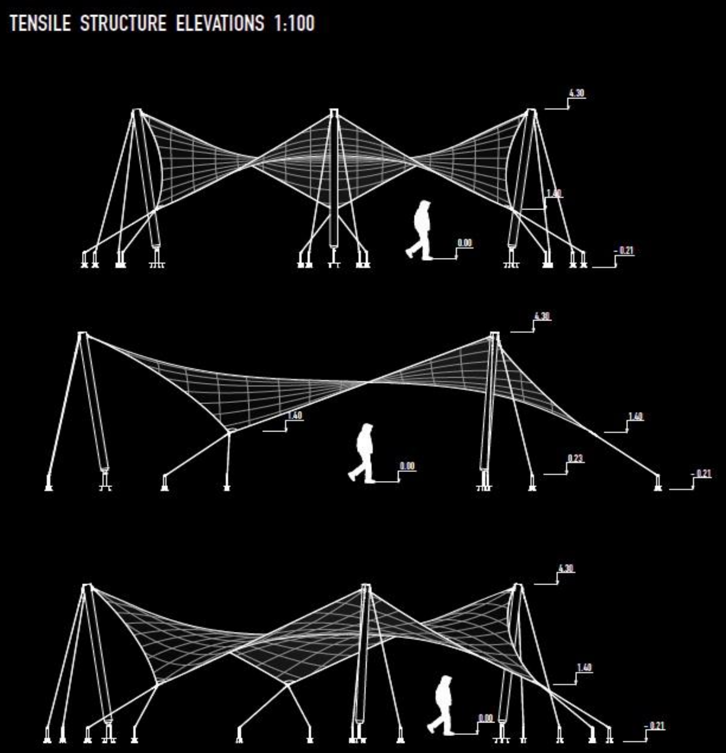
Tensile Structure- Flow Chart of KangarooPhysics

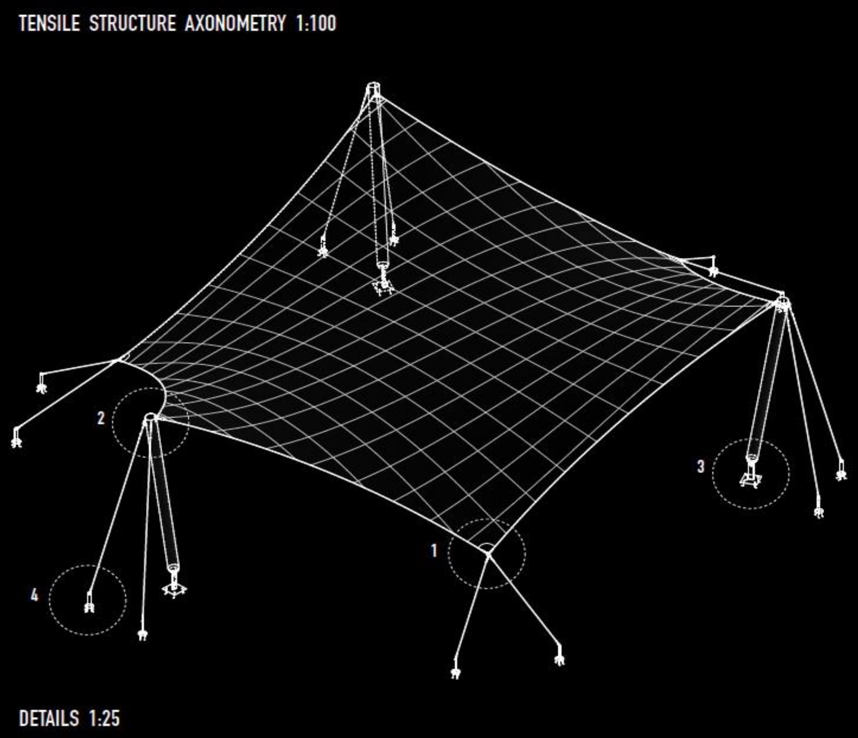


Since these are structures whose thickness is negligible compared to other dimensions, we can speak of structures whose static efficiency is based on their shape.

What do they have in common?

1. They are spatial
2. They are doubly curved
3. They are prestressed
4. They are nice



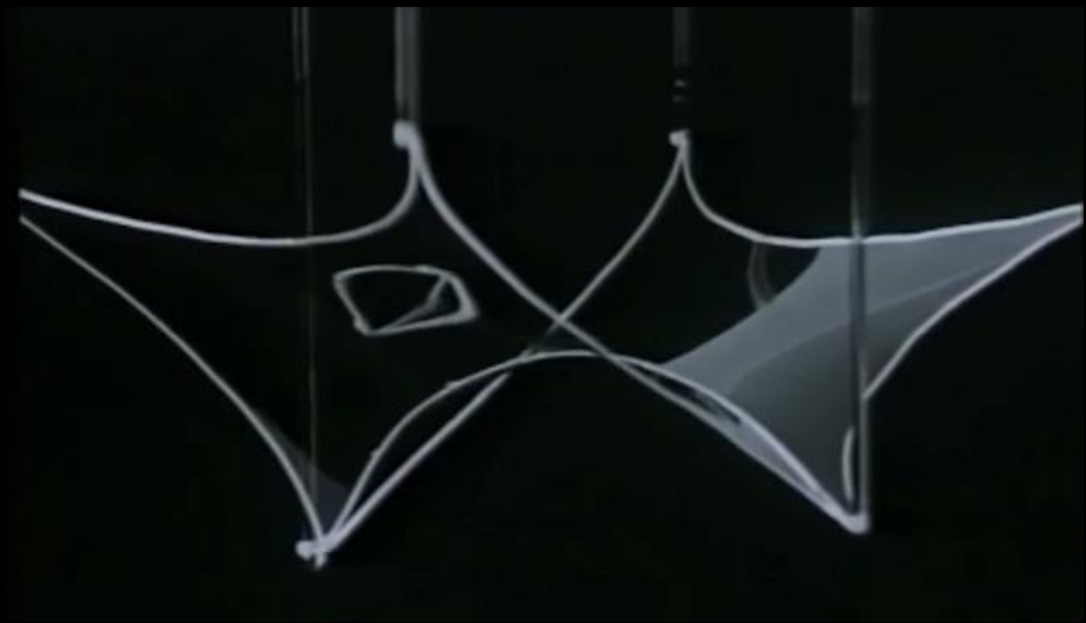


They are shaped in aform of minimal surface

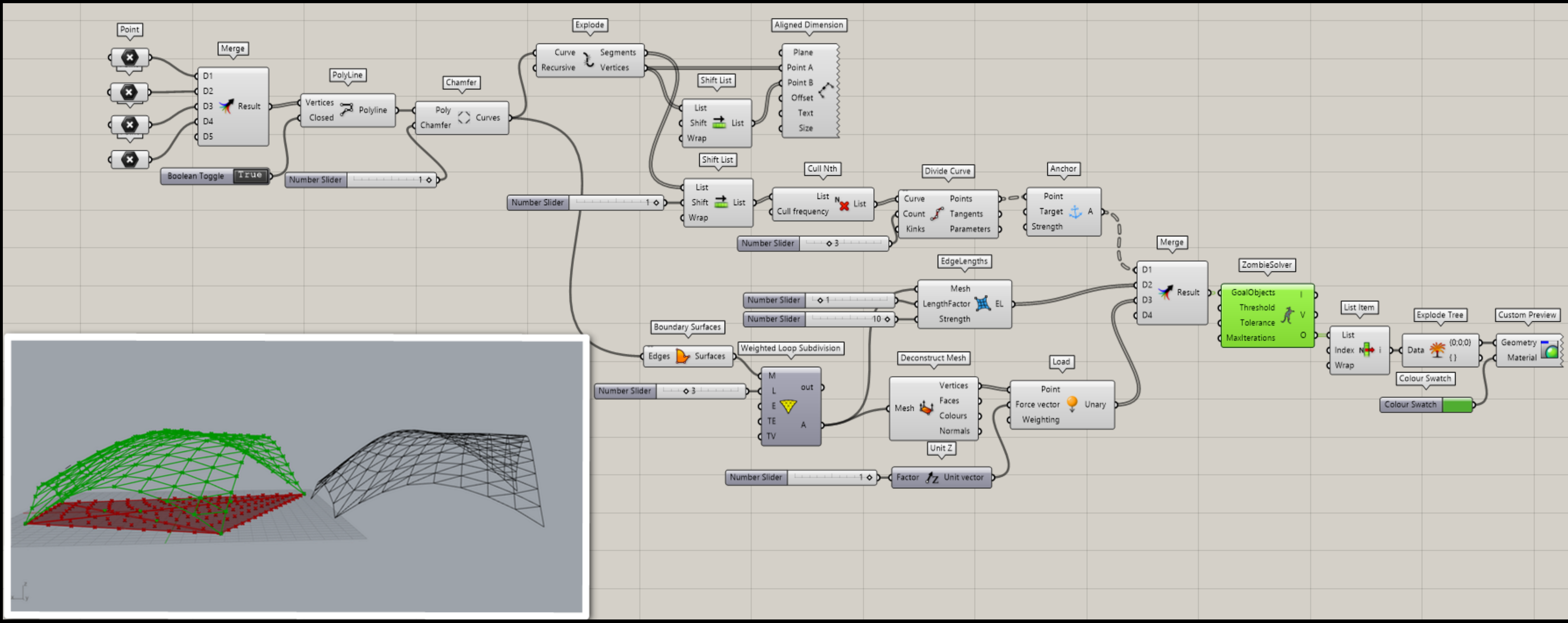
What is that .... Minimal surface?

- It is a surface, that localy minimizes its area
- Localy means under certain constraints
- Constraints are represented by boundary conditions - supports

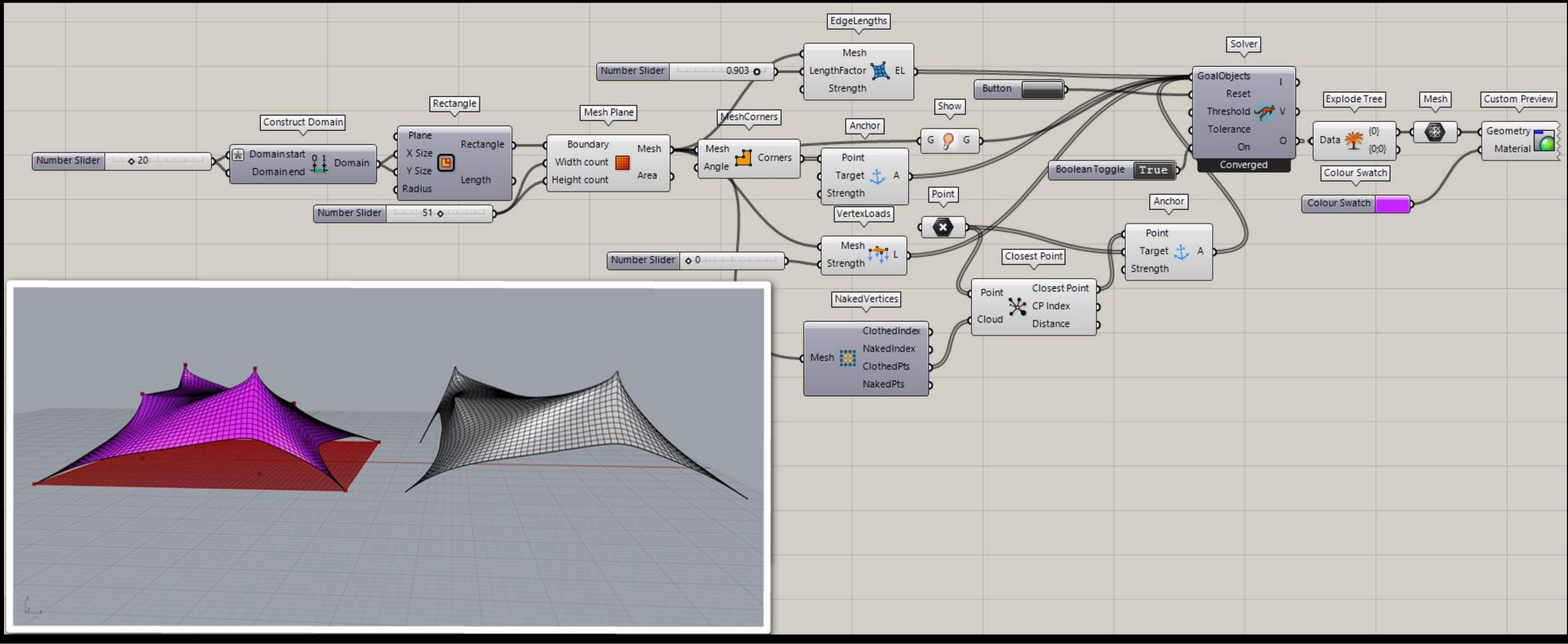
Soap bubble



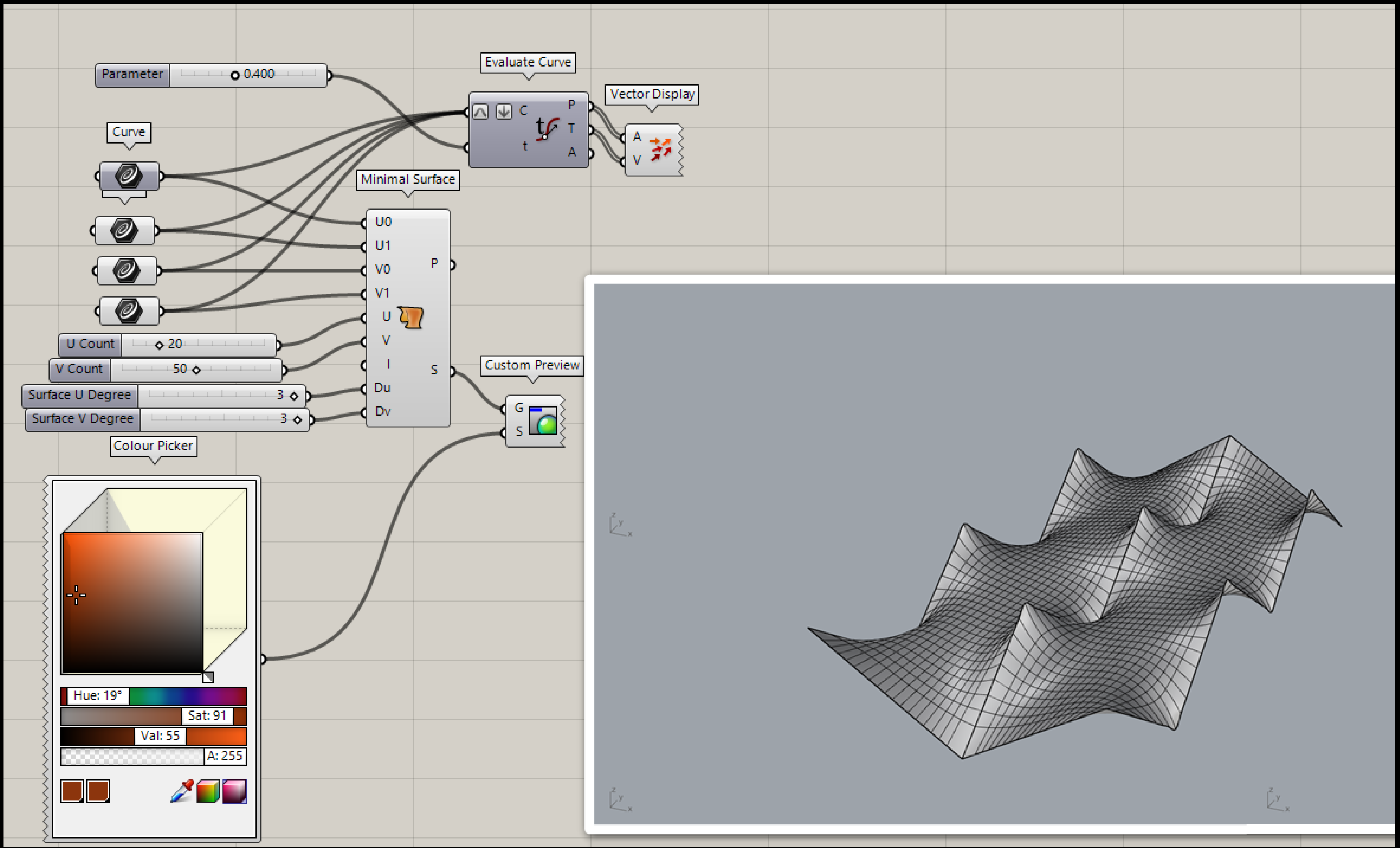
Tensile Structure - Flow Chart of Grasshopper



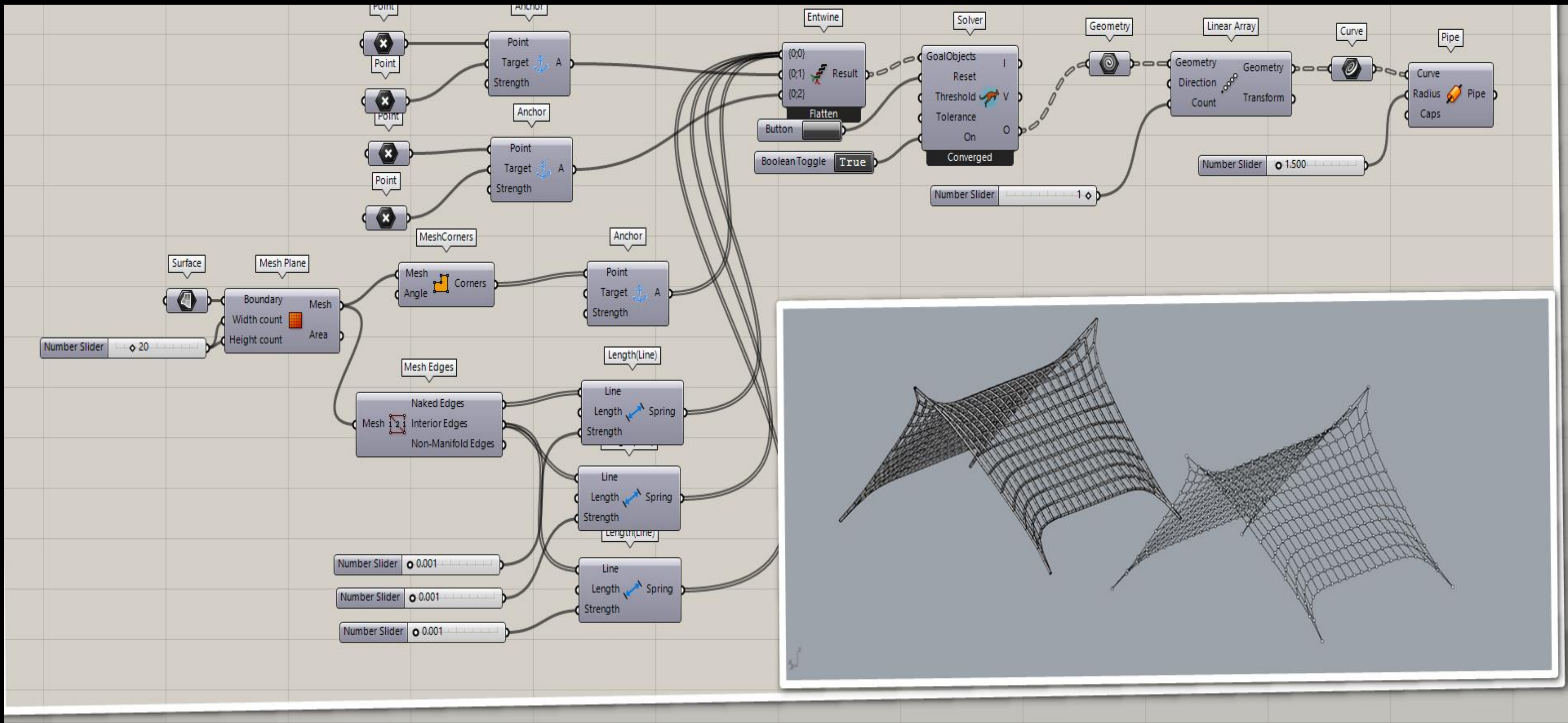
Tensile Structure- Flow Chart of Grasshopper



Minimal Surface- Flow Chart of Grasshopper



Tensile Structure- Flow Chart of Grasshopper

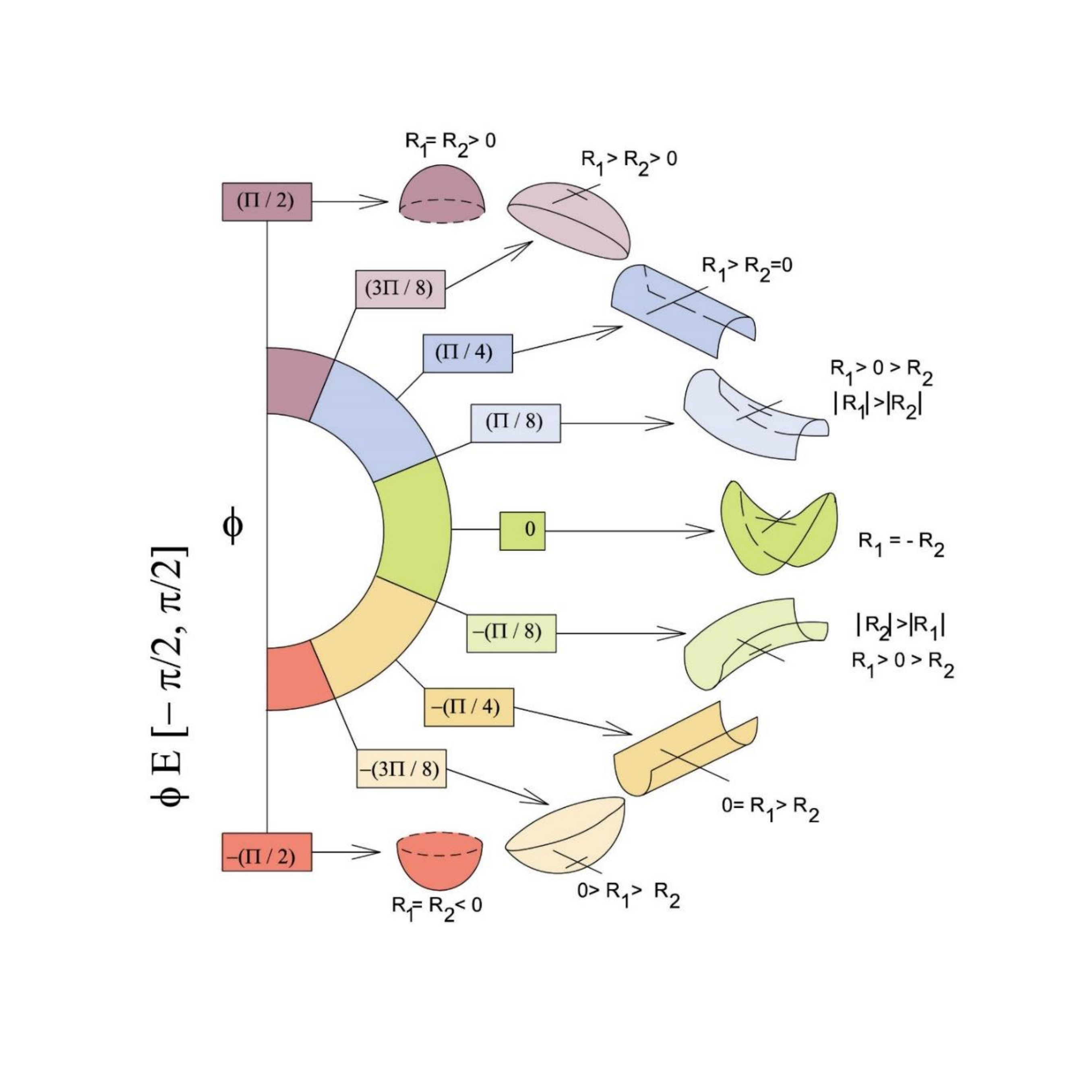


Minimal architecture: Frei Otto

Minimum areas are defined as areas that, between the specified boundary conditions, form a surface with the smallest possible content and using the minimum amount of potential energy required to create it.

The main characteristic of the minimum surfaces from a constructional point of view is that they are curved in two directions, their mean curvature is equal to zero and have a uniform stress distribution.

Surface Classification Scheme to Determine Directional Constraints



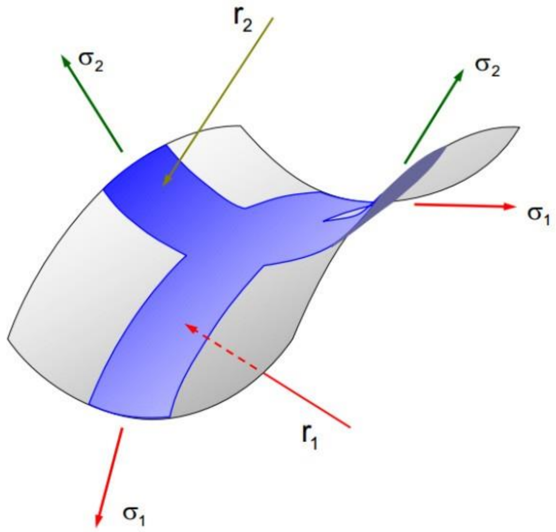
Form follows force

For the surface in equilibrium, it have to stand = $\frac{\sigma_1}{r_1} + \frac{\sigma_2}{r_2} = w$

No stiffness = No loadings possible: $w = 0$

Let´s make it simple: $\sigma_1 = \sigma_2 = 1$

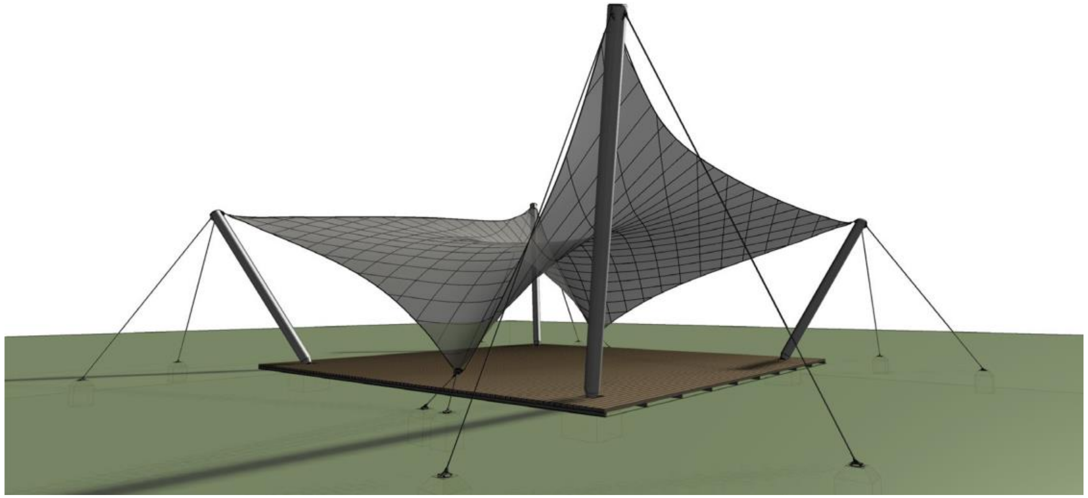
What do we have now? $\frac{1}{r_1} + \frac{1}{r_2} = 0$



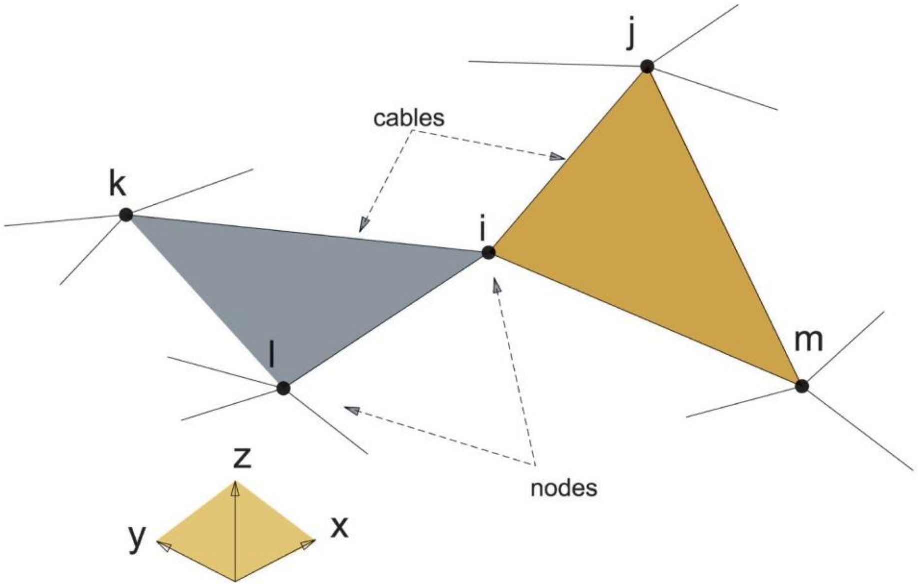
That means: $H = \frac{1}{2}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = 0$

How do we divide them?

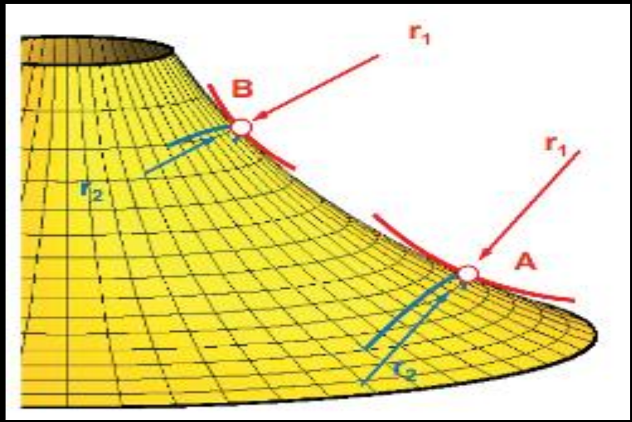
-Construction



Membranes



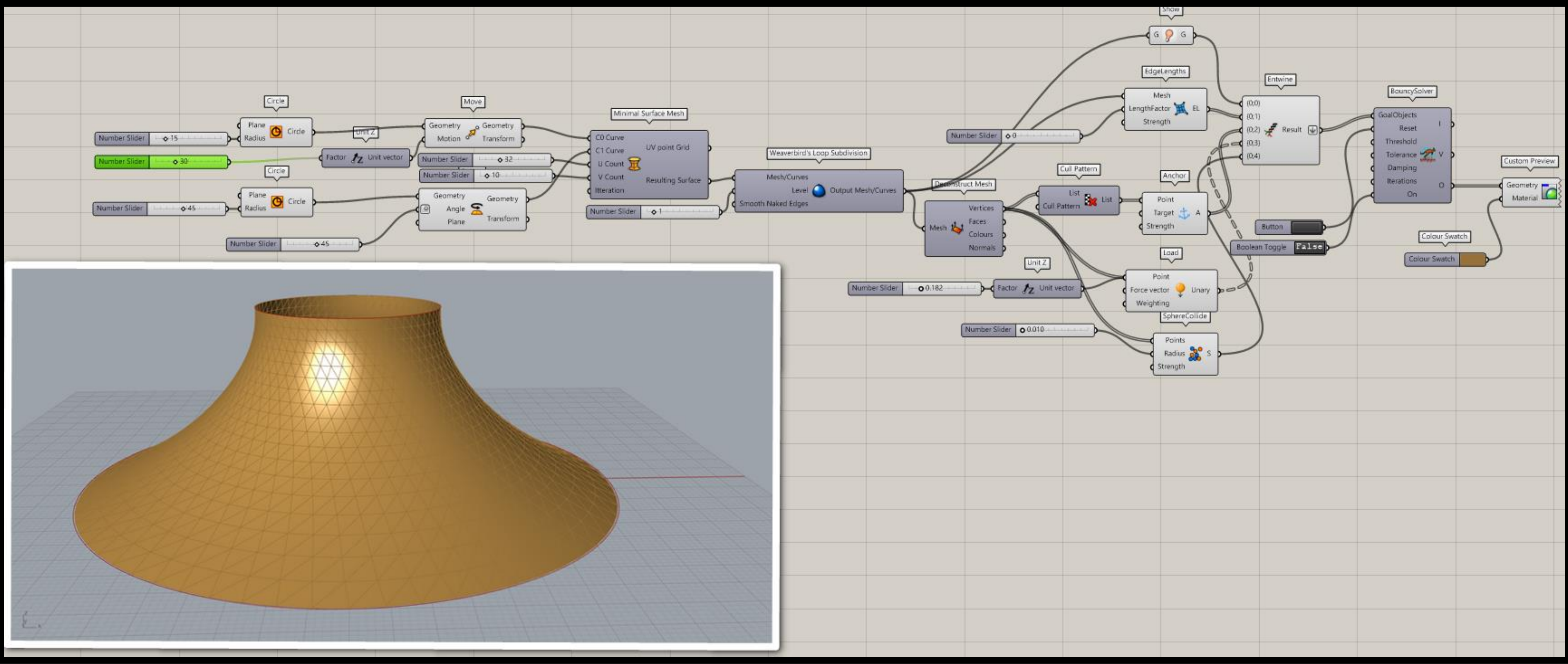
Cable Structures



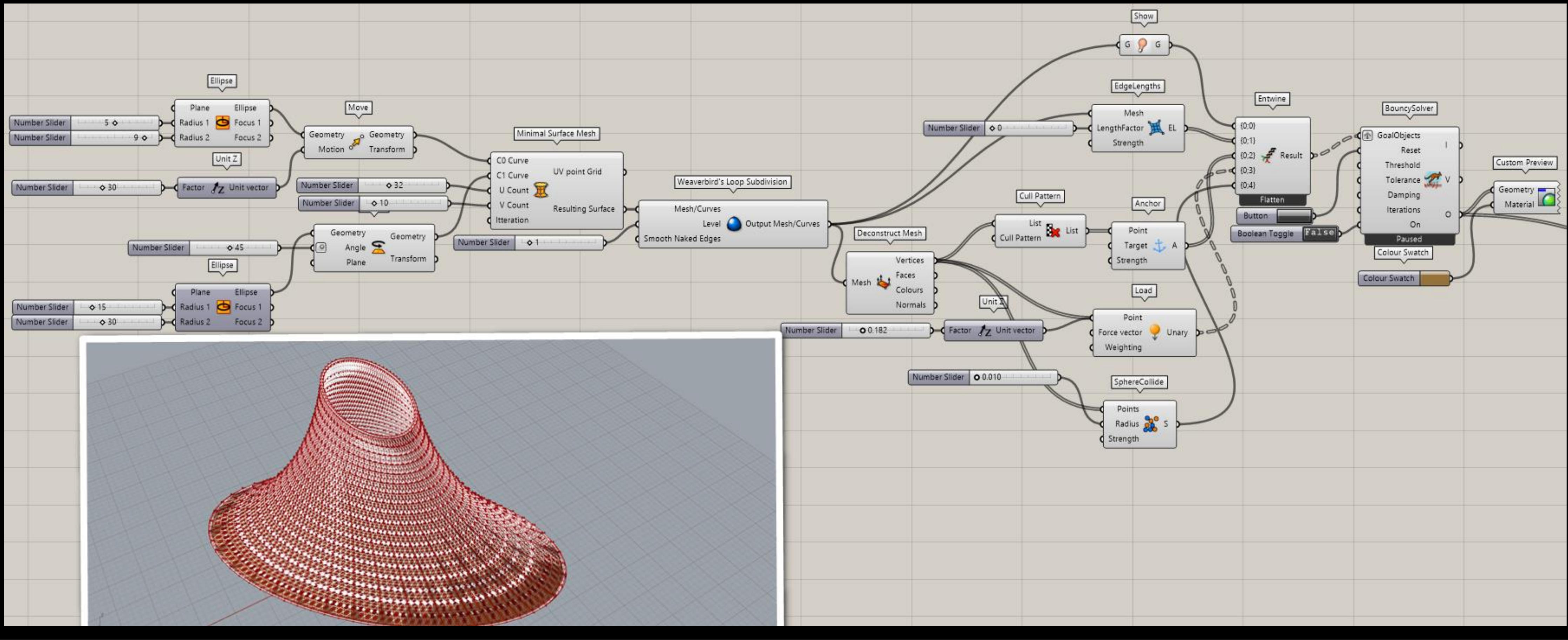
In the case of a conical surface, the boundary conditions of which do not allow the formation of a minimum surface, the imbalance is evident from its unequal curvatures.

At points A and B on one meridian section, r1 is constant and r2 is variable, which means that r1/r2 is not equal to r1/r2.

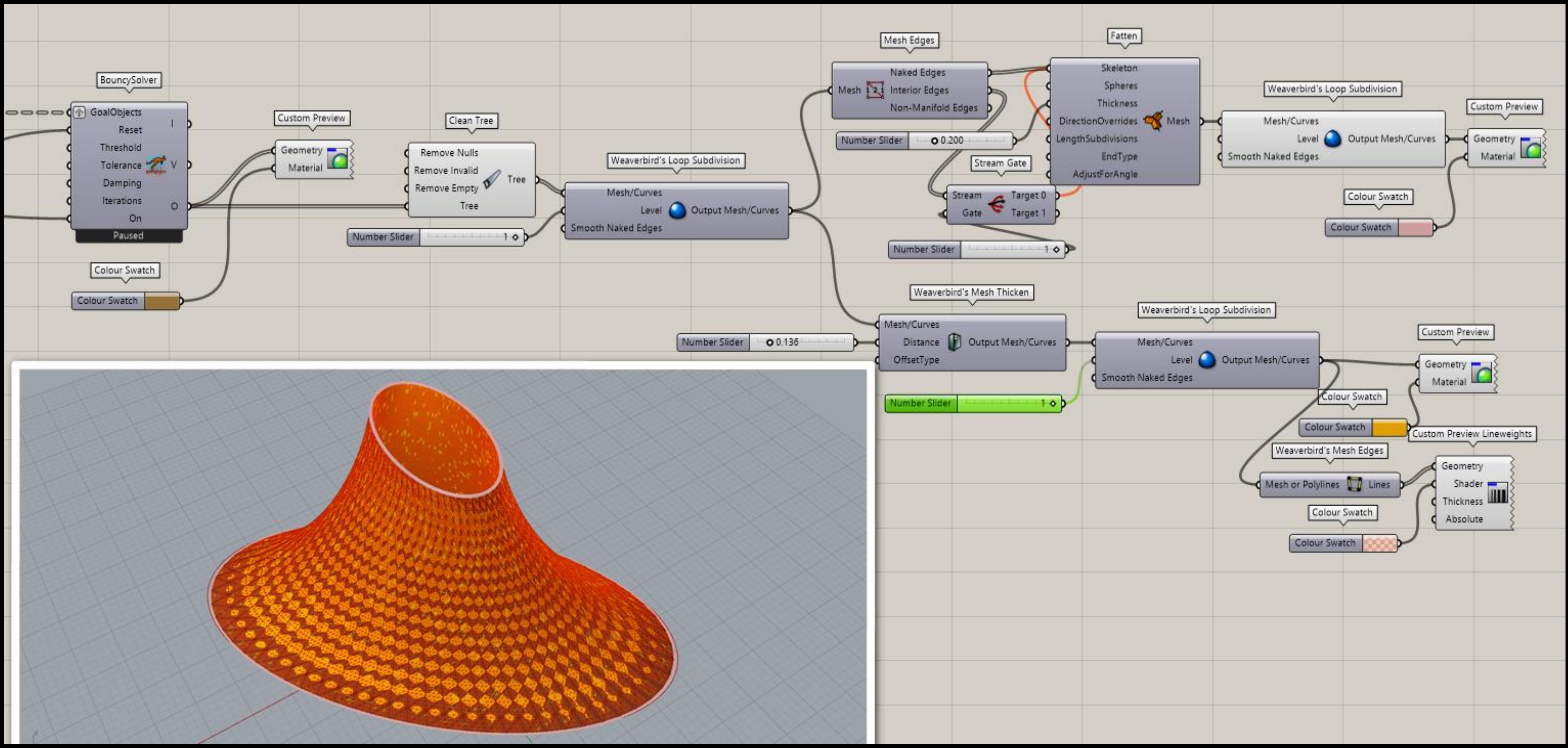
Conical Surface, Paramertic Design



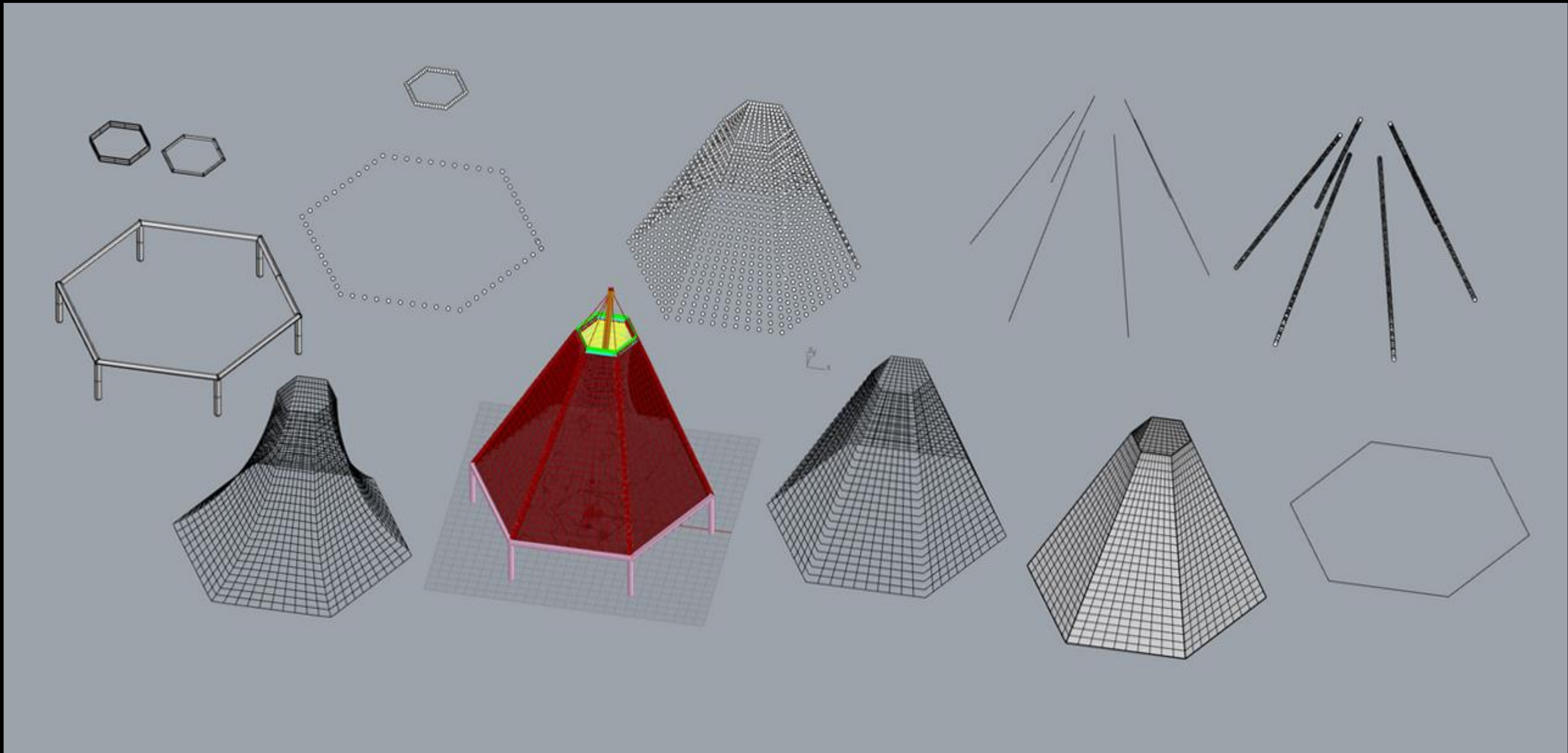
Conical Surface, Parametric Design



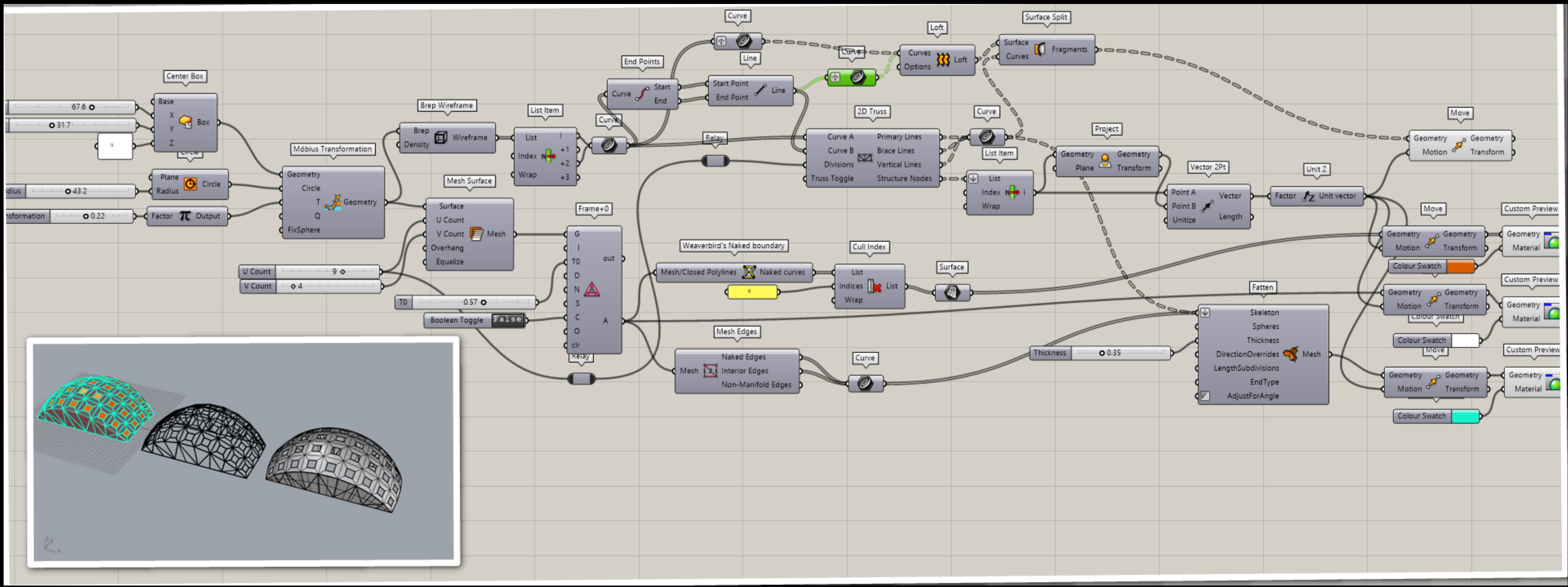
Conical Surface, Parametric Design



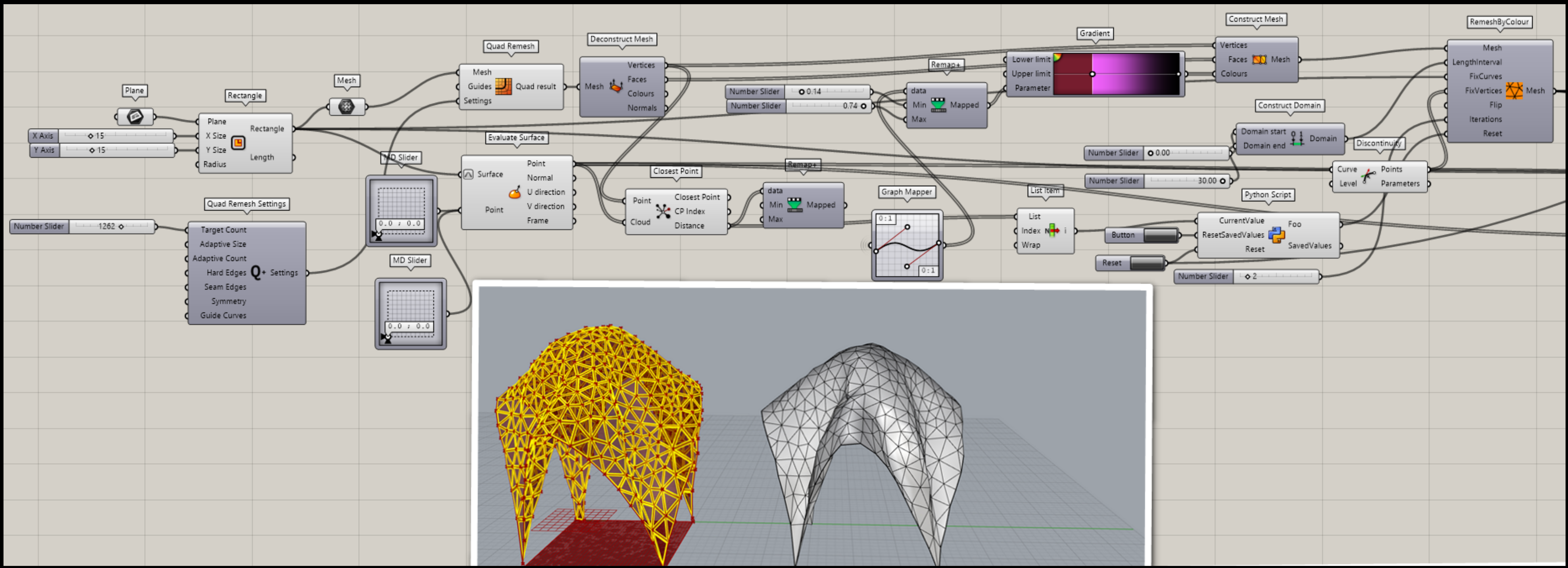
Conic Shape Tensile Structure-Process of Thinking



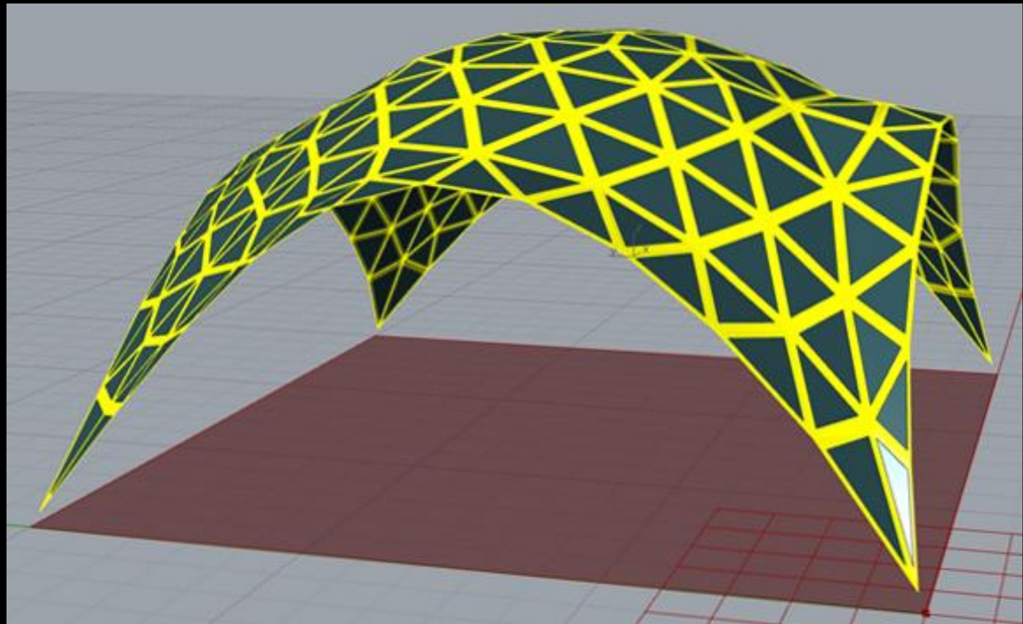
Parametric Synclastic Membrane Structure Grasshopper Algorithim

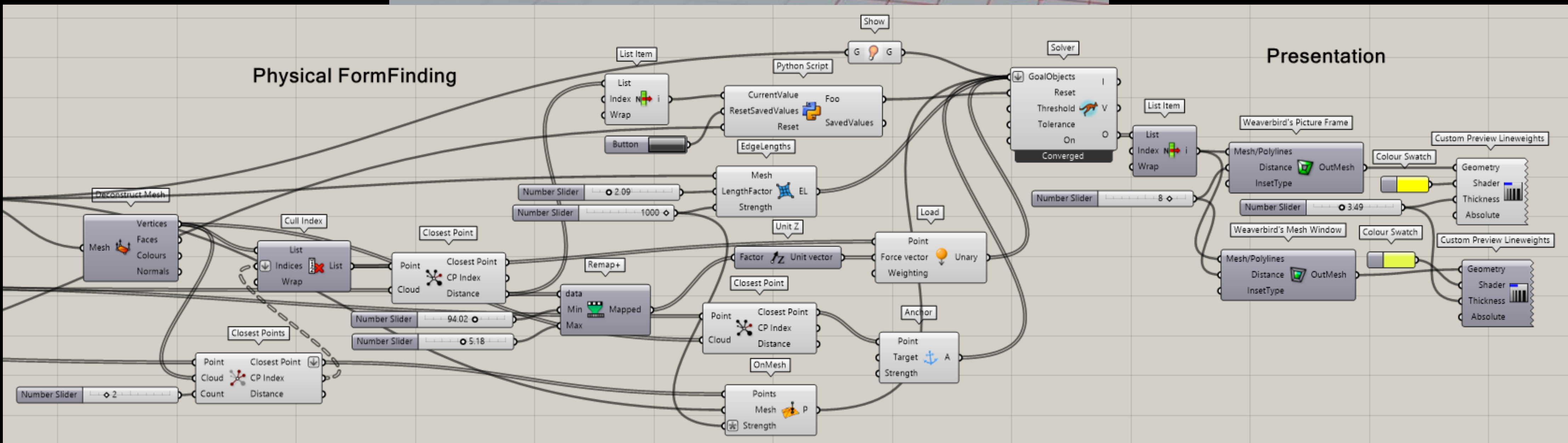


Parametric Membrane Structure Grasshopper Including Kangaroo Algorithm

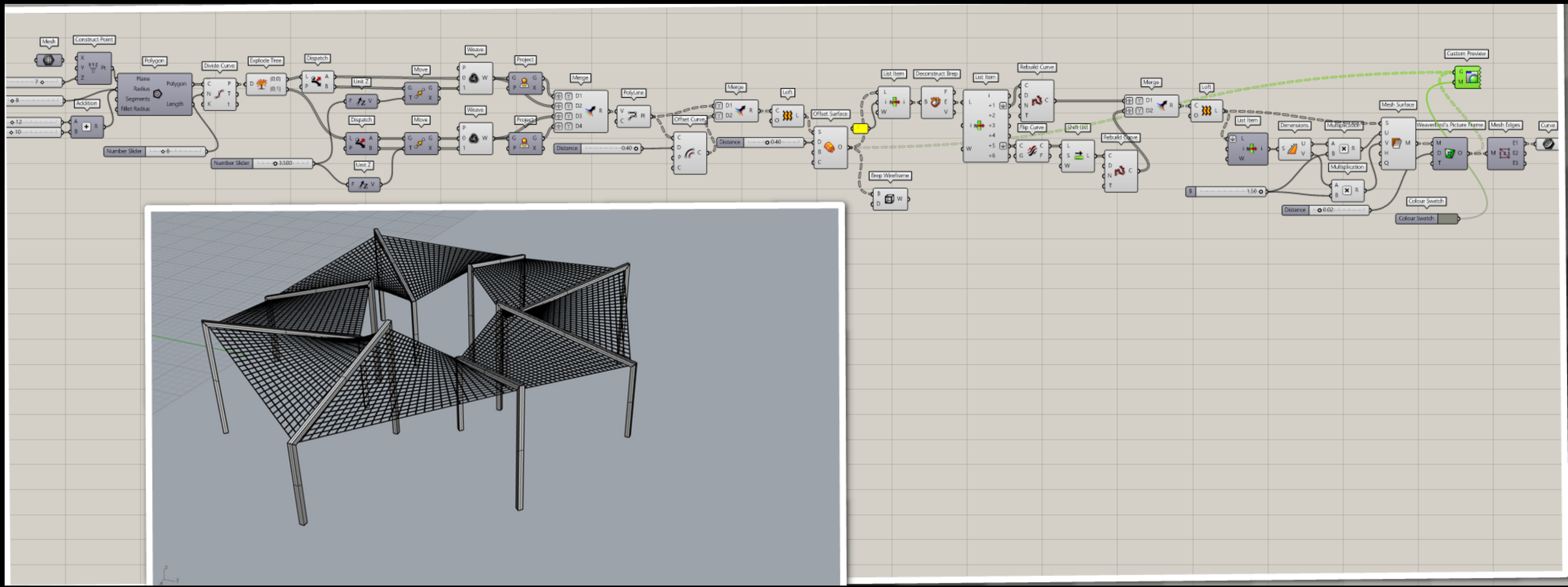


Parametric Membrane Structure Grasshopper Including Kangaroo Algorithim





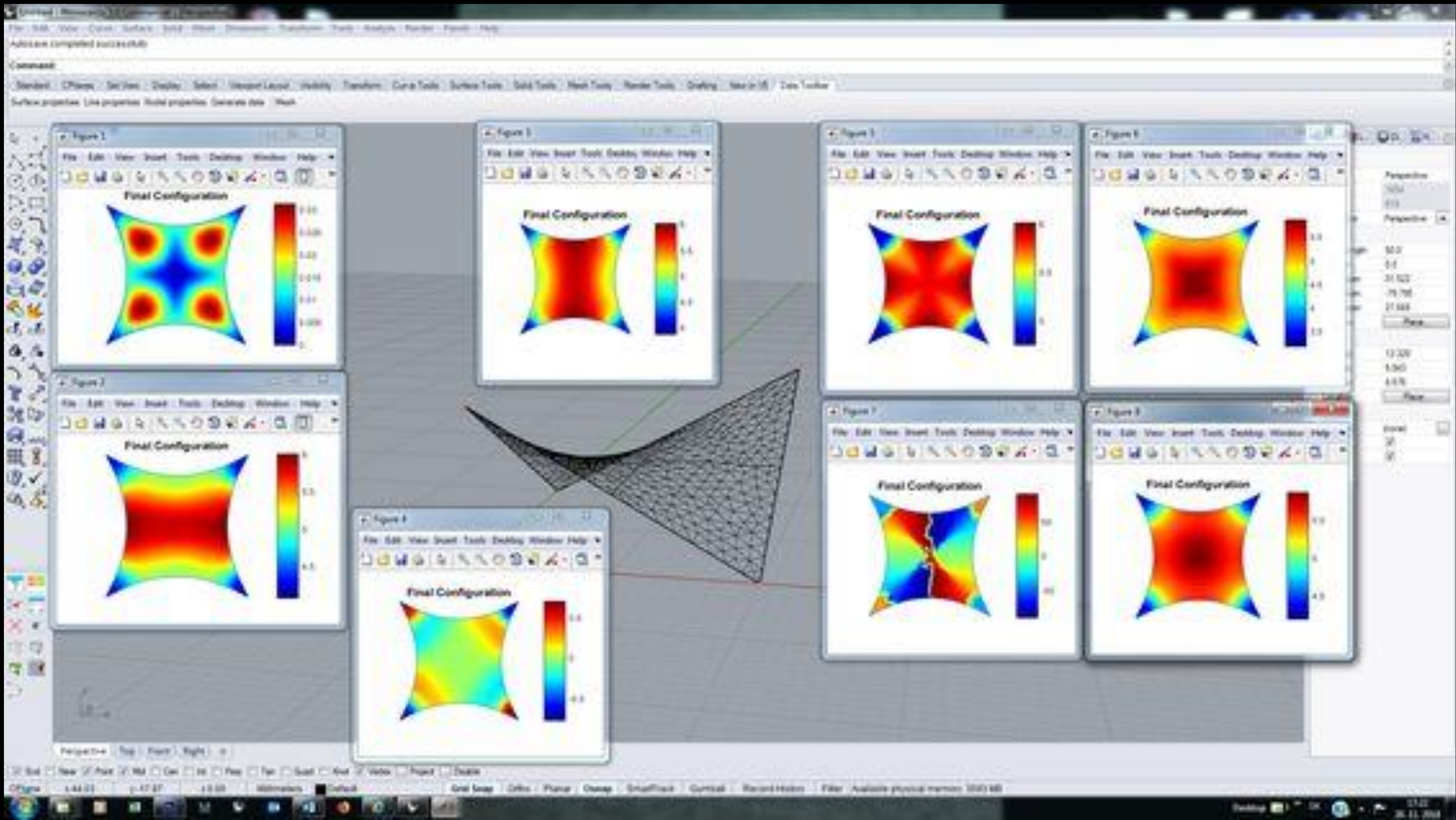
Parametric Hyperbolic Paraboloid Membrane Structure Grasshopper Algorithm



Design Process

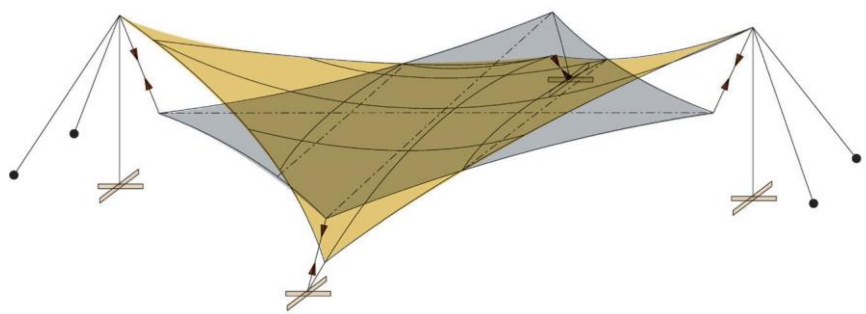
In opposite direction is the right way

In the case of lightweight structures, the state of stress or the magnitude of the deformations, from which the equilibrium geometry is determined, is known in advance (designed by the designer).



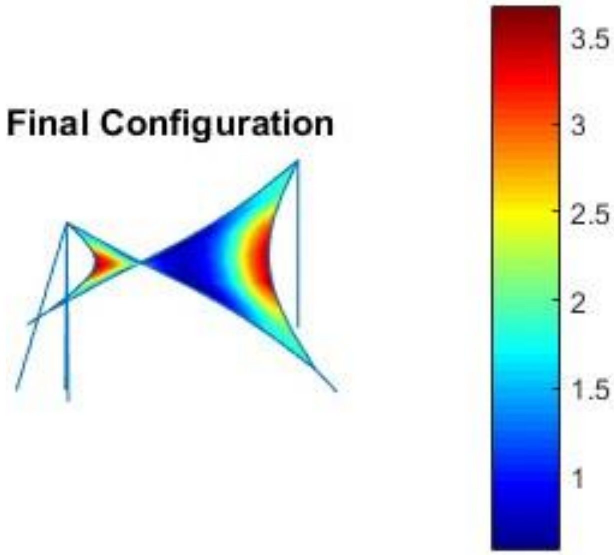
Form finding

Form finding is a process to find the equilibrium state of a cable-membrane structure at a given stress level and with specified boundary conditions.



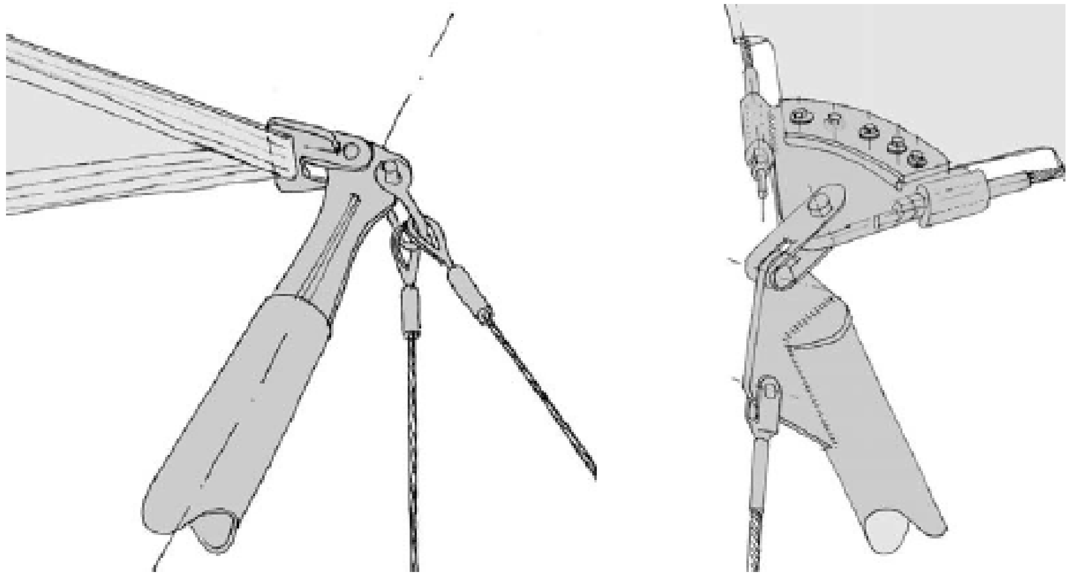
Structural Analysis

Process that determines structural response under given loading and supporting conditions. Stress state and structural displacements are investigated.

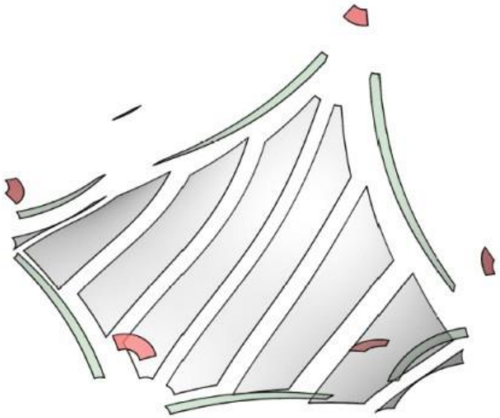


Detailing

Detailing can have significant impact on the global behaviour of the whole structure and therefore have to be realized precisely according to assumptions done in analysis stage.

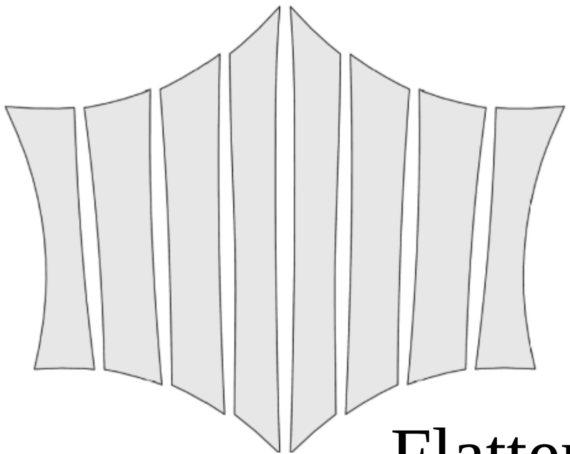


Cutting



Cutting pattern Generation

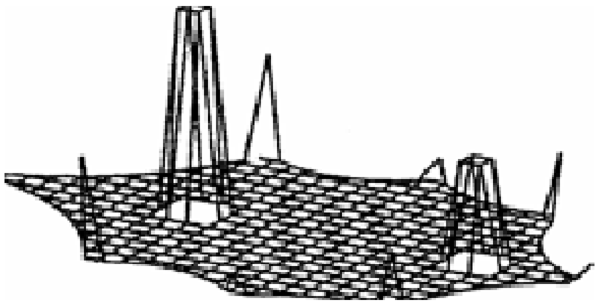
The production plan of cable-membrane structure is called cutting pattern. This step is deals with cutting, developement and compensation of fabric cloths.



Flattening

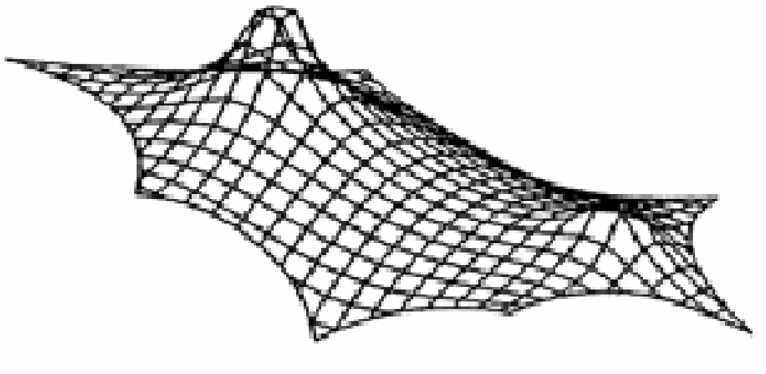
Process of form finding - in a final equilibrium state

Known



Forces

Unknown



Geometry

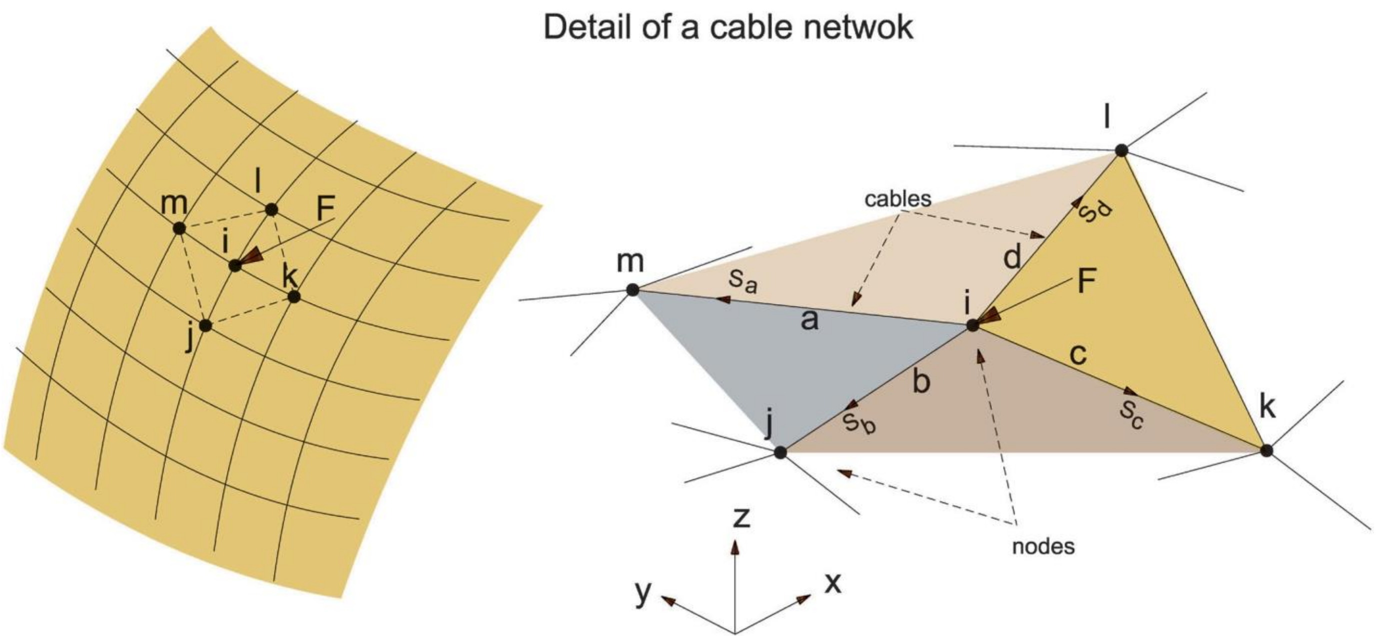
FDM

$$N_{ij}\frac{x_j - x_i}{L_{ij}} + N_{ik}\frac{x_k - x_i}{L_{ik}} + N_{il}\frac{x_l - x_i}{L_{il}} + N_{im}\frac{x_m - x_i}{L_{im}} + F_{xi} = 0$$

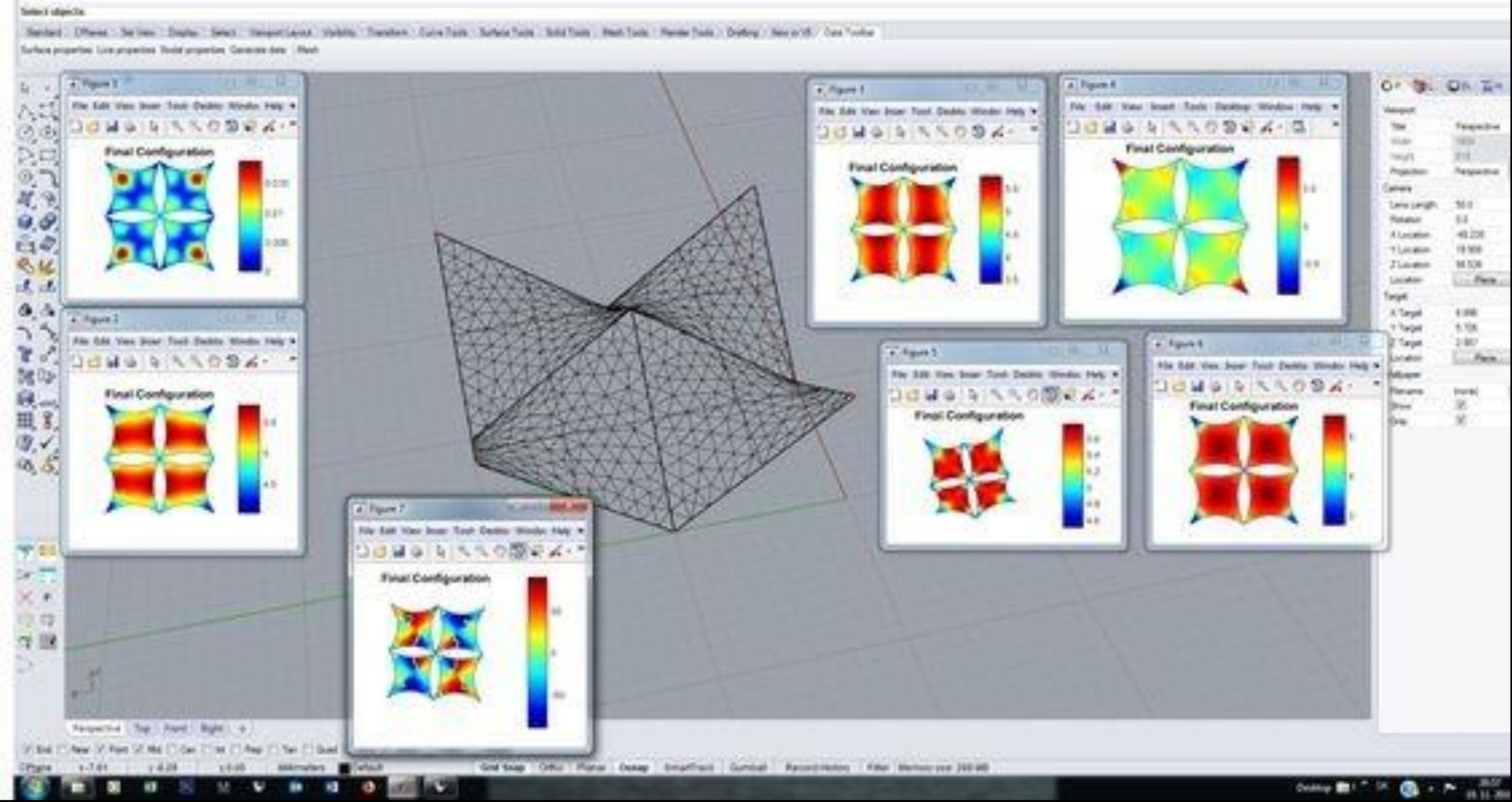
$$N_{ij}\frac{y_j - y_i}{L_{ij}} + N_{ik}\frac{y_k - y_i}{L_{ik}} + N_{il}\frac{y_l - y_i}{L_{il}} + N_{im}\frac{y_m - y_i}{L_{im}} + F_{yi} = 0$$

$$N_{ij}\frac{z_j - z_i}{L_{ij}} + N_{ik}\frac{z_k - z_i}{L_{ik}} + N_{il}\frac{z_l - z_i}{L_{il}} + N_{im}\frac{z_m - z_i}{L_{im}} + F_{zi} = 0$$

Process of form finding - in a final equilibrium state

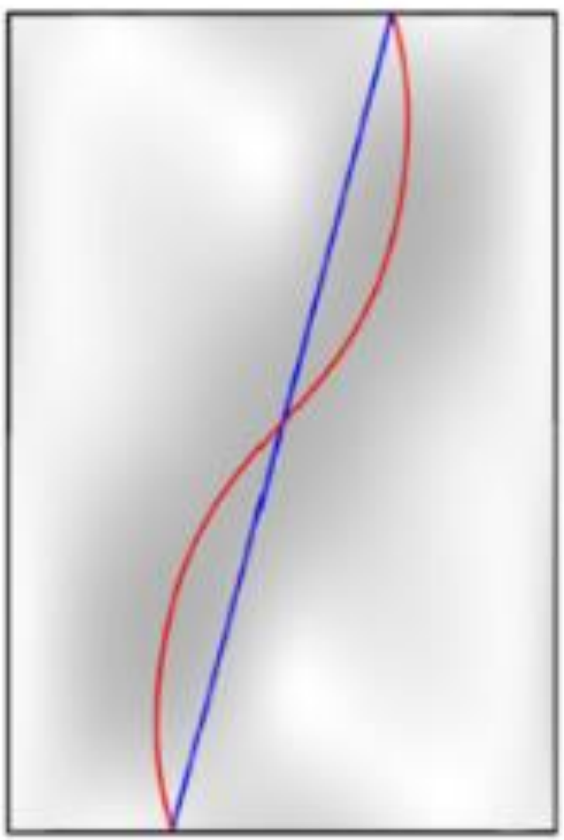


Analysis



Keep the structure in admissible tensile stress state under every load combination and preserve the reaction forces as small as possible.

Surface cutting

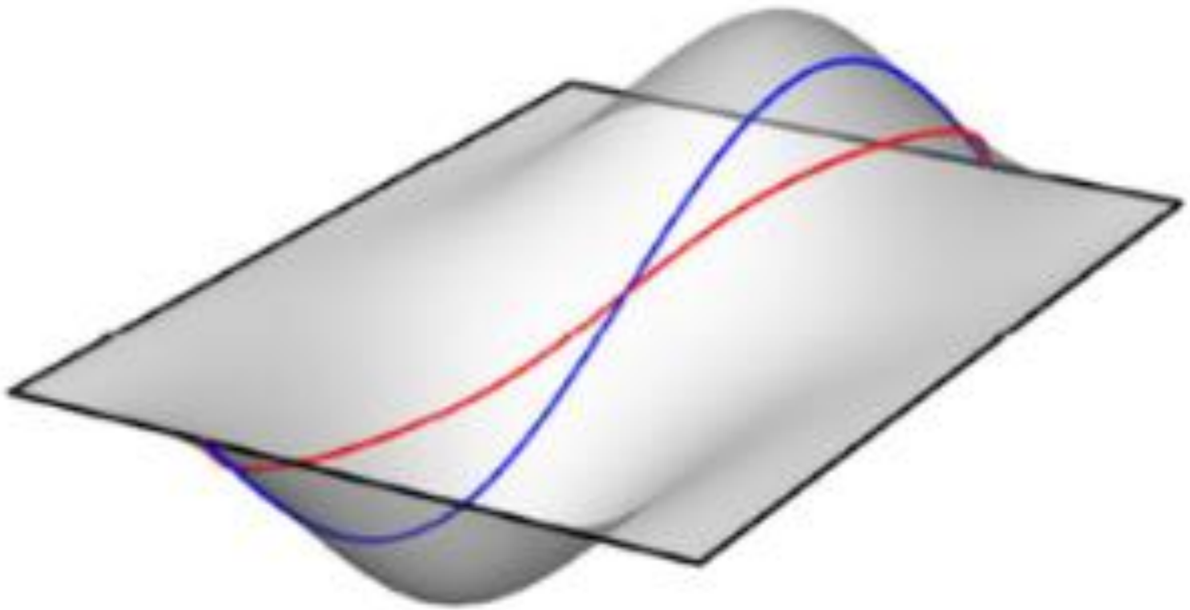


VERTICAL CUT

VS.

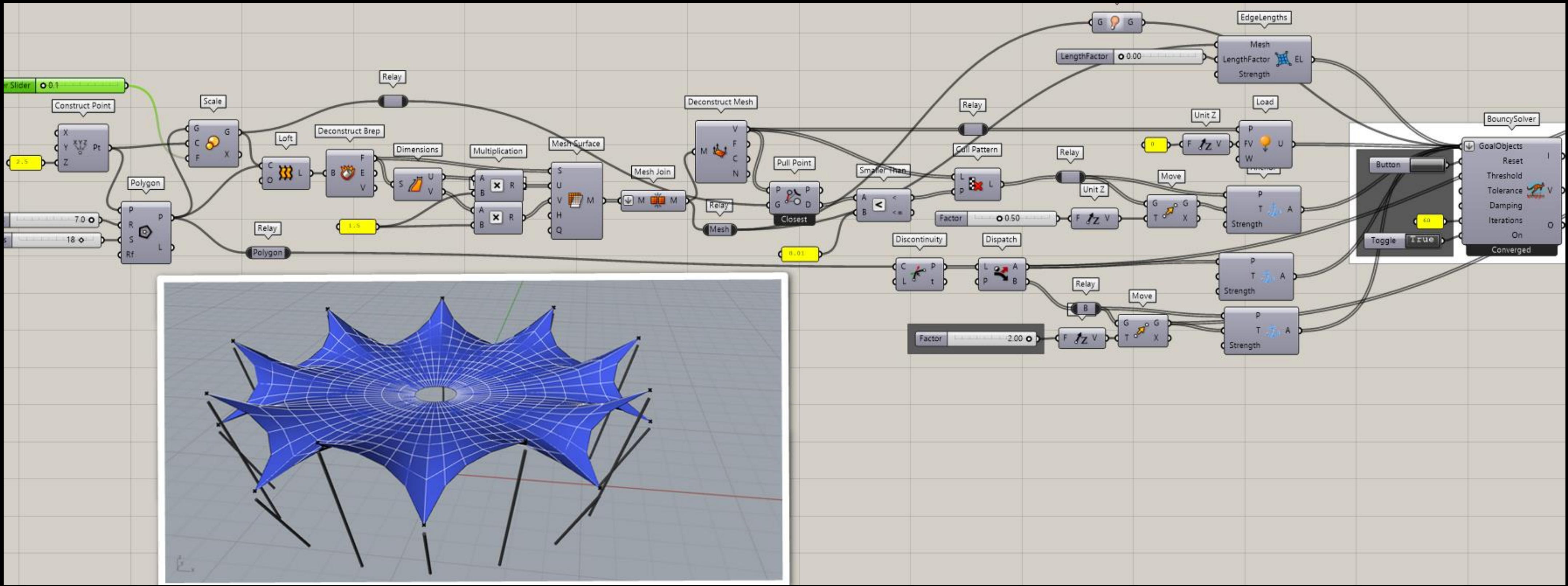
GEODESIC LINE

Which line is shorter ?

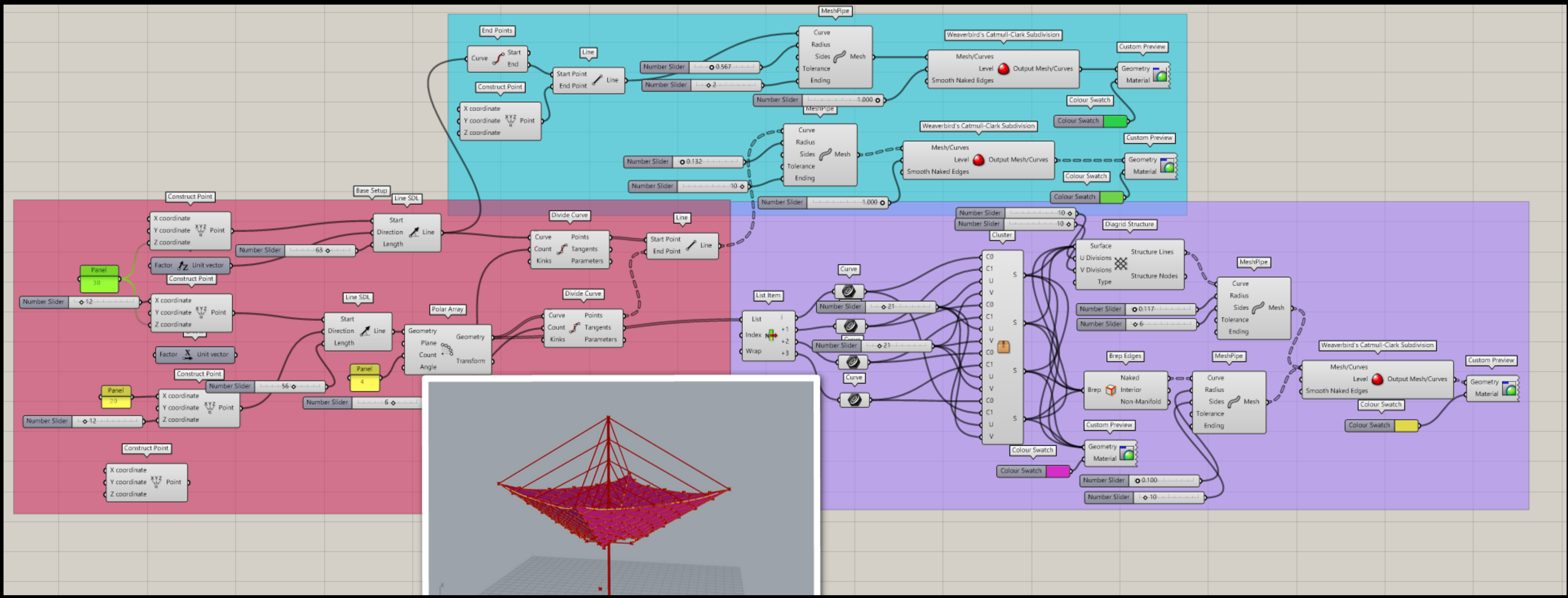


Red one !

Parametric Radial Tensile Structure



Parametric Cable Net Membrane Structure



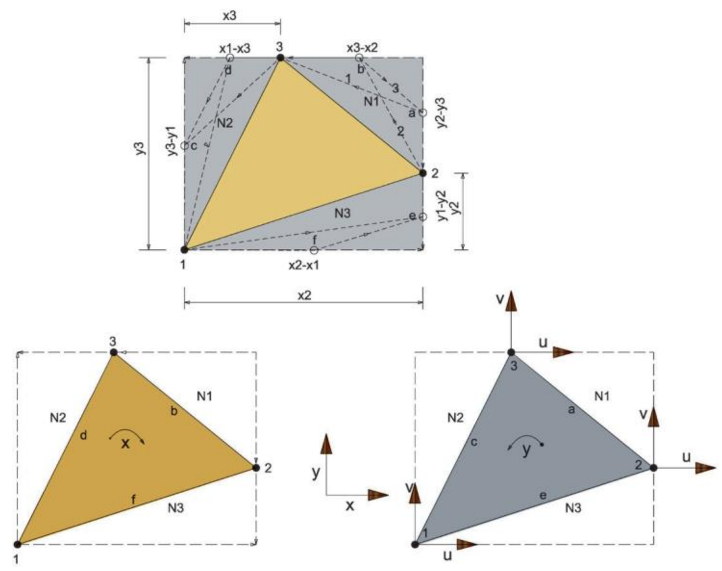
CONCLUSION

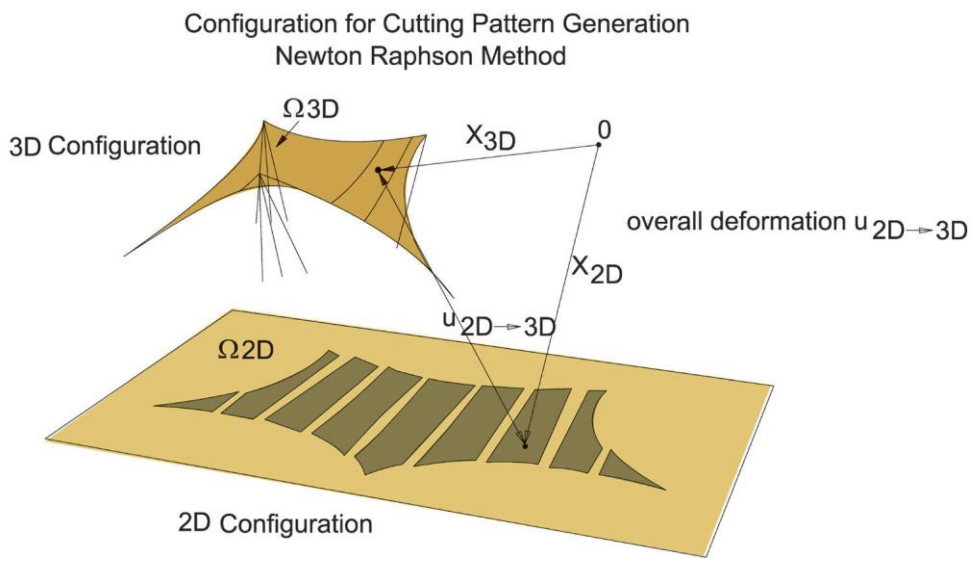
repetito est mater sapientia

Tensile Structures

Prestress tendon

Membrane





Combination

Design Process

Physical Models

1. Model
2. Measure
3. Build

Numerical Methods

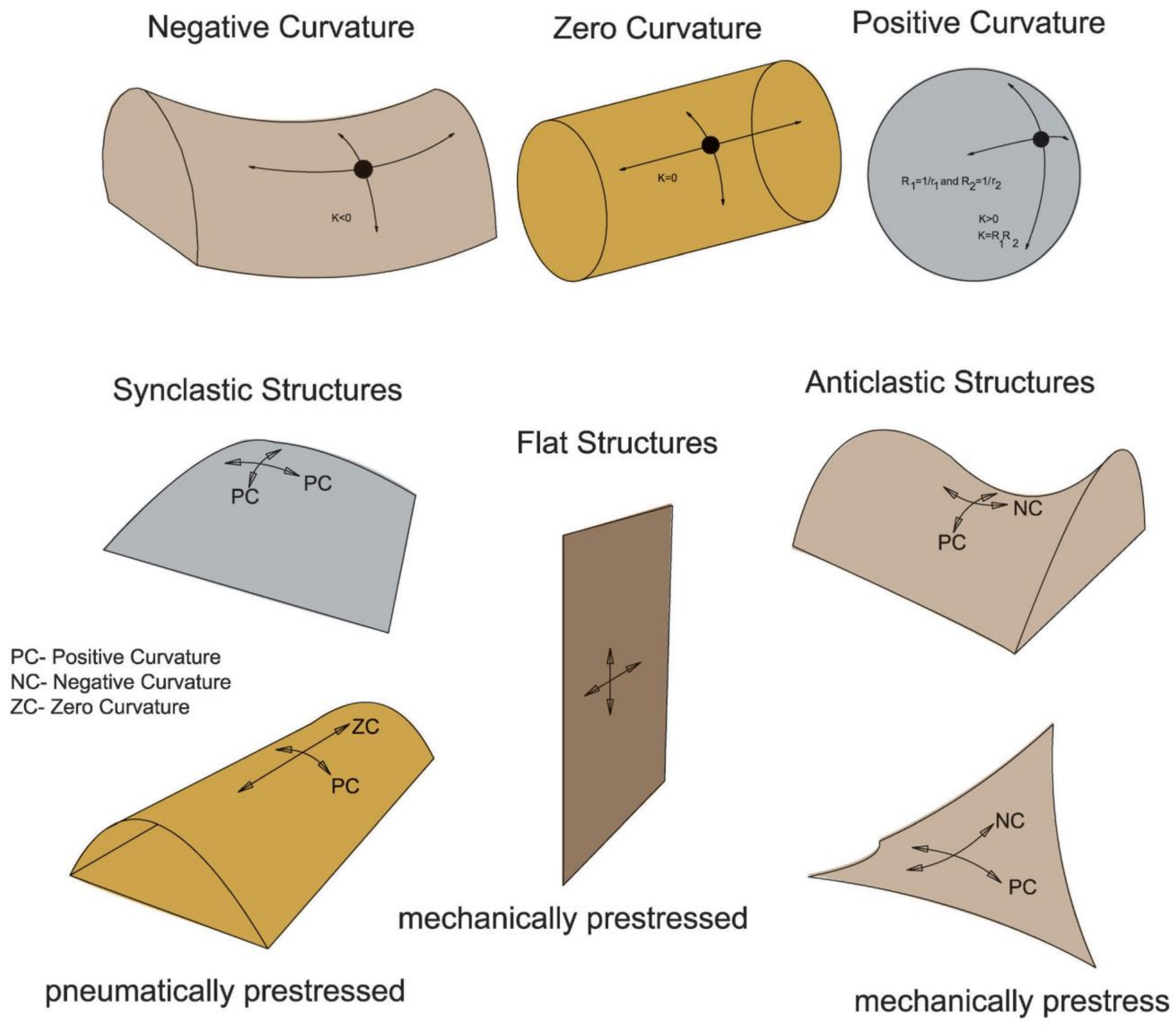
Form Finding

Analyze

Details

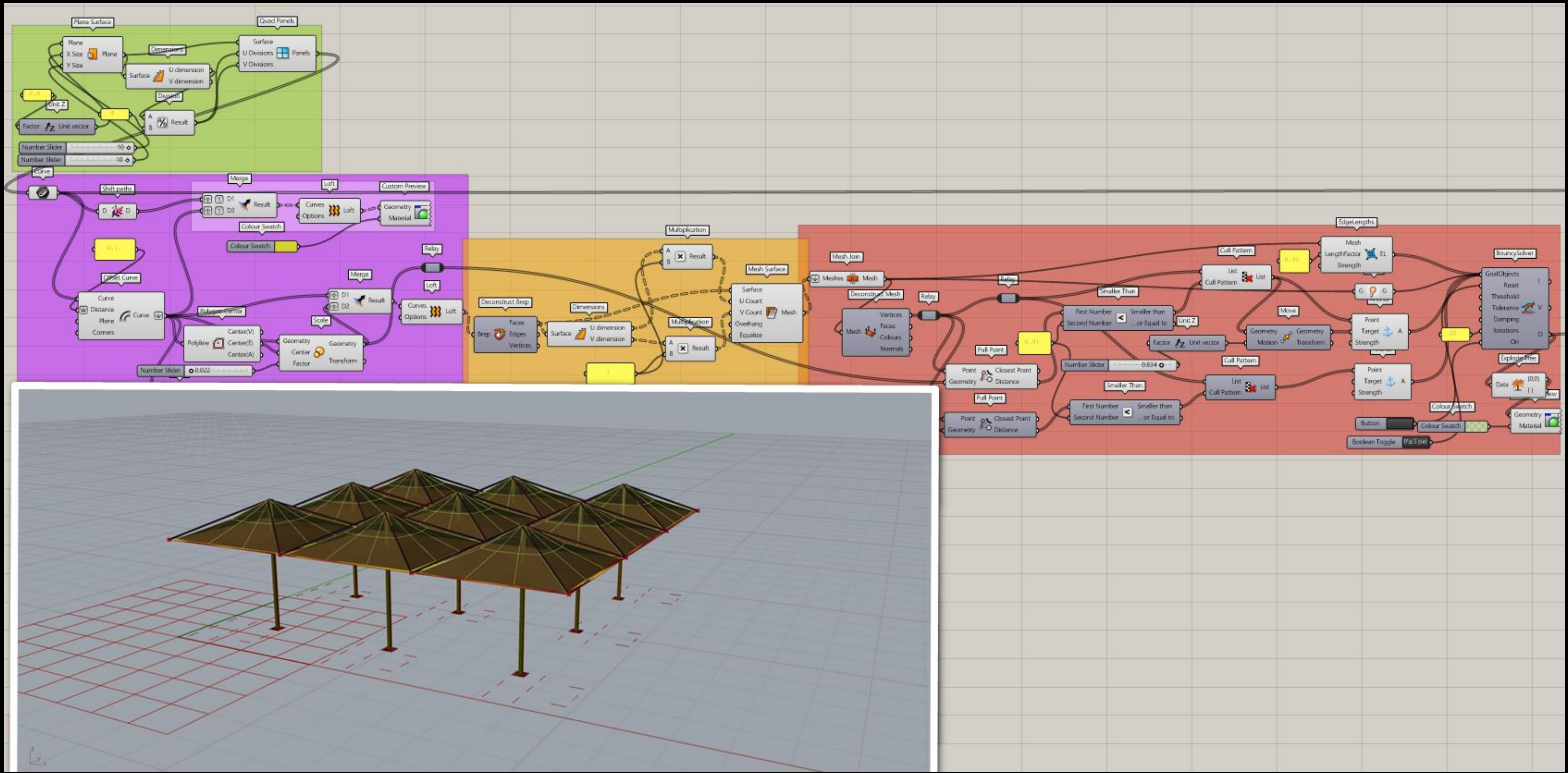
Pattern- Cut-Flatten-Compensate

Typical shapes of Membrane Structures

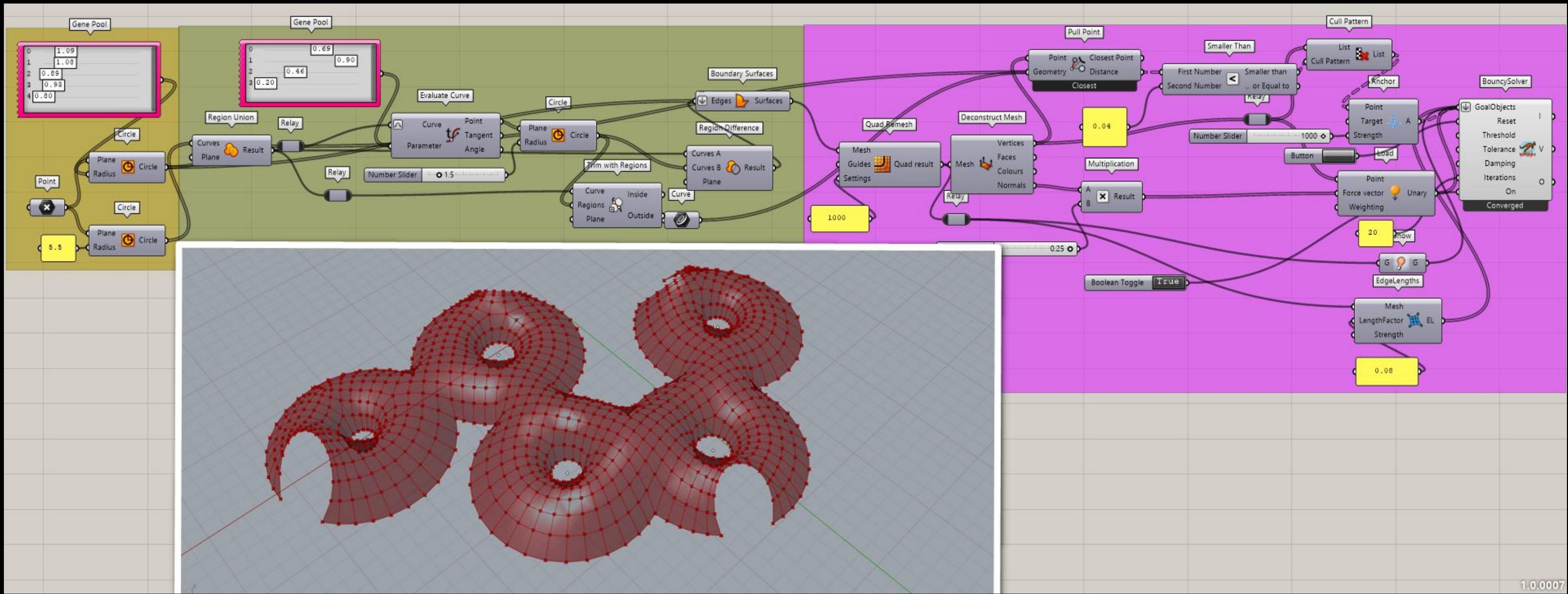


Typical shapes of membrane structures

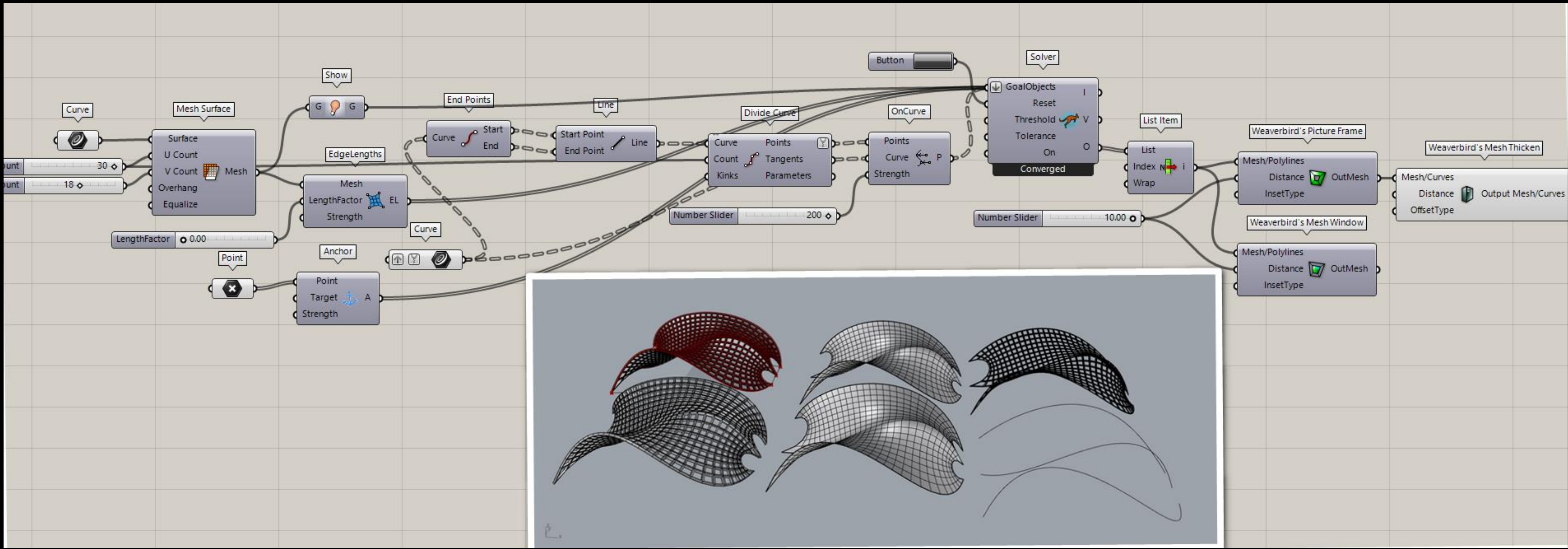
Parametric Design- Tensile Structures



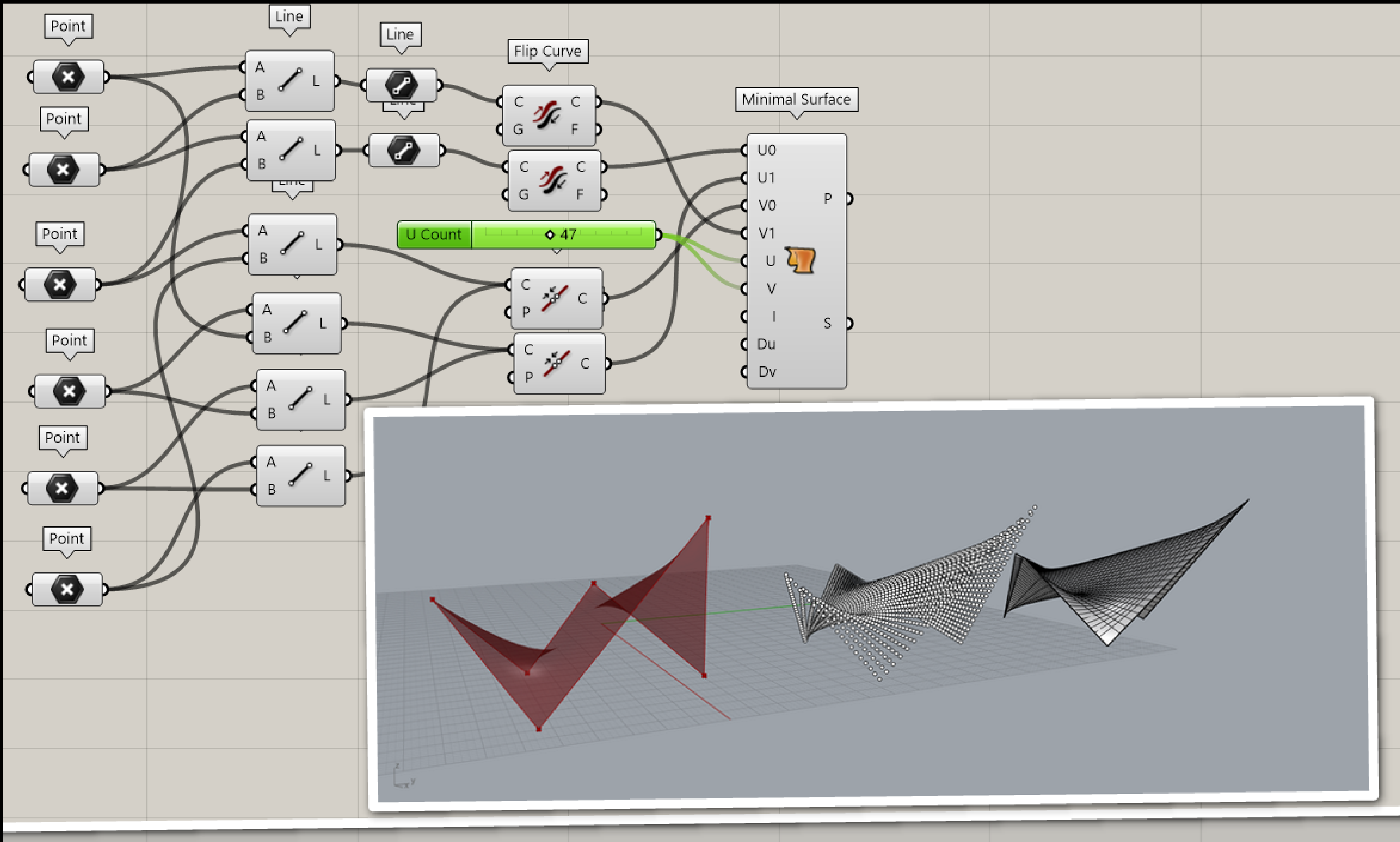
Parametric Design- Tensile Structures



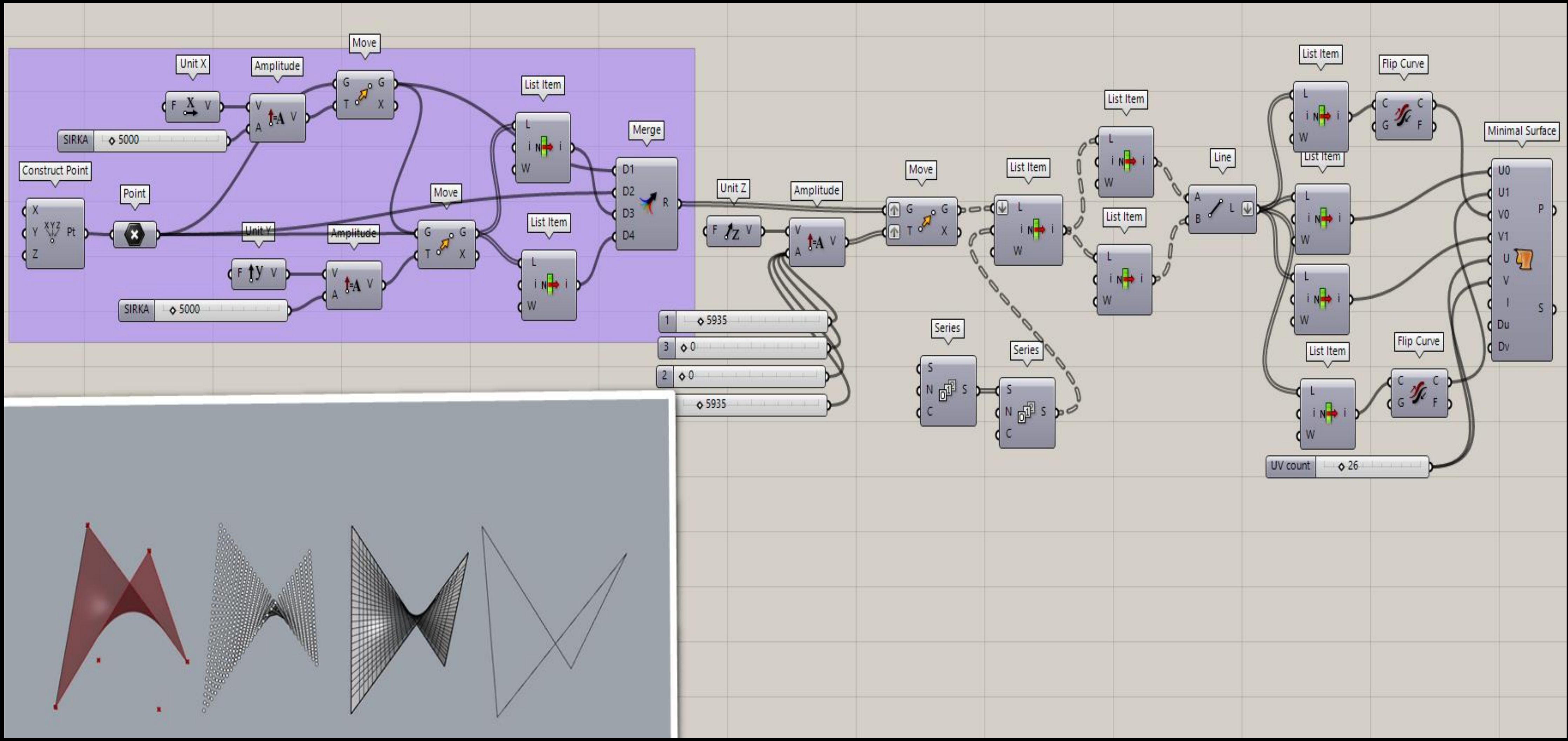
Non form-found- Flow Chart of Grasshopper Tensile Structure



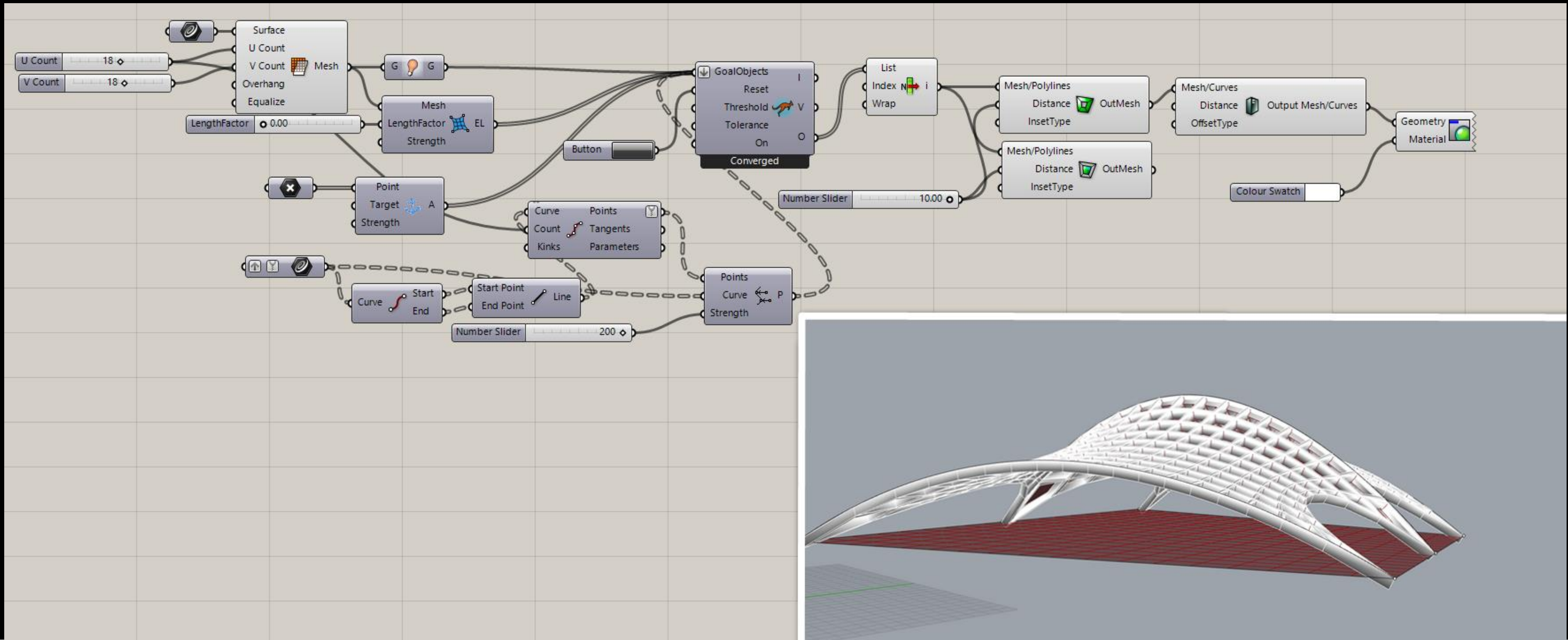
Anticlastic Geometry - Flow Chart of Grasshopper



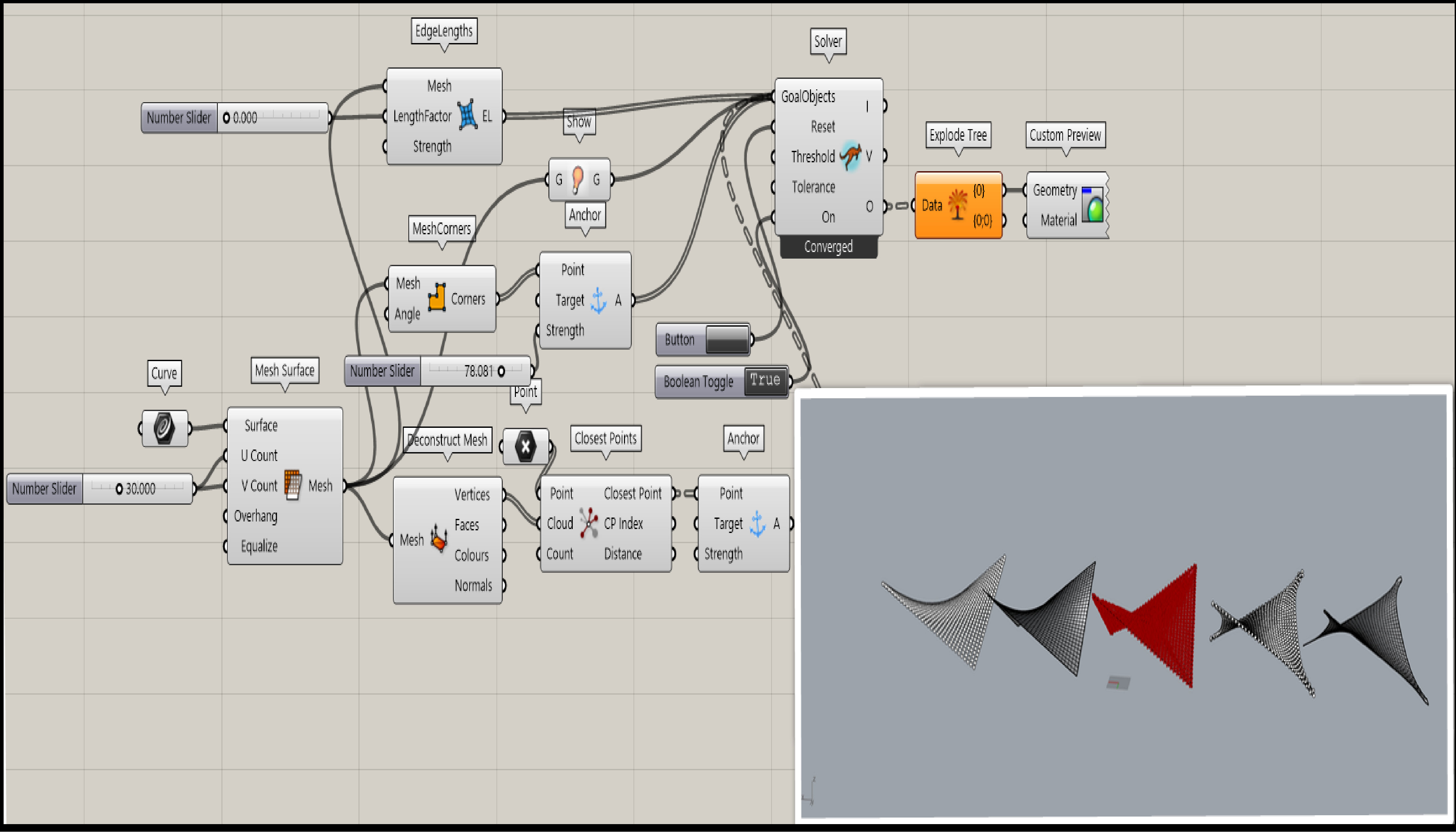
Tensile Structure - Flow Chart of Grasshopper



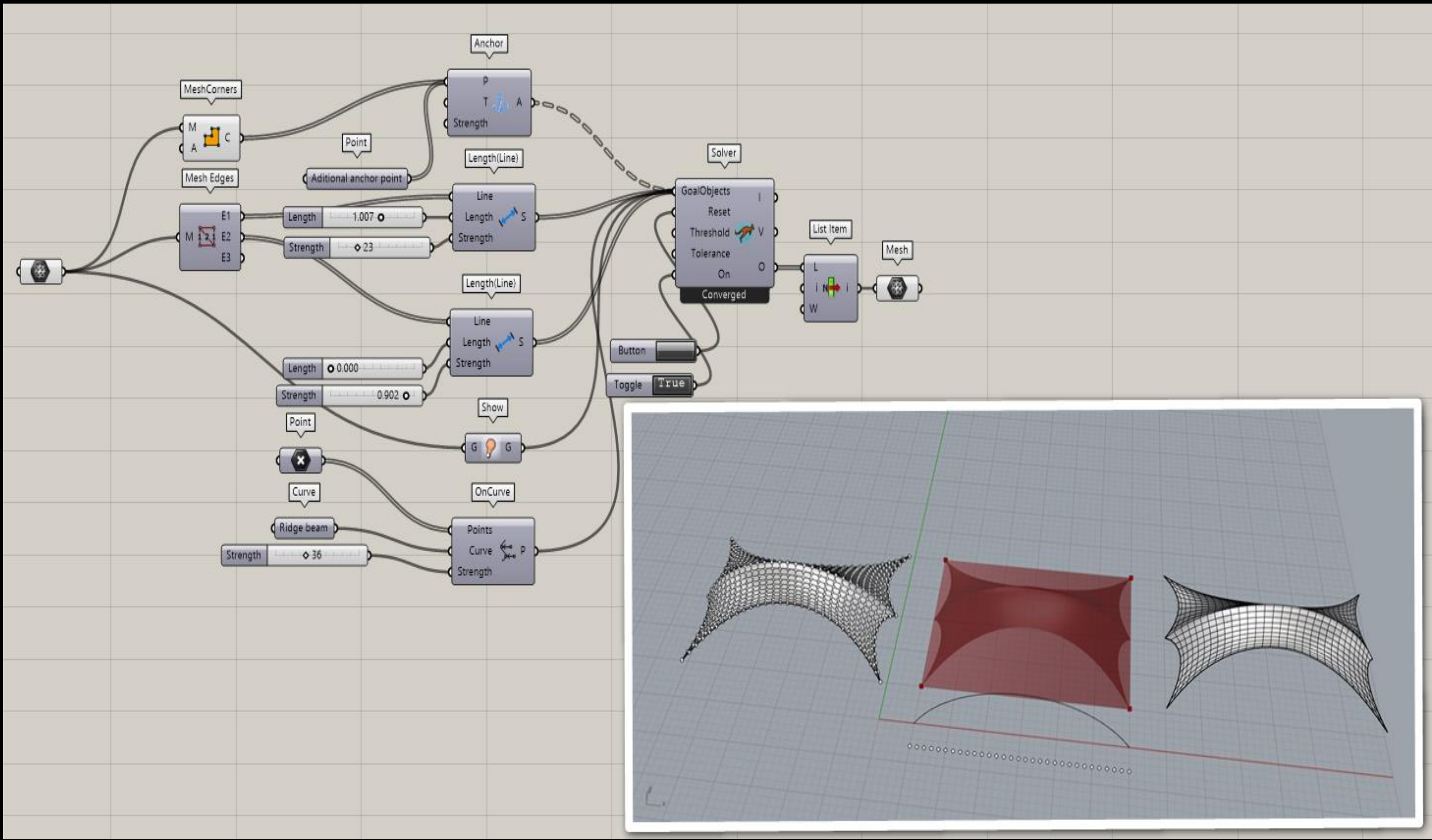
Non form-found- Flow Chart of Grasshopper Tensile Structure



Anticlastic Geometry - Flow Chart of Grasshopper



Non form-found- Flow Chart of Grasshopper Tensile Structure



As we know from mathematical diagrams, the hyperbolic paraboloid is a ruled surface, which means that we can create it using only straight lines even though it is curved. On the image bellow shows our model of a hyperbolic paraboloid made of forty straight 100cm long wood elements. First, we created an equilateral triangle using three elements of our straight timbers. Then we used this triangle as a template to form two skewers into a 60-degree angle, completing 2/3 of another equilateral triangle.

Connecting the first triangle by one skewer to the second triangle, created together a regular tetrahedron shape. Further, we marked the edges of the tetrahedron in regular 5 cm intervals to connect the skewers between the marks. Then we connected a skewer to the first marks on each of the edges. In another step, we created another layer of skewers so that they would overlap. We kept connecting skewers by moving one interval mark on each edge. The overlap got greater each time. To reach the goal we had to use two of the other edges to form the other ruling lines.

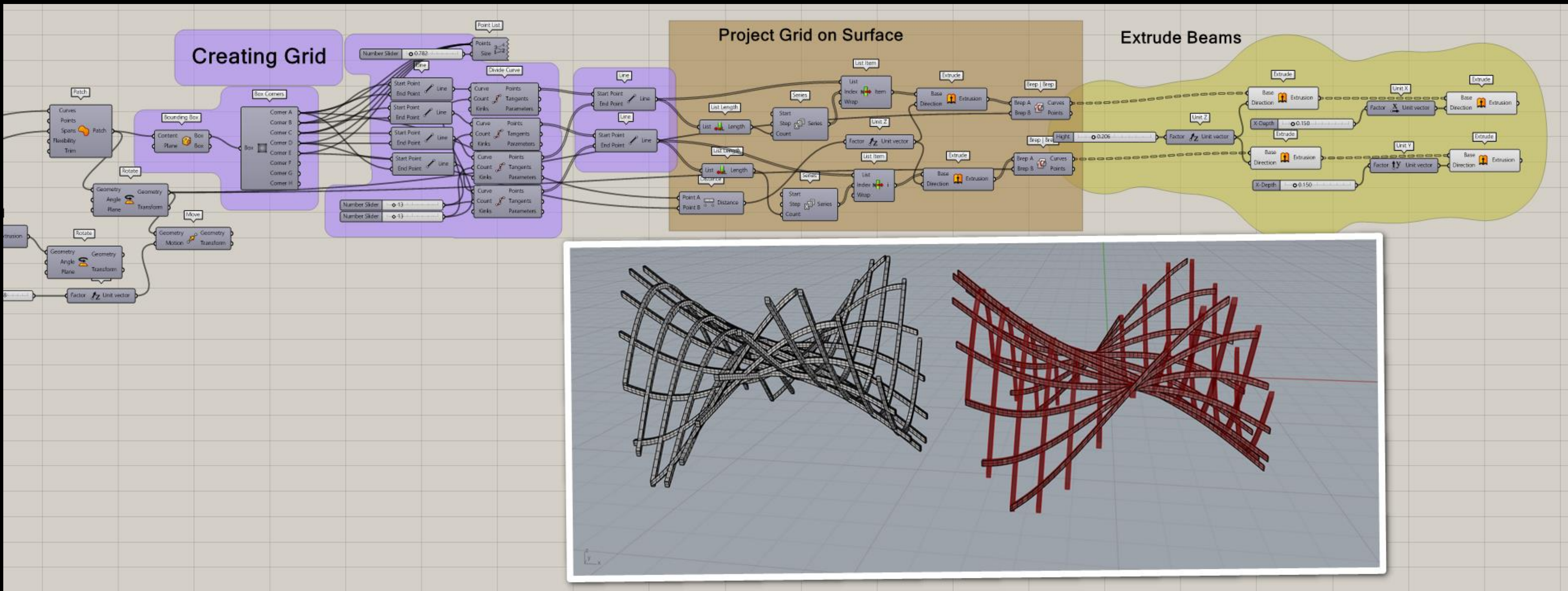
Hyperbolic Paraboloid Model
(Shawkat)

Hyperbolic Paraboloid Model

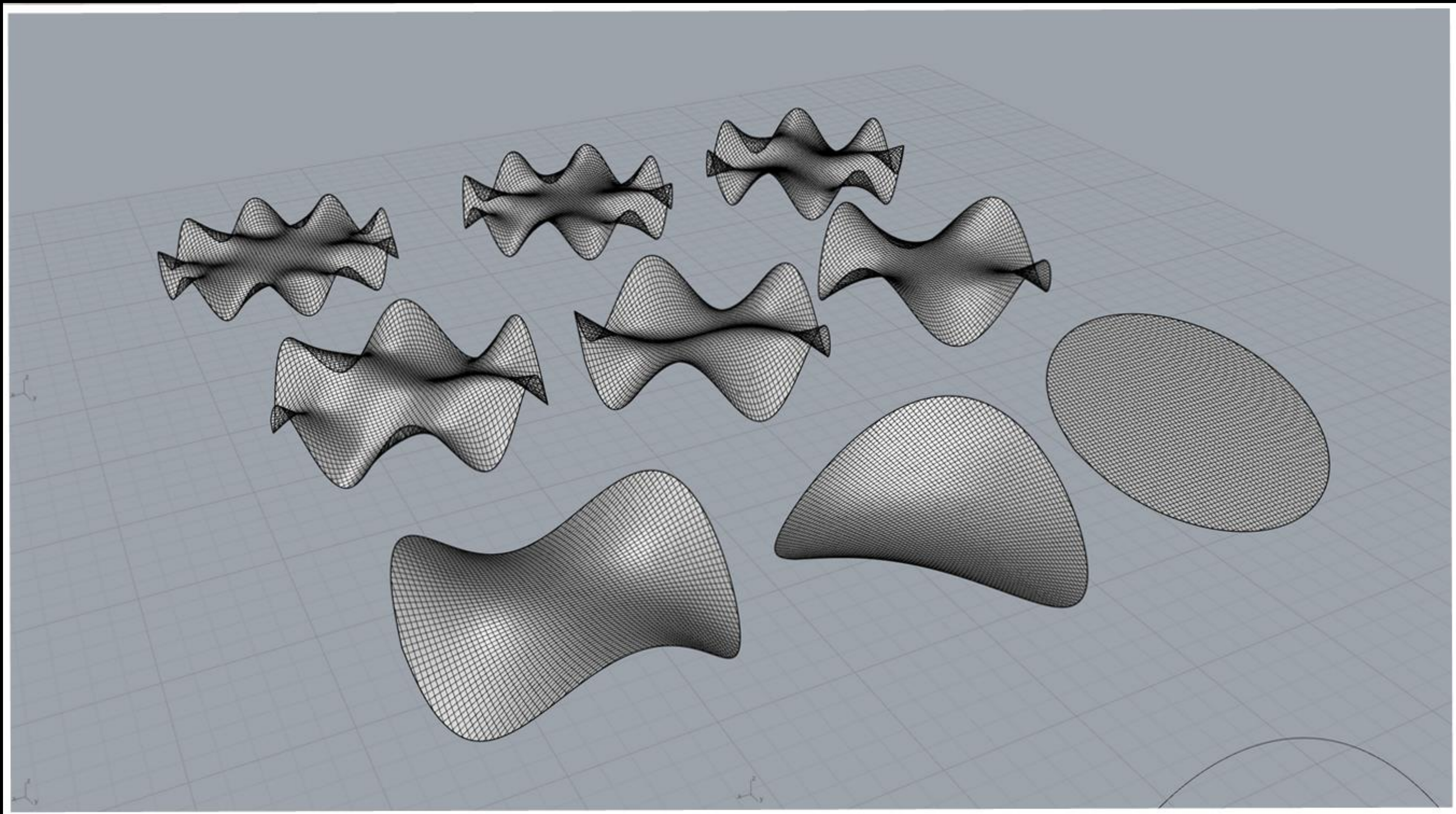
They produce aesthetic shapes, then shape governs the load-bearing capacity of the structure.

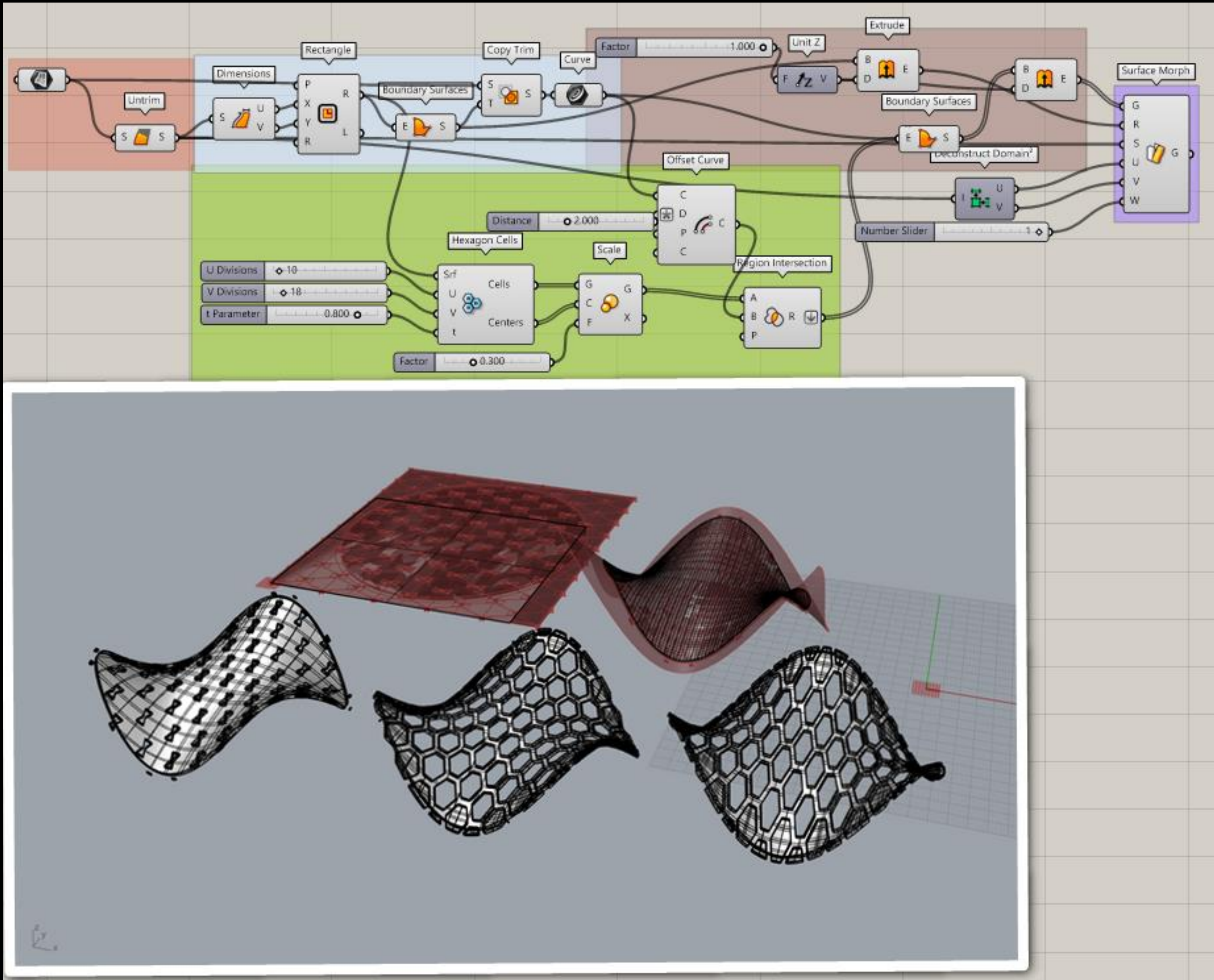
Anticlastic:

whose curvature has the opposite character, in case their size is the same, we are talking about the minimum area.

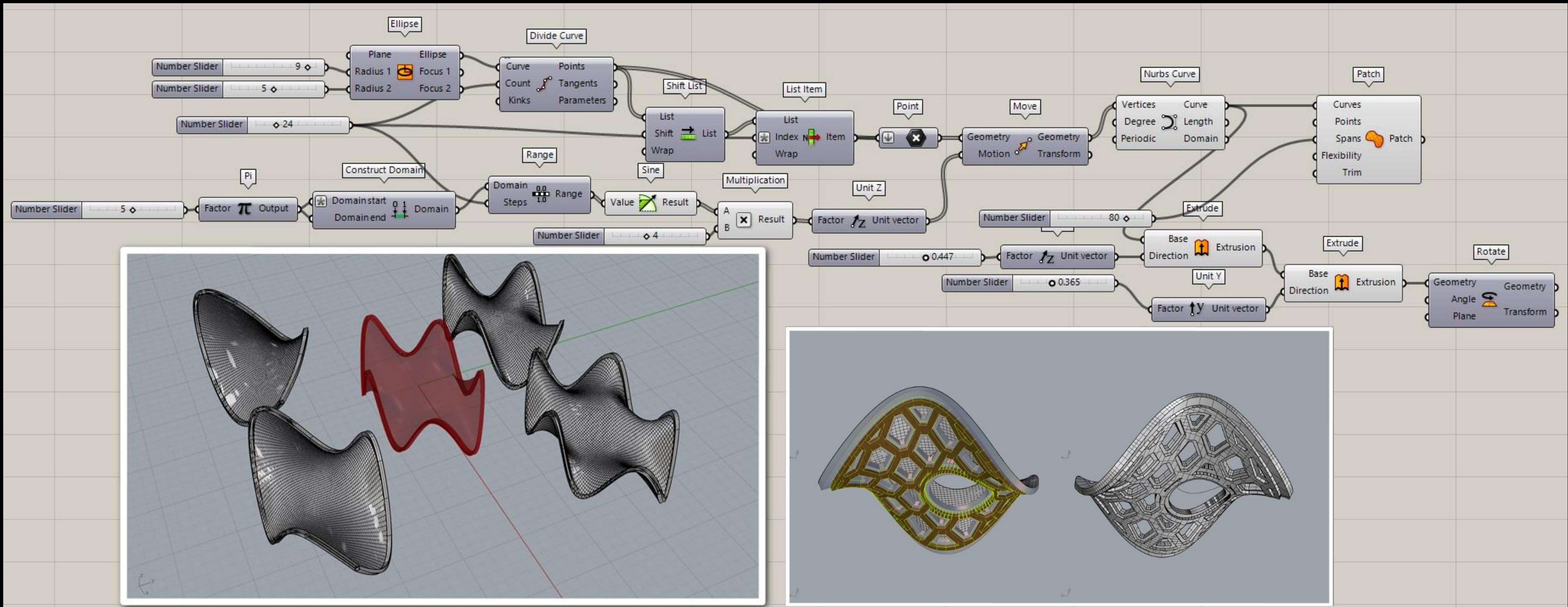

Creating Grid
Project Grid on Surface
Extrude Beams

Parametrising the Circle by increasing the Number of Π




Rectangle
Dimensions
Untrim
Boundary Surfaces
Copy Trim
Curve
Factor
1.000
Unit Z
Extrude
Boundary Surfaces
Surface Morph
Deconstruct Domain²
Offset Curve
Distance
2.000
Hexagon Cells
Scale
Region Intersection
U Divisions
10
V Divisions
18
t Parameter
0.800
Factor
0.300
Number Slider
1
Cells
Centers

Parametrising the Elipse by increasing the Number of Π



“Bending-active structures are **structural systems that include curved beam or shell elements that base their geometry on the elastic deformation from an initially straight or planar configuration**.”

Form-finding and Performance of Bending-Active Structures

The process of designing the shape of membrane and shell structures is referred to as the form finding process.

It is an iterative process in which the designer adjusts the boundary conditions - the geometry of the supports, the external load, the tension of the structure based on the suitability or unsuitability of the equilibrium state that arises between the given boundary conditions.

Light grid structures are particularly suitable for application where large span and low weight are required. This makes them potential candidates for architecture purposes.

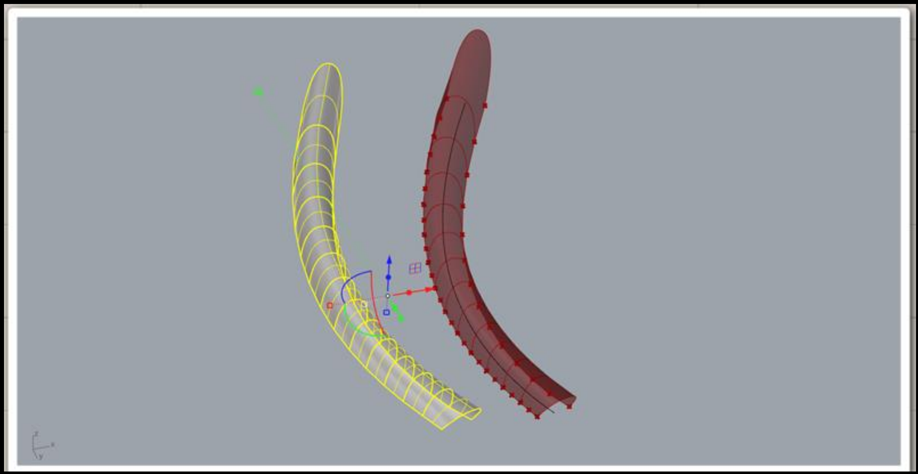
They can be built quickly and with a small budget.

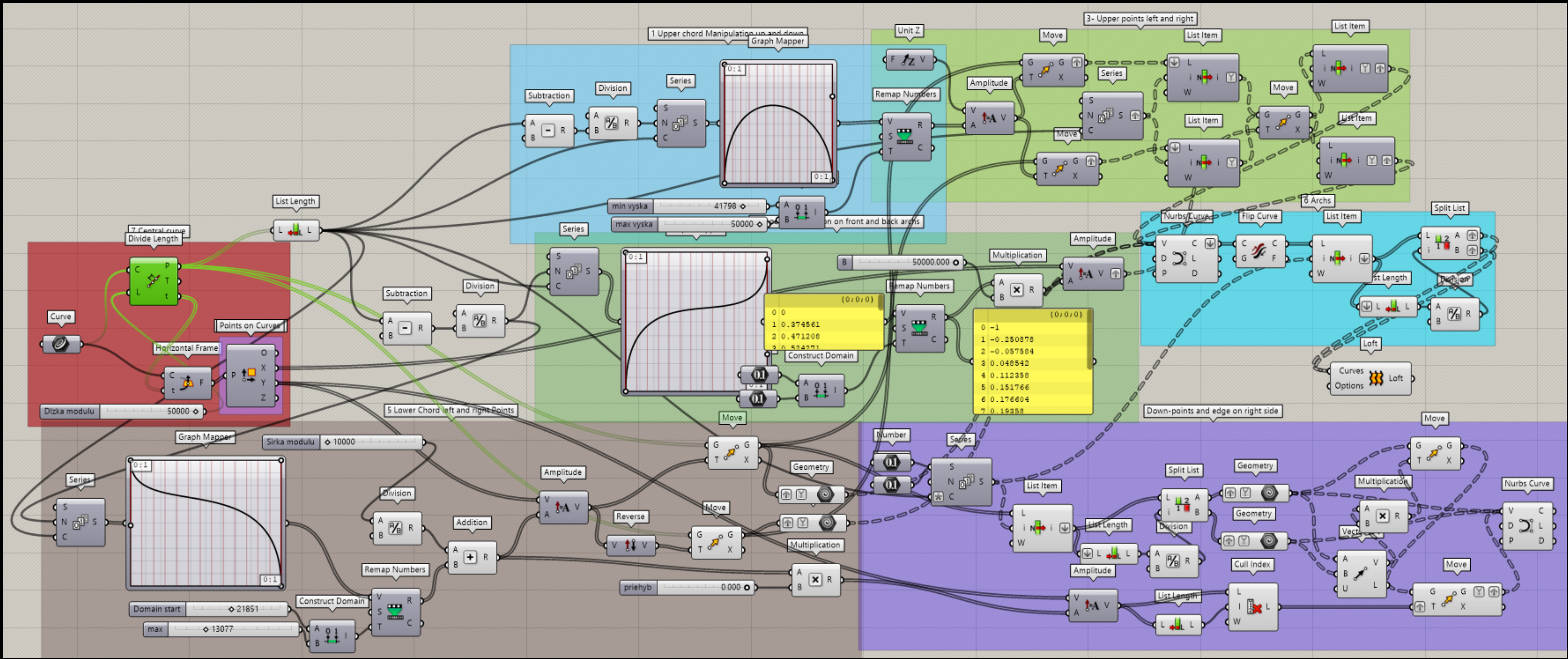
Geometry and Performance of Timber Grid-Shells

- The idea to build using elastic deformation - elastic bending as a strategy to achieve a structural shape was adopted by Frei Otto.

Timber grid-shells are a very efficient way of covering large spaces while also providing a unique architectural and material quality.

Parametric Design- Grid Shell



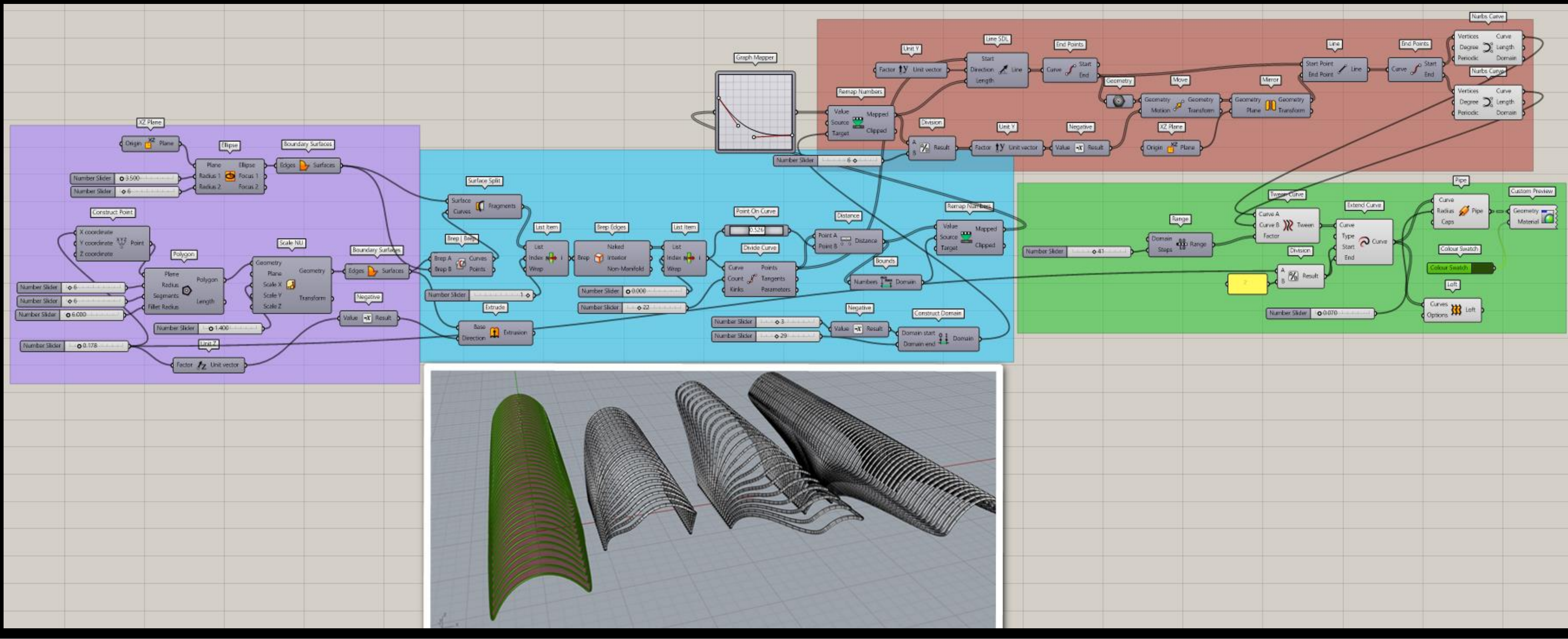


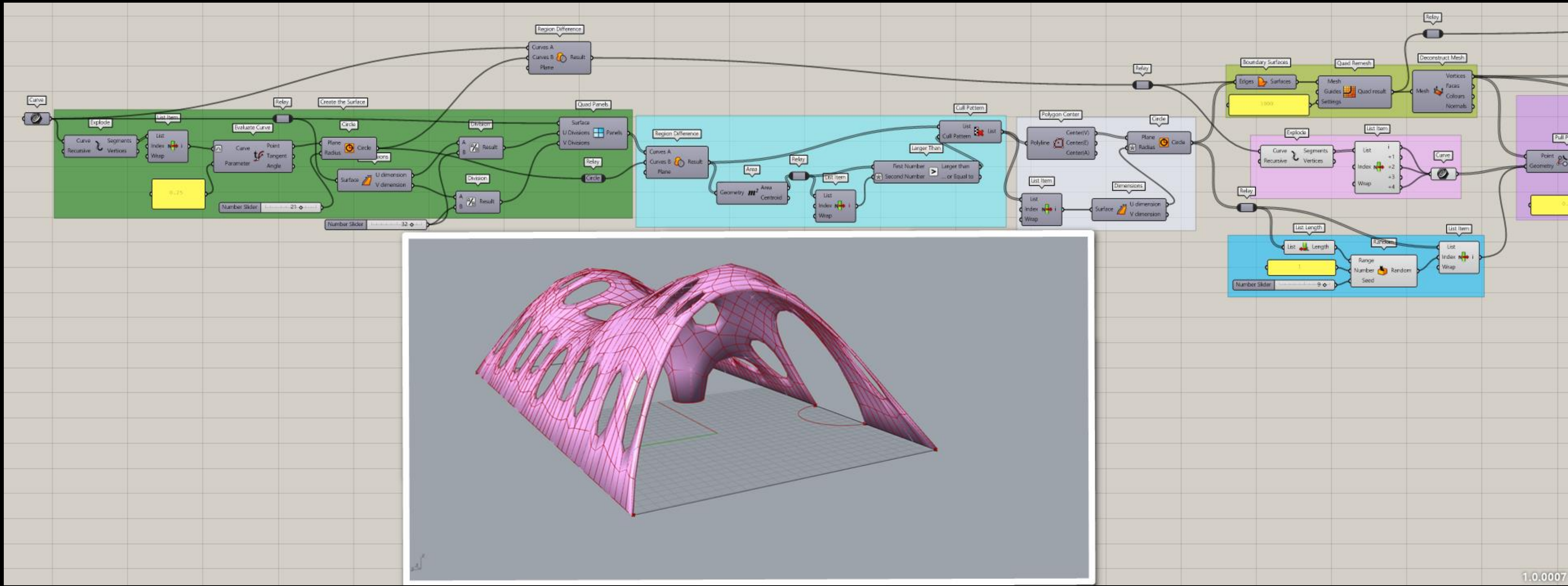
Grid Shell Form Finding- Physical Model

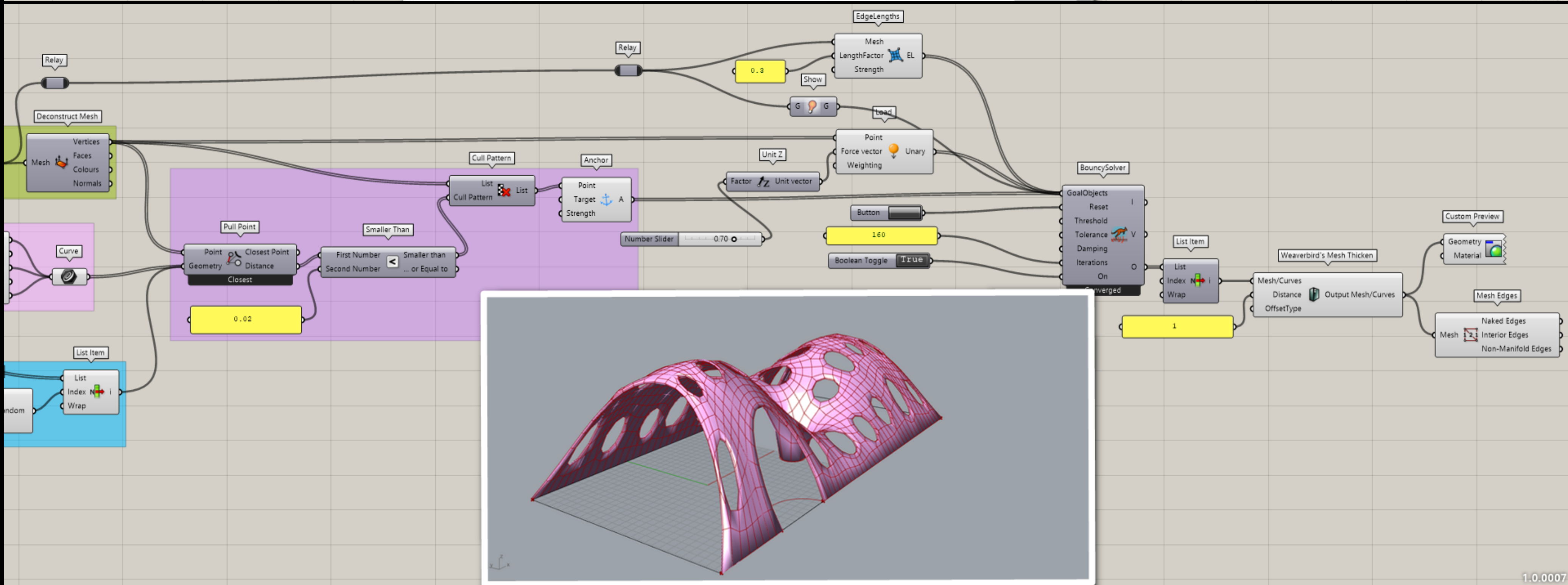
Gridshells are a type of spatial structure which follow the structural principles of shell action and which inherently resist the applied loads through their shape.

Non-Euclidean Parametric Shell

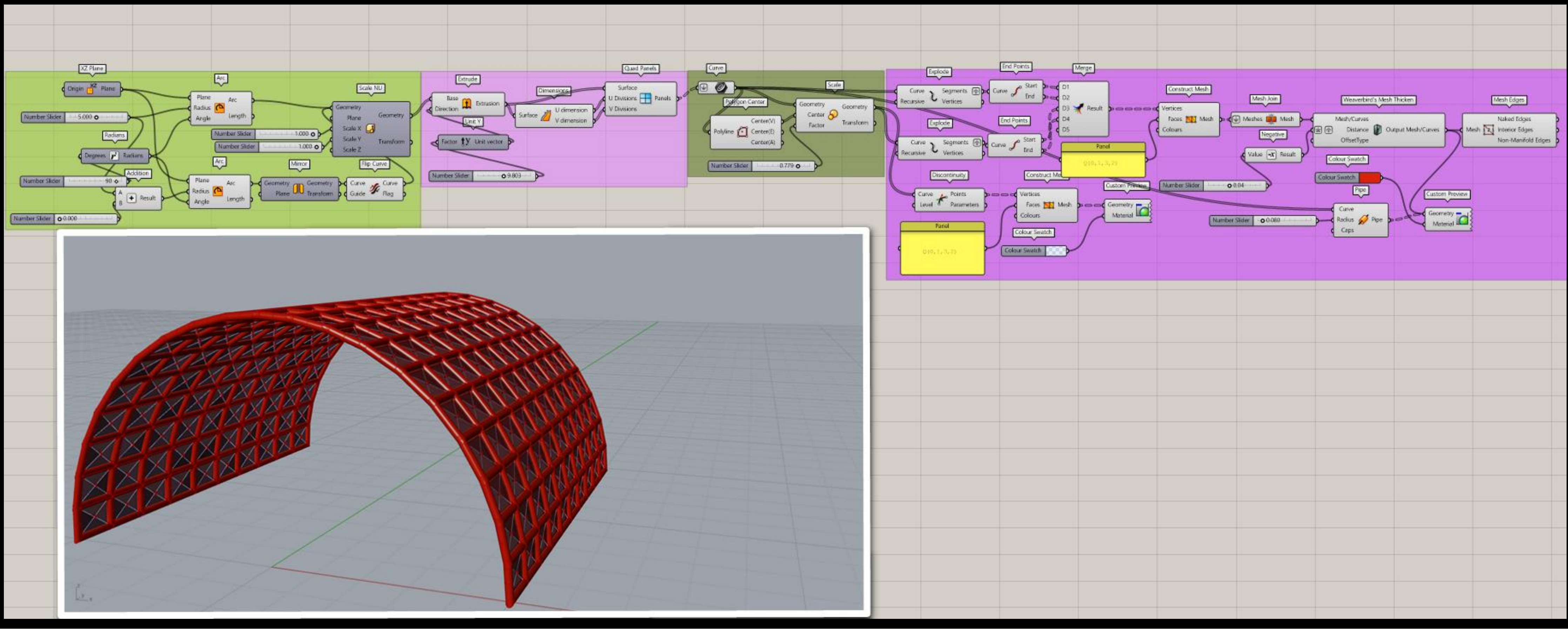
- Well-designed curved shapes, as in the case of arches and shells, create effective mechanisms to transmits loads and lead to lightweight structural solutions with low material consumption.



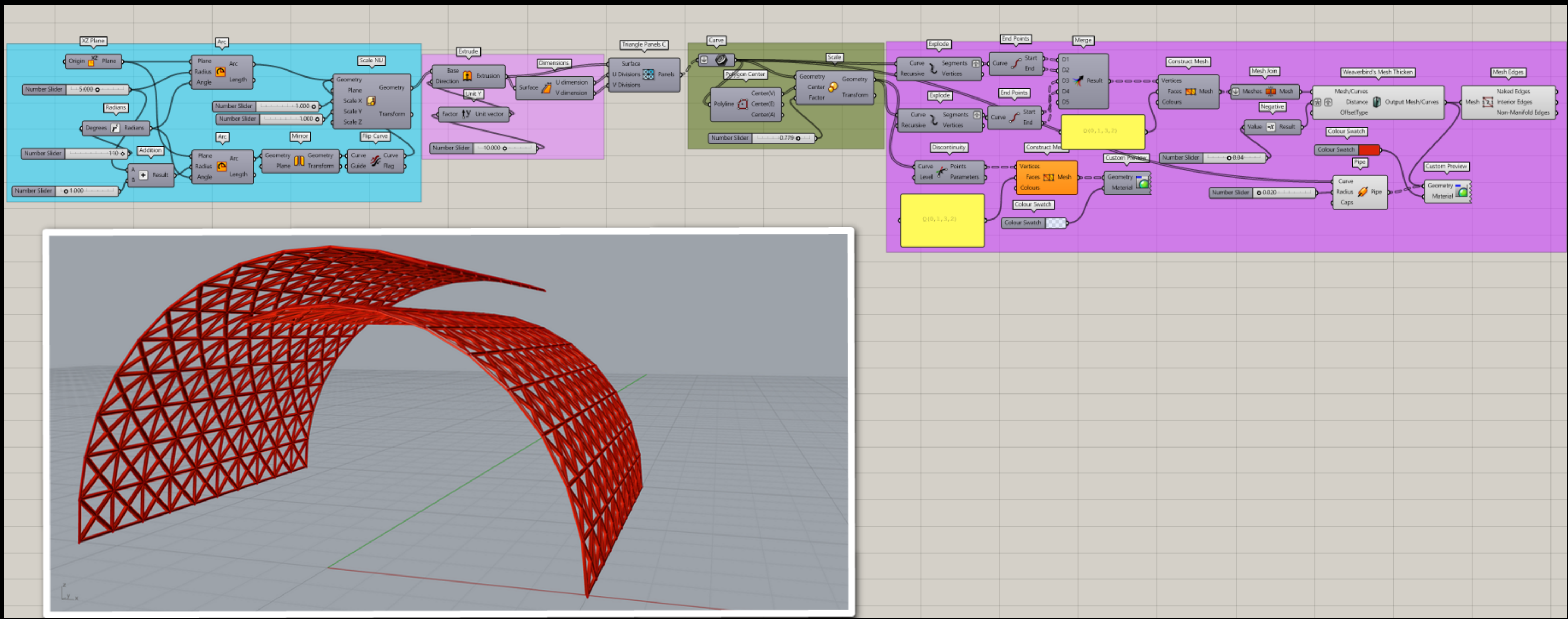

Region Difference
Curve
Explode
List Item
Relay
Create the Surface
Evaluate Curve
Circle
Division
Quad Panels
Region Difference
Area
Cull Pattern
Larger Than
Polygon Center
Circle
List Item
Dimensions
Boundary Surfaces
Quad Remesh
Deconstruct Mesh
Explode
List Item
List Length
Random
1.0.0007


Relay
Deconstruct Mesh
EdgeLengths
Show
Load
Unit Z
Cull Pattern
Anchor
Pull Point
Smaller Than
BouncySolver
Button
Boolean Toggle
List Item
Weaverbird's Mesh Thicken
Custom Preview
Mesh Edges
Curve
List Item
0.3
0.02
160
1
1.0.0007

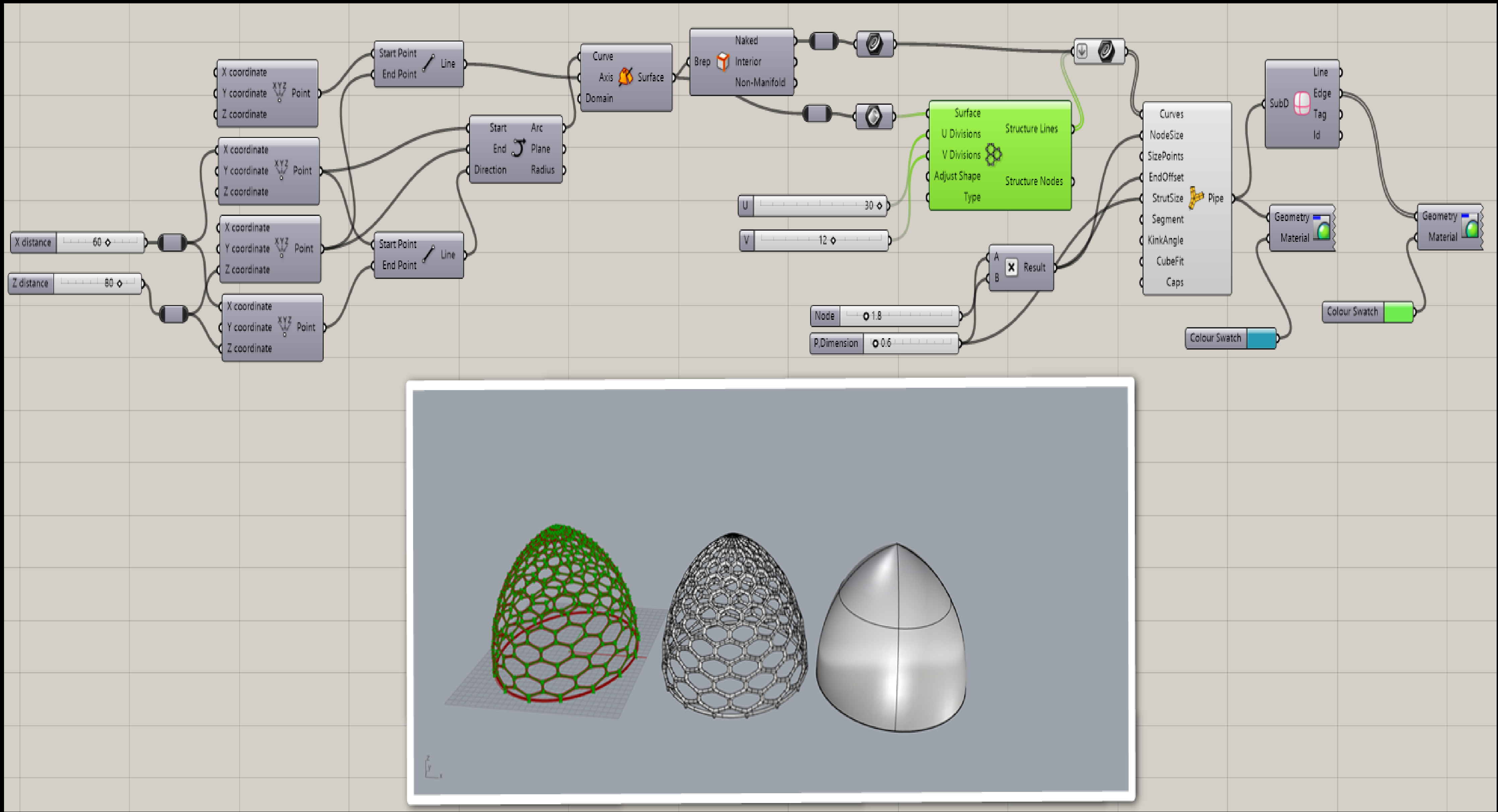
Quad Panels Grid Shell- Parametric Design



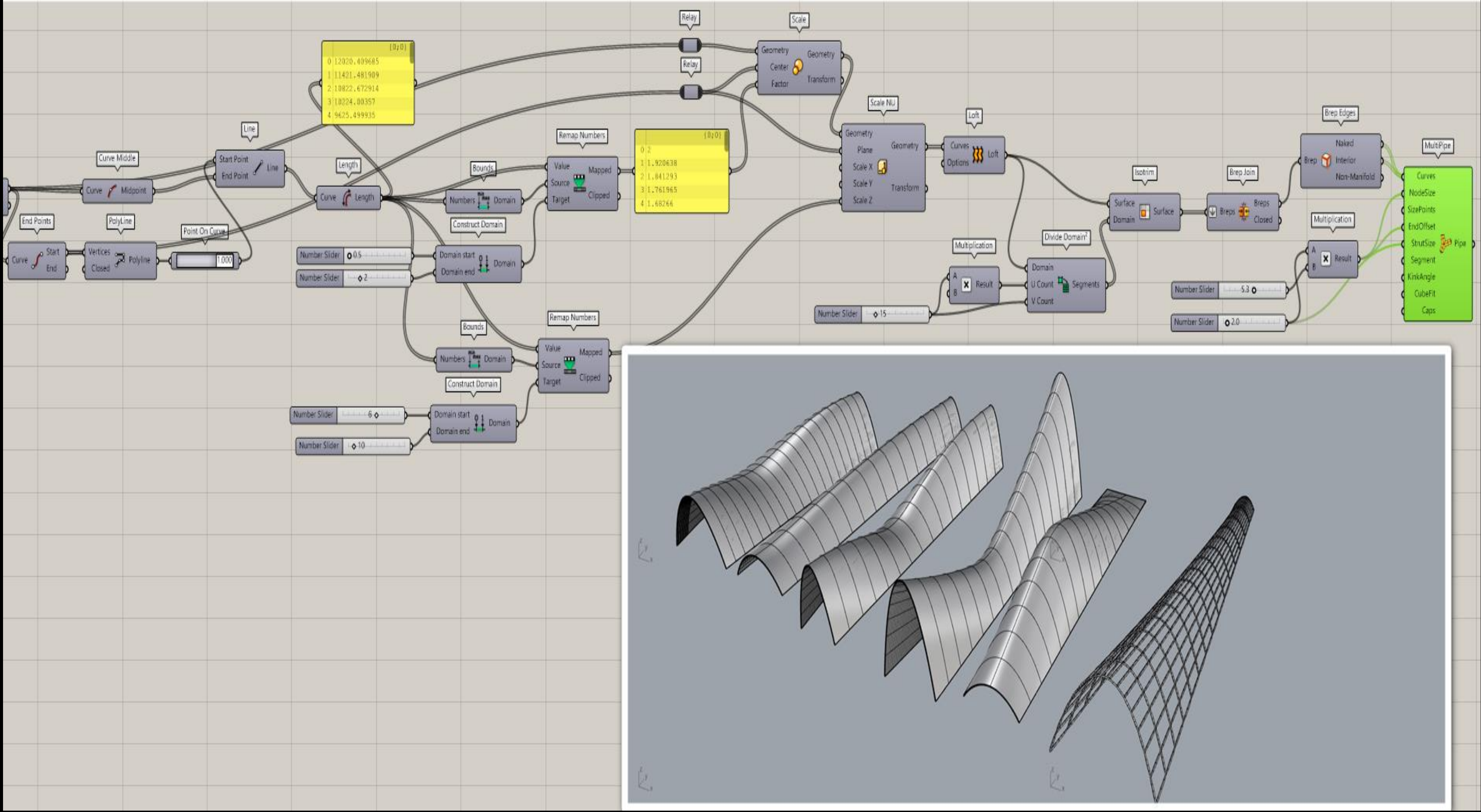
Triangle Panels C Grid Shell- Parametric Design

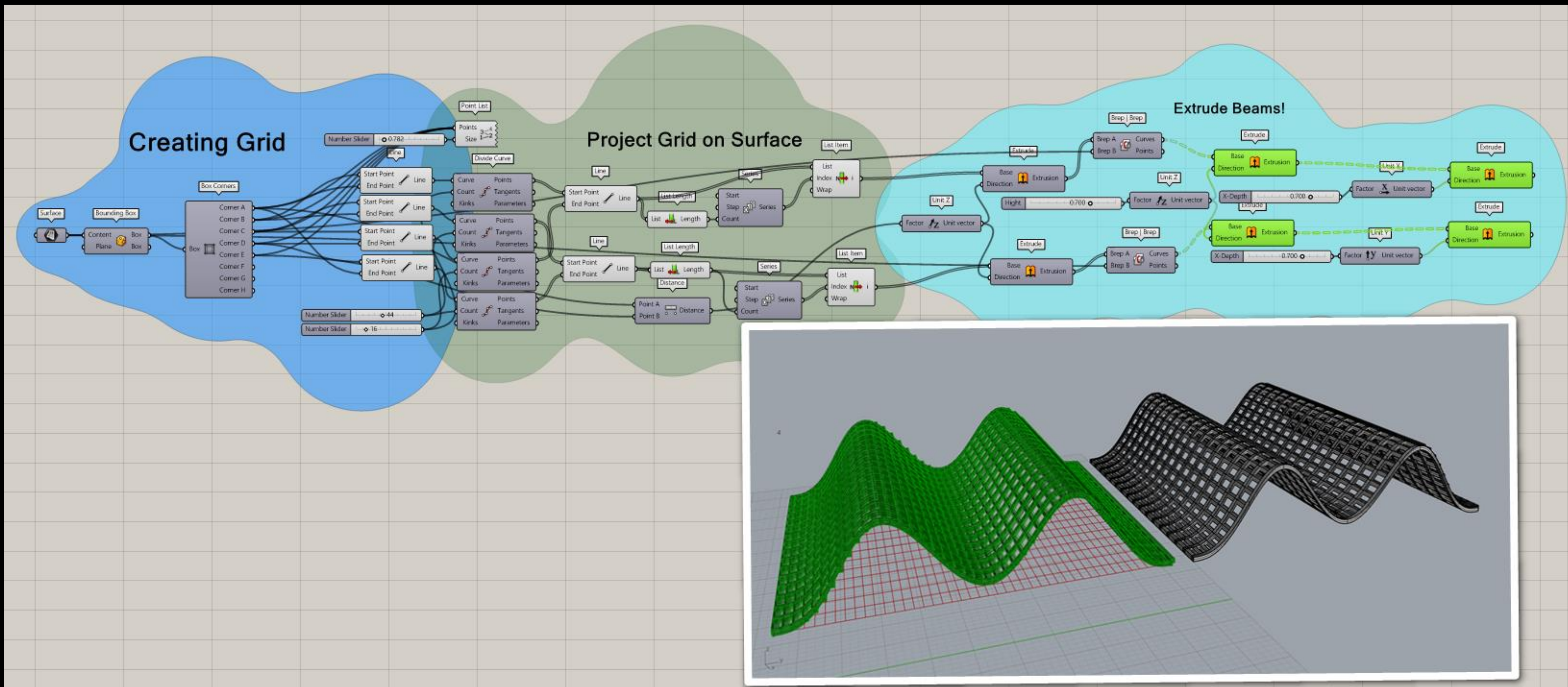


Synclastic Geometry - Flow Chart of Grasshopper

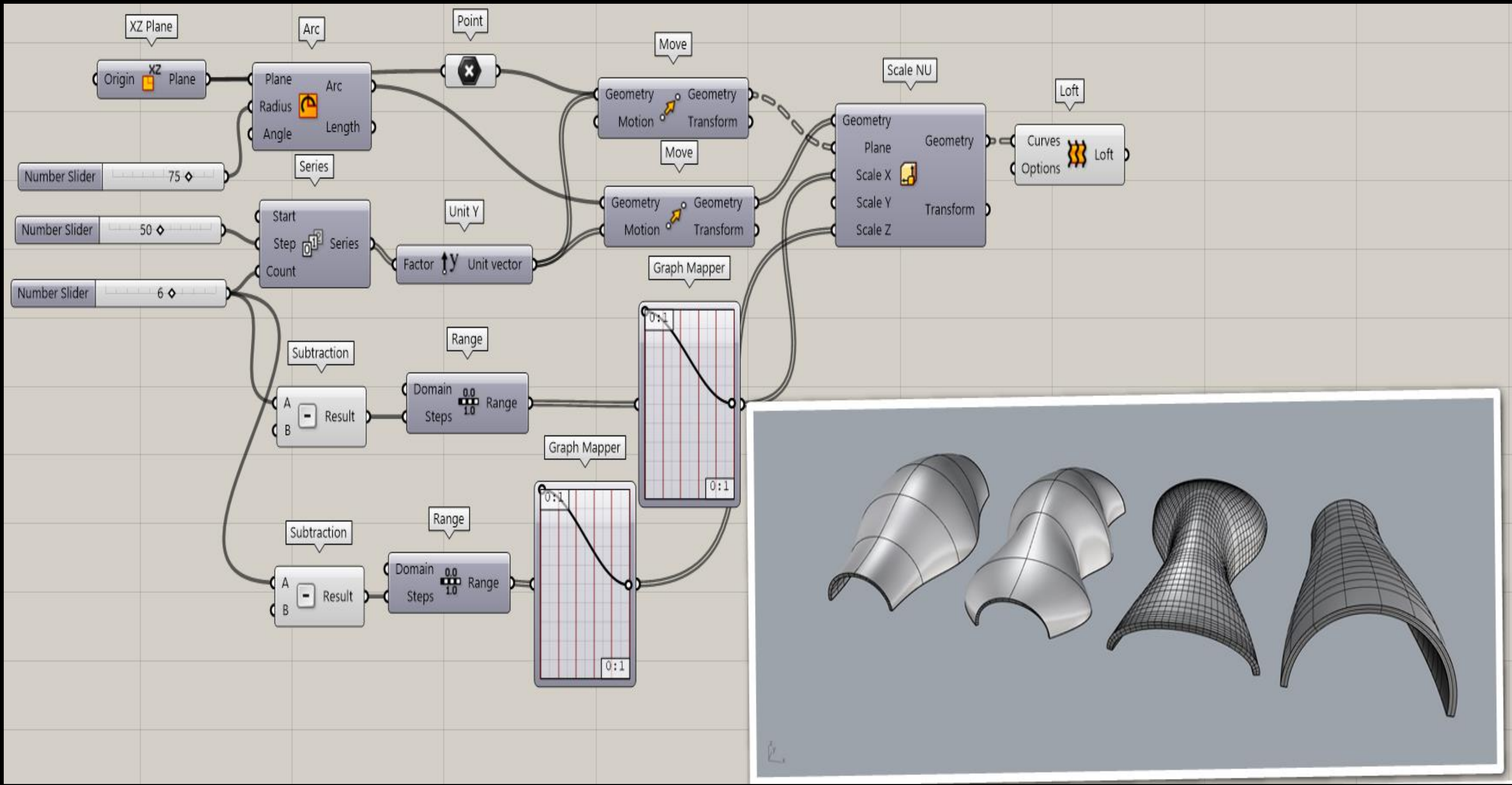


Parametric Design-Organic Form Finding Grid Shell

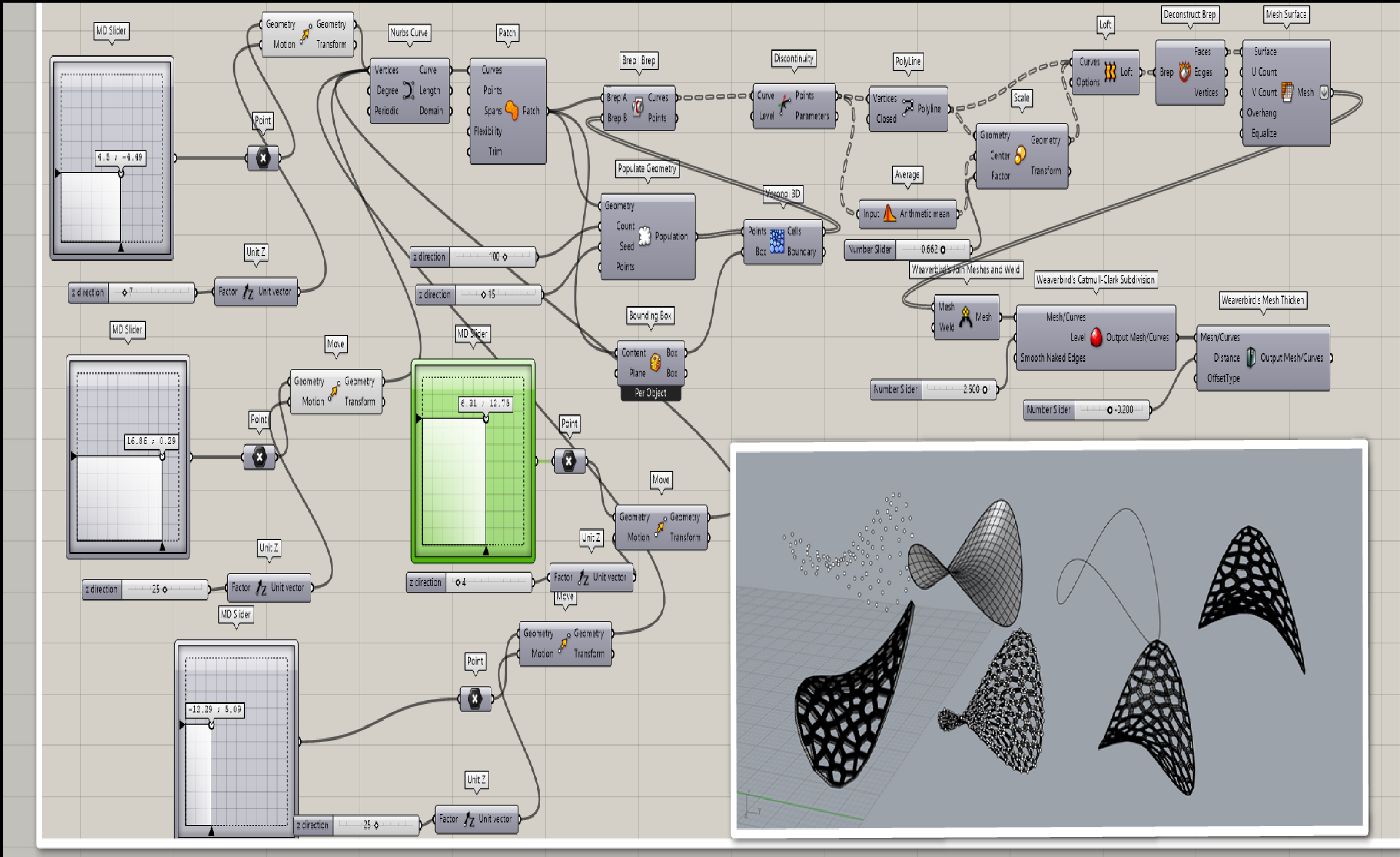



Creating Grid
Project Grid on Surface
Extrude Beams!

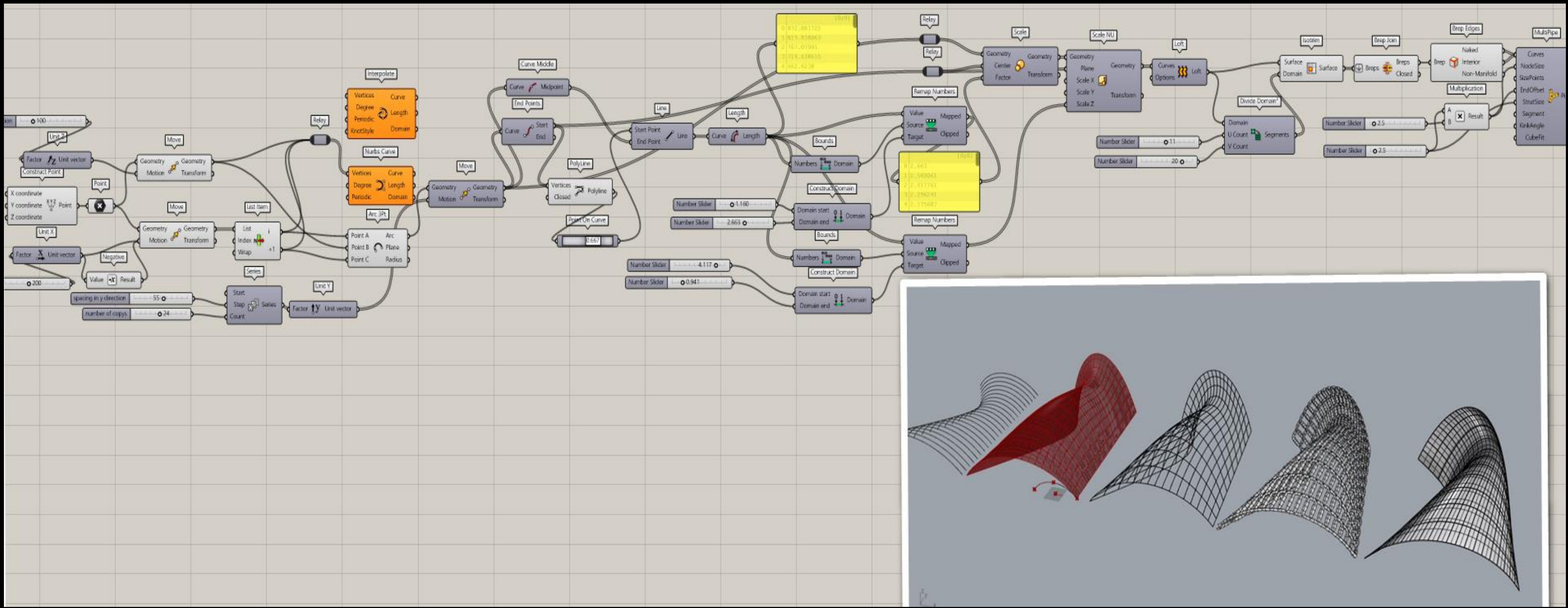
Parametric Design-Organic Form Finding Grid Shell



Parametric Design-Randum Surface- Form Finding



Parametric Design-Organic Form Finding Grid Shell



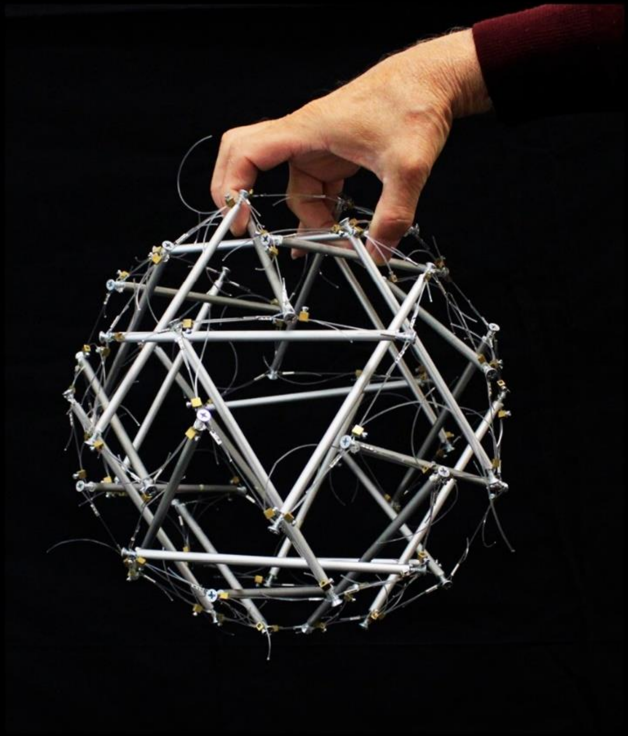
Lighten flat shell structures and simplify their construction.

Parametric surfaces use the display of a planar region 2D into a region in 3D space.

The term “geodesic” can be understood as the shortest distance between two points (Fuller,1962). Geodesic structure consists of as many struts of the same length as possible as well as congruent surfaces. It is a network of equal triangles whereby the cross points are always situated on the surface. This triangulation guarantees strength and rigidity of the ball-shaped structure. There is no direct contact between the compression elements as seen on the models on the figure bellow. The struts are combined to triangles, pentagons, or hexagons, whereby each strut is aligned in a way that each connection point is held in a firm position. This guarantees the stability of the whole structure.

Tension is distributed equally to all parts of the whole construction. Increased tension in one part provides increased tension in all parts. A global increase of tension is balanced by an increase of tension in various parts. Whilst tension is thus distributed evenly in the whole system, only individual parts balanced by compression. There is a balance between tension and compression, we can define the system as “stable self-equilibrium”. The tensegrity network is a stable and at the same time an adaptable construction. The whole system reacts to an outside force with an adaptive tension distribution.

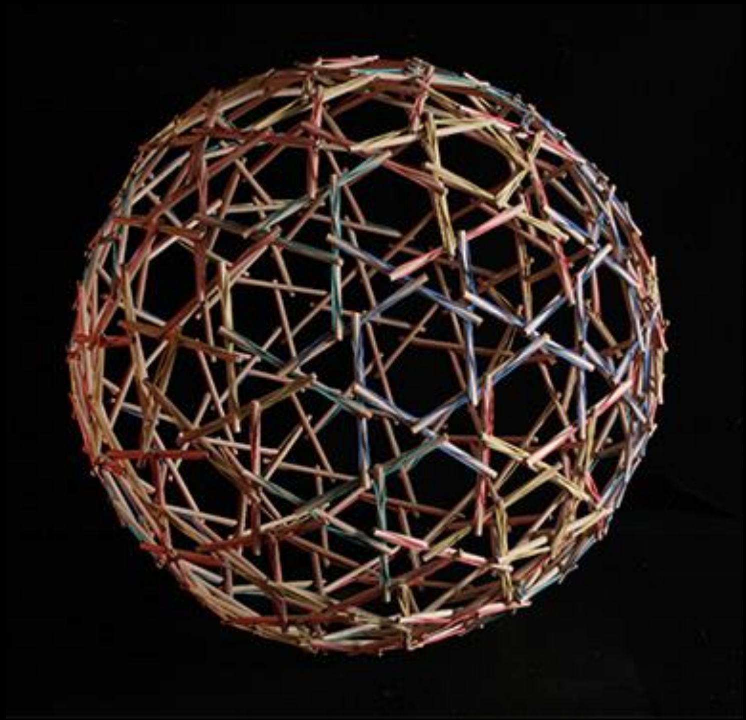
This type of structure depicted on the figure use separate elements for tension and compression as we can nicely see in this visual example. These tensegrity systems can be defined as spatial structures consisting of compression (struts) and tensile (cables) components which stabilize each other through pre-stress, tension and compression work together to resist the applied load.



Tensegrity as a Geodesic Dome (Shawkat)

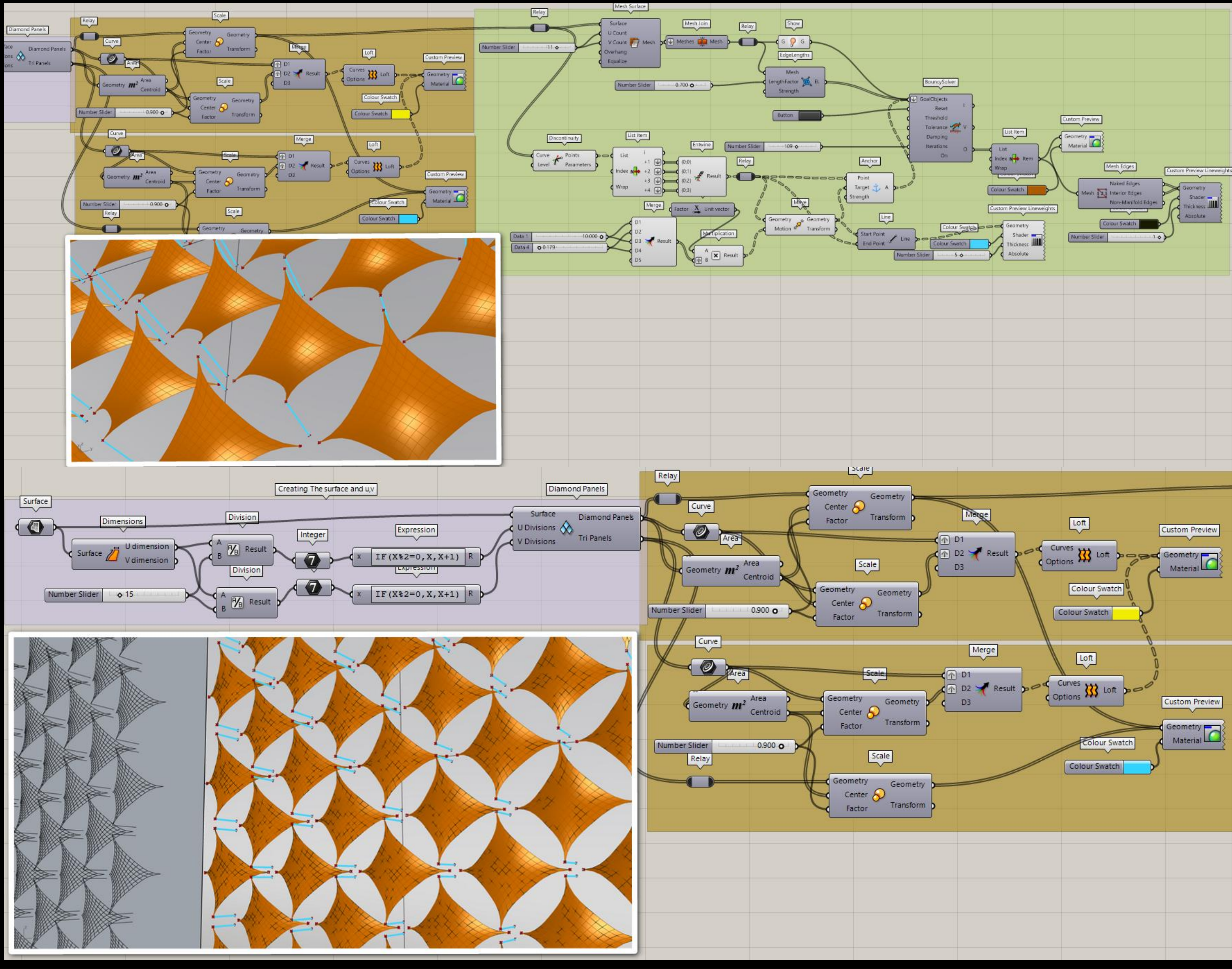
The tensegrity model. According to Buckminster Fuller the icosahedron is a basic tensegrity structure (Buckminster Fuller 1975). It is a three dimensional structure consisting of twenty triangle surfaces. Loads applied at any point distribute about the truss as tension or compression. There are no levers within the truss. Only trusses are inherently stable with freely moving hinges.

The only way to fully stabilize and constrain any structure is by triangulating surfaces or cavities in compression and/or tension in all three dimensions. Tensegrity structures on the other hand show the forces acting upon them by differentiating out tension and compression vectors into separate components.

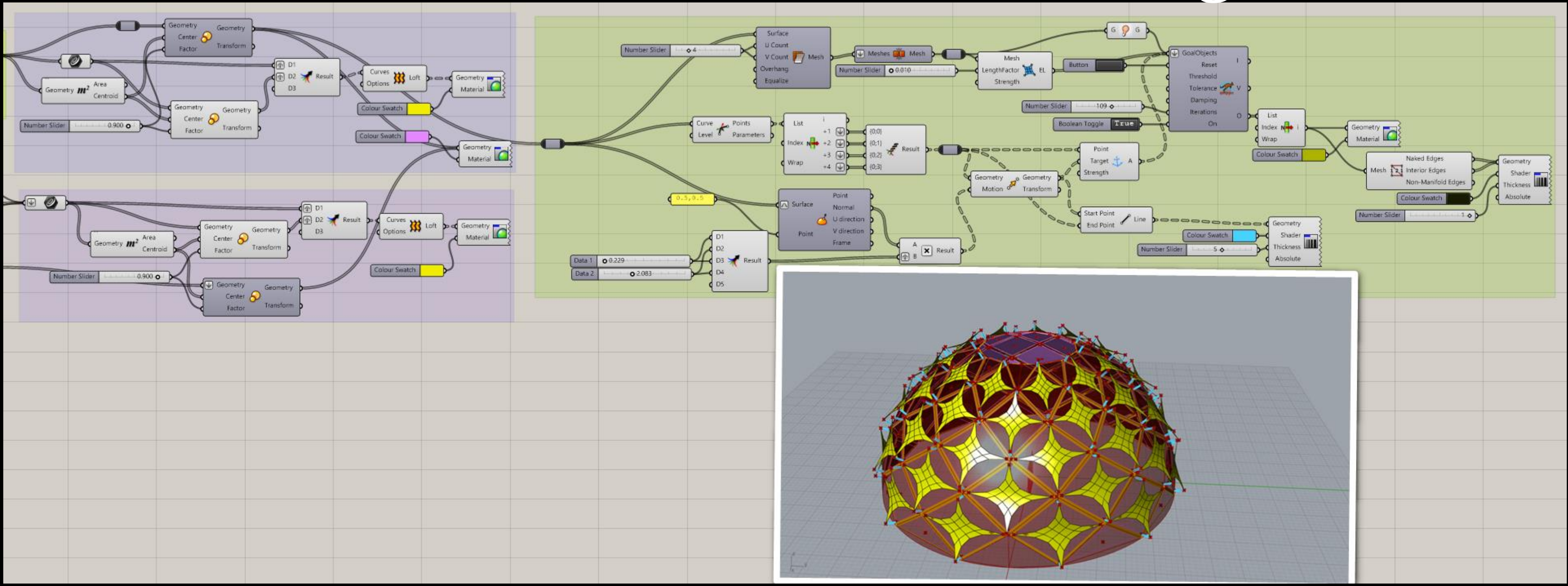


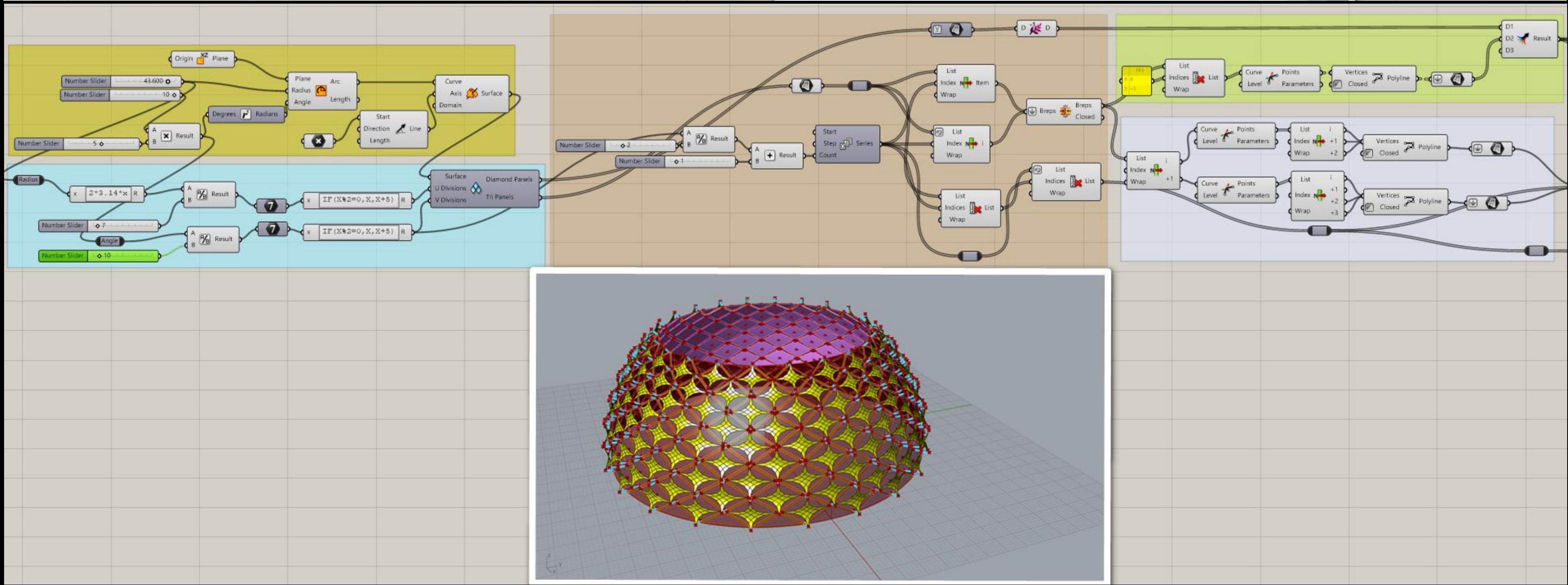
Physical model - Constructing a multiple RF grid dome

Fasad – Tensile Structure Design

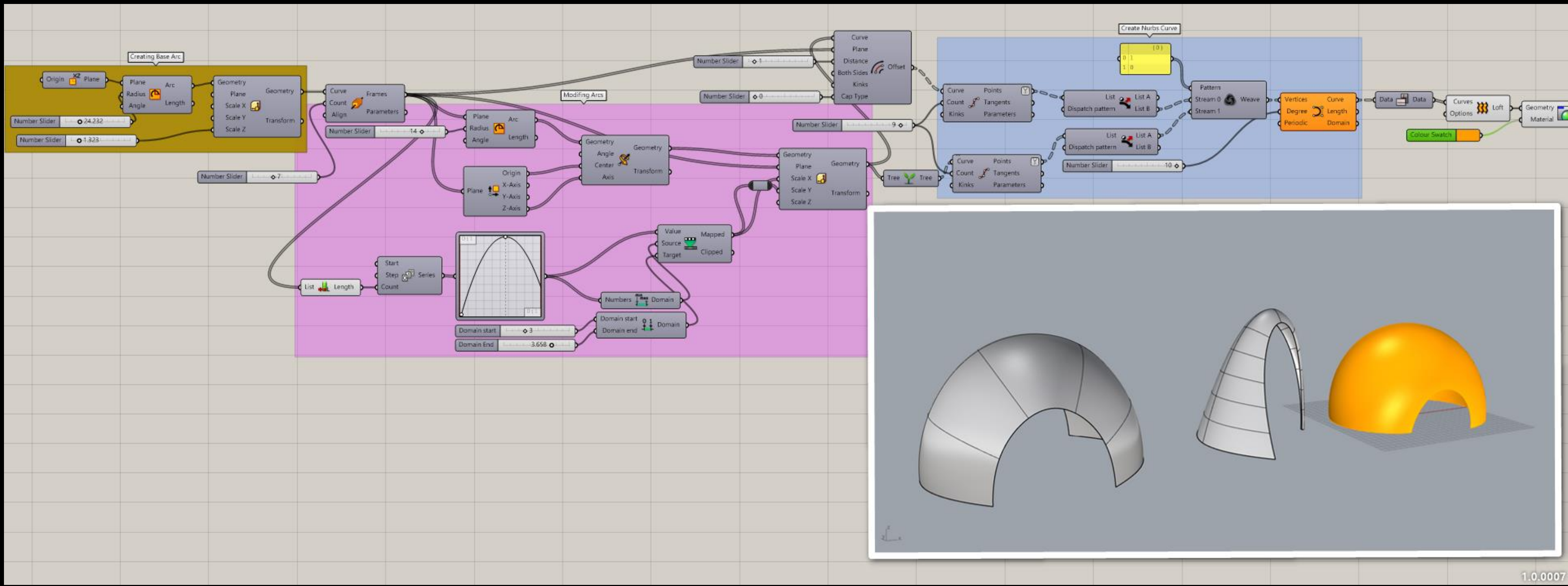


Fasad – Tensile Structure Design





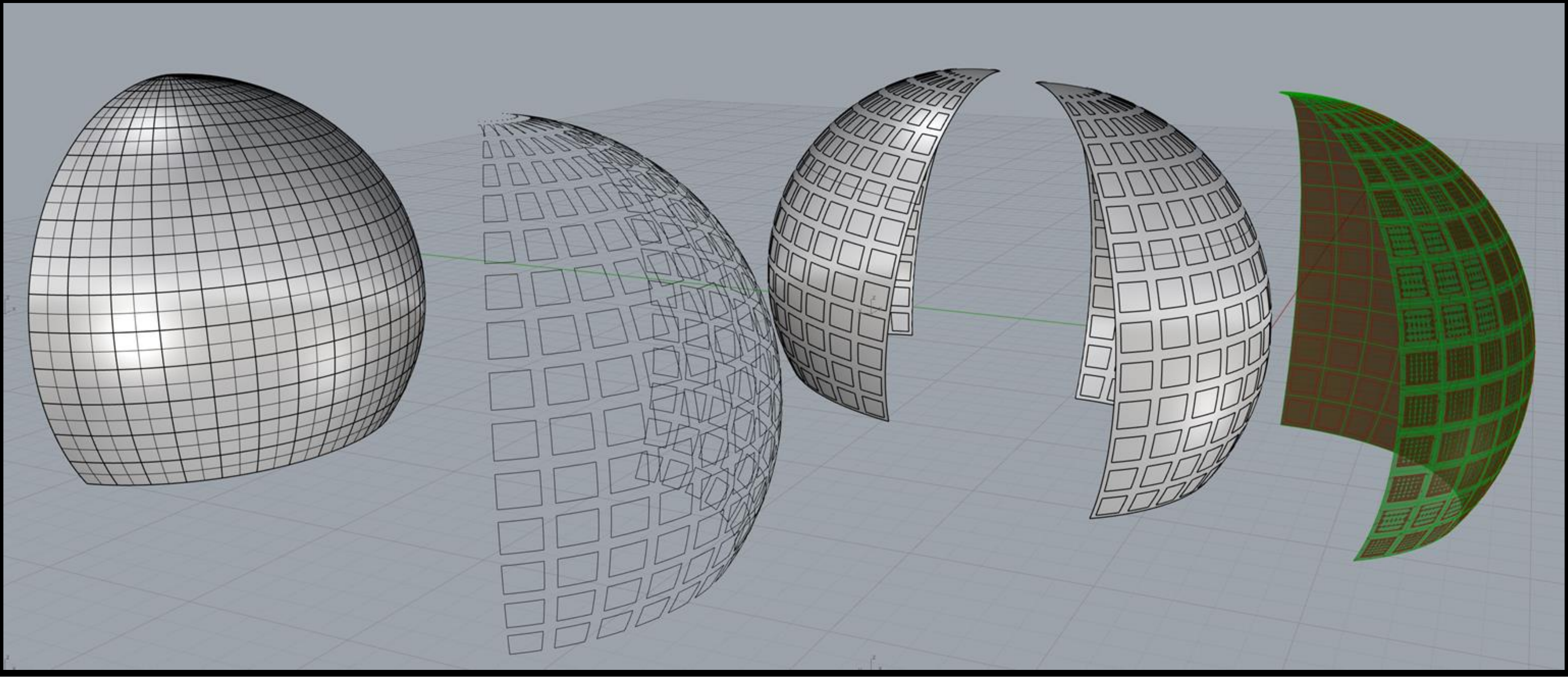
Create Nurbs Curves



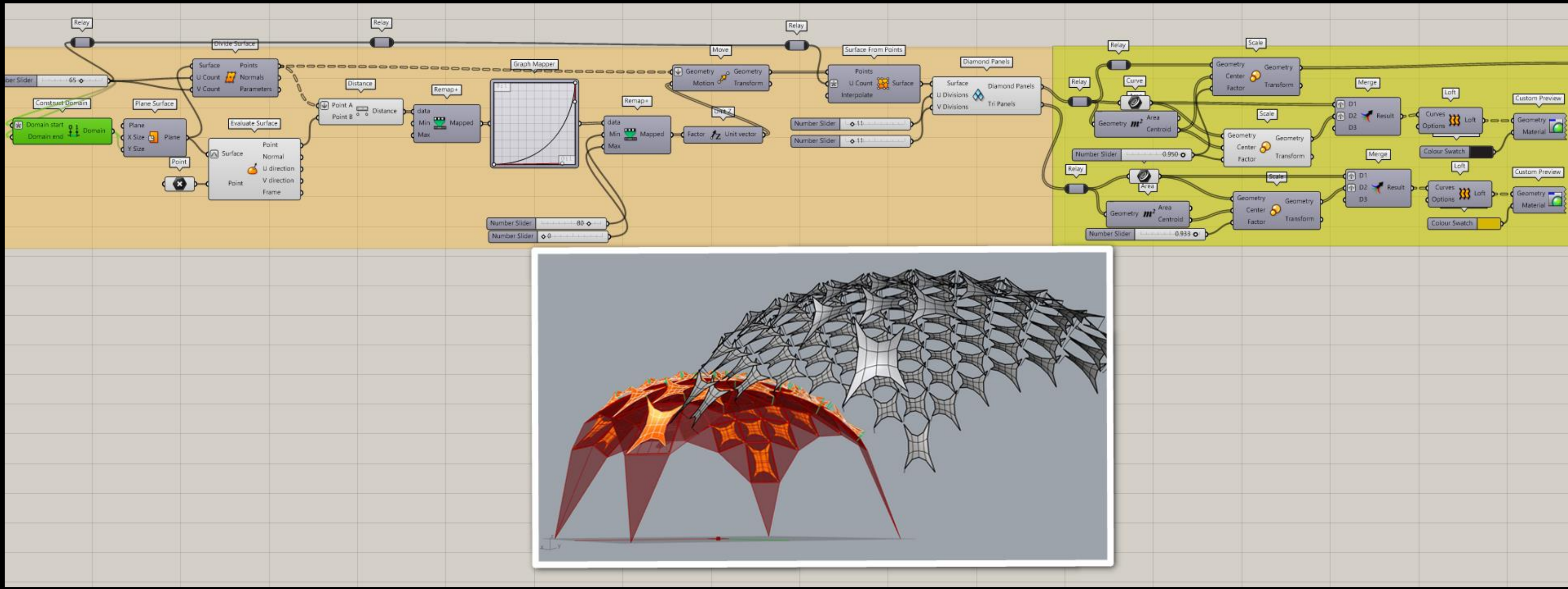
Synclastic Geometry-Grid-Shells

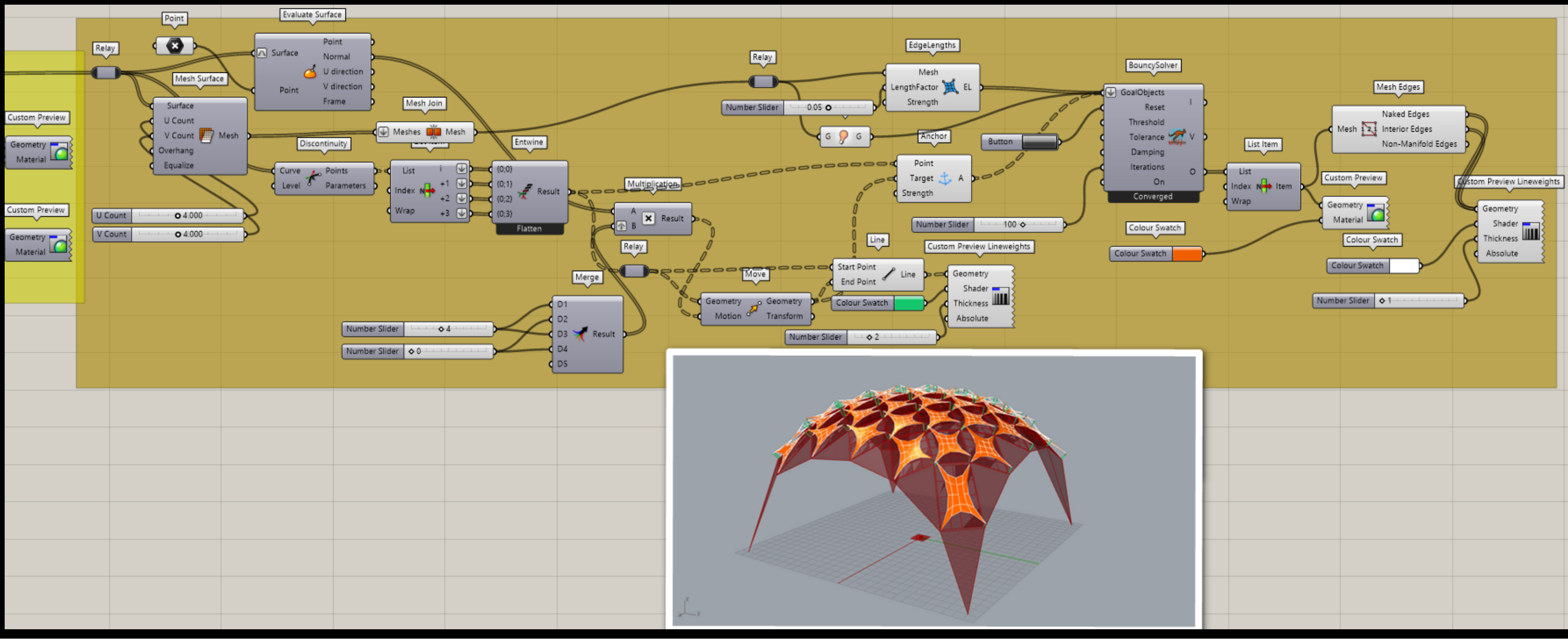
The characteristics of timber gridShells – long-span, light-weight, affordable, sustainable – argue that it should be a perfect fit to the architectural programmes of our time.

However, the use of timber gridshells has so far been limited to experimental pavilions and a few very worthy, large-scale, permanent buildings.

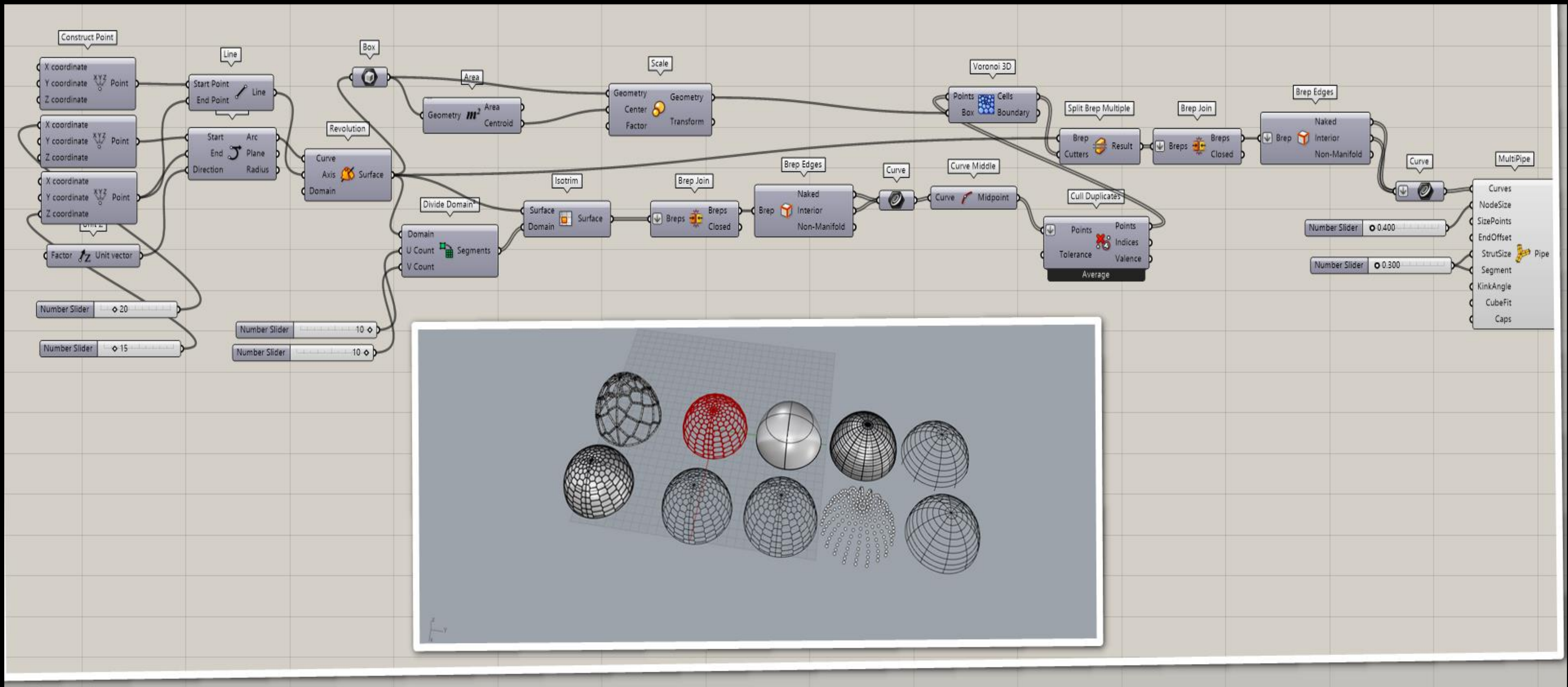


Fasad – Tensile Structure Design

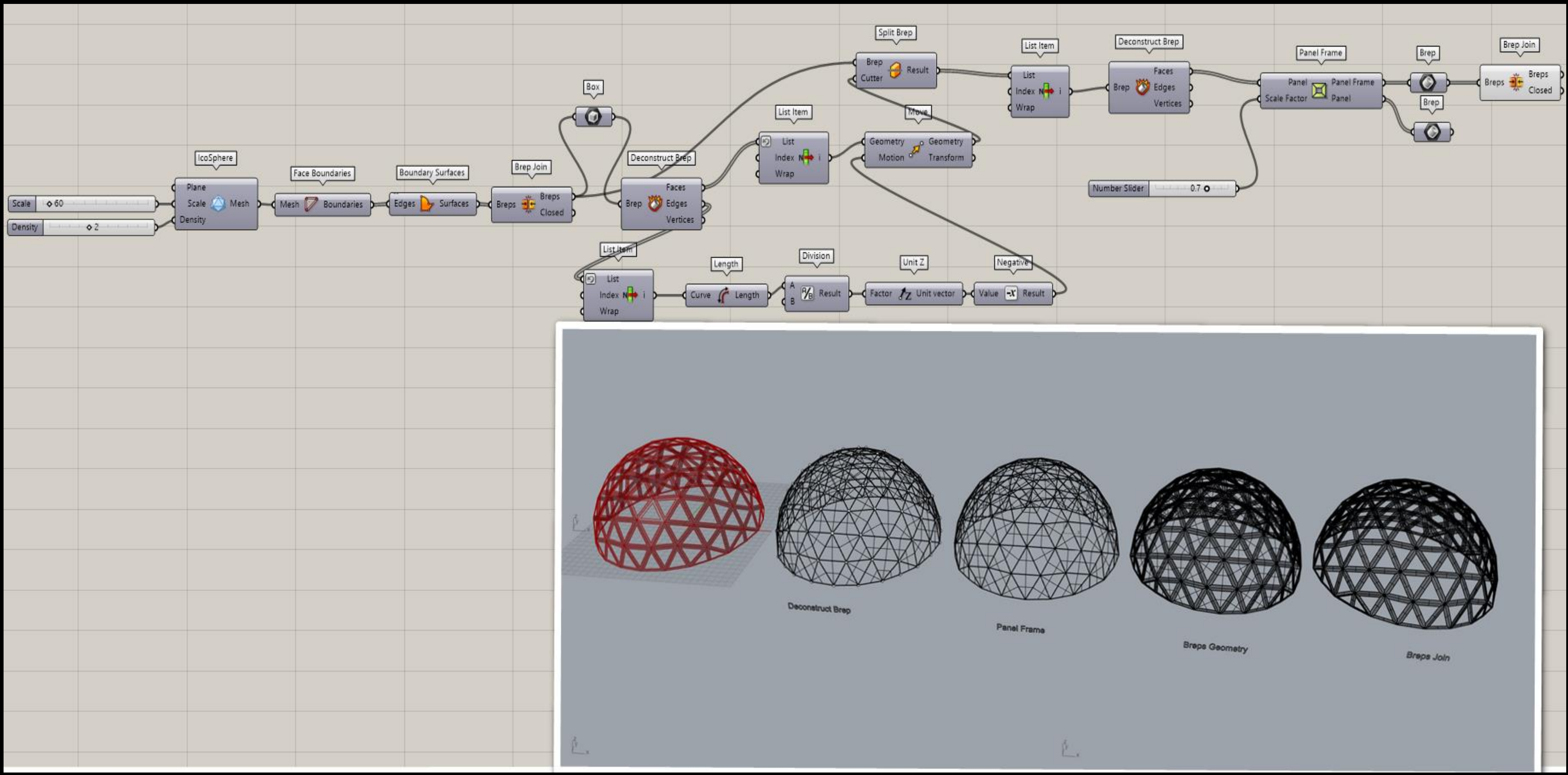




Parametric Design- Flow Chart of Grasshopper

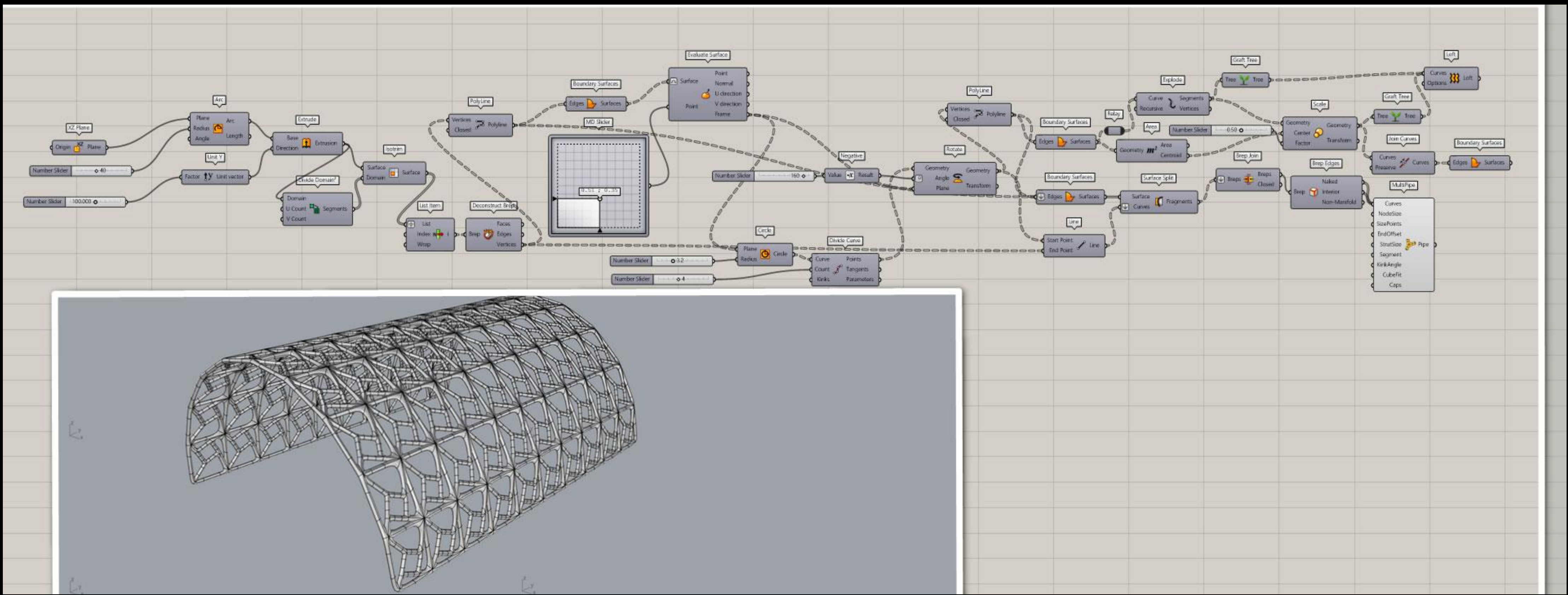


Parametric Design- Flow Chart of Grasshopper



Parametric Design- Flow Chart of Grasshopper

- Nowadays, modern architecture is focused the possibility to produce lightweight solutions with maximum elegance in shape.



Synclastic:

they mainly have the same sign of curvature; they can meet the conditions of minimality only in the case of non-zero external load.

- The required materials should have a high ratio between strength and Young’s modulus to reach significant curvatures while keeping enough elastic reserve.

- The result is a lightweight structure, rapidly assembled and with low material consumption.

- The structural principle is called active bending.

- Behaviour of very flexible structures subject to large deformations.

- Buckling as a method to shape structures.

There are many questions still open in active bending:

- Where are the limits of applicability for bending-active structures?

- Wich are the main parameters in the assessment of the structural response of a bending-active system?

- Are bending-active structures advantageous over passive (standard) ones?

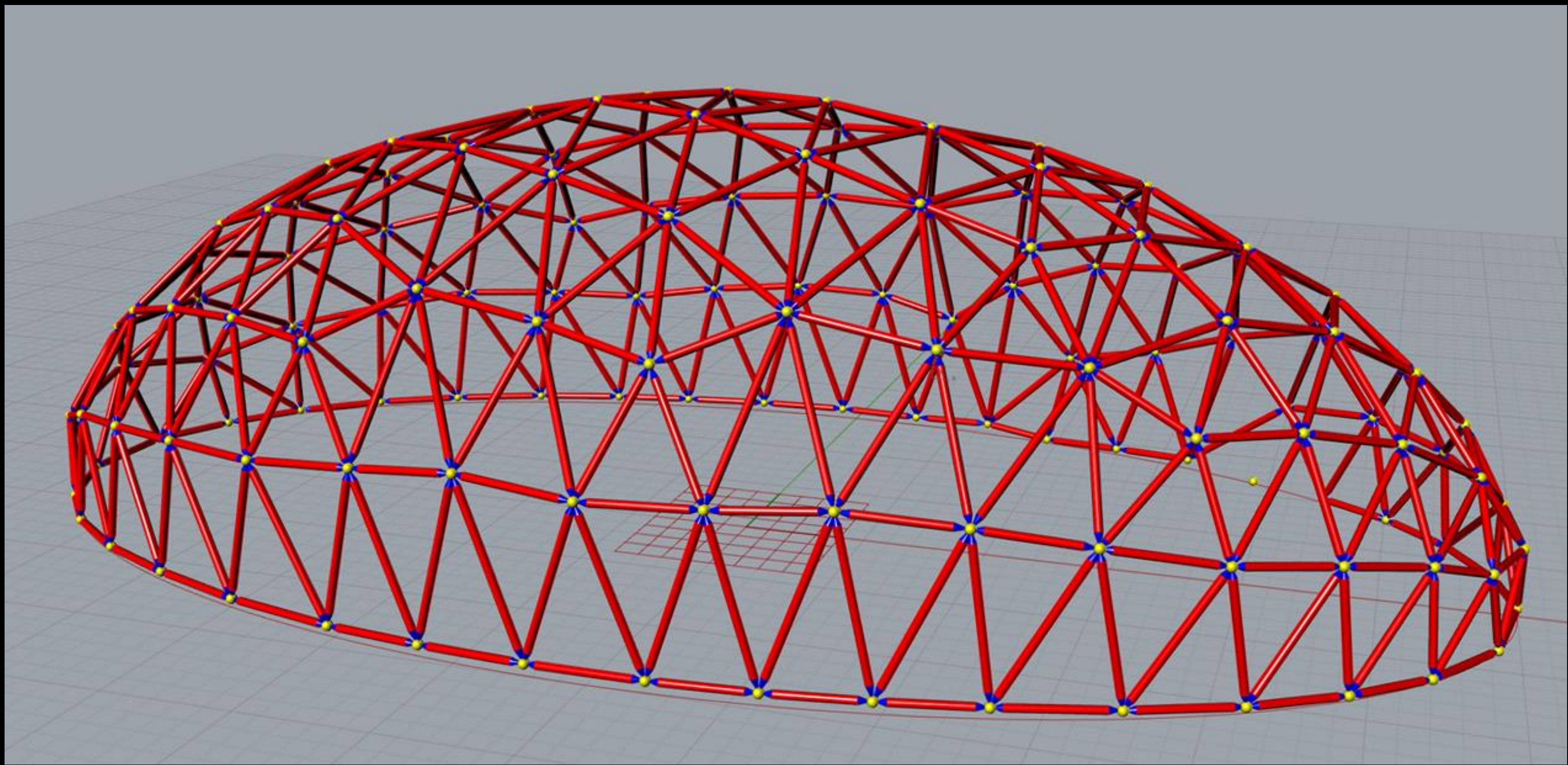
Domes are said to be those whose structure is in a state of compression.

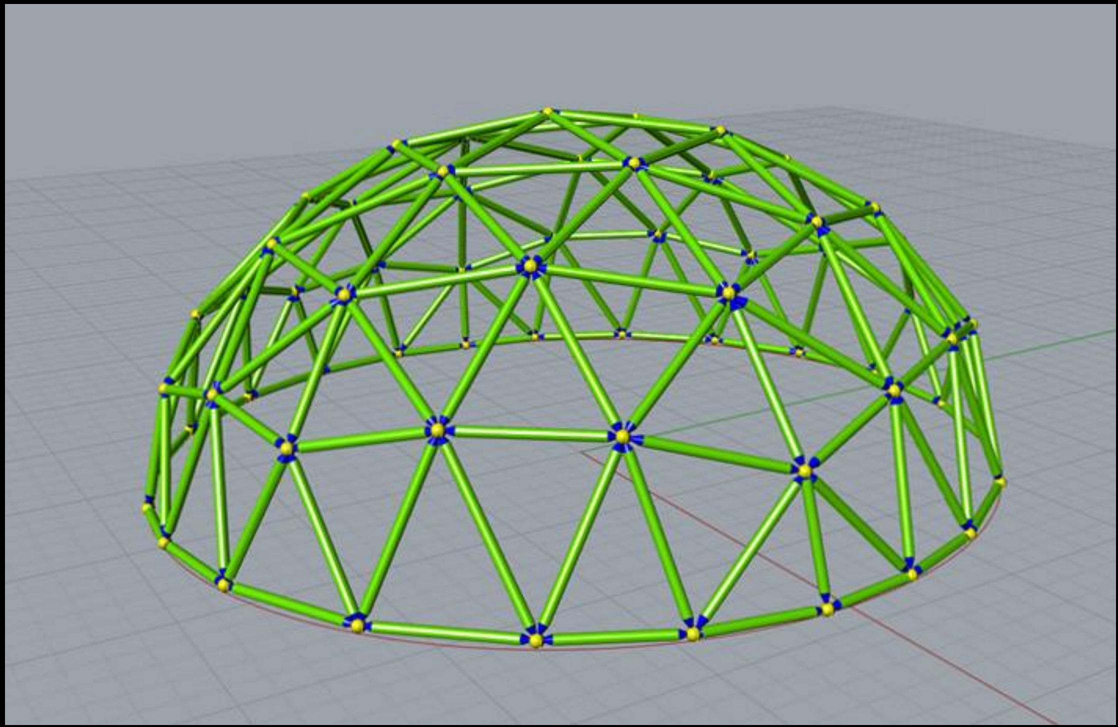
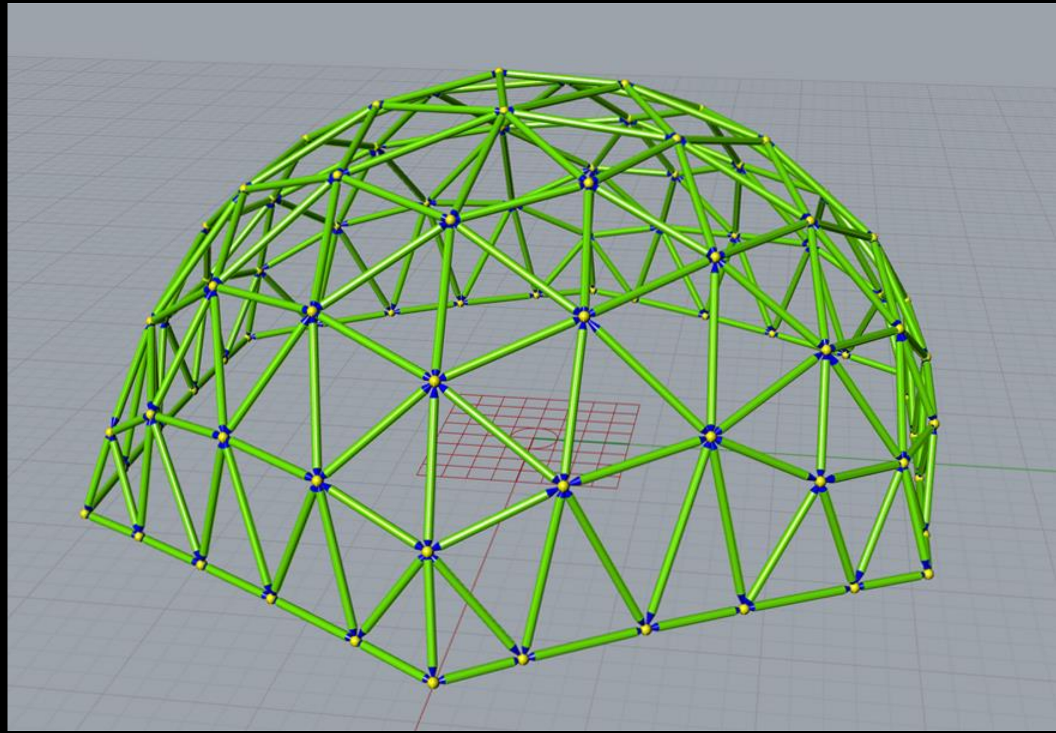
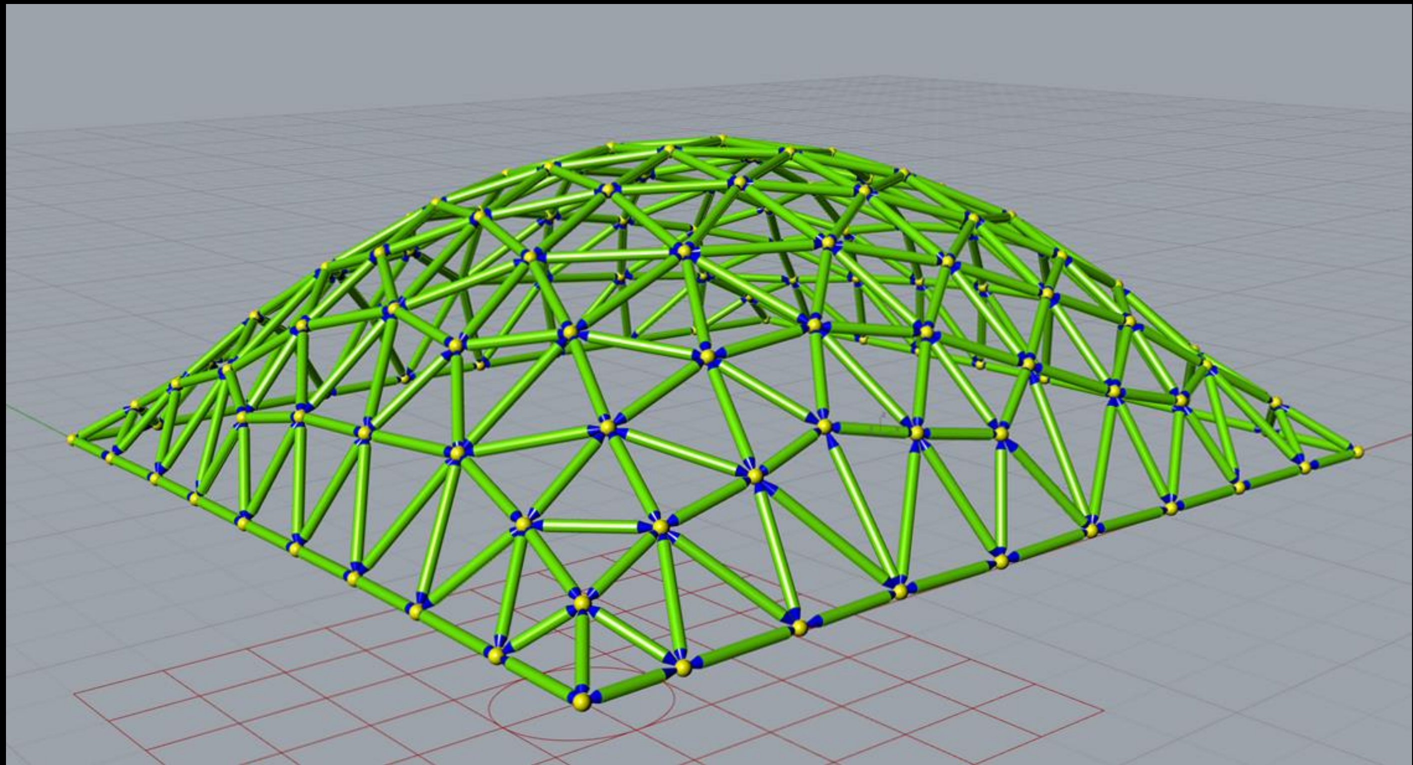
Geodesic means the shortest distance between two points on synclastic surface.

EGD-Node - Size – Calculation

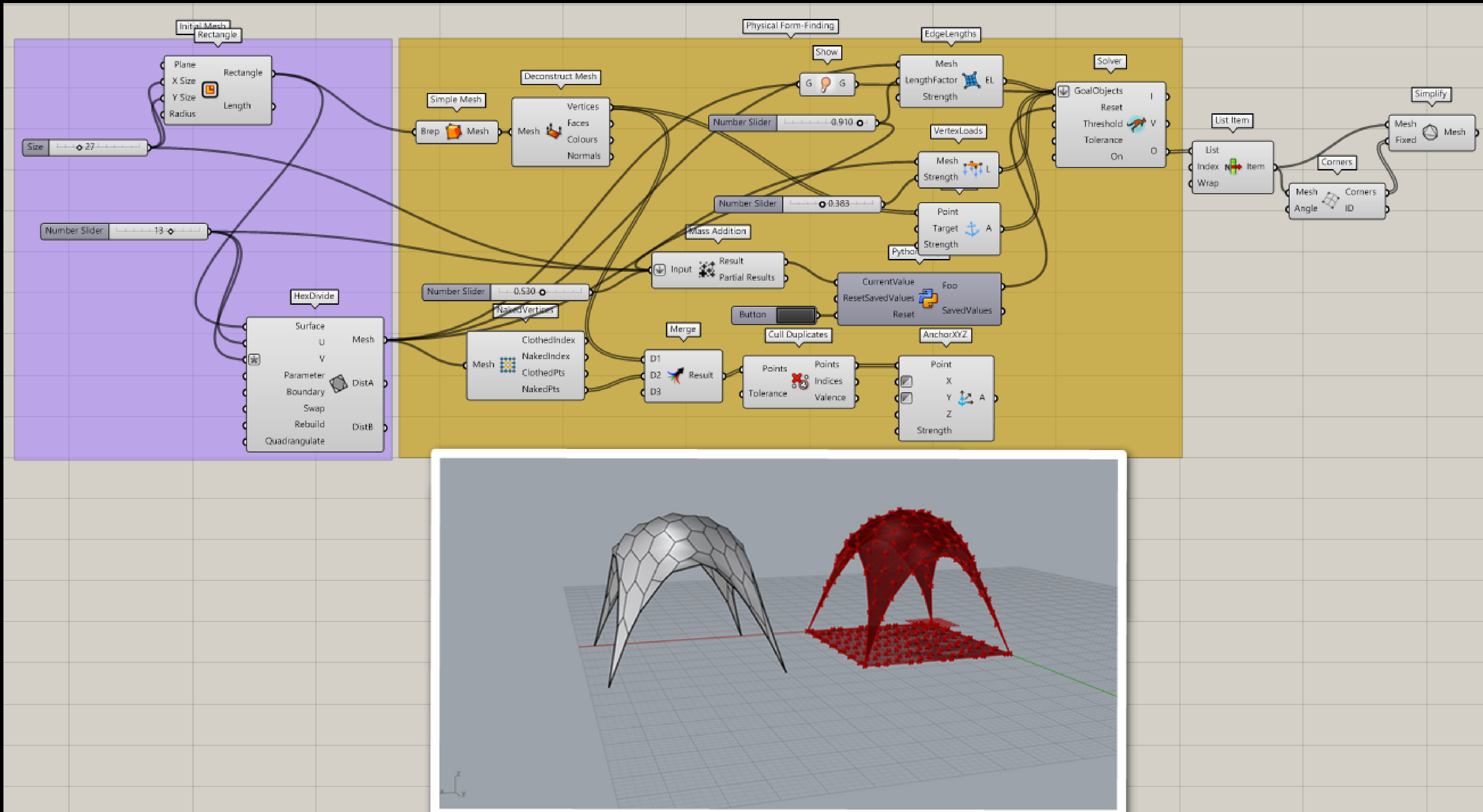
- Initial Rectangle
- Triangular Remesh
- Physical Form Finding
- Unify Borders Directions
- Extract Surrounding Meshes of each Node
- Node Planes
- Extract and Sort Surrounding Elements of each Node
- Elements Length Calculations
- Connections Detail

Elastic geodesic grid EGG, can be deployed from planar state to doubly curved shape state, the transformation between these states can be performed by pulling the two corners of planar grid apart and applying some additional bending.

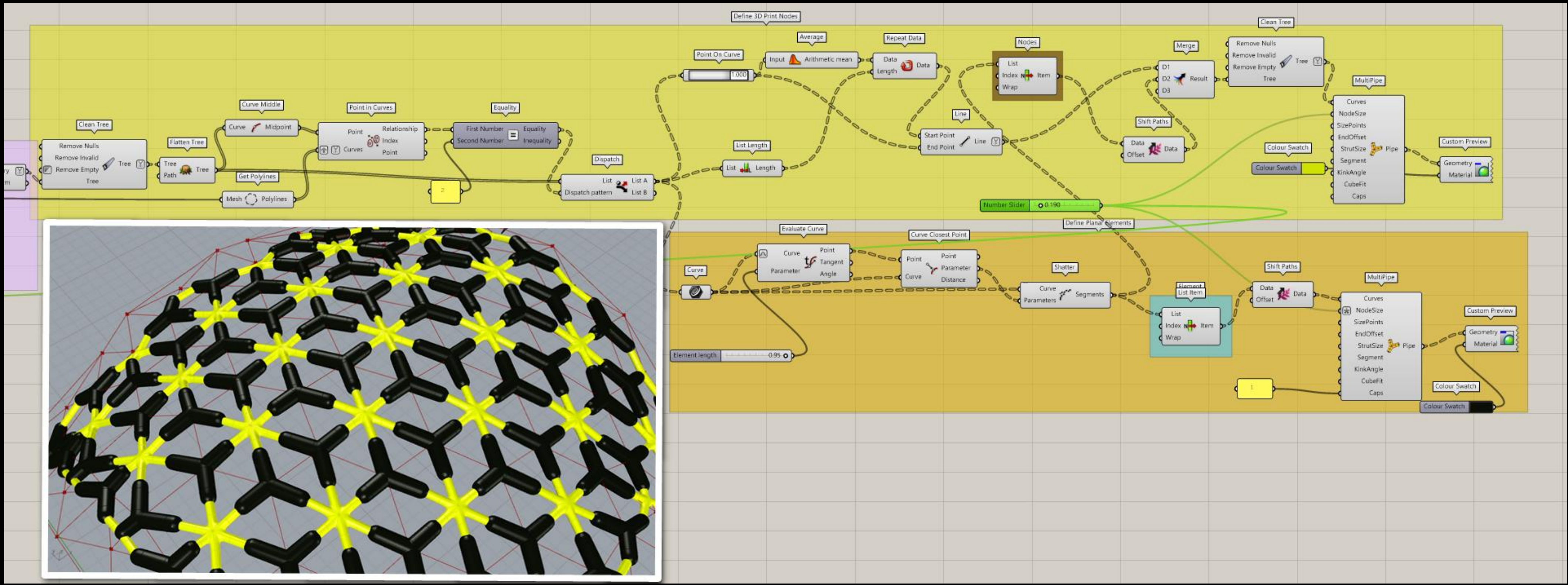


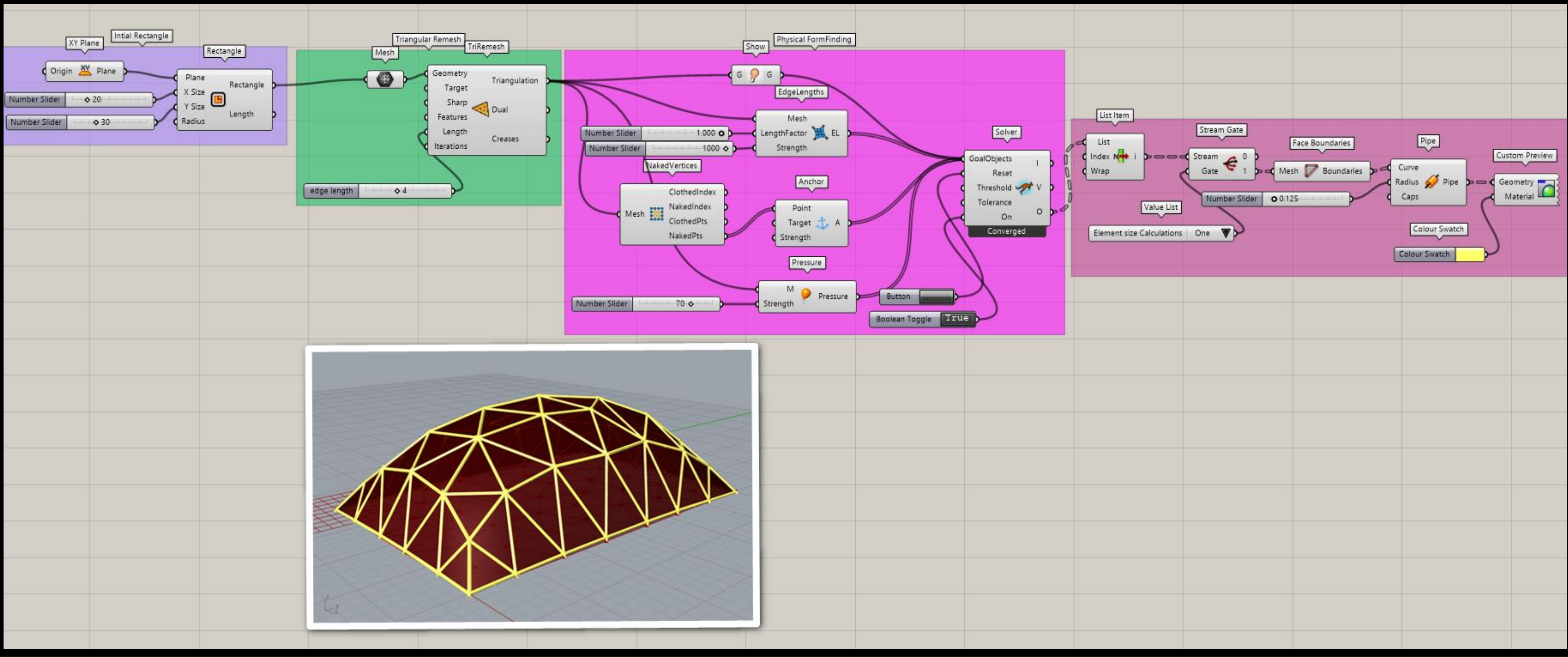
Parametric Shell Using the Ngon Plugin and Then Design 3D Connections for the Vertices.



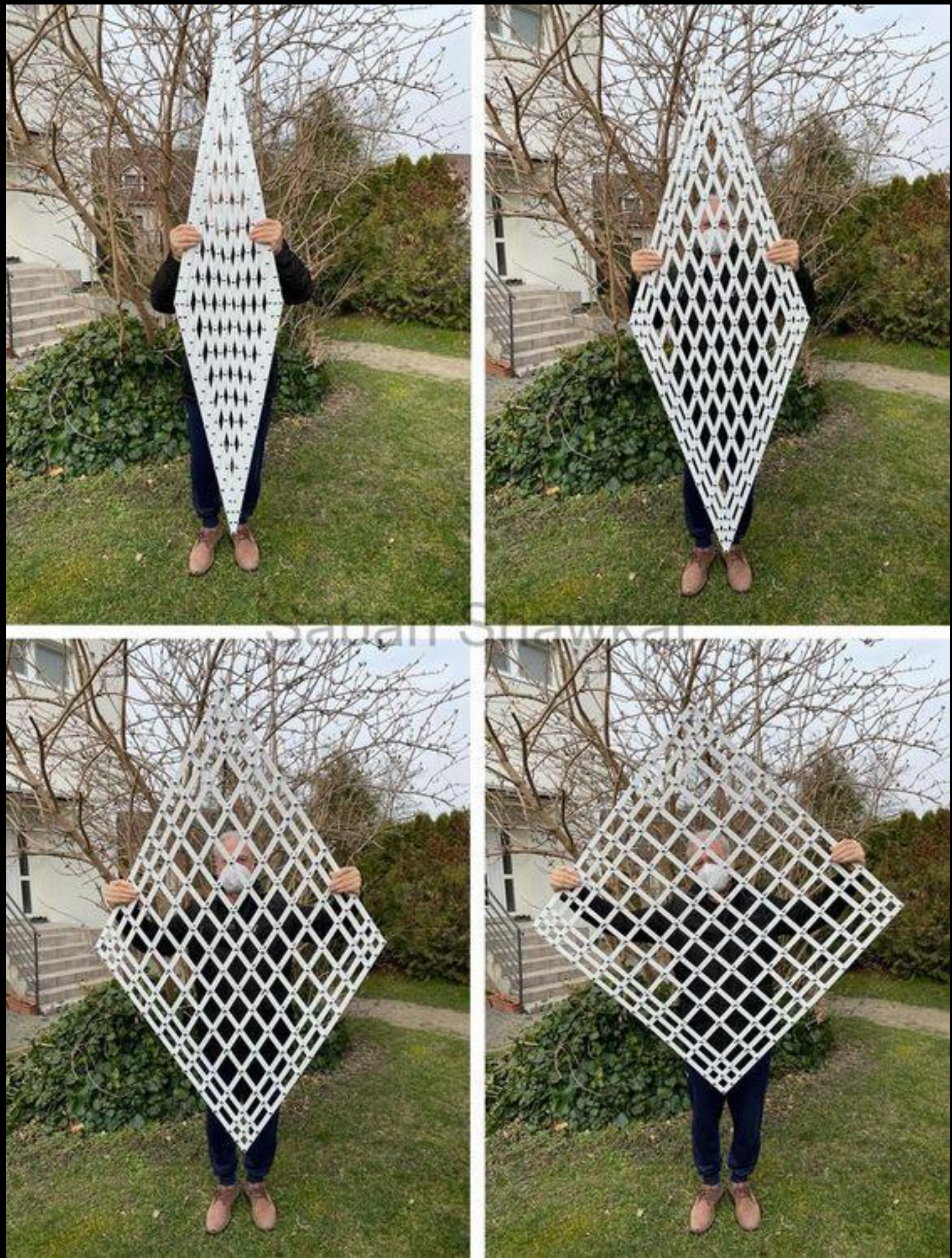
Parametric Shell Using the Ngon Plugin and Then Design 3D Connections for the Vertices.



Pneumatic Membrane Structures- Physical Form-Finding



Elastic geodesic grid EGG



Bending-active structural systems include curved rods or shells which have been elastically bent from an initial straight or plane configuration

Biomimicry Design

"When we look at what is truly sustainable, the only real model that has worked over long periods of time is the natural world."

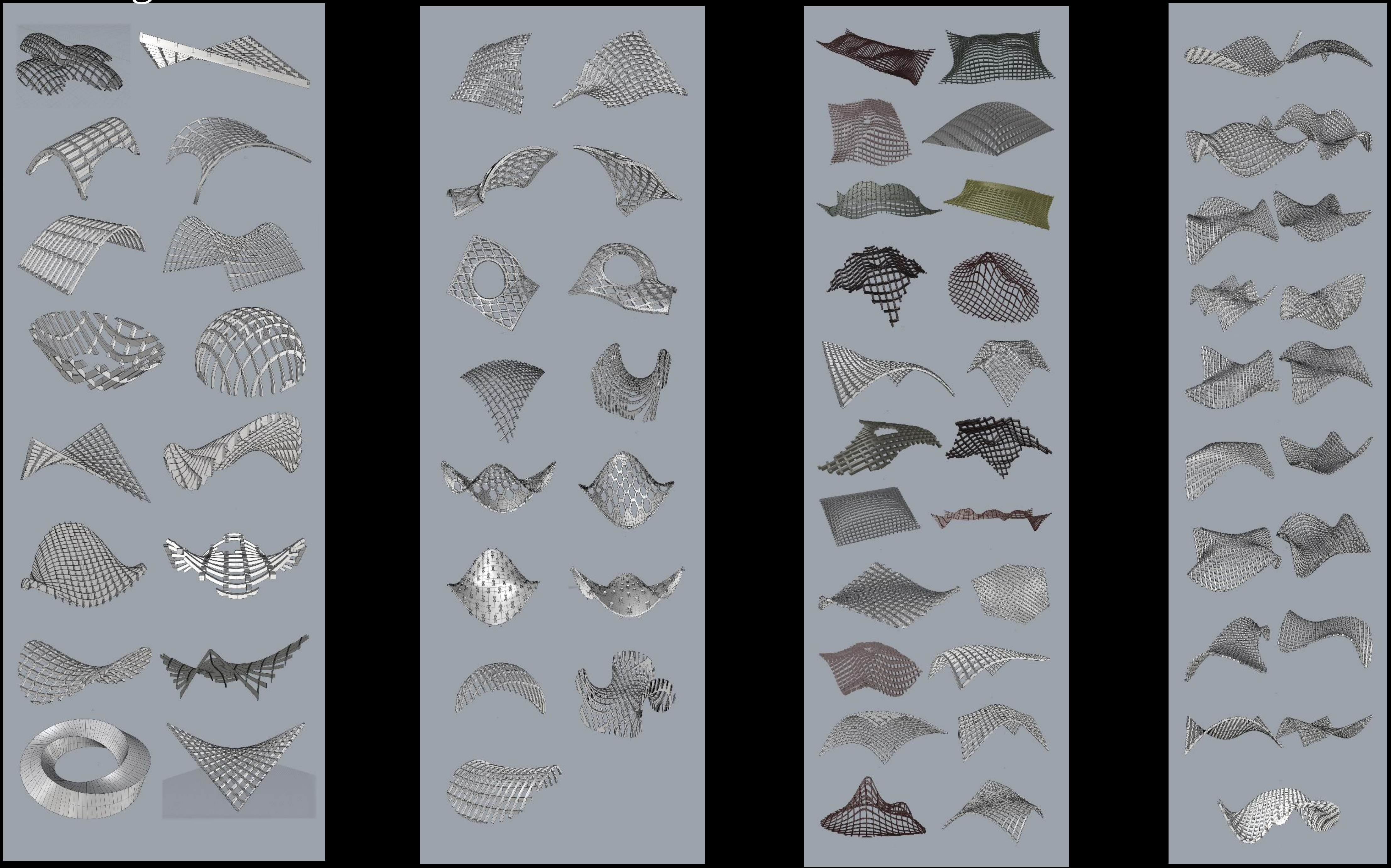
Janine Benyus

Biomimicry design has significant effect in the development of ecological sustainable design and no material waste, offers not only affected human life but also participating with nature instead of against it and at the end brings relief.

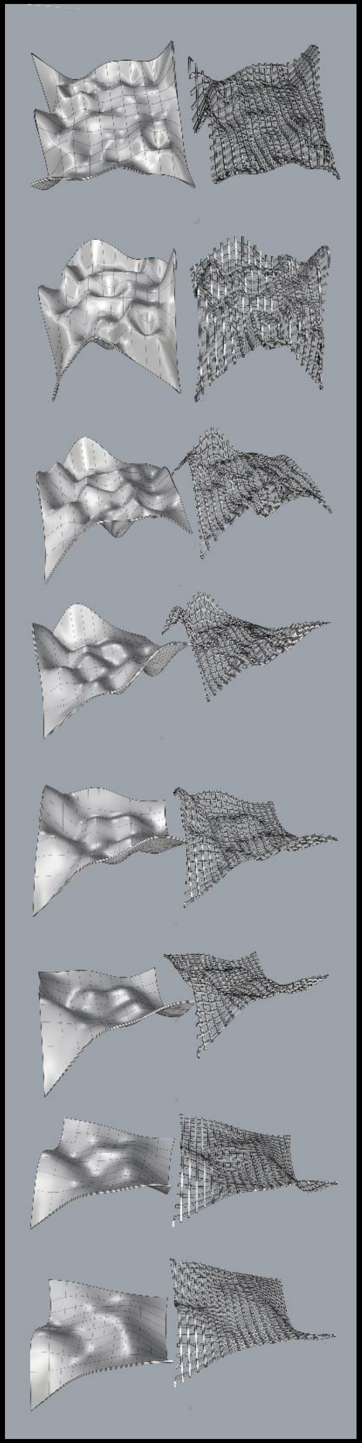
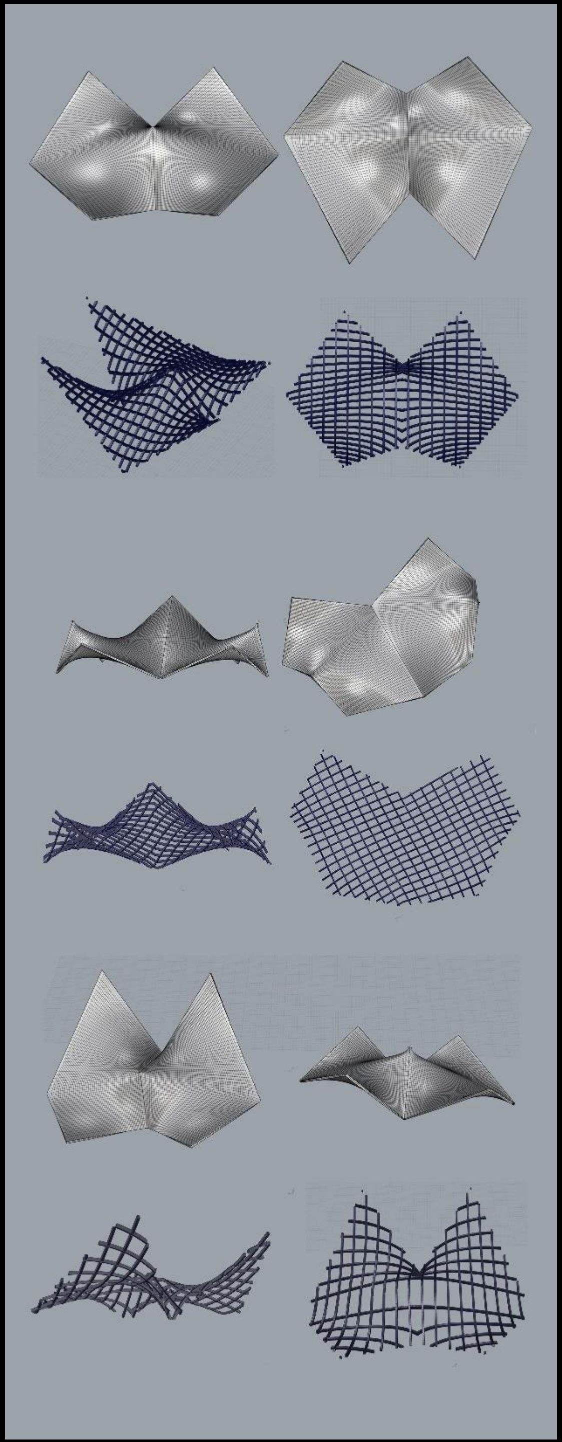
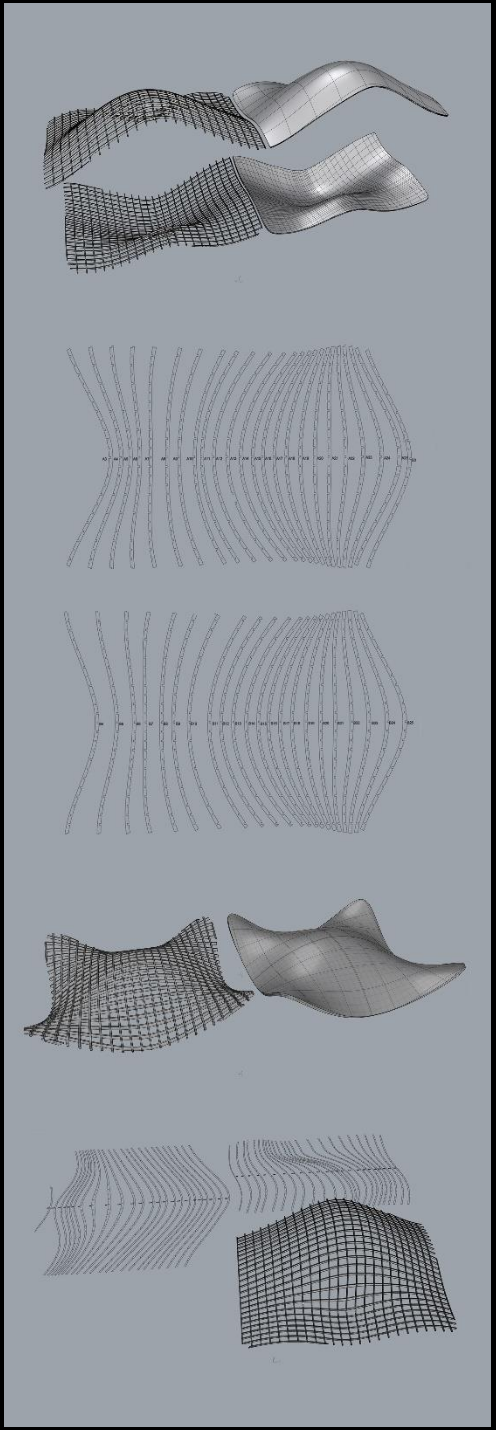
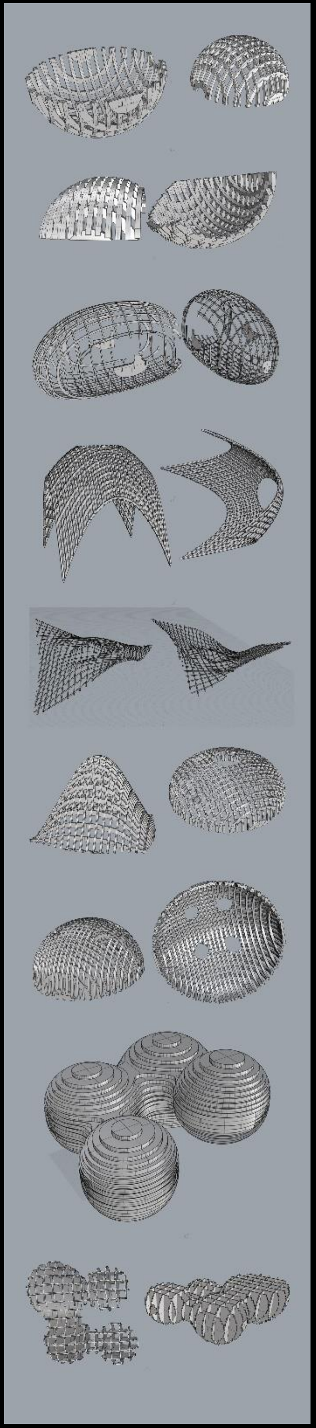
Describing such innovative design methods that take in to account the modelling behaviour, the properties of materials and the effect of environmental factors, will be a proper requirements of Biomimetic design to architecture.

As we know the idea of biomimicry is not applied as a design method. To implement the design of biomimicry properly at a real scale requires the participation of others professions such as biologists, ecologists and designers who can create the relationships among the organism, systems in nature and the requirements of humans in order for them to undertake reasonable decision for a more sustainable built enviroment

Digital simulation using a parametric grasshopper model–Biomimicry Design

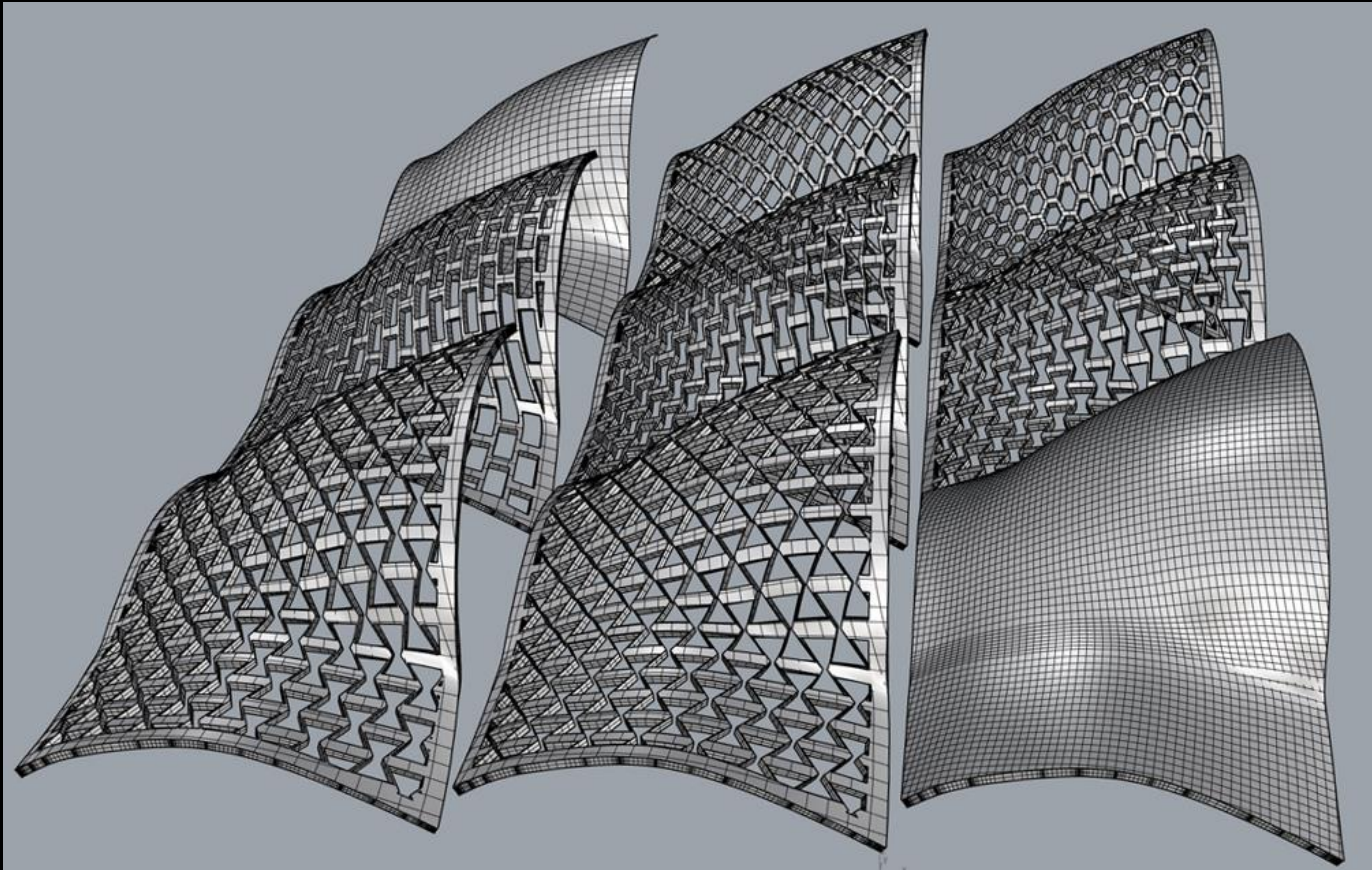


Parametric grasshopper model–Biomimicry Design

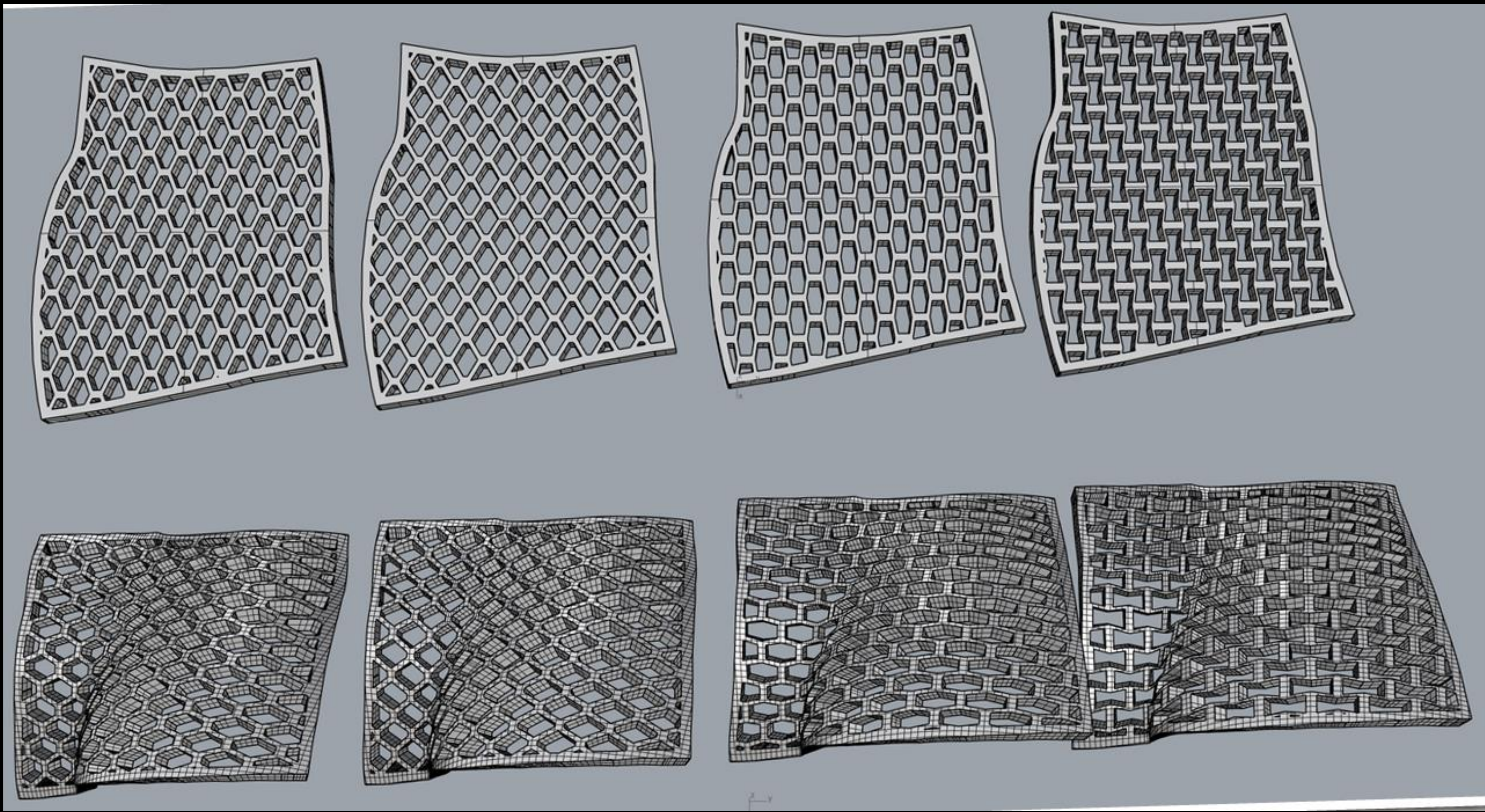
Morphology in Architecture – Biomimicry Design

Changing Parameter Values to Transform Hexagonal Angle

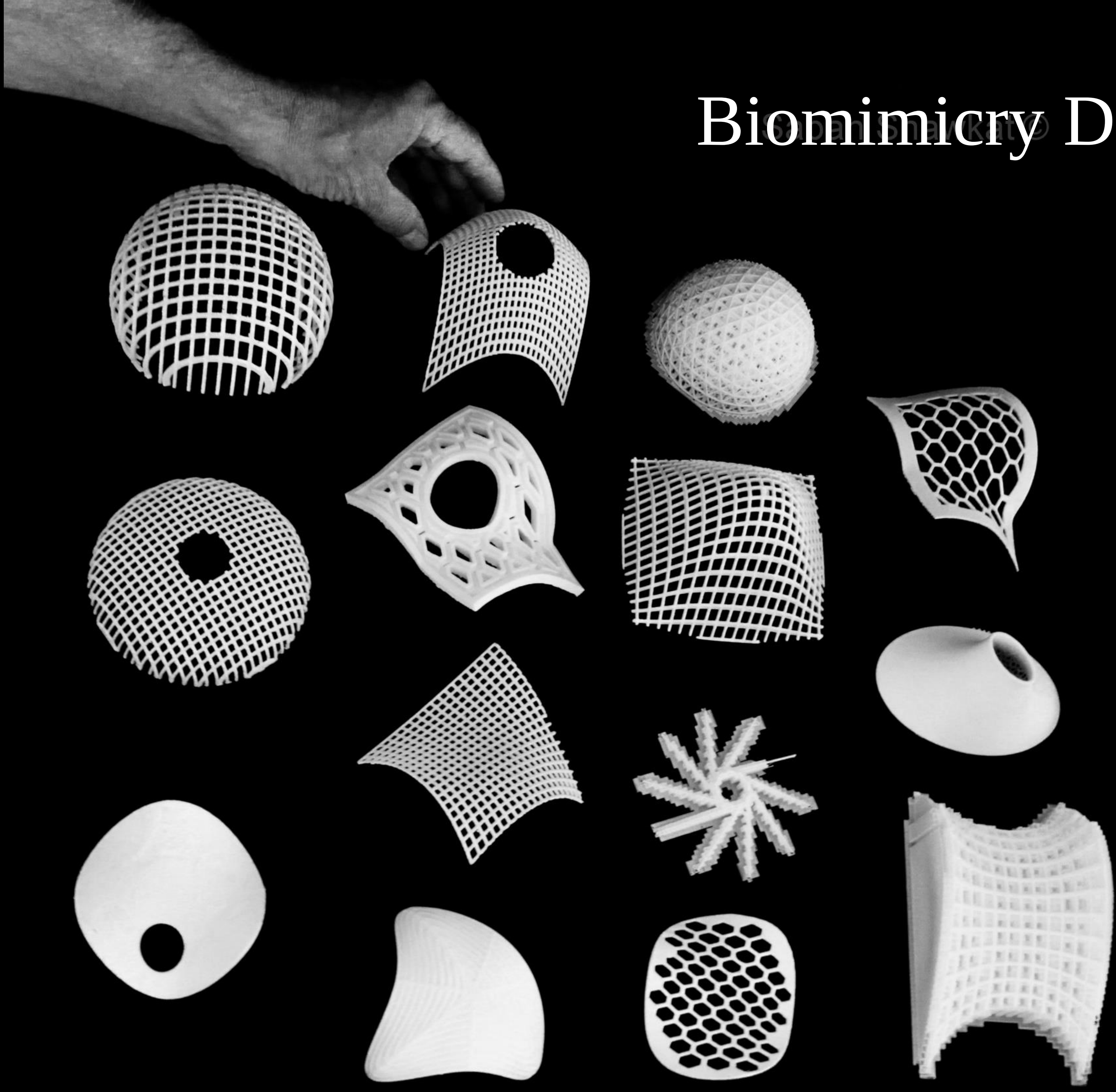


Morphology in Architecture - – Biomimicry Design

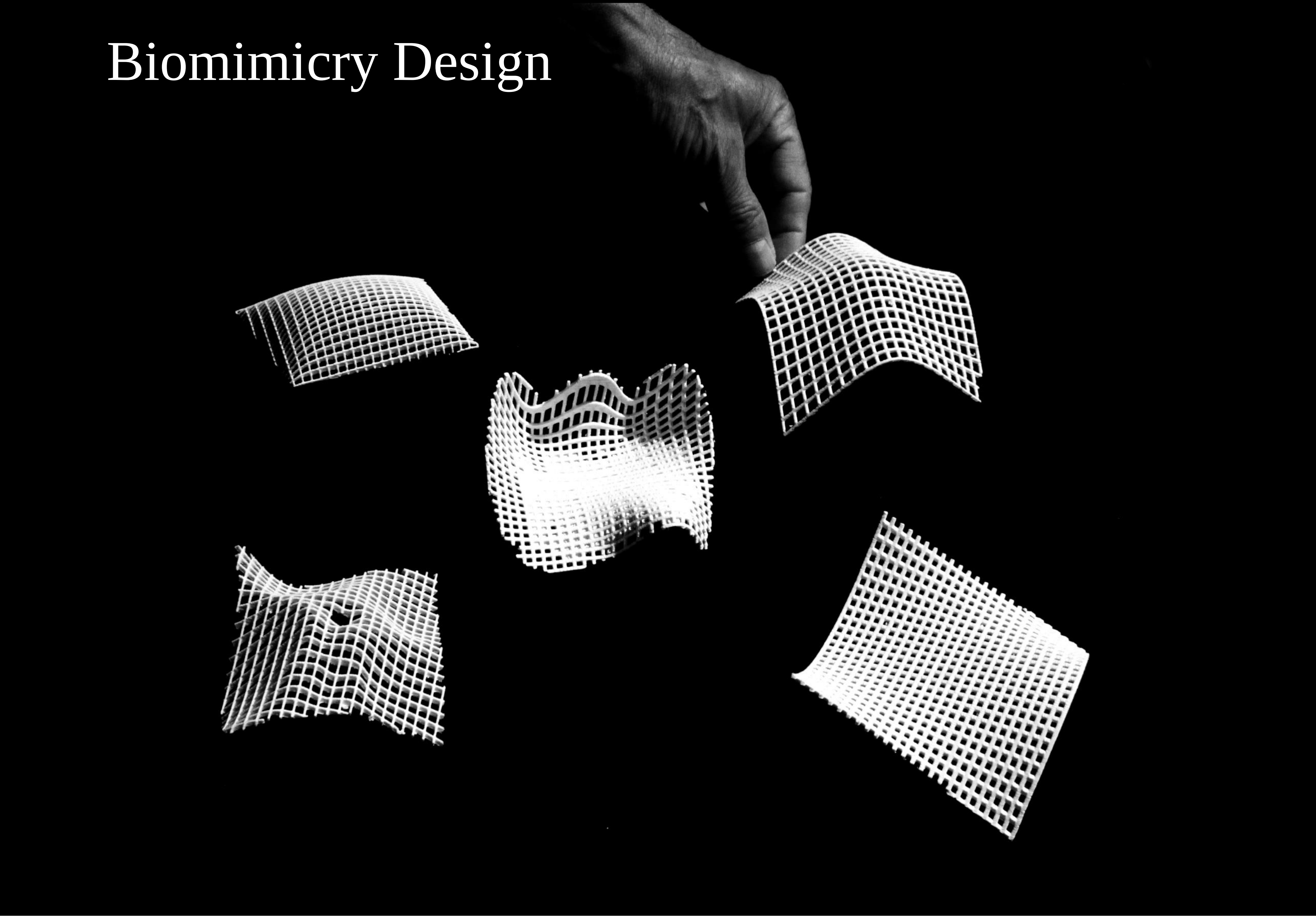
Changing Parameter Values to Transform Hexagonal Angle



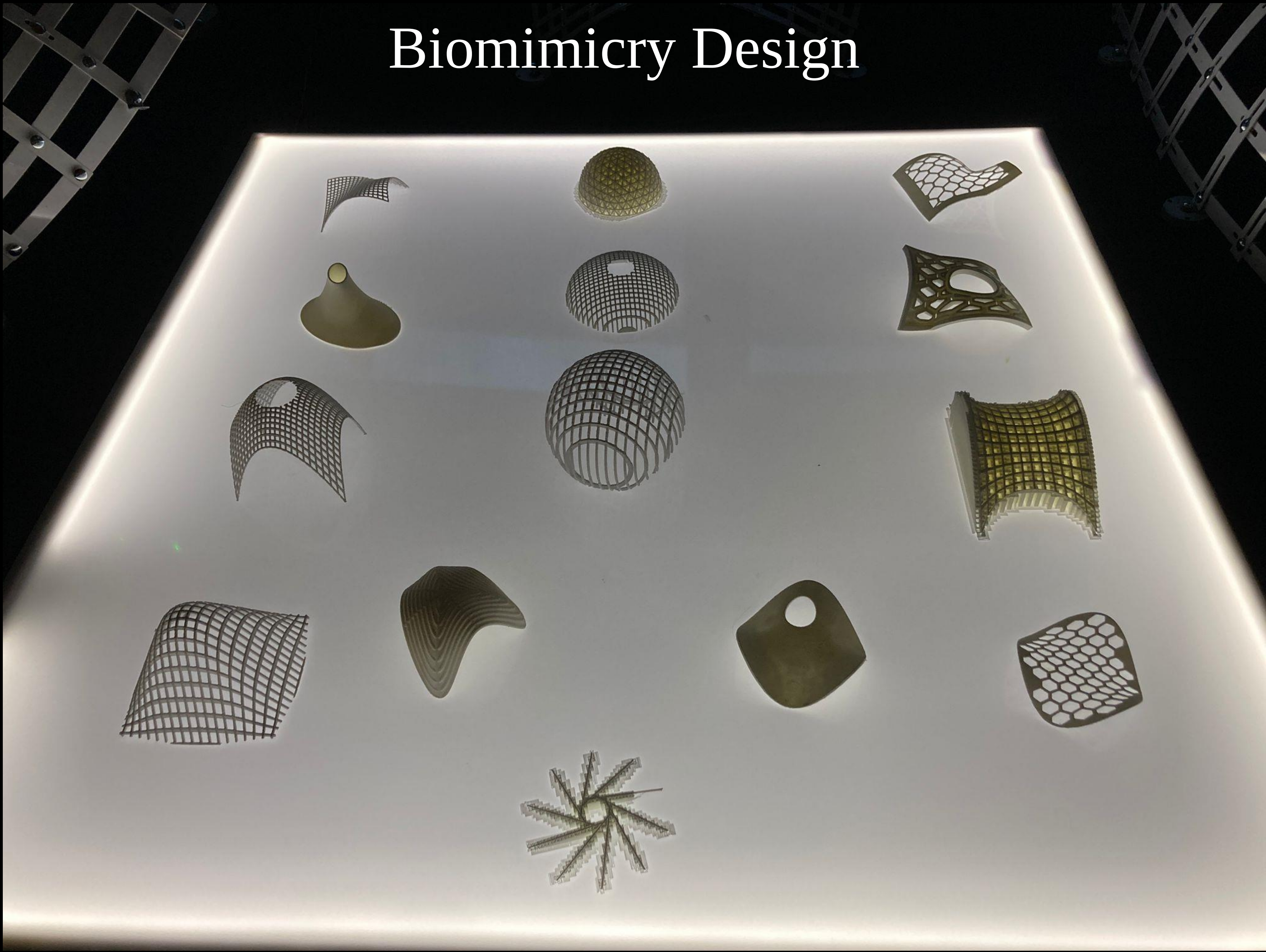
Biomimicry Design



Biomimicry Design



Biomimicry Design

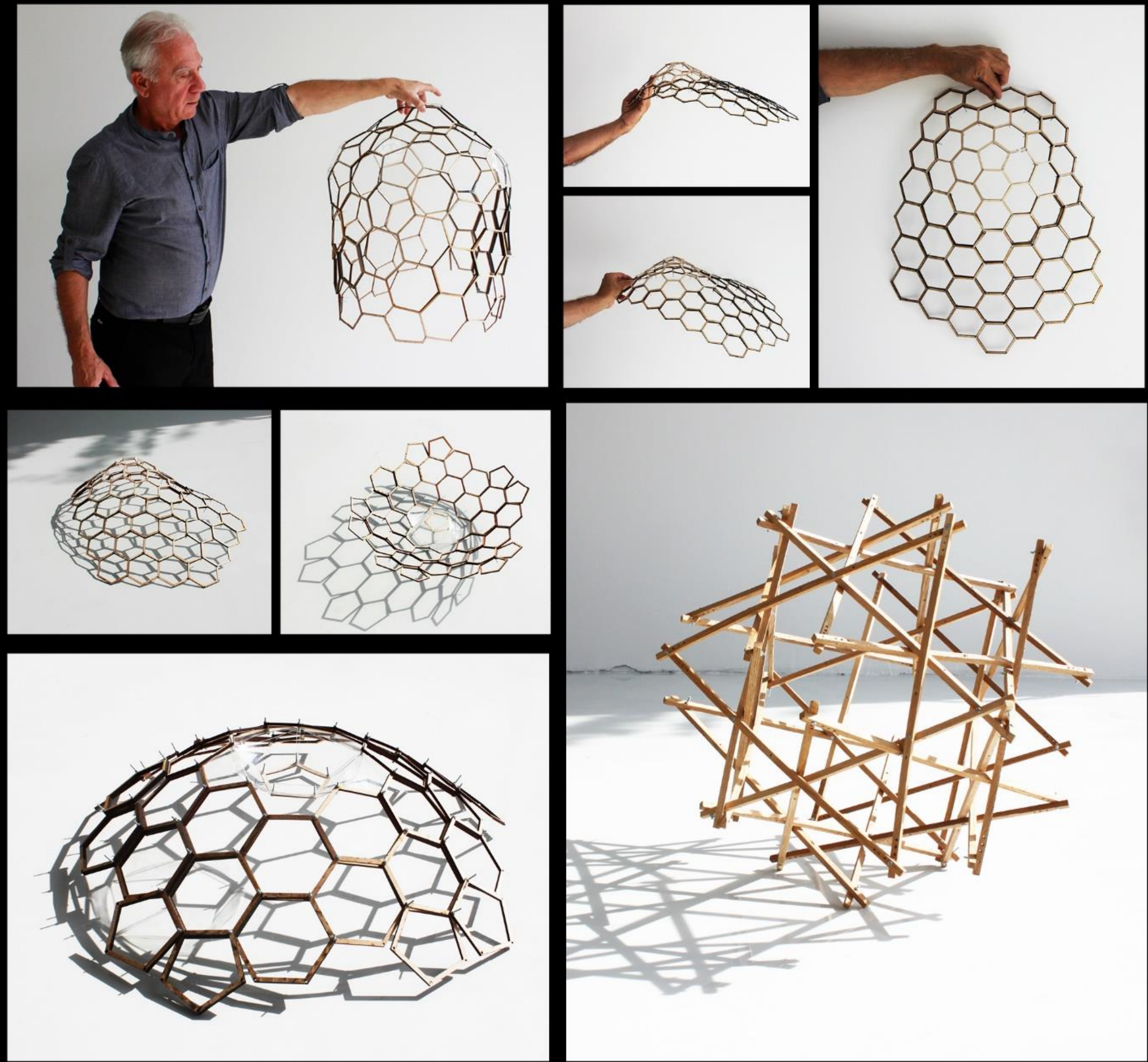


- The concept ’active bending’ refers to a category of structures in which bending is used in the process of shape configuration.

- Bending-active structural systems include curved rods or shells which have been elastically bent from an initial straight or plane configuration.

Biomimicry Design

Geodesic Domes

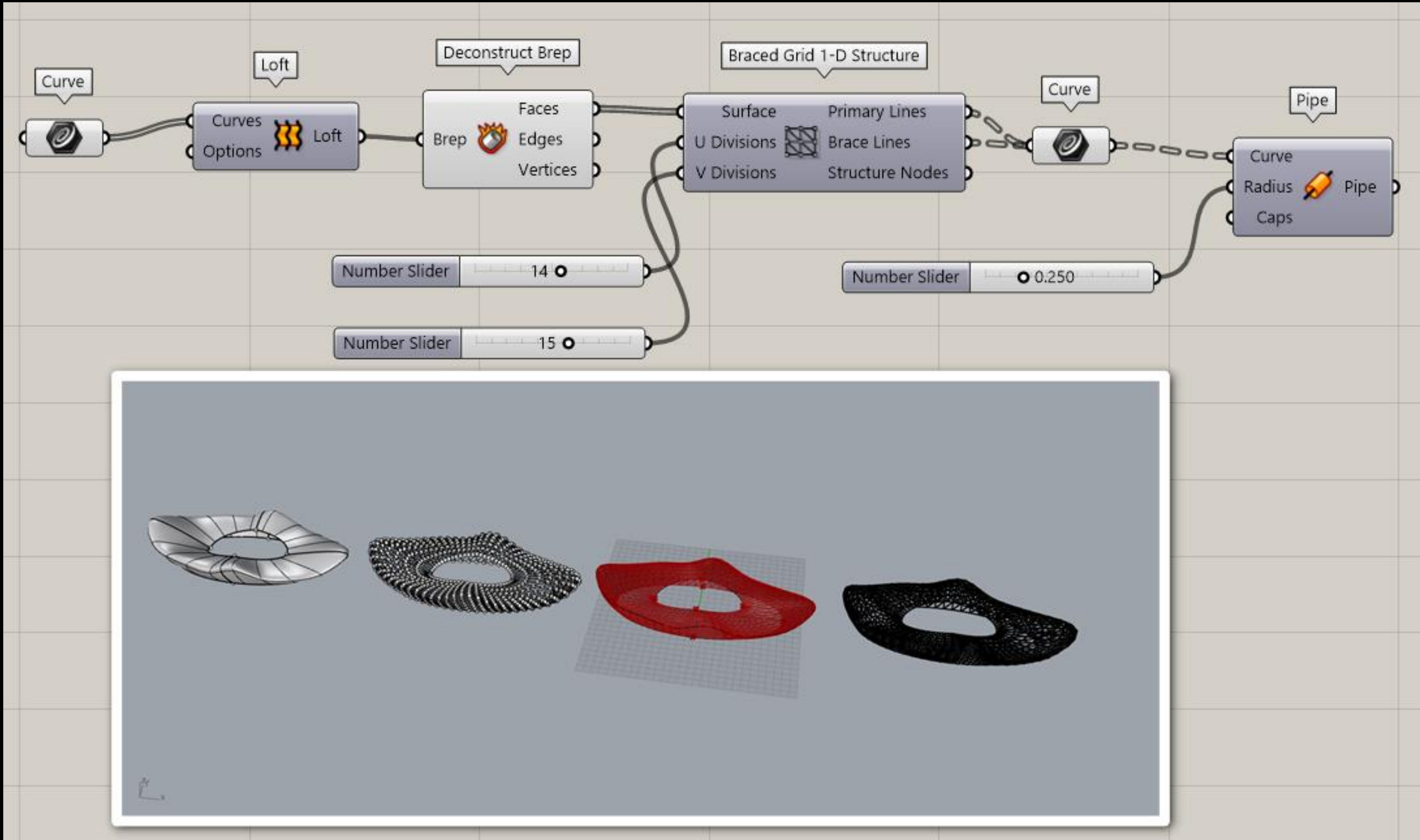


Geodesic domes

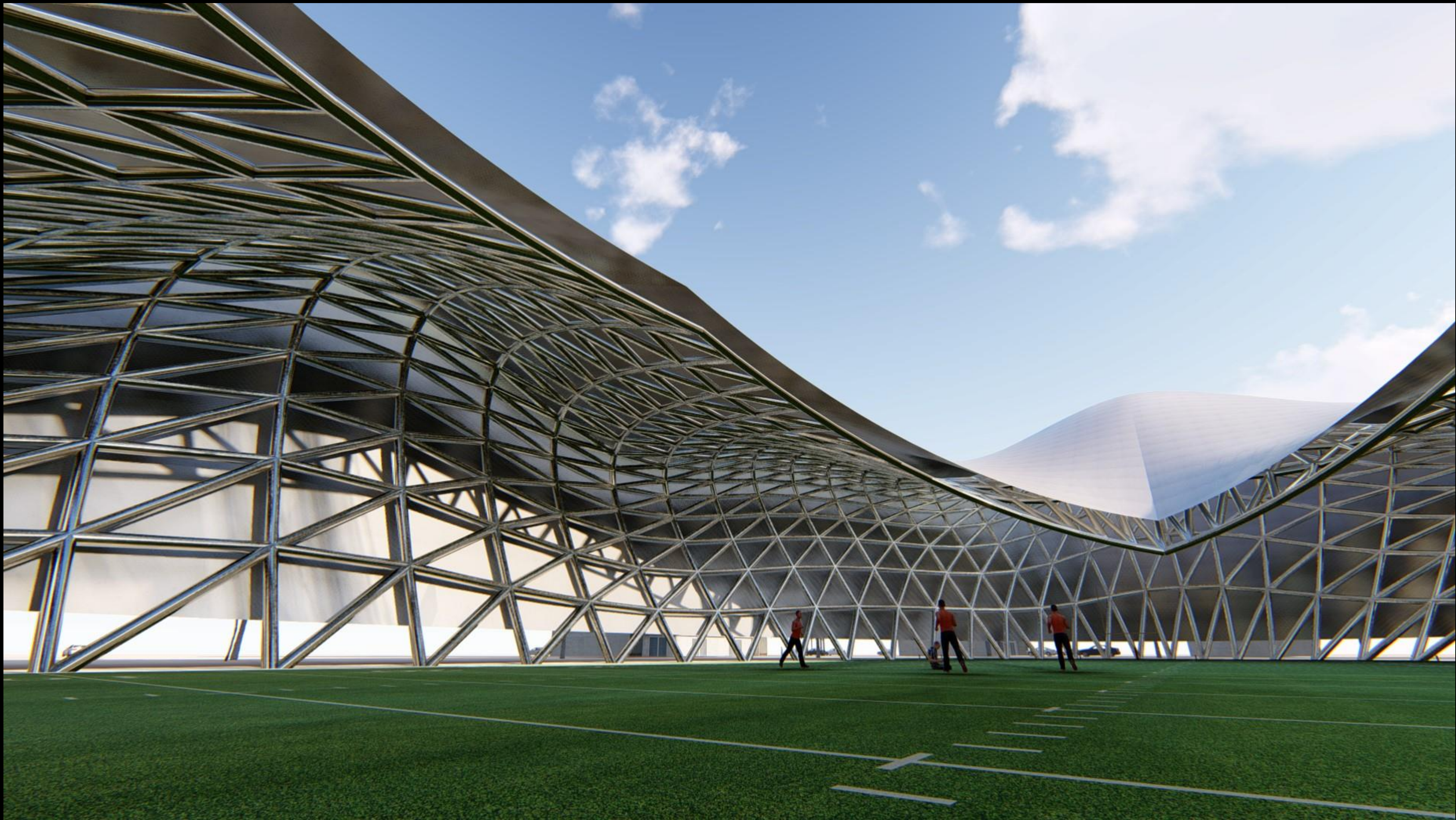
How Virtual Become Real-Geodesic Dome


FANTA

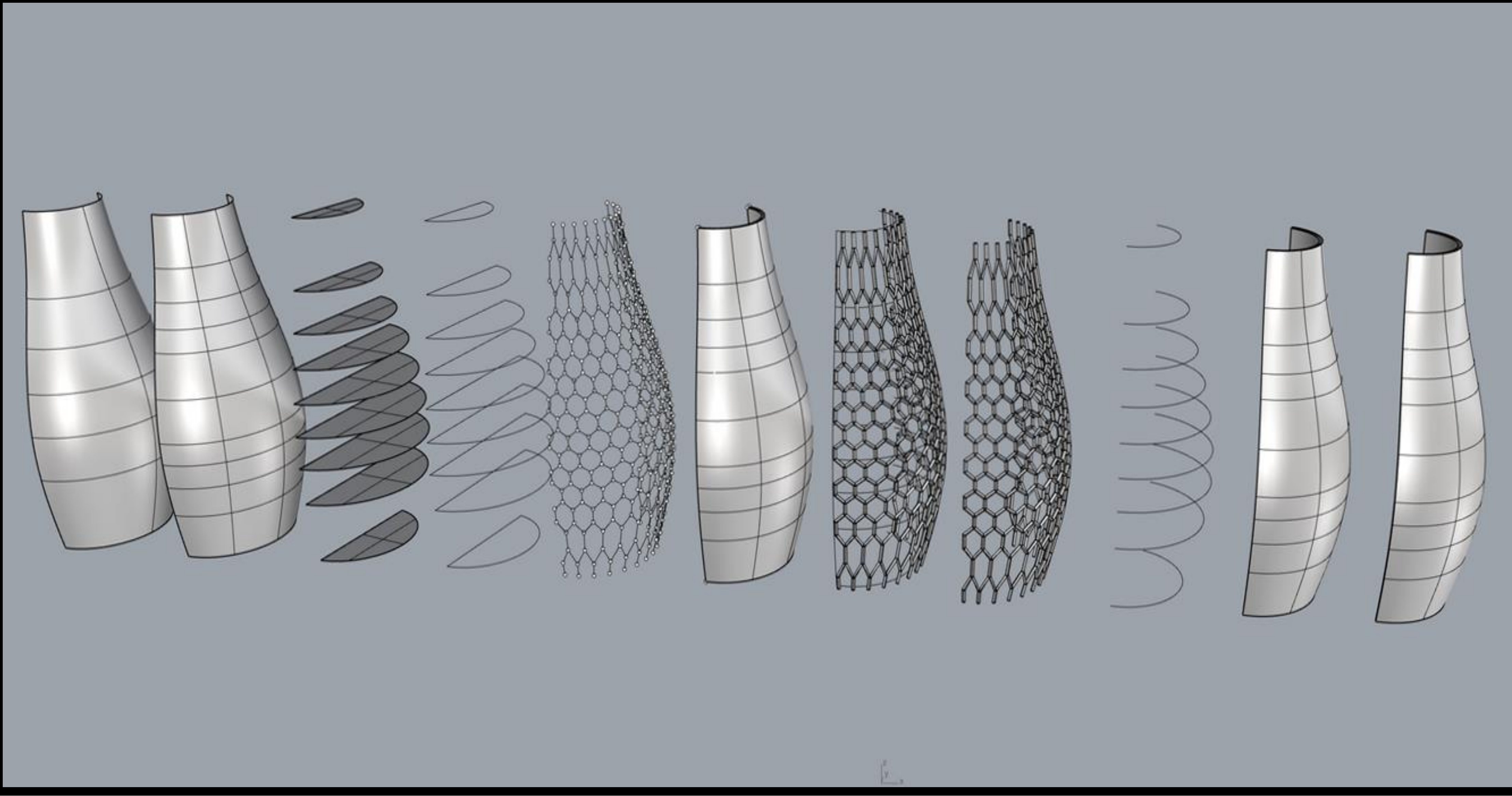
Parametric Design-Grid Shell-Form Finding



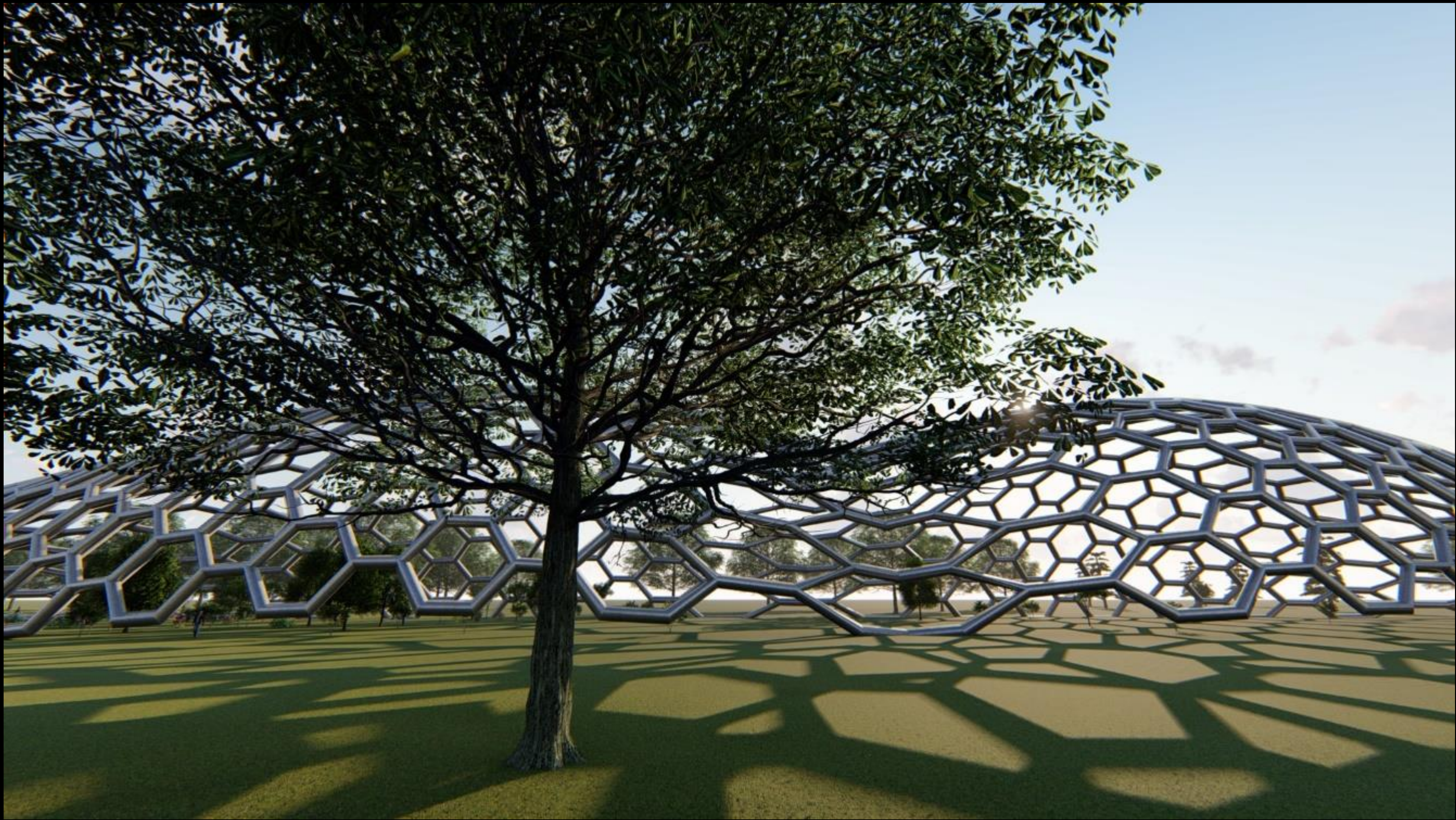
Biomimicry Shell-Form Finding



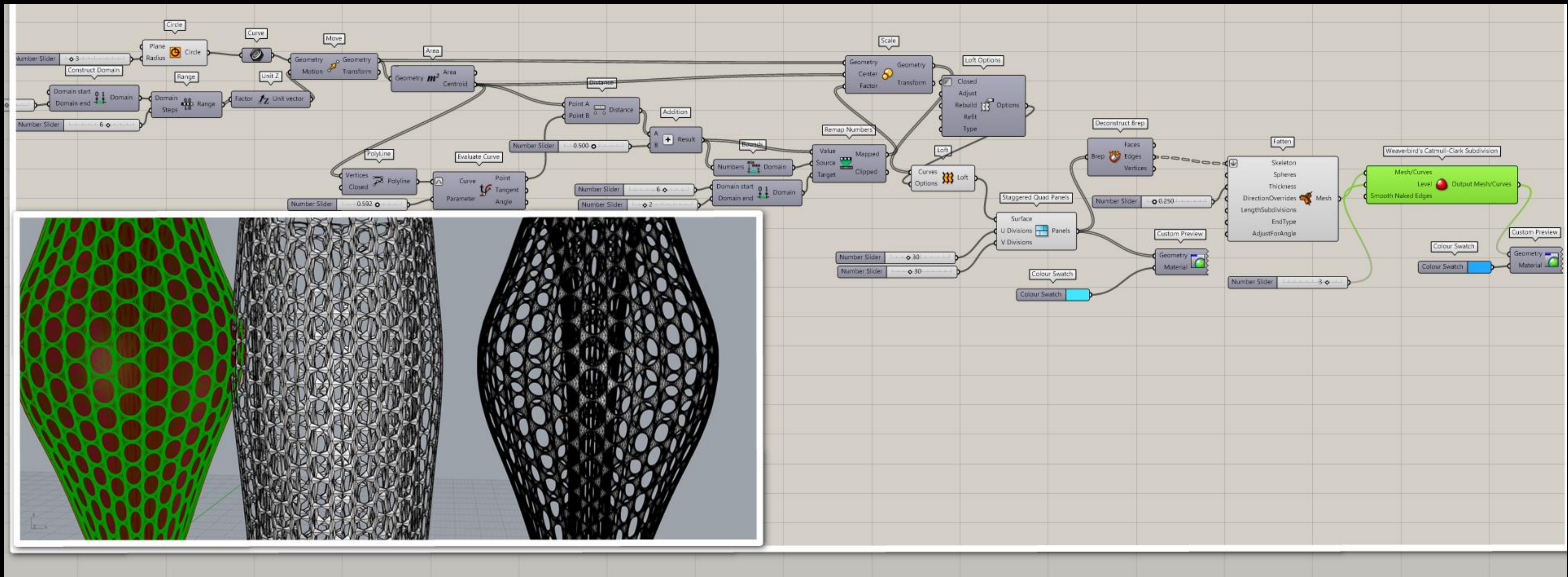
Parametric Design- Grid Shell from a Sine Shape Curve

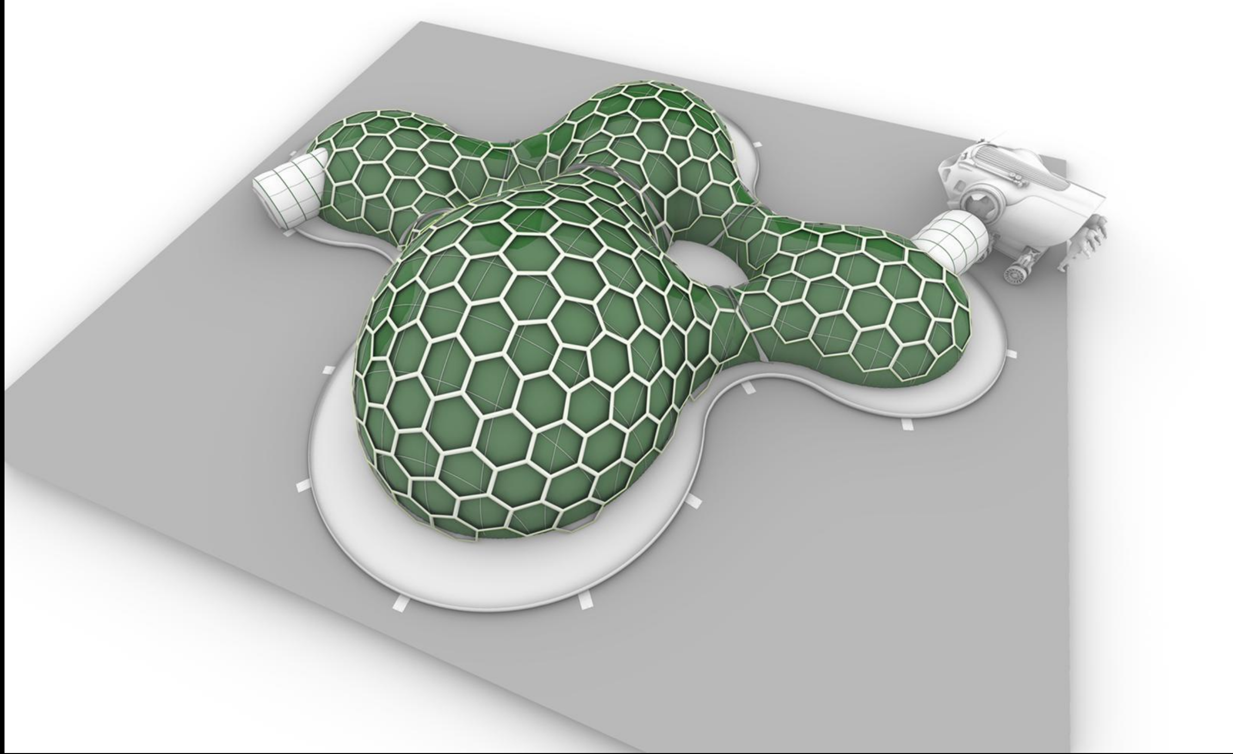


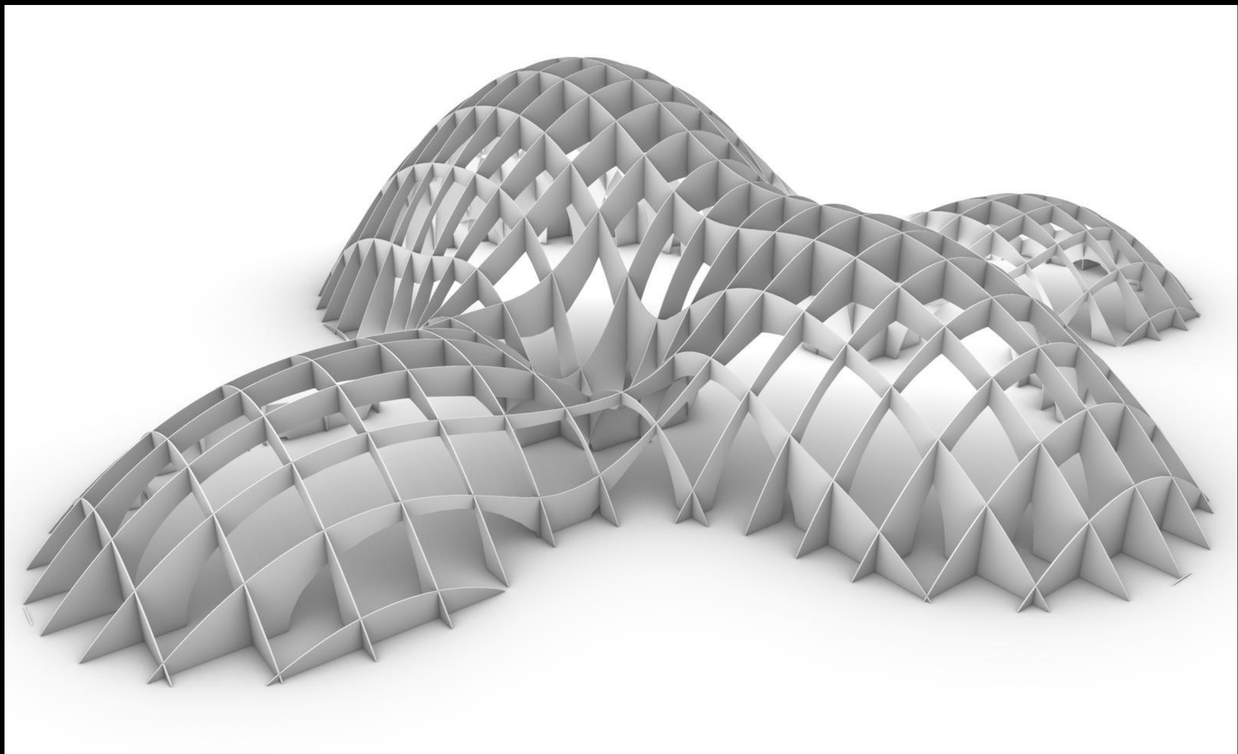
Biomimicry Shell from a Sine Shape Curve



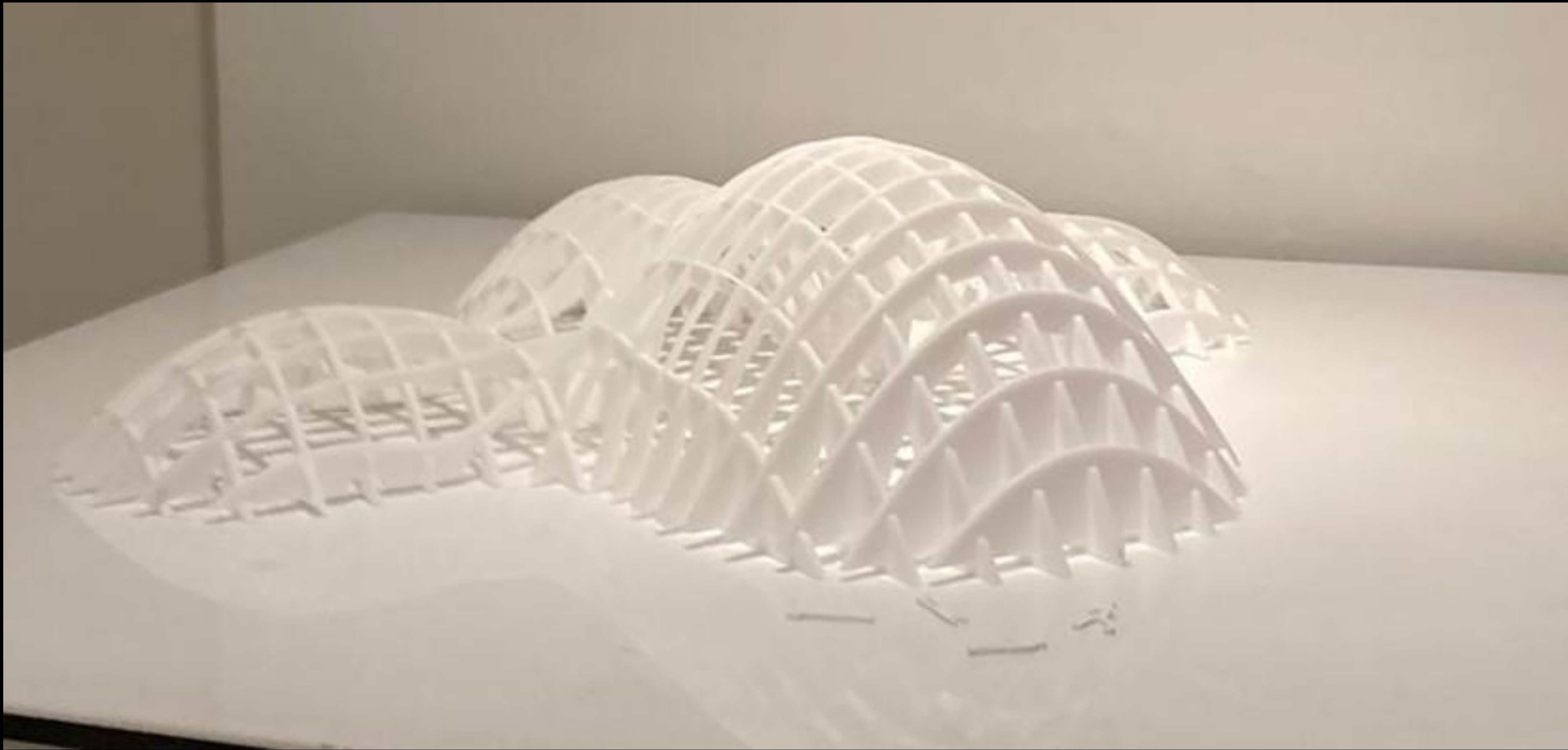
Parametric Design- Biomimicry Shell





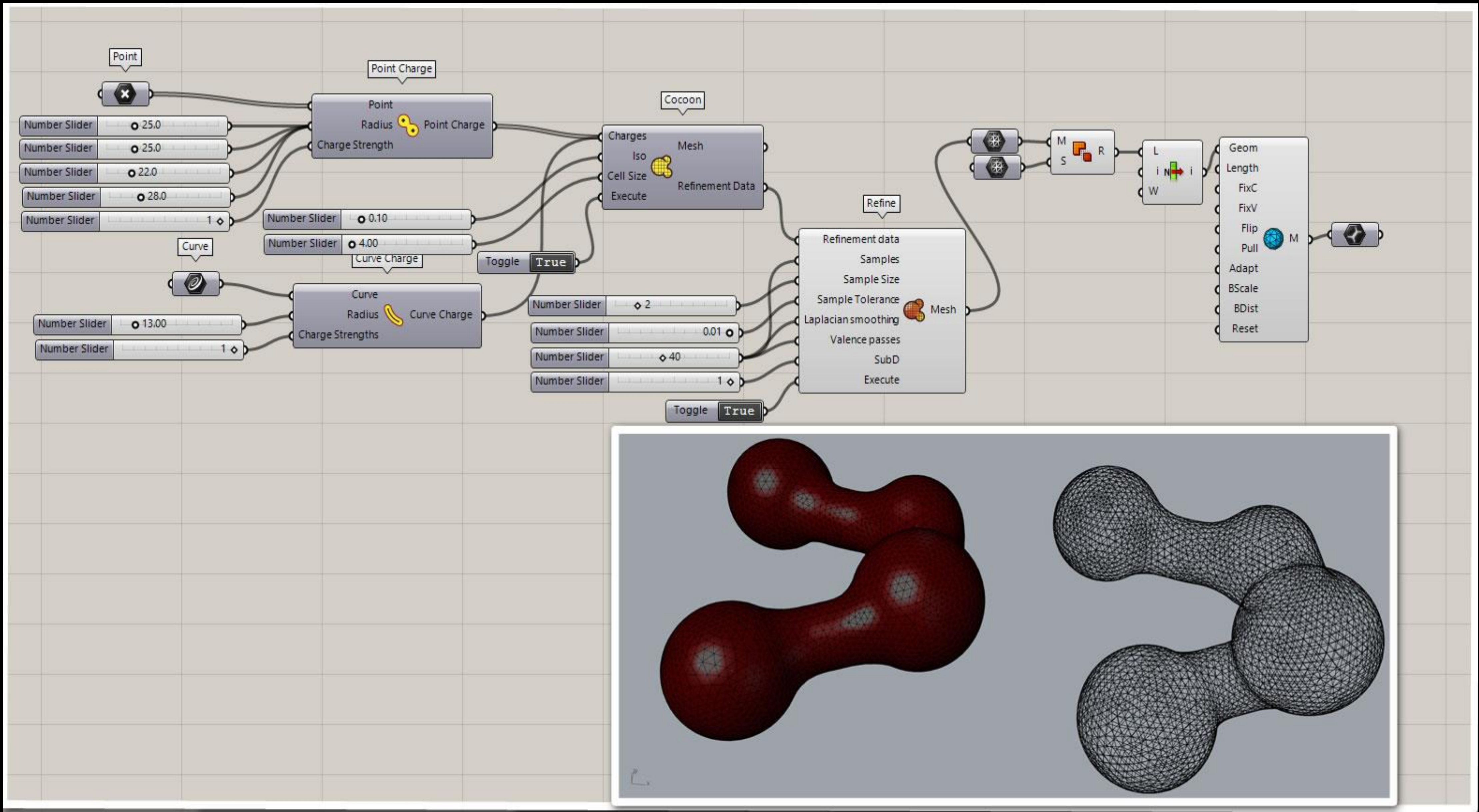


Parametric Design- Tunnel Shelter Concept-Voronoi Diagrams



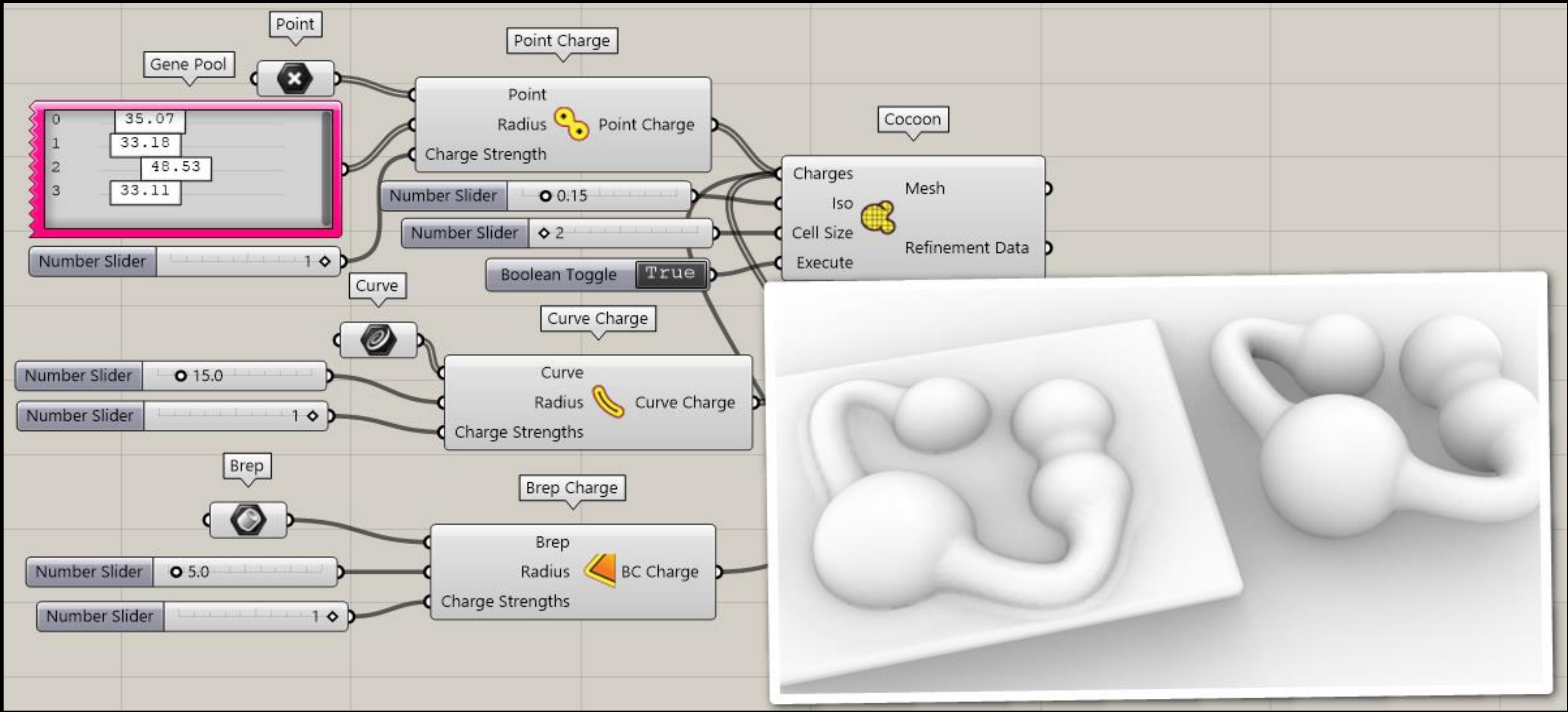
Mannheim Multi-halle (1974) designed by Frei Otto, in collaboration with Ian Liddell and Chris Williams. With no computational power and simulation knowledge –computers were not powerful enough at that time– the geometry of the grid-shell was conceived as a free-form grid of bent timber members and fully form-found by using meaningful physical models.

Parametric Design-Free Form Grid Shell

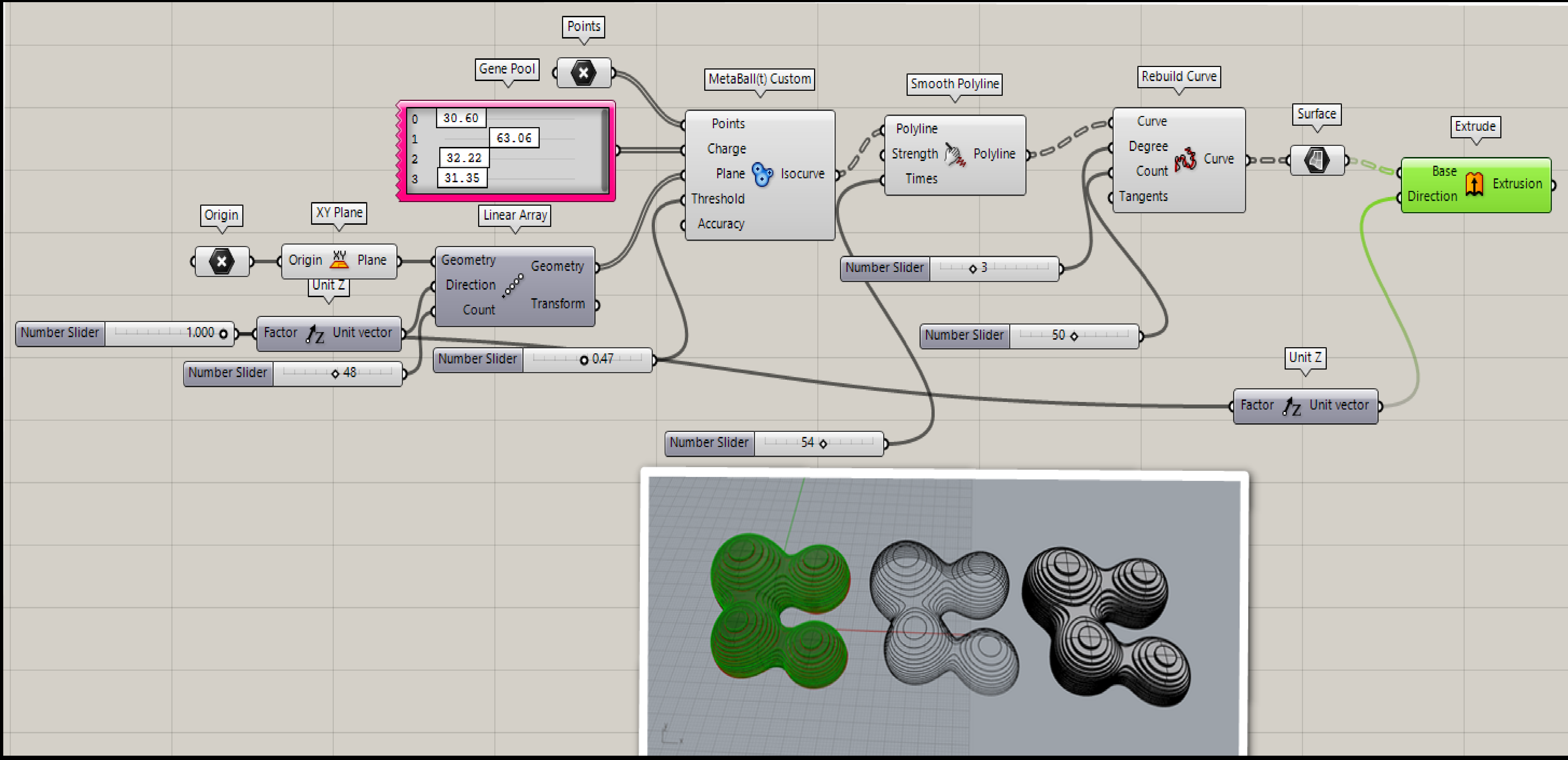


Parametric Design- Tunnel Shelter Concept

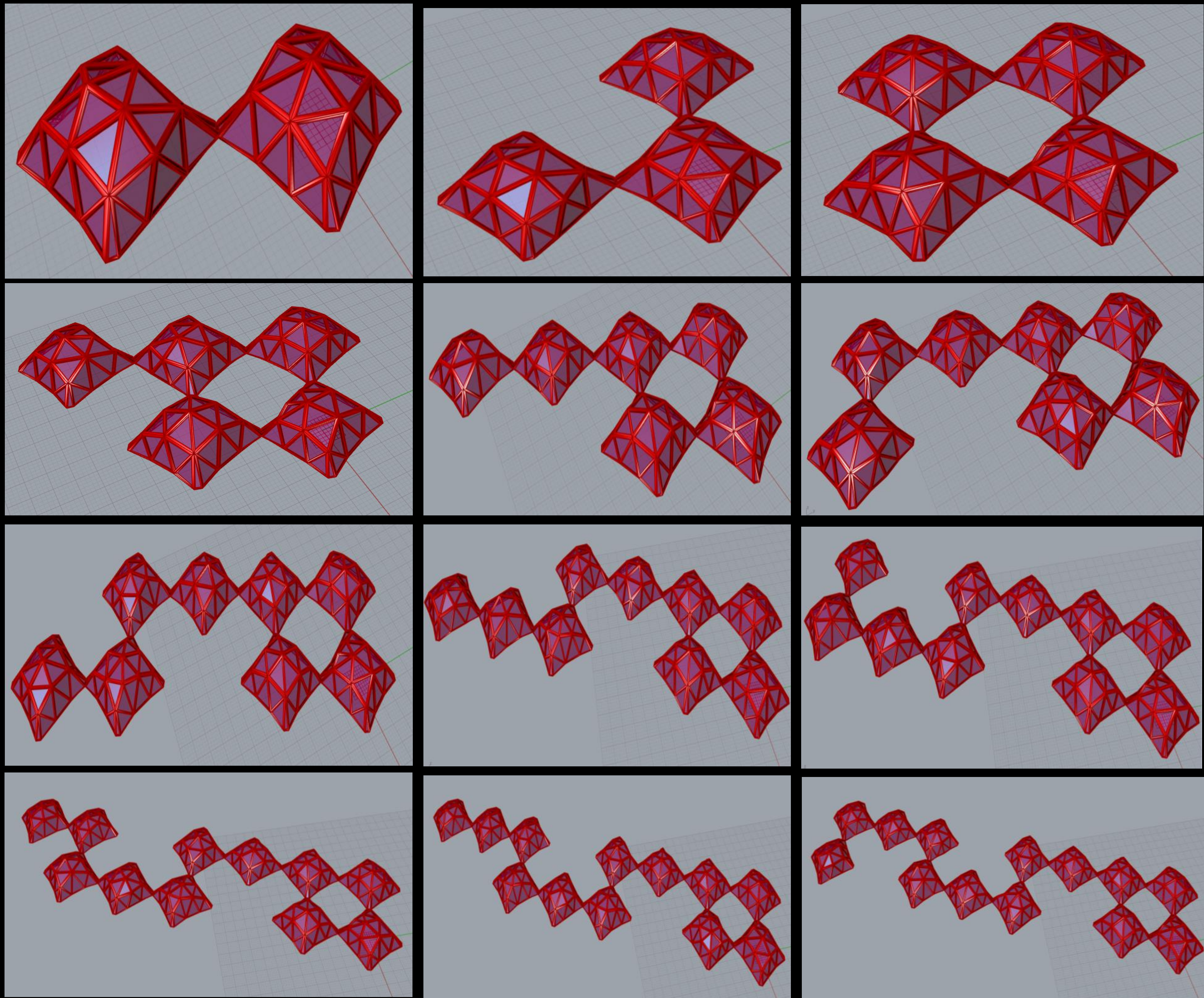
- The parametric design method provides facilities for examination of the number of nodes, the distribution of the elements in certain range of length may be demonstrated, minimal and maximal lengths of elements can be examined.



Parametric Design- Tunnel Shelter Concept



Parametric Design- Tunnel Shelter Concept
Voronoi Diagrams

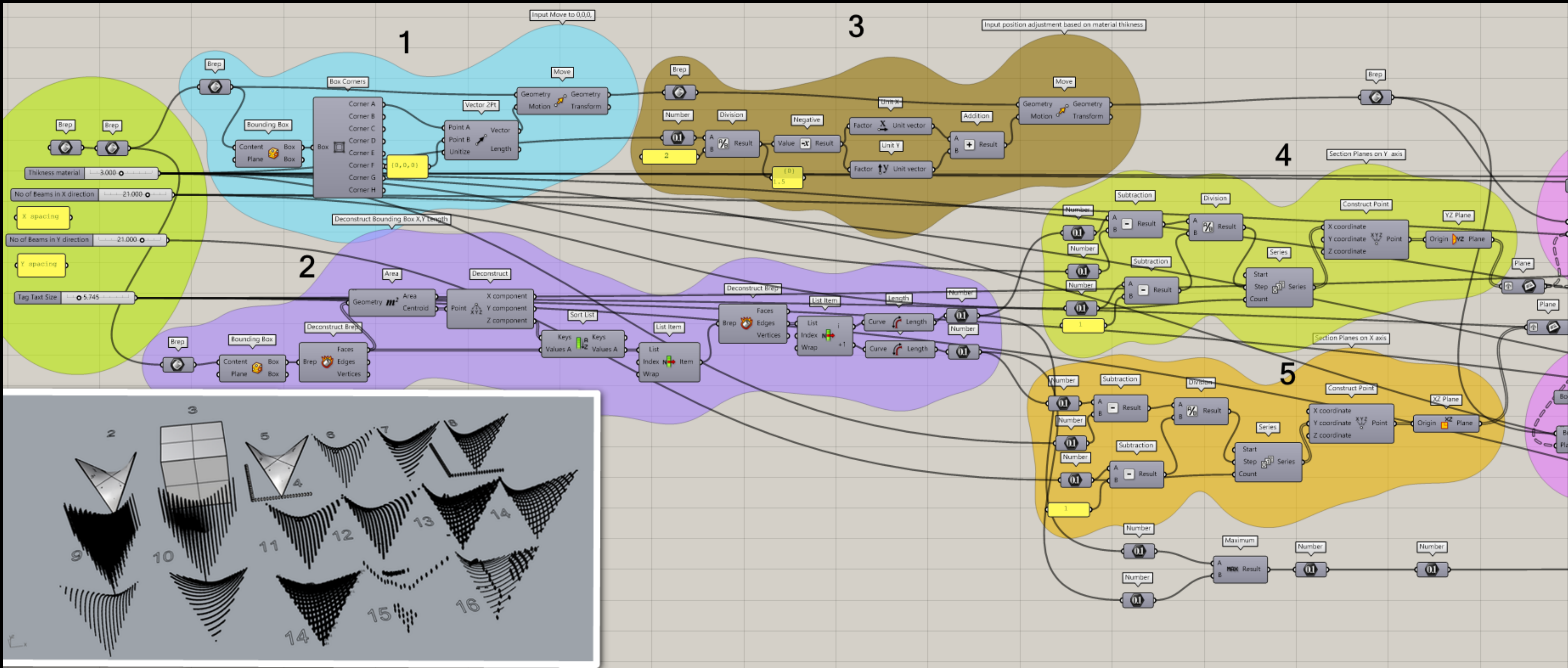


Script for Calculating the Parametric Geometry

The logic which determines the slot position is to analyze each Fries as a Brep(a set of square rods which is a place holder for the slots).

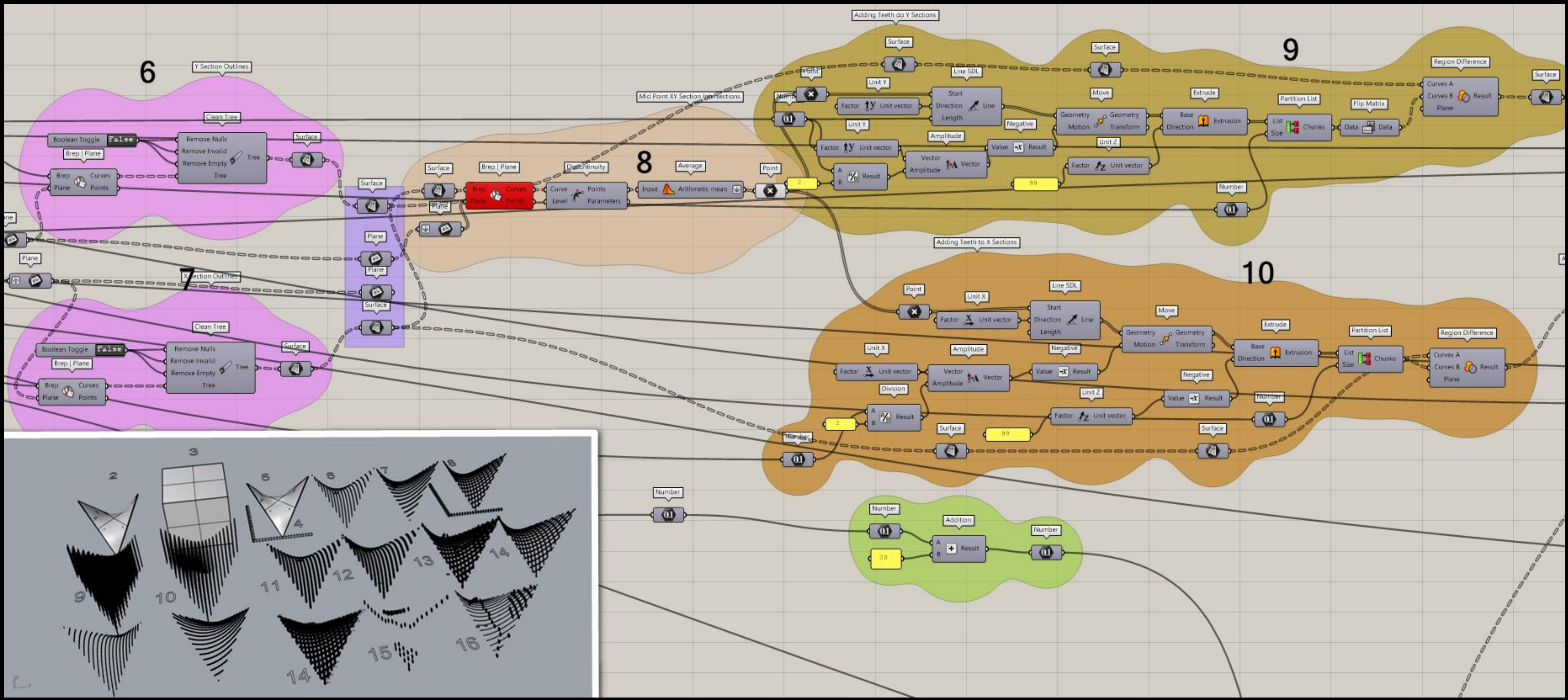
Each Fries represent a slot position. Because some complex forms may be hollow or cantilevering, therefor, each XY coordinate may have multiple Fries in different height.

Using the bounding box analysis on each Fries, the length of each Fries are found. The bounding boxes are then used as a Brep, which is used to boolean out the section slices.

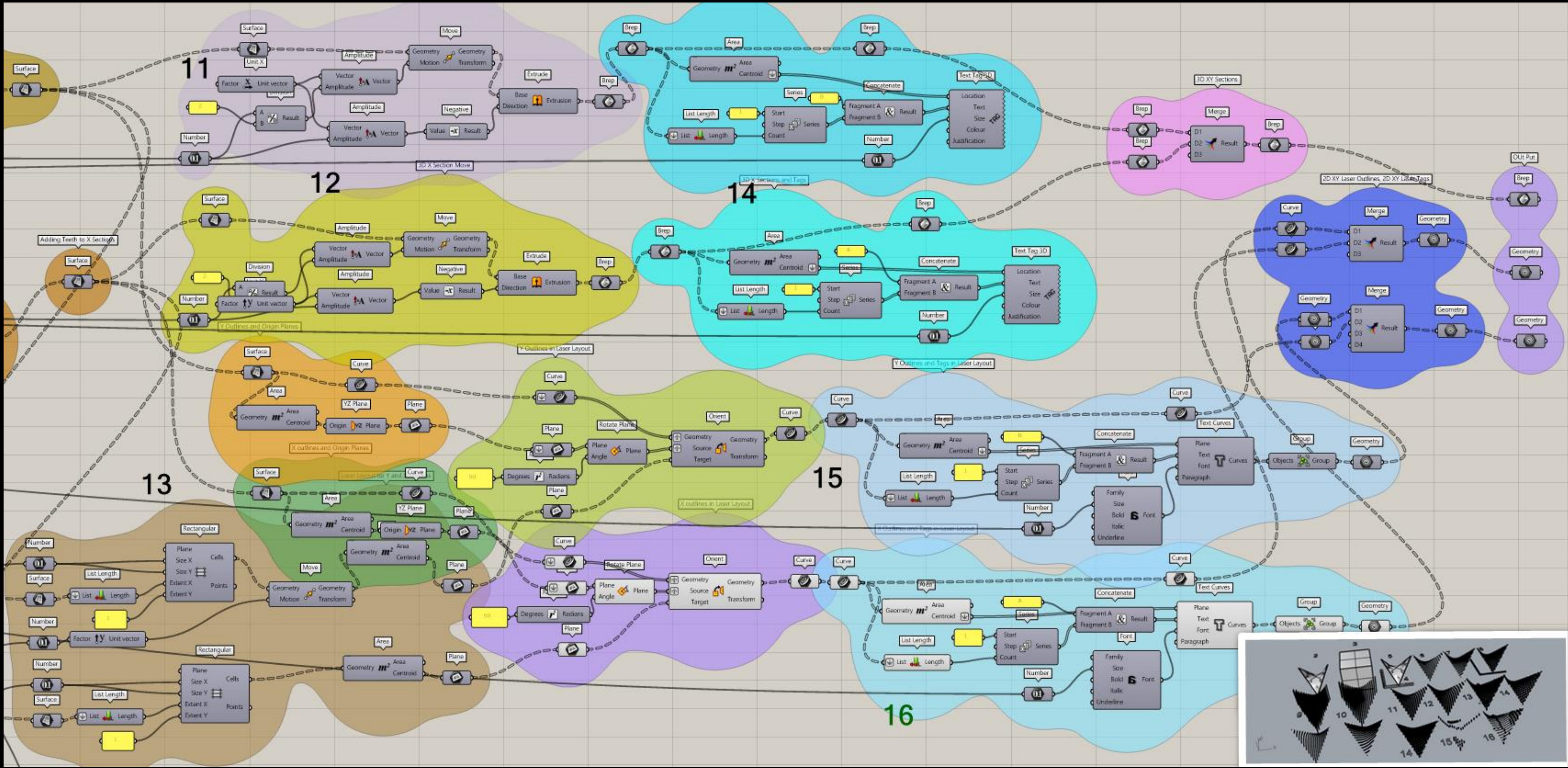


Reverse the slot direction

The logic is that, before boolean, I used a gate to reverse the feed of :
Upper Fries and Lower Fries to
X planes and Y planes



Sometimes boolean fails due to surface 'just touching', I added a tweak to slightly add some more thickness to the Fries.
If the script works fine, set the value to 1.0000, otherwise increase by a small value (eg:1.0025)



After spliting the long Fries into two segments, a slight increase in length is required to perfectly boolean the sections when the surface is not XY-flat.
Usually the value will work from 1.0100 to 1.1000.

I could not determine this value automatically, as the working scale changes, or the slope of the solid is very great, you need to increase this value.
I could not make this value infinitely large, because situations where there are two fries on the same XY location but different height (a horizontal holow pipe.), the fries will intersect if they are infinitely long.

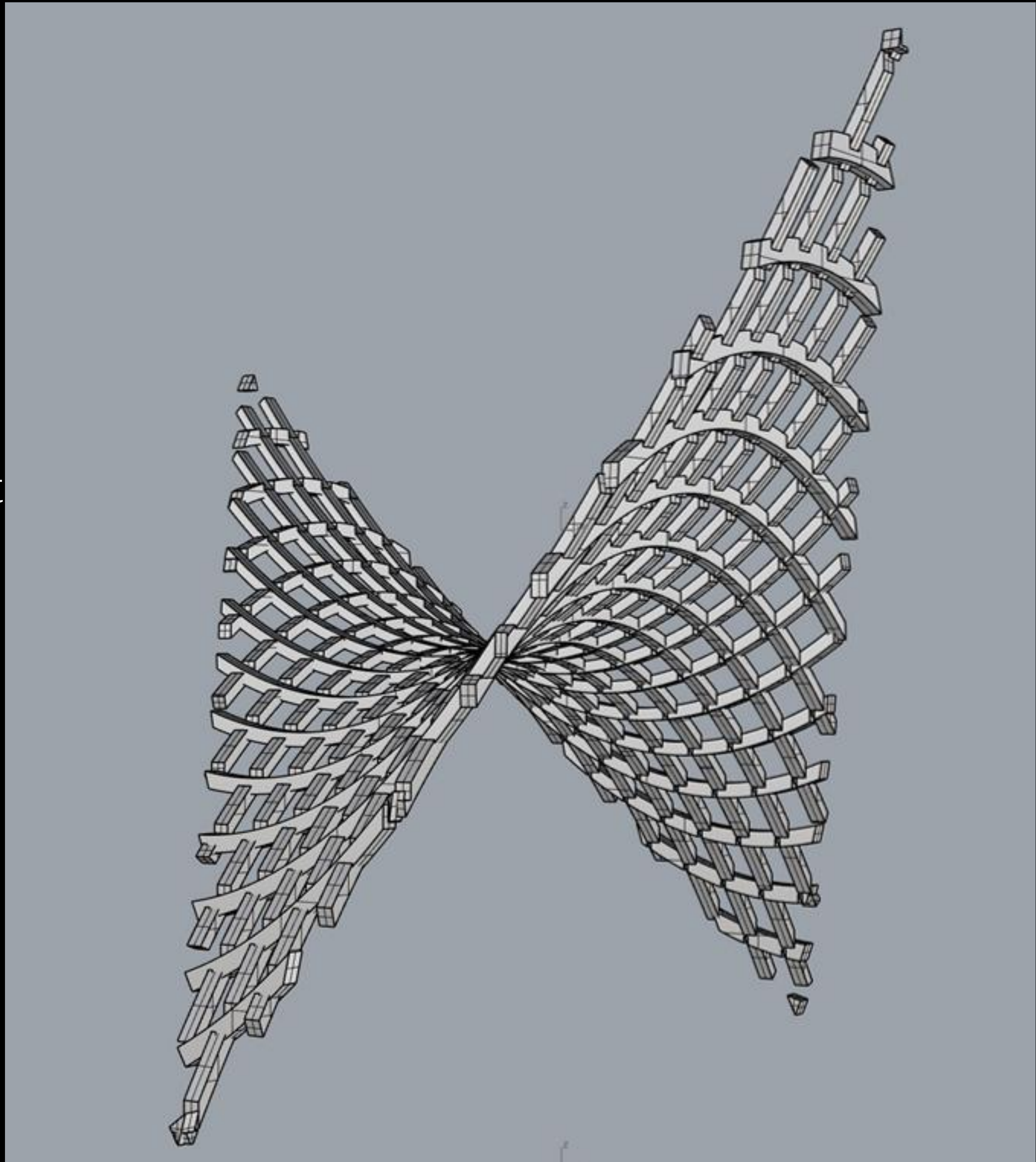
The section planes are created here, with half of the thickness of the material thickness. This ensures a better boolean result.

If you preview this, note that the thickness of the planes are half of actual material thickness.

Boolean Difference Operation that subtract the Fries/slots from the slice plates

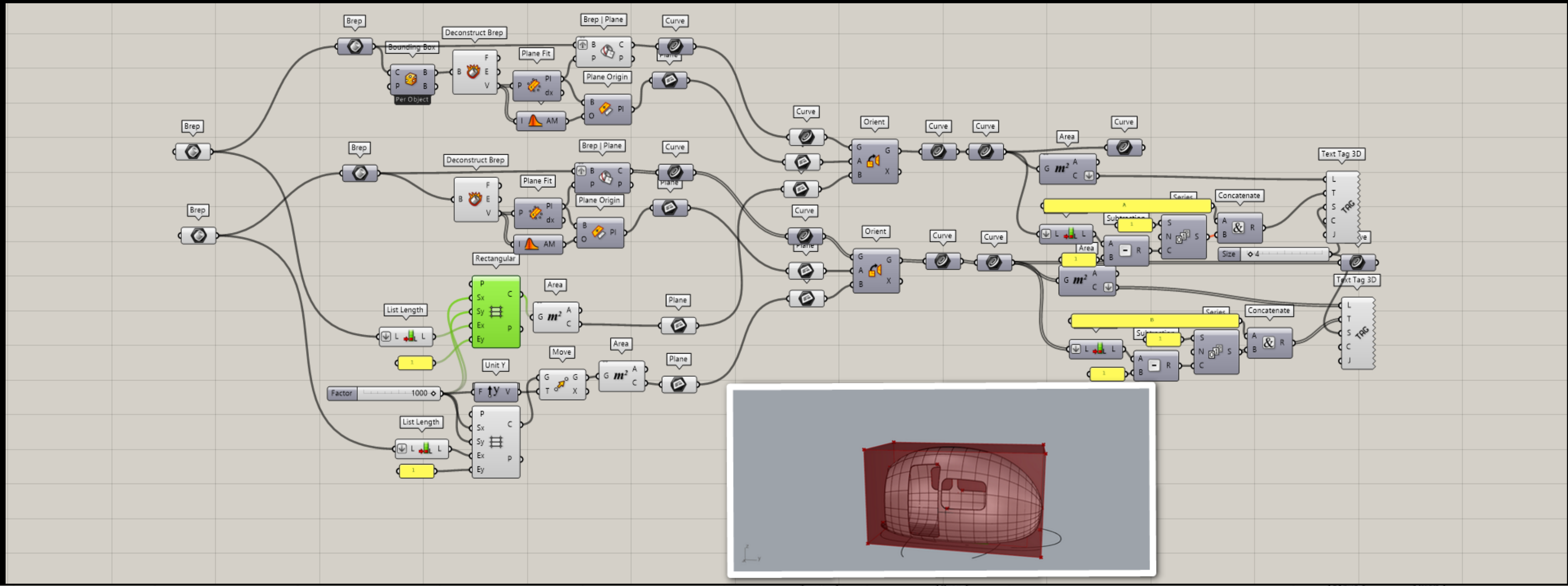
Sectioning the slotted planes with the coordinate grid plane, to generate the cutting curves, and using planer surface to rebuild each cut piece.
This operation allows multiple cutting objects that are on the same plane to be seperated into a different cutting curves.

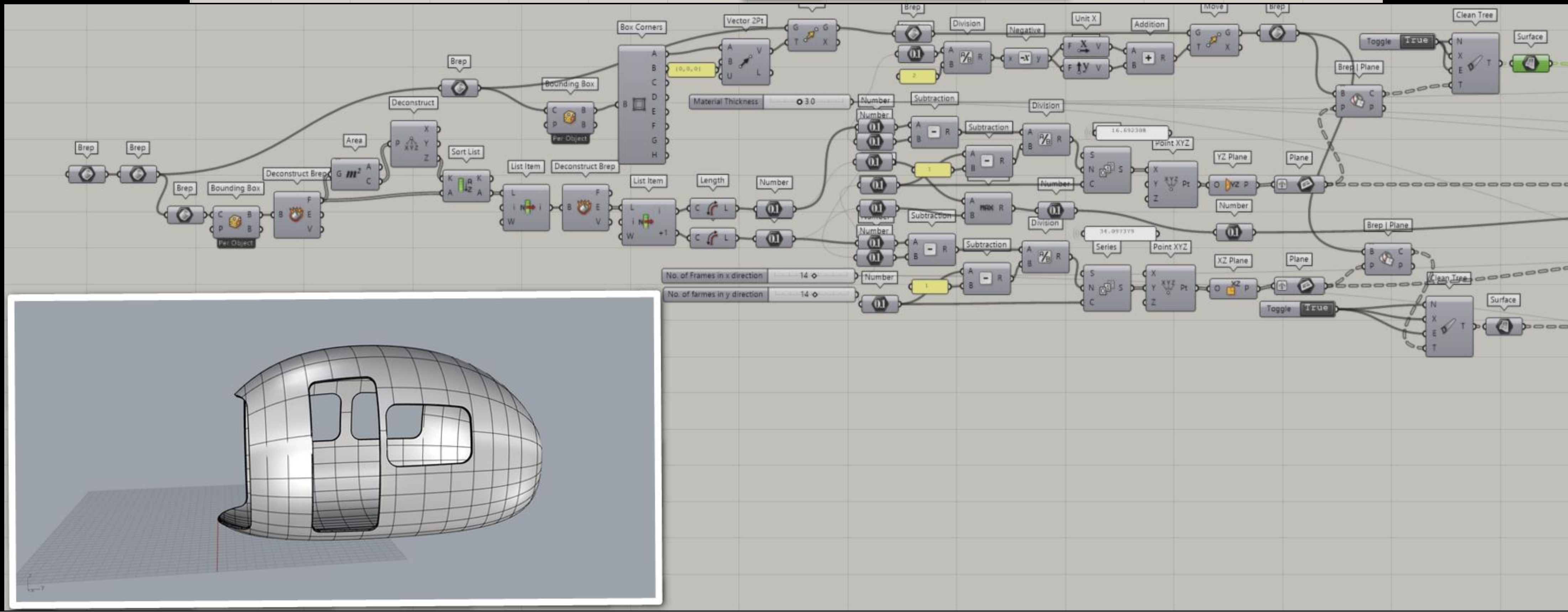
Script created by Sabah Shawkat
Inspired by David Fano's
Parametric Truss script.



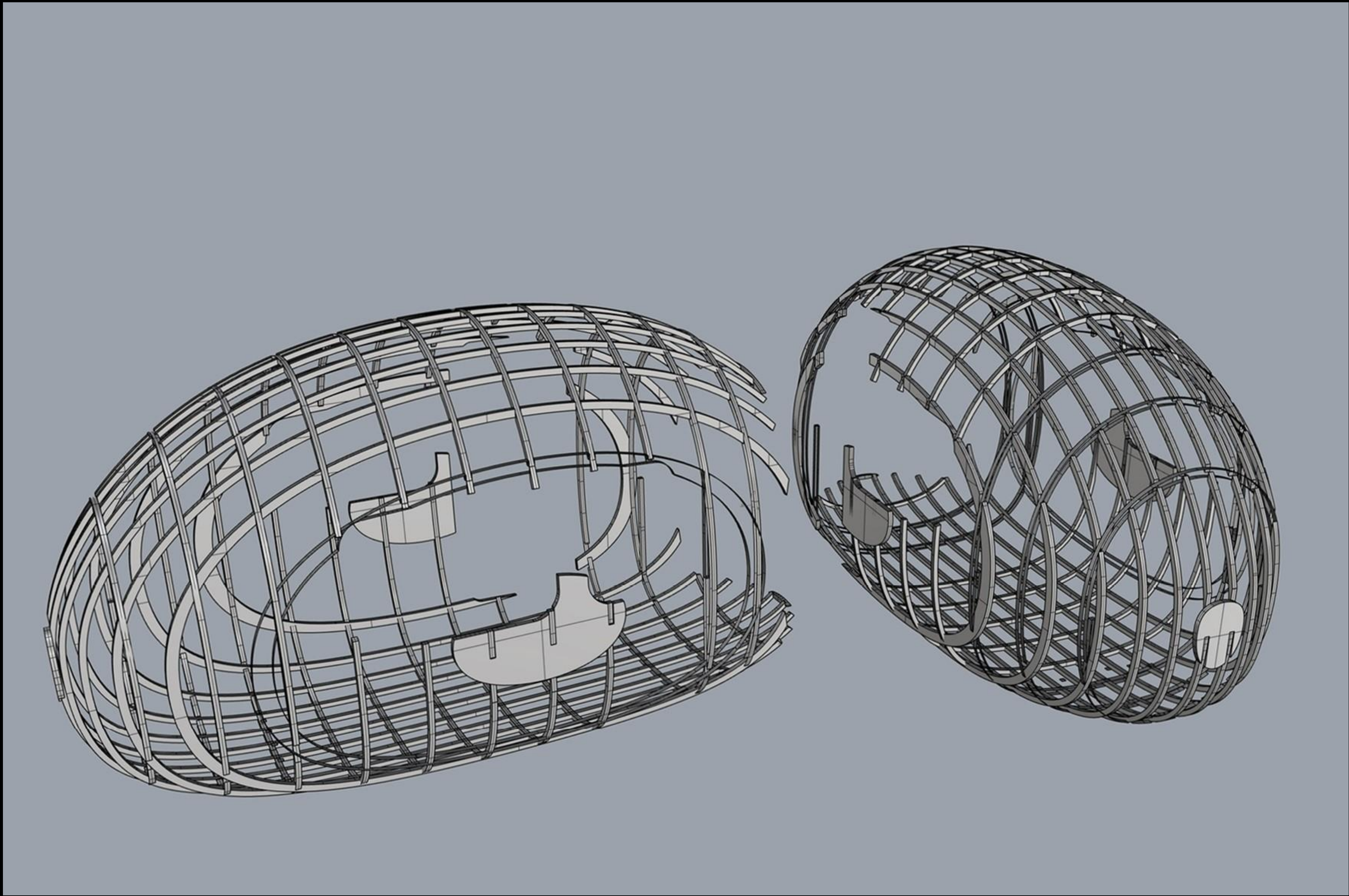
Ecocapsul, is a mobile, energy self-sufficient and intelligent accommodation unit that uses solar and wind energy to operate, while offering medium-term accommodation that takes full advantage of the latest technological advances, enabling people to live in harmony with nature while minimizing negative environmental impacts.

Script for Calculating the Parametric Geometry of Ecocapsule

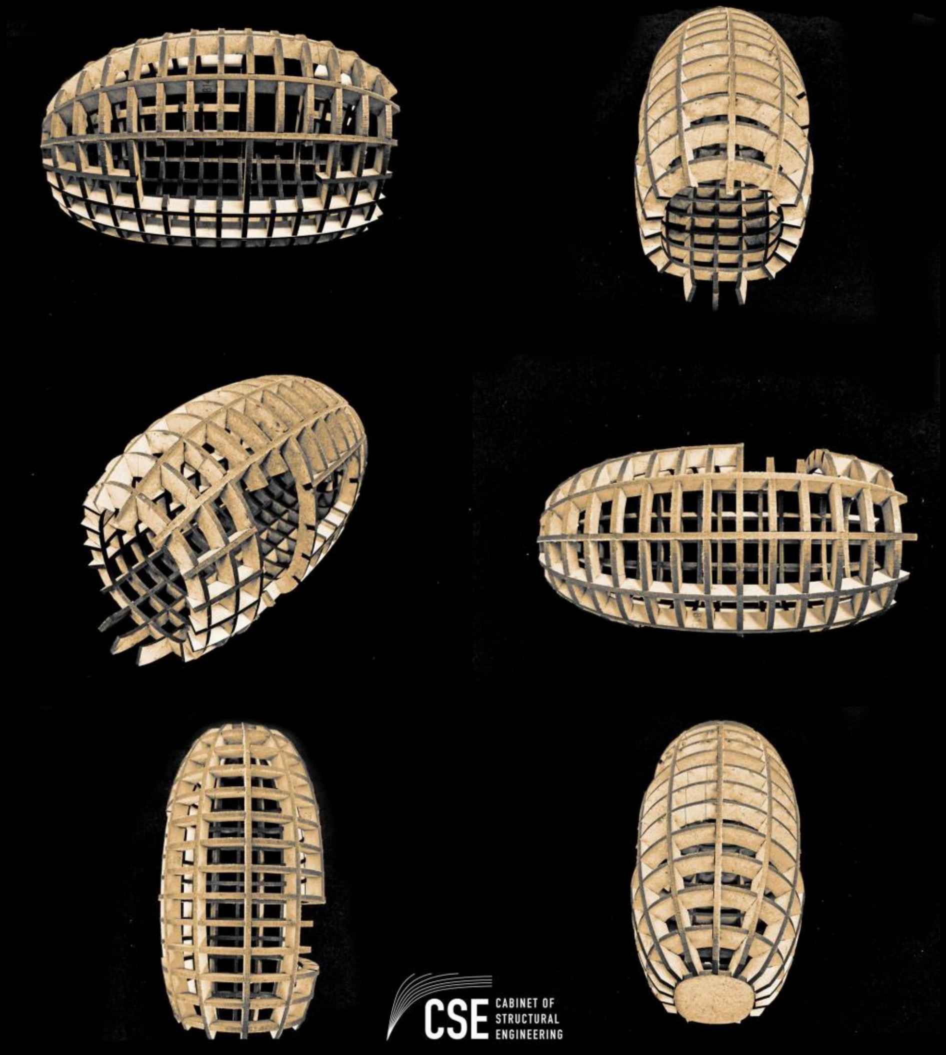




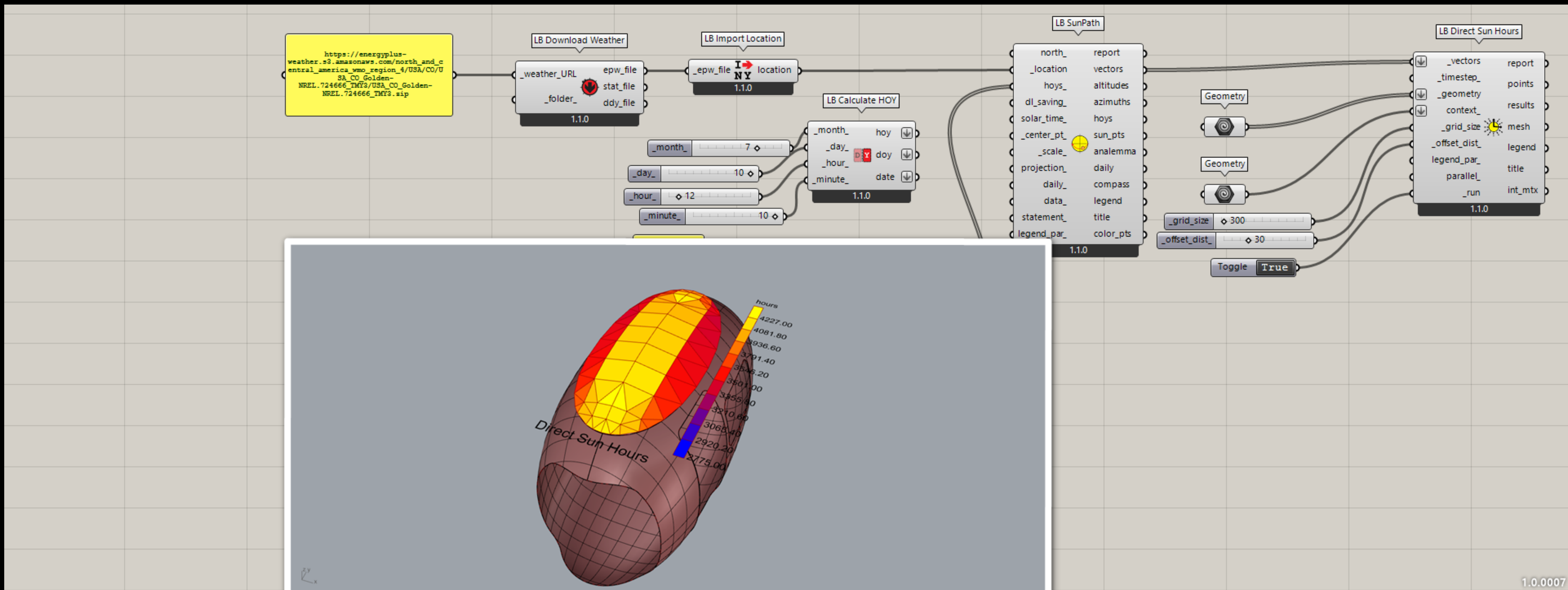
Ecocapsule



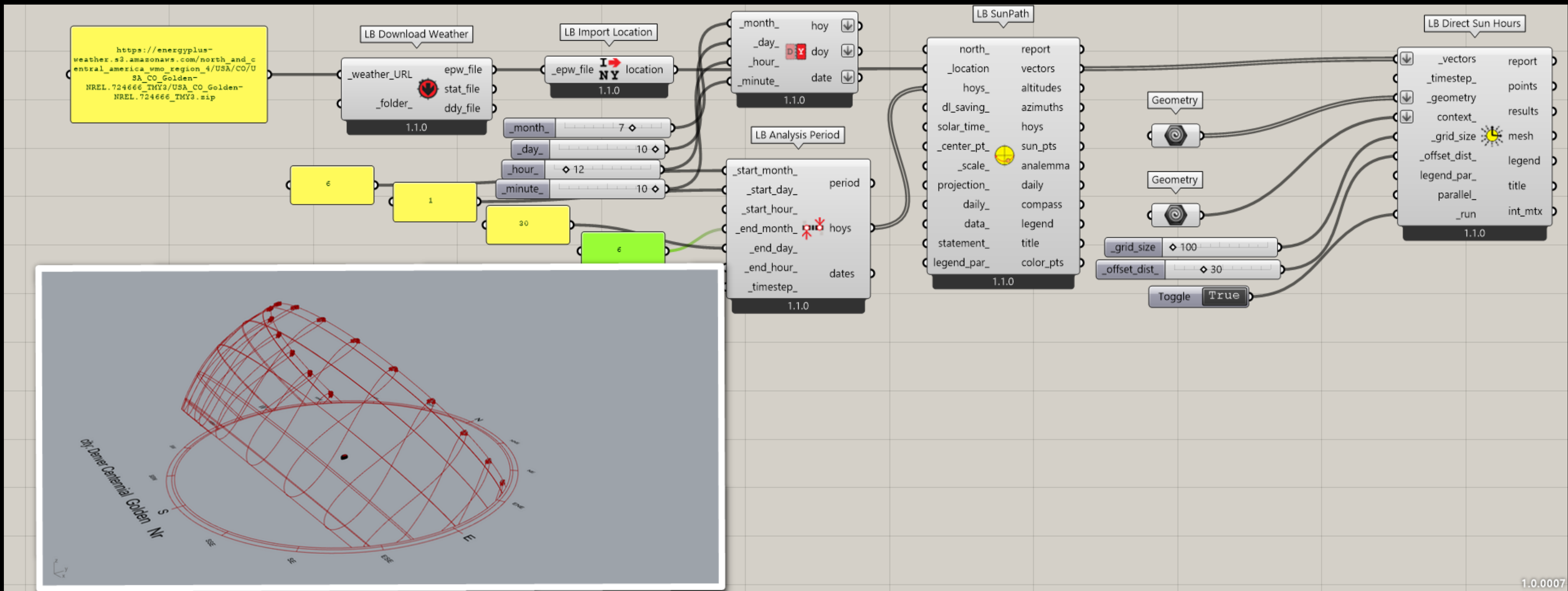
Grid Shell Form Finding - Ecocapsula



Ecocapsula, Self-Sustainable Microhome



Ecocapsule, Self-Sustainable Microhome



Process of Thinking

THANK YOU

Any questions?