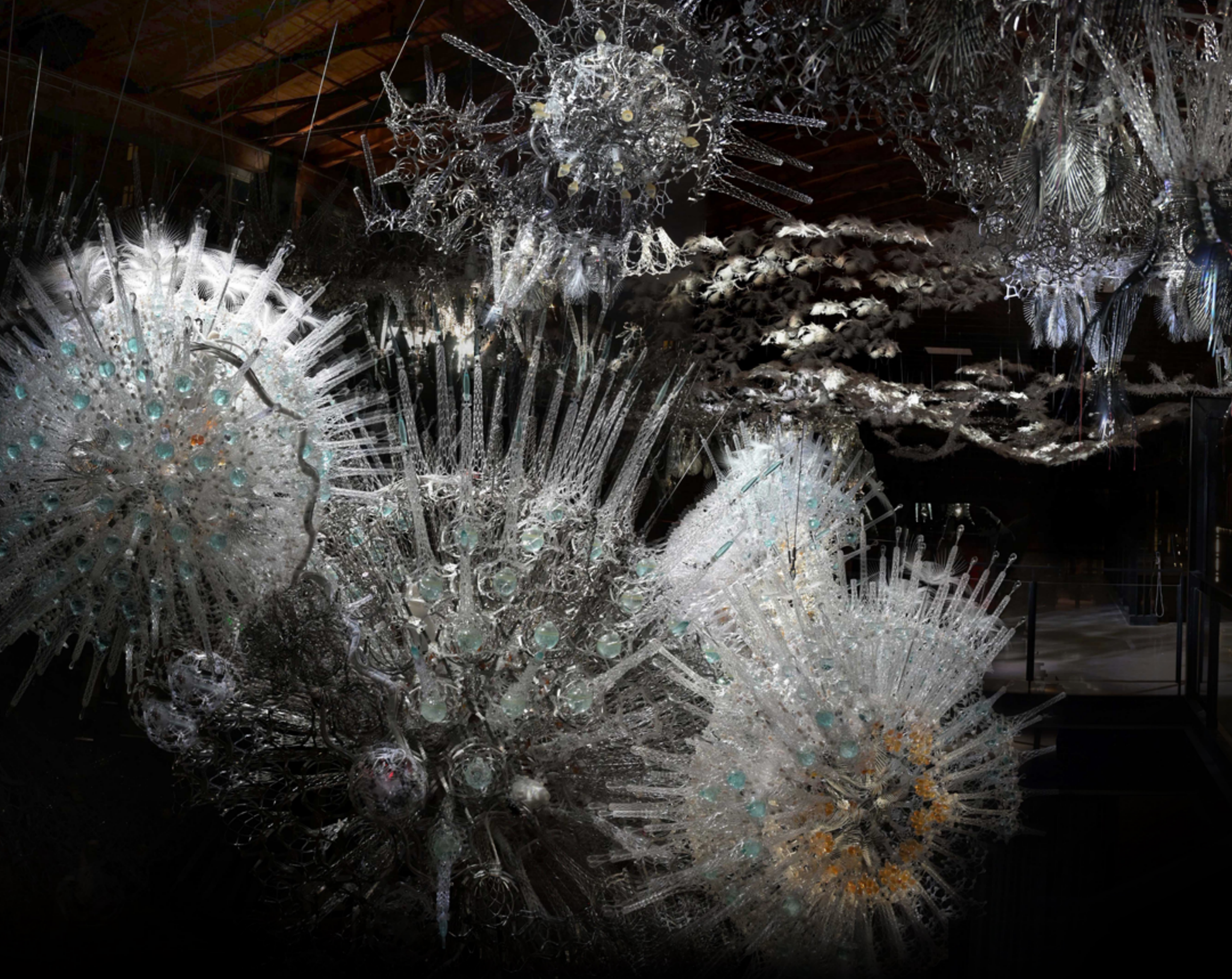

MEANDER

LIVING ARCHITECTURE SYSTEMS GROUP

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MEANDER

Living Architecture Systems Group

edited by Philip Beesley

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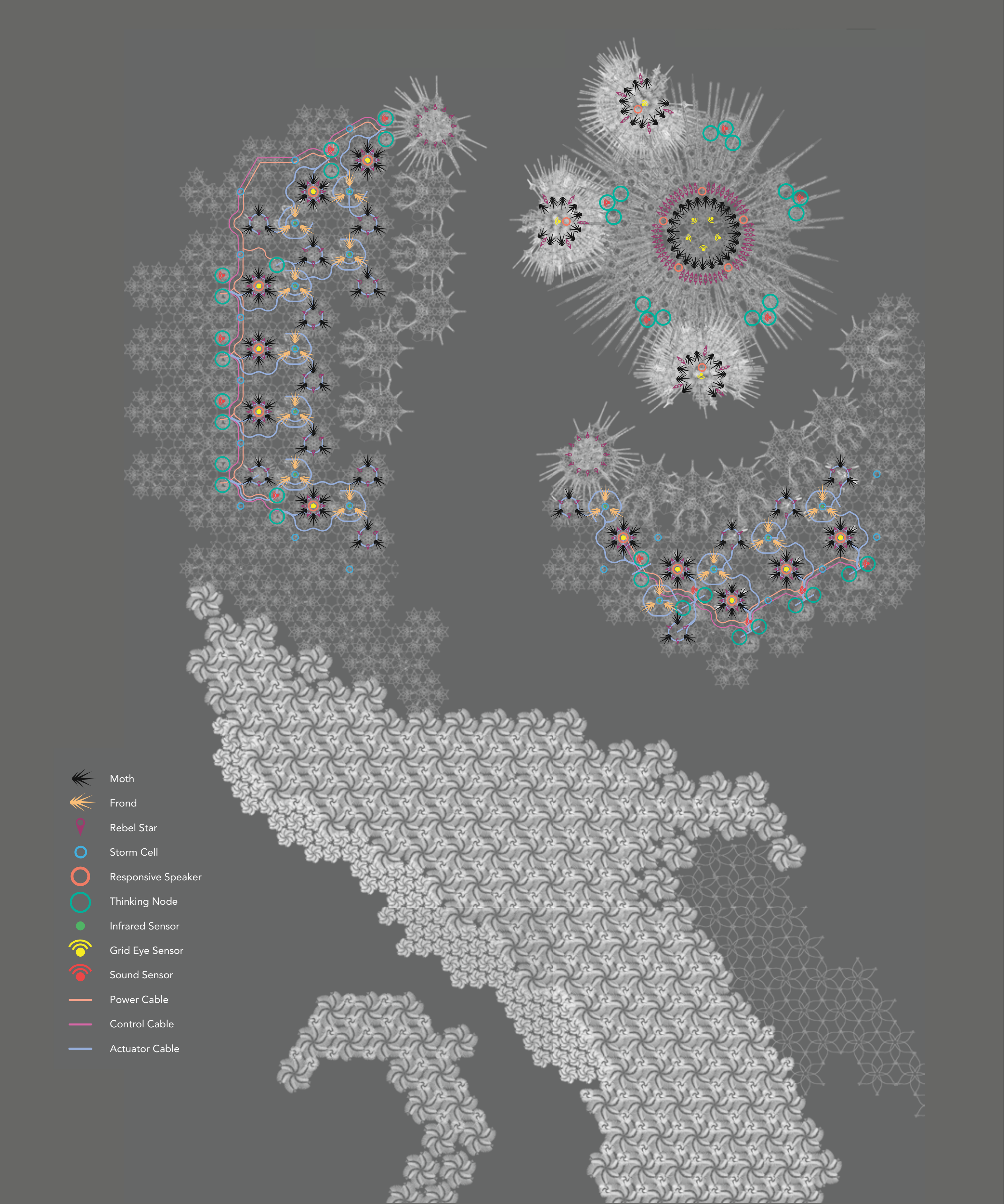


Meander

Meander is a large-scale immersive testbed environment constructed within a historic warehouse building at the centre of a residential highrise development in Cambridge, Ontario. The meshwork scaffolds which comprise the testbed are organized as a series of species within an artificial ecosystem, gently flexing and responding to the movement of viewers. Similar to natural environments such as rivers and clouds, large groups of parts pass physical impulses and data signals back and forth, enabling the entire environment to work as an interconnected whole. The innovations in Meander suggest ways of making adaptive, sensitive buildings of the future.

Early studies for Meander included trips down the Grand River, studying its water flows and diverse wildlife. Like the scouring and depositing forces that create the Grand's oxbow shape, Meander's form is the result of accumulations of material. Flexible geometric tiles make up the undulating membrane surfaces of the sculpture. Live data that monitors the flow of the River continues to feed directly into the interactive environment, creating background swells of light and sound.

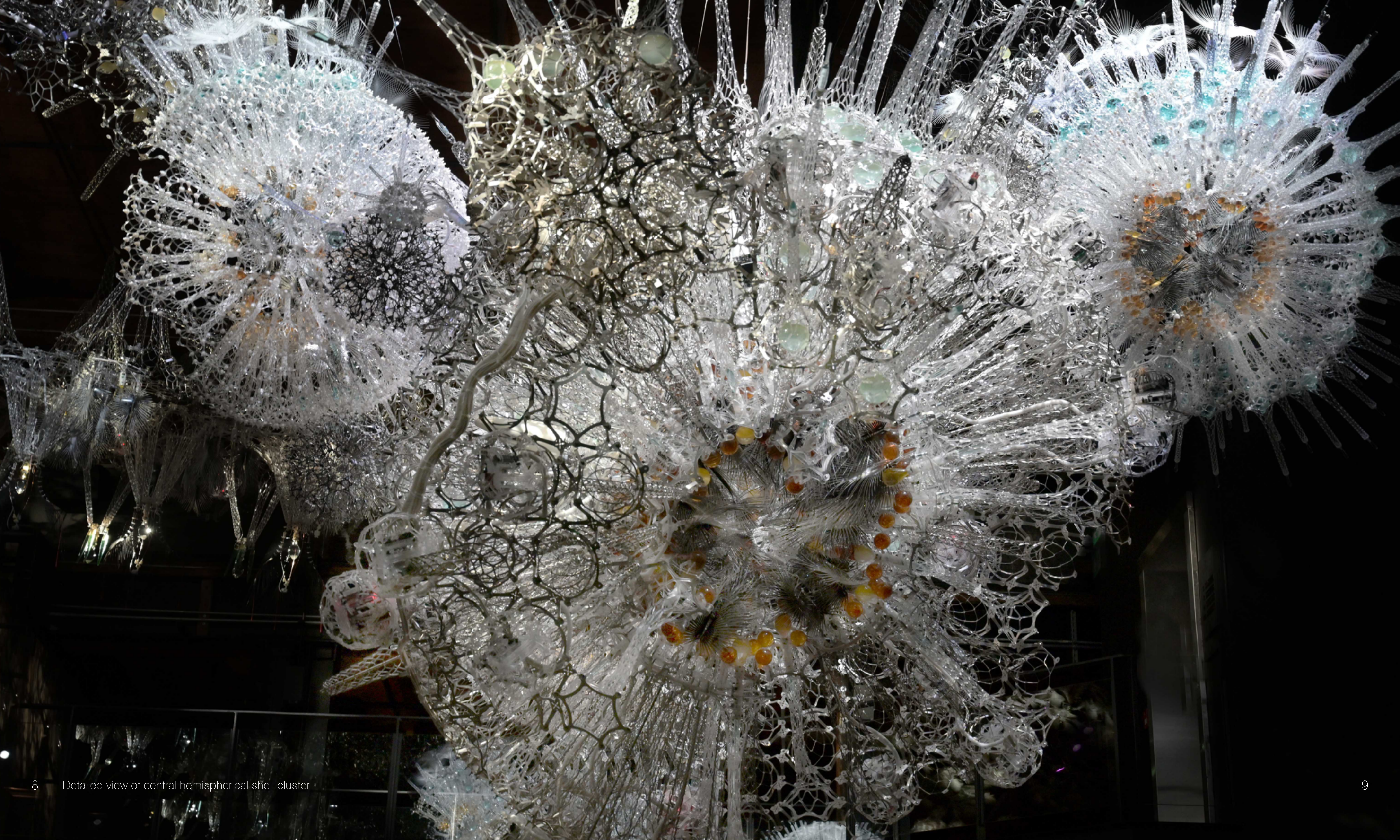
The geometric structures seen in Meander use interlinking, flexible lattices that behave like textiles and natural shell structures. Overlapping strands of materials balance each other within doubly-curved conical stem-shaped forms. The skeletal forms create strong inner and outer shells much in the same way that natural bone structures are formed. Rather than static, closed boundaries, thresholds of new buildings could be deliberately fragile and delicate. By interlinking many delicate parts, robust structures can handle intense amounts of force, accommodating the increasing storms and turbulence of our changing climate. The interwoven structures are developed to handle shifting, unstable environments and are capable of absorbing strong forces. Instead of the heavy masses of material used in traditional building, this kind of process uses extremely light, thin sheets of material, reducing material use and saving energy.

Sensors embedded within the environment signal the presence of occupants, and send ripples of light, motion and sound through the system in response. Software is organized in clusters of interconnected groups that can communicate with neighboring groups resulting in global behavior connections throughout the system. A second layer of sensors provides 'proprioception' – internal sensing. Like the human body's ability to know its own actions, this layer of information provides each cluster of mechanisms with information about action happening within its local structure. By using this constantly-cycling information, the systems can adapt their behavior and form new responses. By creating artificial environments that can learn, this research might help develop new mutual relations and healthy exchanges with urban environments.

The project includes an immersive distributed soundscape developed in collaboration with the Netherlands-based group 4DSOUND. The composition is carried within arrays of custom speakers embedded throughout the environment, making constantly-shifting sound that responds to visitors.

Alongside the sculpture, a Meander STEAM curriculum foregrounds a space where young learners can engage in a collaborative web of science, technology, engineering, arts and math to playfully form new solutions for sustainable technology and design. The interpretive exhibit invites visitors to view detailed visualizations of the interactive systems within the sculpture and includes prototype samples and videography documenting the development of the work.

Panoramic view of central shell cluster and flanking canopies



Detailed view of central hemispherical shell cluster

Panoramic view of central shell cluster and flanking canopies

Elevation view of central shell structures

Elevation view of central shell cluster and reef canopy

Living Architecture

The research of the Living Architecture Systems Group has the potential to change how we build by transforming the physical structures that support buildings and the technical systems that control them. Researchers from architecture, engineering, chemistry, computation, fashion, sound and lighting are working together and creating experimental prototypes. The multiple systems in these constructions suggest new ways of creating adaptive, sensitive buildings. Innovative art, craft, science and engineering methods are being shared with a new generation of designers, providing concepts and skills for working with complex environments.

This sculpture is a 'test bed' that supports ongoing research about future architecture. The sculpture can be studied as a prototype for design systems, advanced manufacturing methods, and computer controls of smart buildings. Meander's lightweight meshwork scaffolds are interwoven with miniature computers, arrays of sensors and interlinked mechanisms. These systems can sense, react, and learn from viewers.

The interactive control systems that have been used within Meander are being used for research about artificial intelligence and interactive behaviour. The lightweight, flexible scaffolds that support Meander are being used for research about sustainable and adaptive construction. Responsive systems in the sculpture include liquid chemistry, lights, movement and sound. Glass cells contain crystal formations that react to changes in the environment. Flexible scaffolds support these active components. Development of the expressive forms within this prototype building system included a collaboration with fashion designer Iris van Herpen. Innovative digital fabrication creates strong, lightweight and flexible components that consume minimum amounts of material. Future buildings could integrate these innovative responsive systems.

Prototype interiors | Prototype envelopes | Integrated systems

Learning from Nature

The Living Architecture Systems Group is influenced by organicism, the art of learning from nature. By studying patterns from nature we can think about buildings in new ways. Instead of closed walls, architecture could create open connections with the surrounding world.

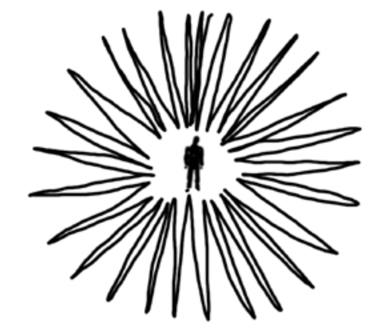
Meander takes inspiration from the Grand River, a complex ecosystem weaving its way through the centre of Cambridge, spanning geological time scale periods in its gradual formation. The Grand River tells stories of constant transformation. What can we learn from nature and Meander to better understand our changing world? With this understanding, can we find a new future for the next generation?

Like the scouring and depositing forces that created the Grand River's oxbow shape, many cycles combining and exchanging groups of layered components have created Meander. Live data monitoring the flow of the river feeds into the interactive environment, creating swells of light, movement and sound.

The geometric structures which comprise the ecosystems use flexible meshworks. Overlapping strands of material balance each other within doubly-curved conical 'spar' forms. By grouping many of these individual structural forms together, strong inner and outer shells are created. The organized structures within these shells are similar to the interwoven lattices of material within natural bone structures. Rather than static, closed boundaries, thresholds of new buildings could be deliberately flexible and delicate. By interlinking many resilient parts, these robust structures can handle intense amounts of force. The structures demonstrate how future buildings could be designed for the increasing storms and turbulence of our changing climate.

Our insecure world often creates isolation

Classical design methods tend to encourage closed walls and boundaries



New buildings could reach out with responsive, open thresholds

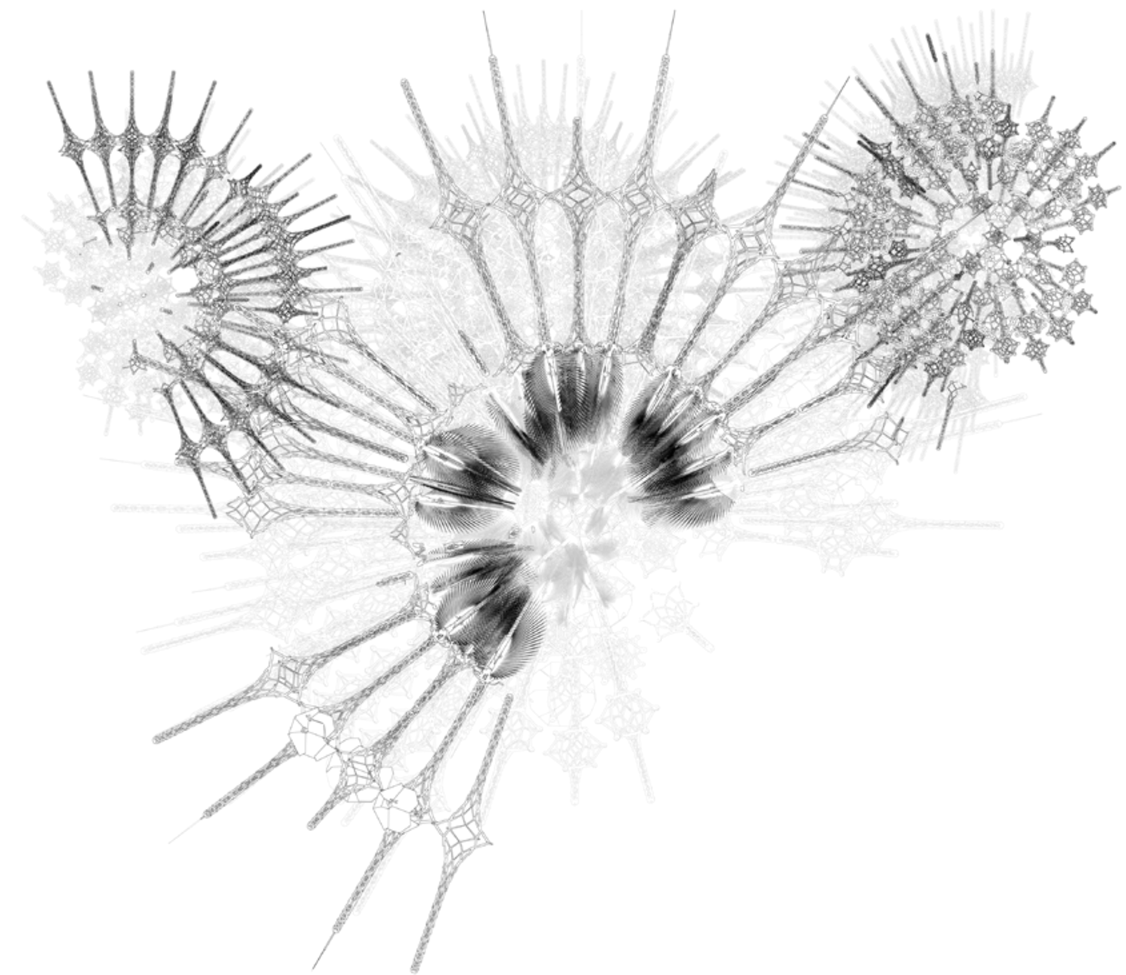
We could connect to wide environments

How Meander is Organized

Meander has three main parts: a central Geode Cluster suspended within the main foyer of Tapestry Hall, canopy Reefs that curve around the edges of the central foyer, and a billowing Cloud that extends out over high levels within the main Event Space of the building. Parts of the Reefs can be viewed up close from mezzanine levels.

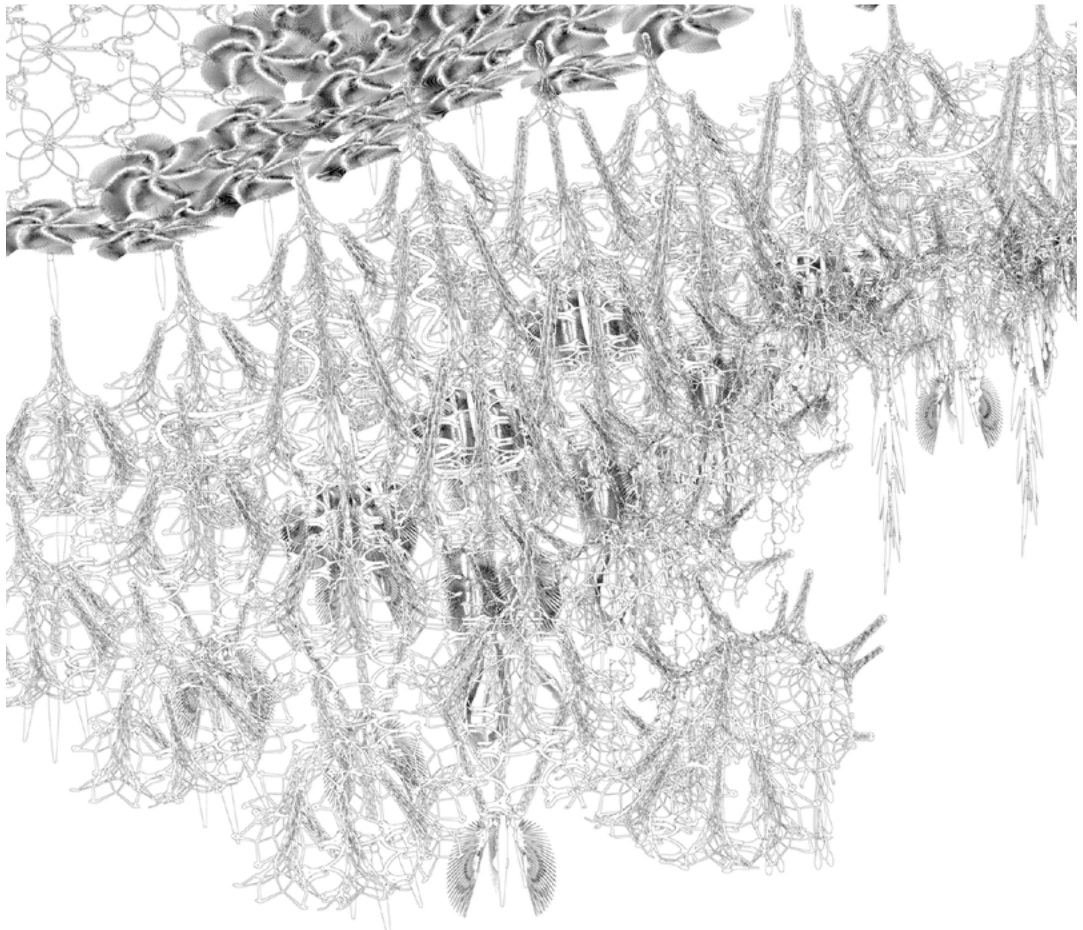
The central cluster and the surrounding canopies are densely interwoven with active electronics and sensors that invite open-ended exploration. The organization of these parts is similar to a nervous network connected with muscles and voice within a living organism. Networks of sensors (the 'eyes') and devices (the vibrating-frond 'muscles', glowing lights and 'voice' sounds) linked to distributed microprocessor control systems give the Reefs and central Geode Cluster areas their behaviour.

Spherical Nest control clusters like miniature brains can be seen mounted along the lower edges of the central sphere and also along the surfaces of the Reef canopies. Gesture-sensing sensors that invite open-ended exploration are located along the edges of the mezzanine level.



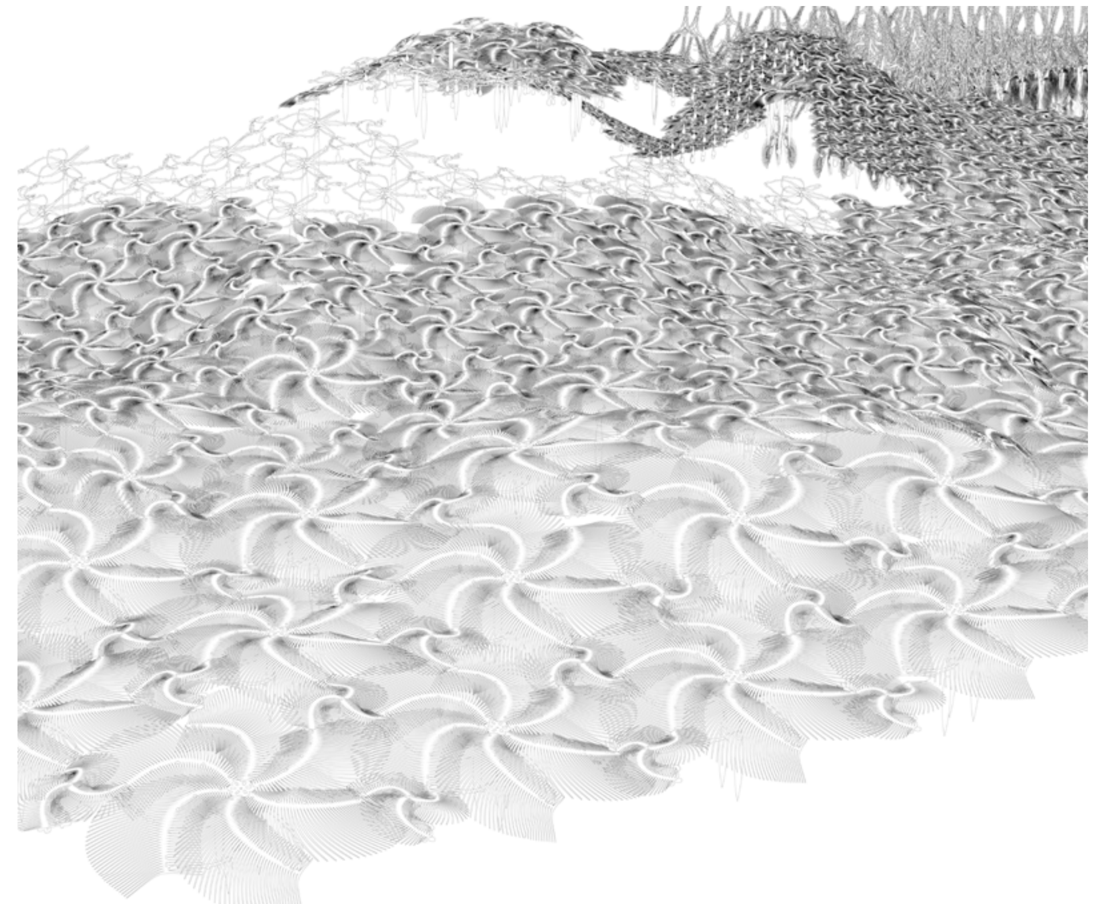
Geode Cluster

A cluster of curved shell forms making up the centre of the sculpture, constructed from lightweight expanded meshwork elements. The geode cluster's weight is distributed over multiple suspension points. Within the cluster are illuminated glass vessels, vibrating motors with mylar fronds, and custom responsive speakers.



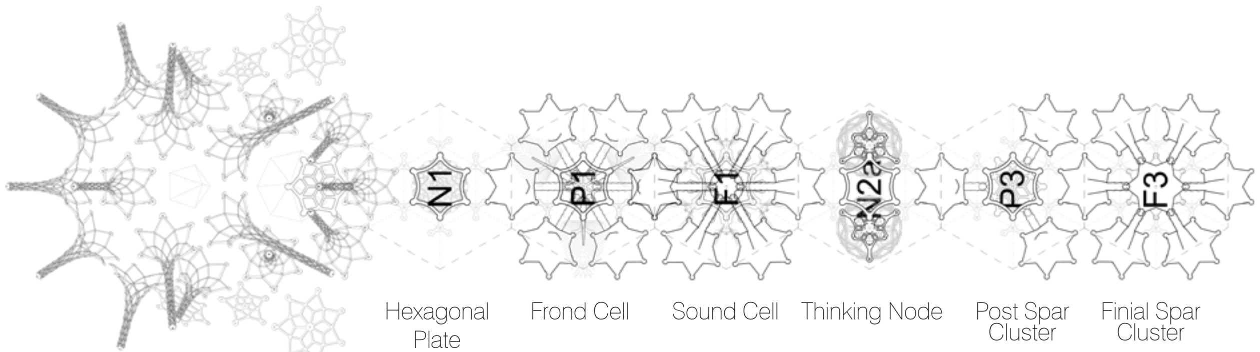
Reef Canopies

Two suspended lattices of interlinking skeletal forms are composed of metal and polymer structural components. Mylar fronds and fluid-containing glass vessels are embedded within this scaffold.



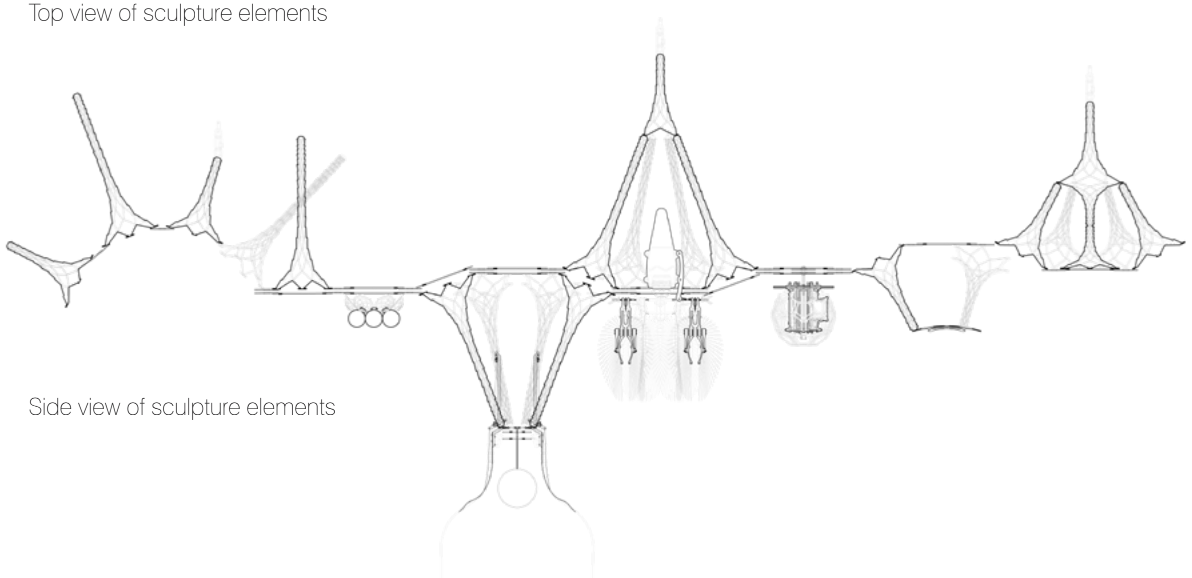
Cloud

The sculpture includes passive suspended membranes made up of interlinking, lace-like skeletal frames with Mylar frond and glass vessel dressing.



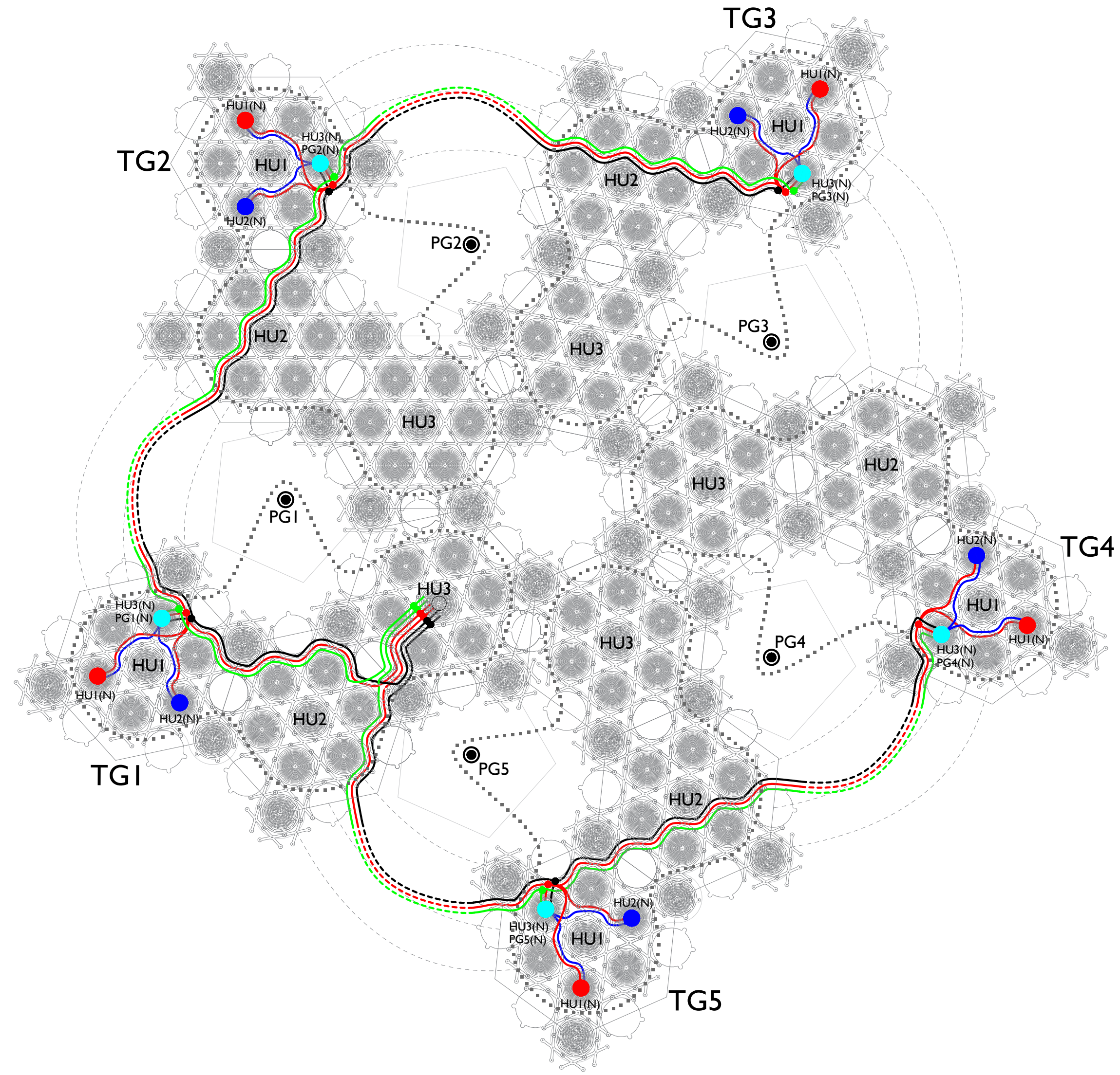
Part of Geode Core

Top view of sculpture elements



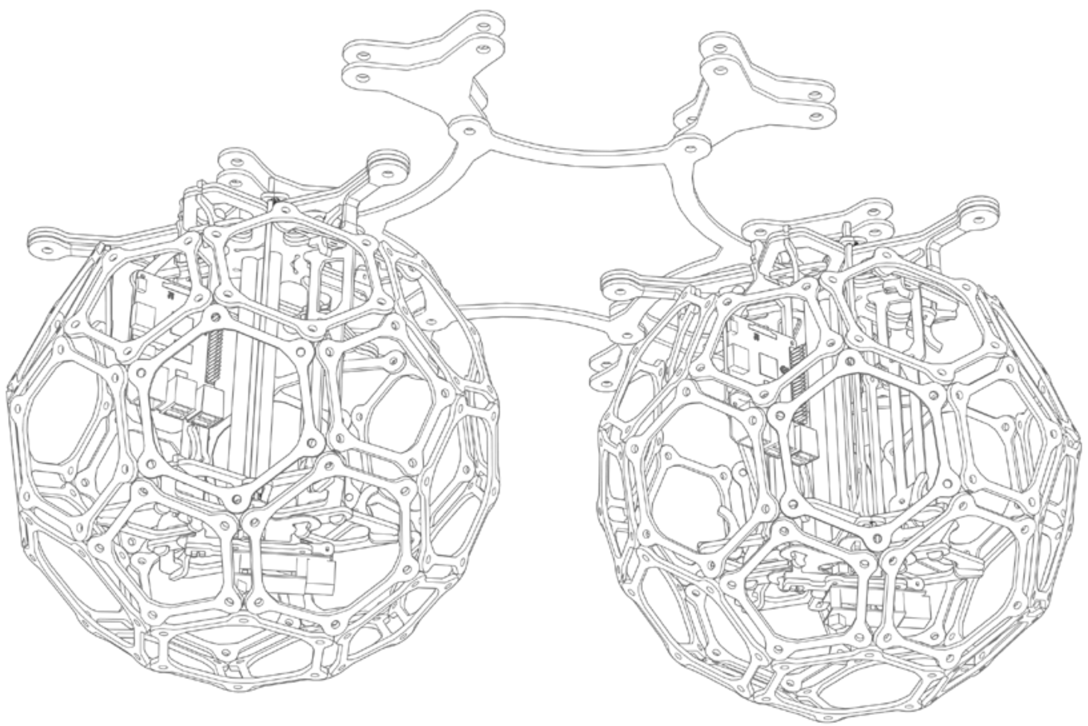
Side view of sculpture elements

Systems Assembly and Detail



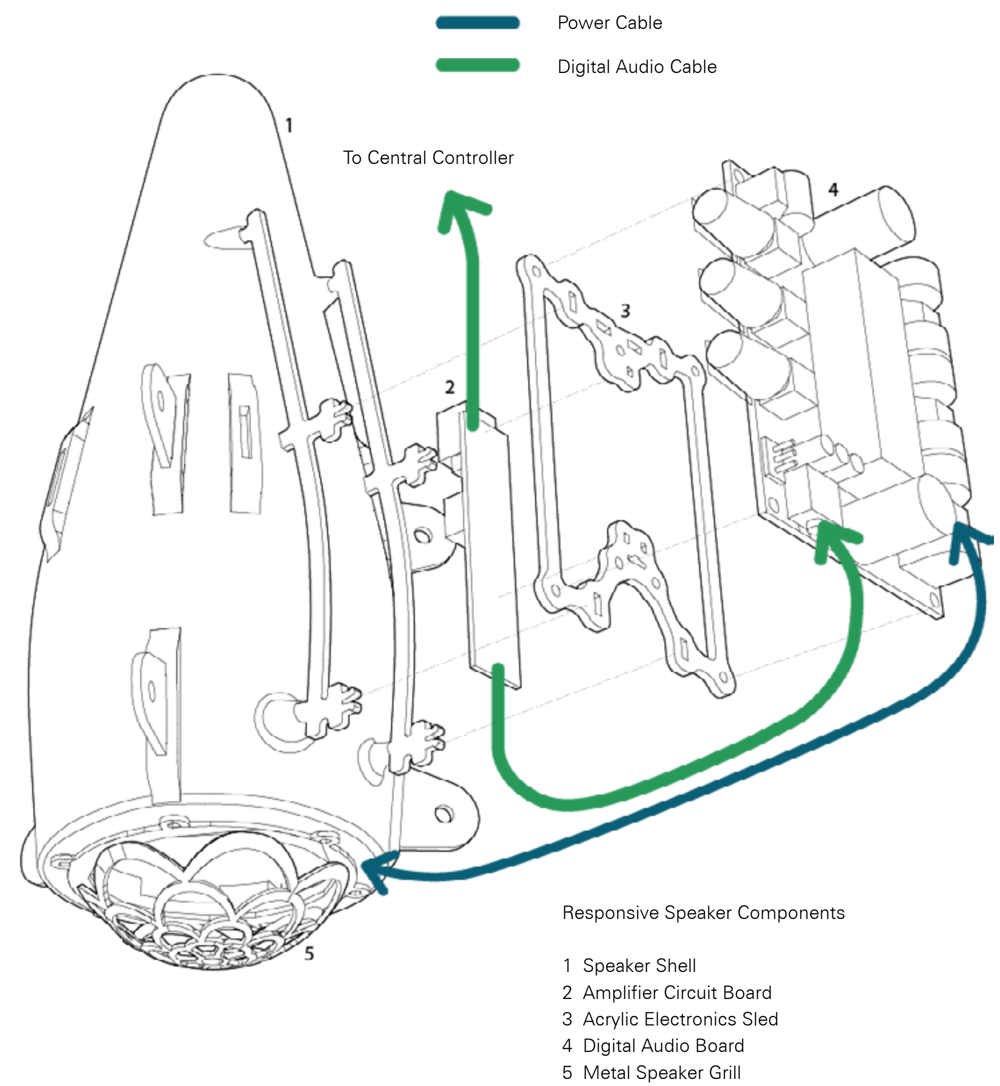
Unfolded Sphere Assembly

Primary Nest
Secondary Nest
Actuation Bundle
Cable Splitting
Cable Splitting
Ethernet
12V Power
POE Audio
USB
Umbilical Drop Point



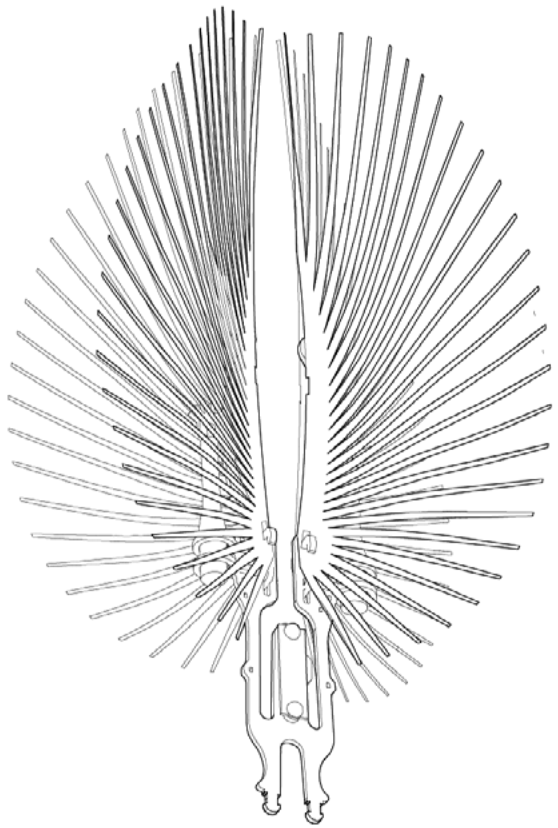
Thinking Node

Small computers are connected all through the sculpture. They work together, constantly passing signals back and forth.



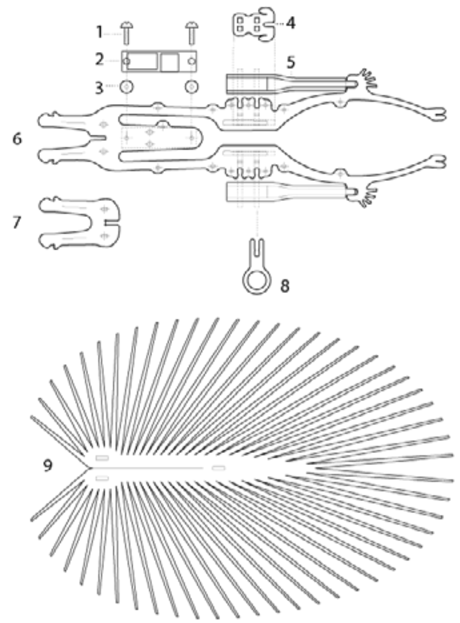
Responsive Speaker

Layers of individual sounds are stored within the sculpture's electronics. If you listen carefully you may be able to hear how sounds move all around you. Can you tell what happens when you move close to the sensor mounted on a speaker?



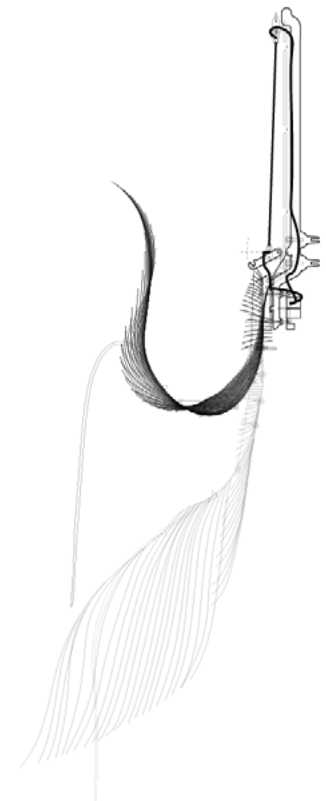
Moth Components

1 Screw
2 Electronic Board
3 Acrylic Washer
4 Ring Clip Fastener
5 Motor and LED Assembly
6 Acrylic Moth Profile
7 Moth Clip Arm
8 Ring Clip
9 Mylar Frond



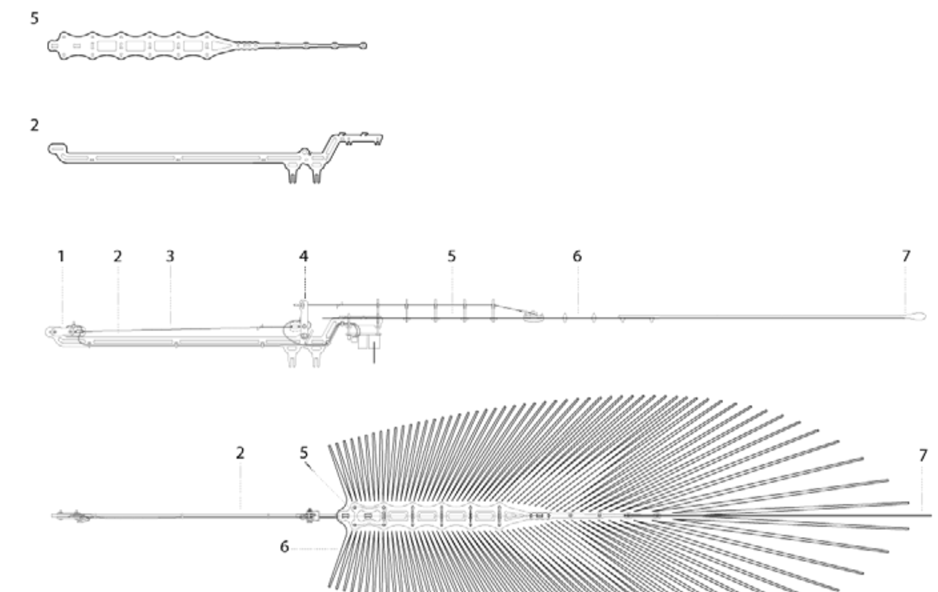
Moth Cluster

Tiny motors make these moths vibrate. Each moth is gentle but when large groups of moths vibrate together they can be very strong. Do you hear the rustling from vibrations passing you?



Kinetic Frond Components

1 Adjustable Clip
2 Metal Spine
3 Shape Memory Alloy (SMA) Wire
4 Acrylic Lever
5 Stainless Steel Tongue
6 Mylar Frond
7 Silicone Lash



Frond

A special kind of wire called Shape Memory Alloy makes these fronds curl and wave. When an electrical current runs through the wire it shortens and pulls on the flexible tongue.

Meander's Behaviour

What might future buildings be like if they could move and breathe? Can buildings learn from their occupants, and care about them?

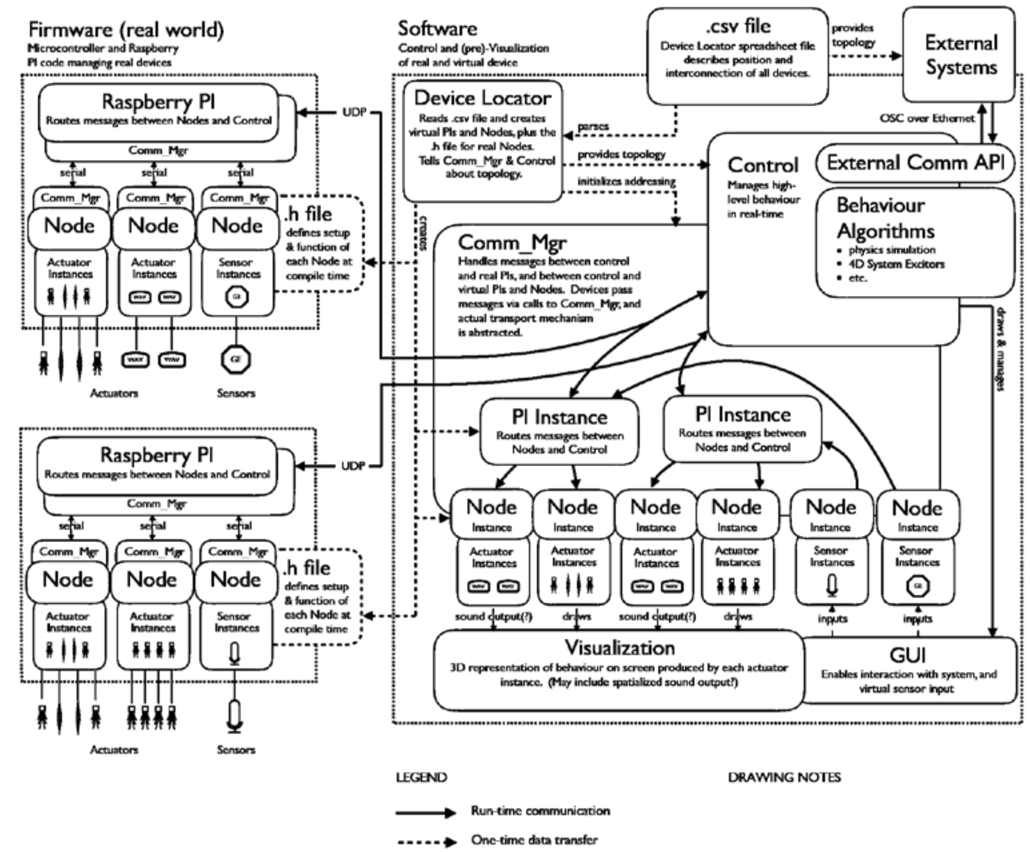
Using robotics, electronics, and new kinds of software controls, Meander's researchers are developing ways for buildings and people to interact. Software is organized in clusters of interconnected groups that can communicate with each other. Sensors signal the presence of occupants and send ripples of light, motion and sound through the system in response. Additional controls provide internal sensing for the sculpture. The sculpture can cycle this information internally and begin to adapt its behaviour to form new responses.

Meander's electronic system processes human interaction with arrays of sensors and actuators. These two types of devices are connected to multiple layers of computers that collectively form Meander's distributed brain and control its behaviour.

Meander's sensors can detect closeness, movement, and sound. Sensors are Meander's tools for observing visitors and the environment. Actuators are devices that generate light, movement, and sound. Meander's lights, movement and sound allow the sculpture to respond and display its own internal activity.

A custom software system contains decision-making modules that control Meander's behaviour. The system is used to control the actuators and sensors that are distributed throughout the sculpture.

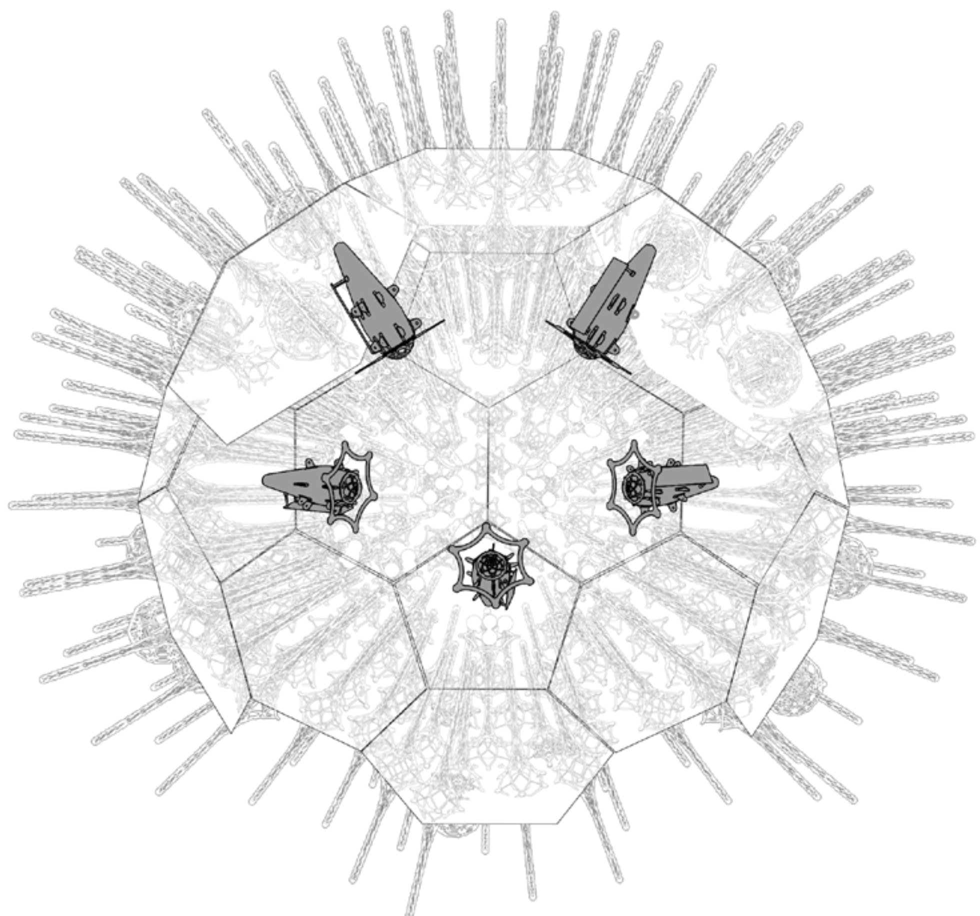
The software modules decide how to act on sensor readings and other inputs. A central control computer acts as the central point in the organization of the software. The central control computer works together with a distributed system of miniature computers- 24 Raspberry Pi's and 81 microcontrollers- located within the sculpture.



Meander's behaviour system is divided into central and distributed parts. These two parts work together. The distinction between 'centralized' and 'distributed' behaviour is based on where decision making takes place. These terms refer to the physical location and organization of decision-making software modules. For centralized behaviour the control computer is the decision maker, and for distributed behaviour a Raspberry Pi or microcontroller is the decision maker. These two systems work together to choreograph Meander's expression.

Immersive Sound

Meander incorporates layers of sculpted sound, created in collaboration with composer Salvador Breed and lead software developer Poul Holleman of 4DSOUND. The composition is played through arrays of custom speakers throughout the environment, making constantly-shifting sound that responds to visitors. The sound composition is inspired by the concept of complex forms of life emerging from inorganic material.

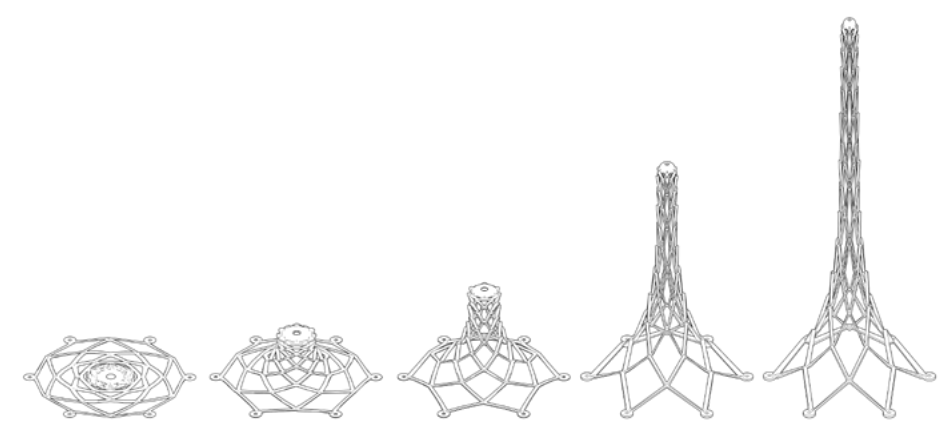


Making Meander

The sculpture is 100 feet long and 45 feet wide, and 30 feet high. Approximately 500 component patterns have been used to create over 400,000 parts. Meander weighs 500+ pounds, a fraction of the weight of traditional canopy and tent structures of this size. A small team of designers developed the original patterns creating this work. Many community members assisted them, organized in a series of workshops and assembly teams. Assembly took approximately 4,000 hours and lasted four months.

The interwoven structures are developed to handle shifting, unstable environments. Instead of the heavy materials used in traditional buildings, this new process uses light, thin sheet forms, reducing material use and saving energy. These flexible meshwork systems use advanced digital fabrication, including computer-controlled laser cutting and 3D printing, allowing precise tuning and shaping of materials.

Materials include impact-resilient polymer sheets, filaments and resins, combined with custom-fabricated aluminium and stainless steel components, and custom-printed circuit boards.



Laboratory-grade glass vessels contain noncombustible fluids, and mylar cut into leaf-life fronds line the overhead meshwork. Moving parts use electronic 'muscle wires' that pull and stretch like natural muscle fibres. The material was manufactured by the design team using laser cutters, photo-setting digital resin printers and mechanical stretching rigs. The mechanical stretching rigs use thermal forming, a process where laser-cut flat patterns are heated in small ovens and stretched while the components are in a softened state. When the components cool, they stiffen and permanently retain their stretched forms.

The open mesh grid-like construction is composed of thin sheets of materials. Metal materials include stainless steel and aluminum. Polymer materials include recyclable sheets of polyethylene terephthalate glycol (PETG) and a special kind of impact-resistant clear acrylic. These materials are commonly used in architectural constructions today. The forms that are used in these constructions reflect new research pursuing sustainable construction that uses a minimum of material. These forms acquire their strength by cutting, folding and stretching sheets into thin skeleton structures.

Elevation view of Meander, seen from mezzanine

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Meander

Philip Beesley & Living Architecture Systems Group

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