



Living Architecture Testbed

Delft Science Centre

DELFT UNIVERSITY OF TECHNOLOGY
LIVING ARCHITECTURE SYSTEMS GROUP



LASG



TU Delft



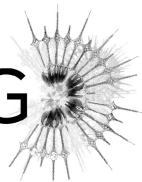
Living Architecture Testbed

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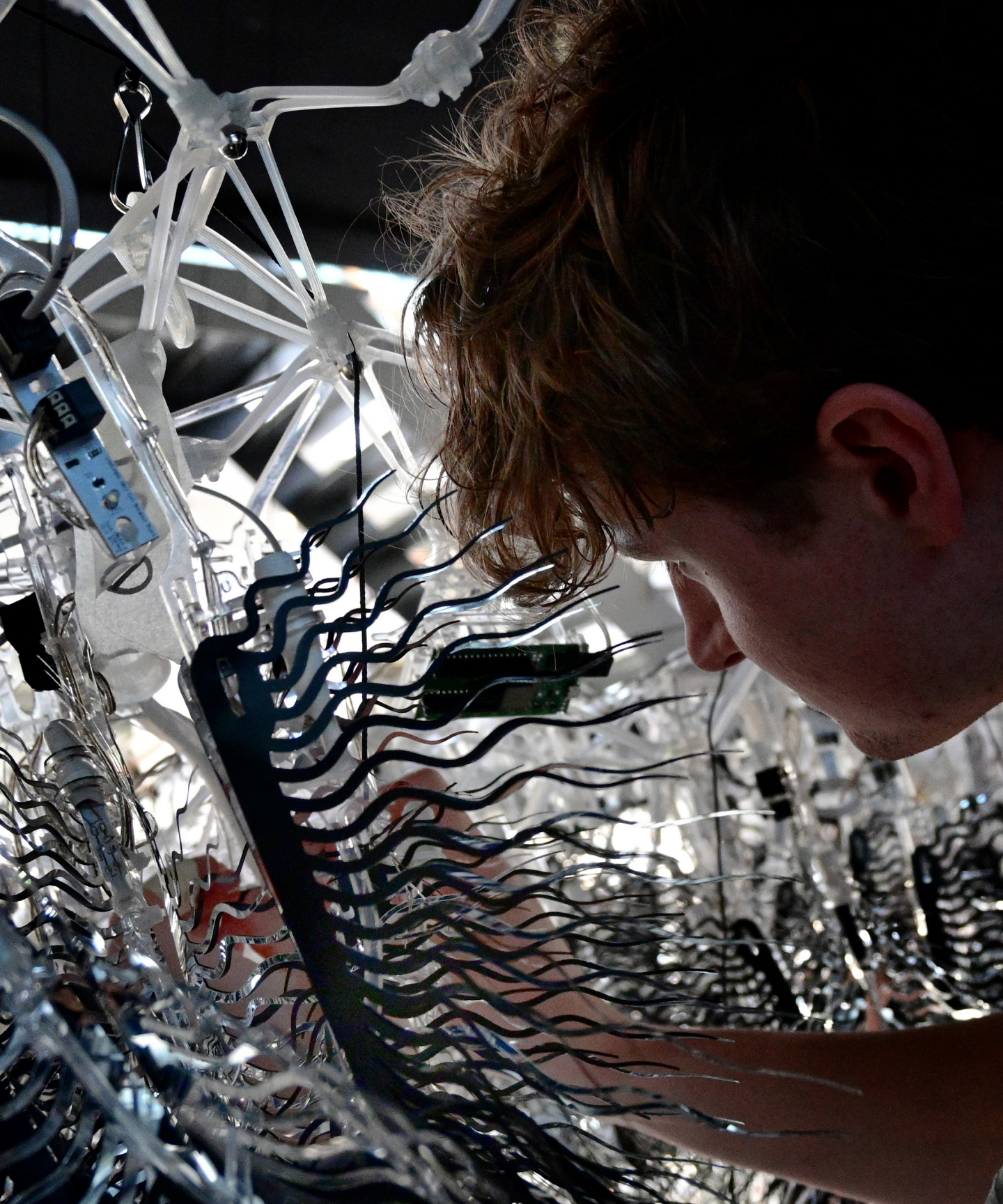


Errors or omissions would be corrected in subsequent editions.
This book is set in Garamond and Zurich BT.



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A Living Lab for TU Delft

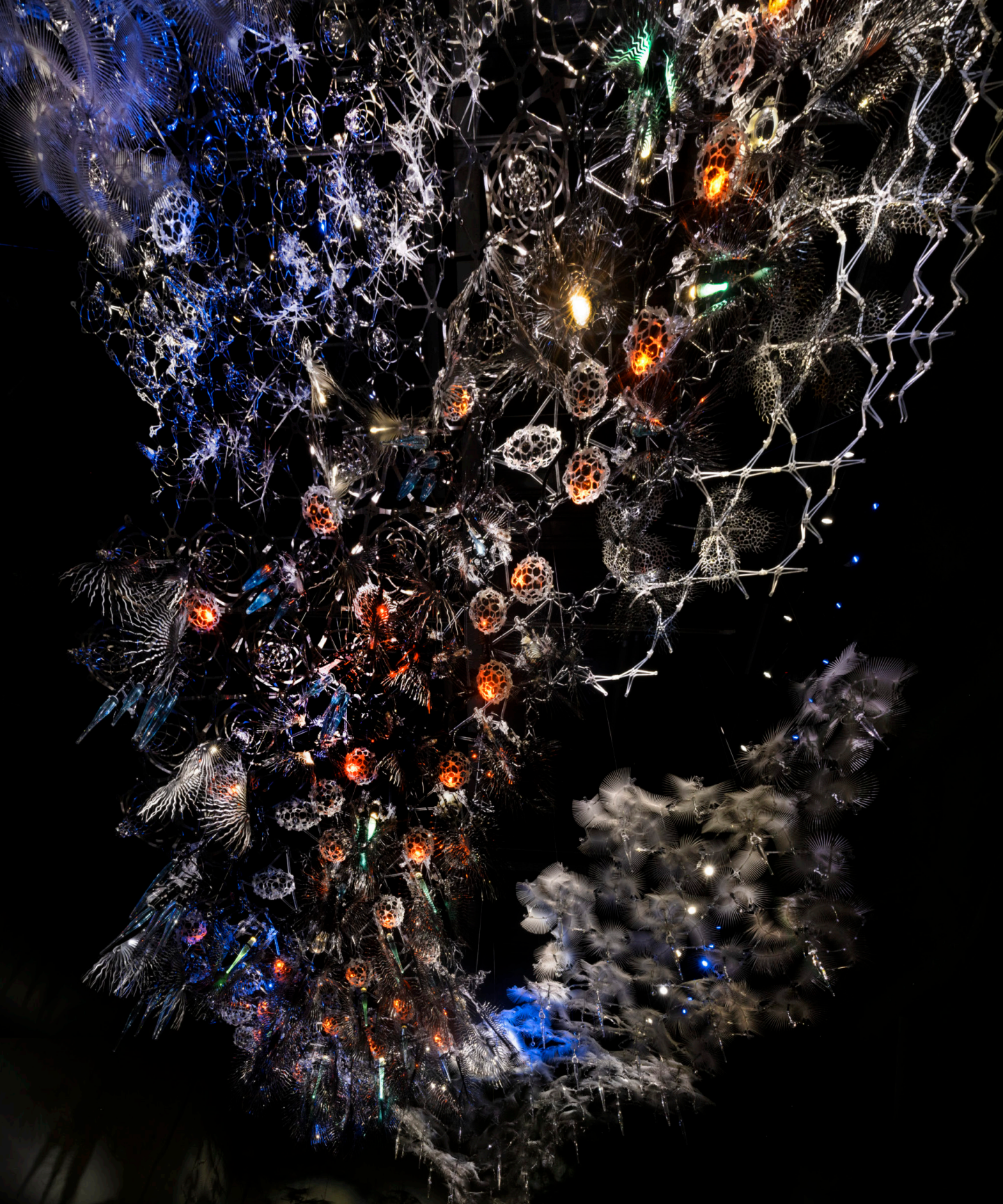
Delft Science Centre, Living Architecture Systems Group (LASG) and Philip Beesley Studio Inc. (PBSI) are bringing a visionary, immersive environment to TU Delft. The first stages of this multi-year project set the stage for a permanent program that combines public art on the campus of TU Delft, the municipality of Delft, TodaysArt, numerous artists from the Netherlands and Canada, and educators in STEAM. This project is working in close collaboration with TU Delft's Architecture and Engineering departments and multiple Canadian research contributions.

A new LASG sculpture and testbed will be installed at the entry of the new Science Centre facility. The project will act as a public beacon that gathers the public, expressing a sustainable, inclusive vision of future design. This building provides a public face to the University, located at the boundary of the Delft Campus with the city. This site provides strategic connections to the campus and city. The location also relates to a large cluster of experimental architectural structures featuring next-generation construction, alternate energy sources and sustainable material systems.

The prominent central location will present views to the exterior that reach out and along the green lawn that connects the Science Centre to the main circulation spine of the University and areas of the city of Delft. To the interior, the installation will lead to areas for evolving student design explorations and additional workshop-based activities.

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TU Delft Interactive Environments
Minor Workshop, Science Centre Delft,
Netherlands, 2022



Testbed Sculpture

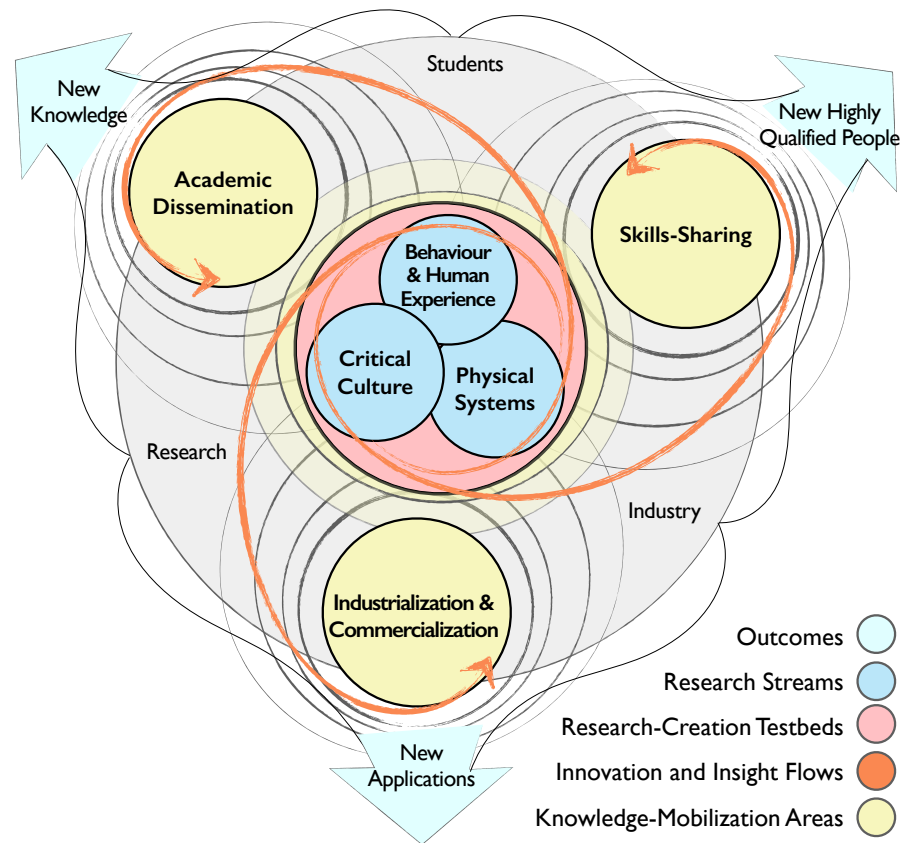
Multiple events will be programmed during the coming period. Workshop with the Interactive Environments Minor curriculum of TU Delft, presentation at the Delft Highlight Festival, experiments with researchers and graduate students, and events for families and young people will lead toward further development of this evolving, open sculpture. These activities will include explorations in fabrication and behaviour programming, working with experimental architecture and interactive systems teams.

Building upon these exchanges, the group will install a permanent testbed that will be used for events, ongoing research and curriculum development around responsive, sentient architecture. This construction will also serve STEAM education for young people and general exhibition display for interested members of the public.

The installation builds on outstanding successes of earlier LASG collaborations with TU Delft including 'Anthozoan Veil', an immersive environment developed during a workshop in 2018 at Delft followed by installation at The Hague's Elektrikfabriek building for TodaysArt, workshops with the Interactive Environments Minor and Architecture 2020-23, and a collaborative installation located at the Tilburg Textielmuseum in collaboration with Iris van Herpen. Student research exchanges between TUD industrial design and the University of Waterloo's Toronto LASG studios have supported this work. Substantial contributions from Canada's Social Sciences and Humanities Research Council and Canada Council for the Arts have provided additional funding.

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Poietic Veil Tilburg - Tilburg Textiel
Museum, Tilburg, 2023



Living Architecture

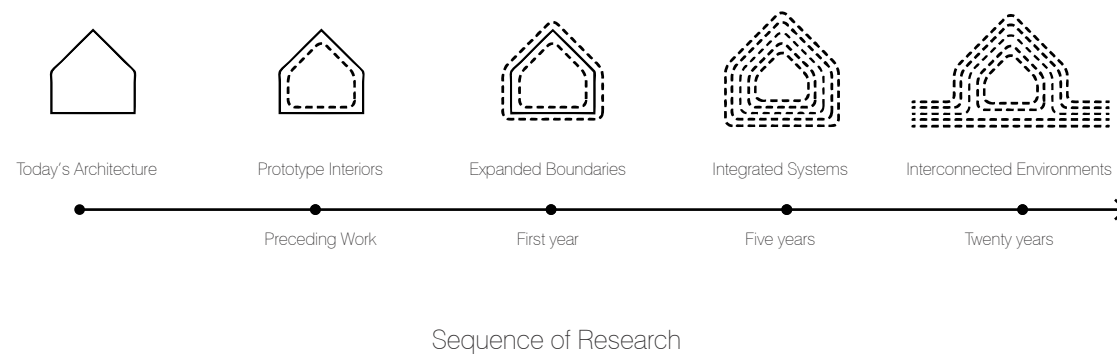
The research of the Living Architecture Systems Group has the potential to change how we build by transforming the physical structures that support buildings and the technical systems that control them. Researchers from architecture, engineering, chemistry, computation, fashion, sound and lighting are 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.

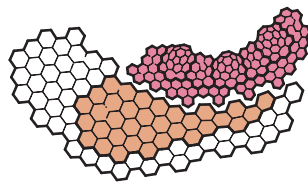
This sculpture is a 'testbed' that supports ongoing research about future architecture. The sculpture can be studied as a prototype for design systems, advanced manufacturing methods, and computer controls of smart buildings. Noosphere is interwoven with miniature computers, arrays of sensors and interlinked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

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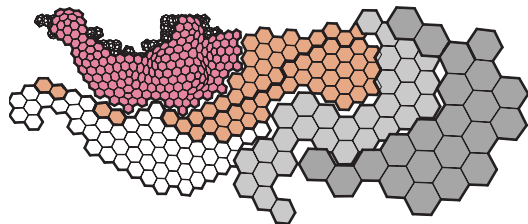
Diagram shows Living Architecture Systems Group collaboration with TU Delft Science Centre creating new knowledge, new highly qualified people and new applications



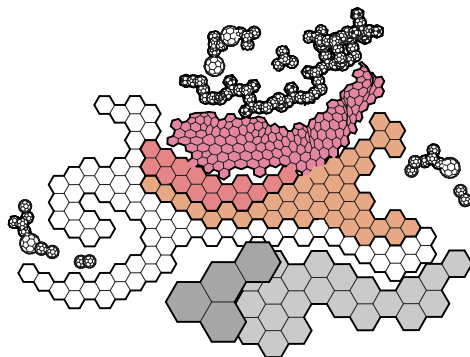
Proto-Poietic Veil Workshop
2022



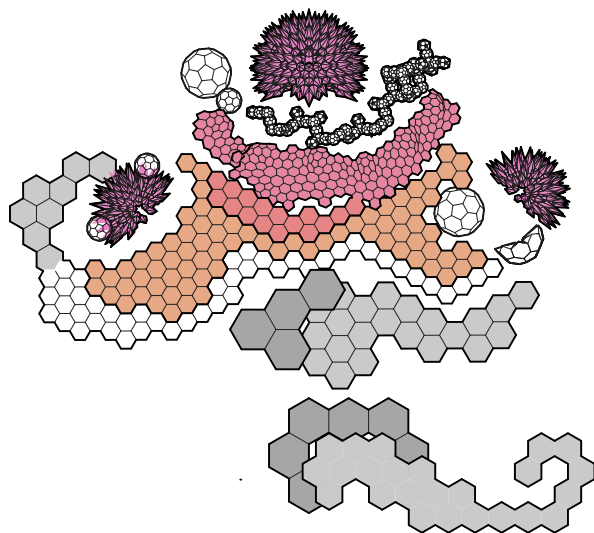
Tilburg - "Is It Alive"
2023



Delft Science Centre
Minimum Scope
2024



Delft Science Centre
Full Scope
2024



Strategies for Integration of Evolving Components

The DSC Testbed Sculpture is strategically designed to support ongoing evolution and changes. Circular design can be directly seen in a succession of workshops and installations including Poietic Veil, 2021, Poietic Veil Tilburg, 2022, Delft Highlight Festival 2023, and the current DSC Testbed 2024-5. Following circular economies, preceding investments that have consumed physical components and raw materials are recycled and reused. Modular, layered organization permits additions and substitutions.

This method can be seen at multiple scales that include individual components, assemblies, and large-scale events. The open-source pattern-language developed for Living Architecture constructions provides a substantial resource that supports harmony and coherence in this growing and changing work.

Facing Page
Diagram shows the evolution of design and the re-use of physical components throughout four Living Architecture projects.



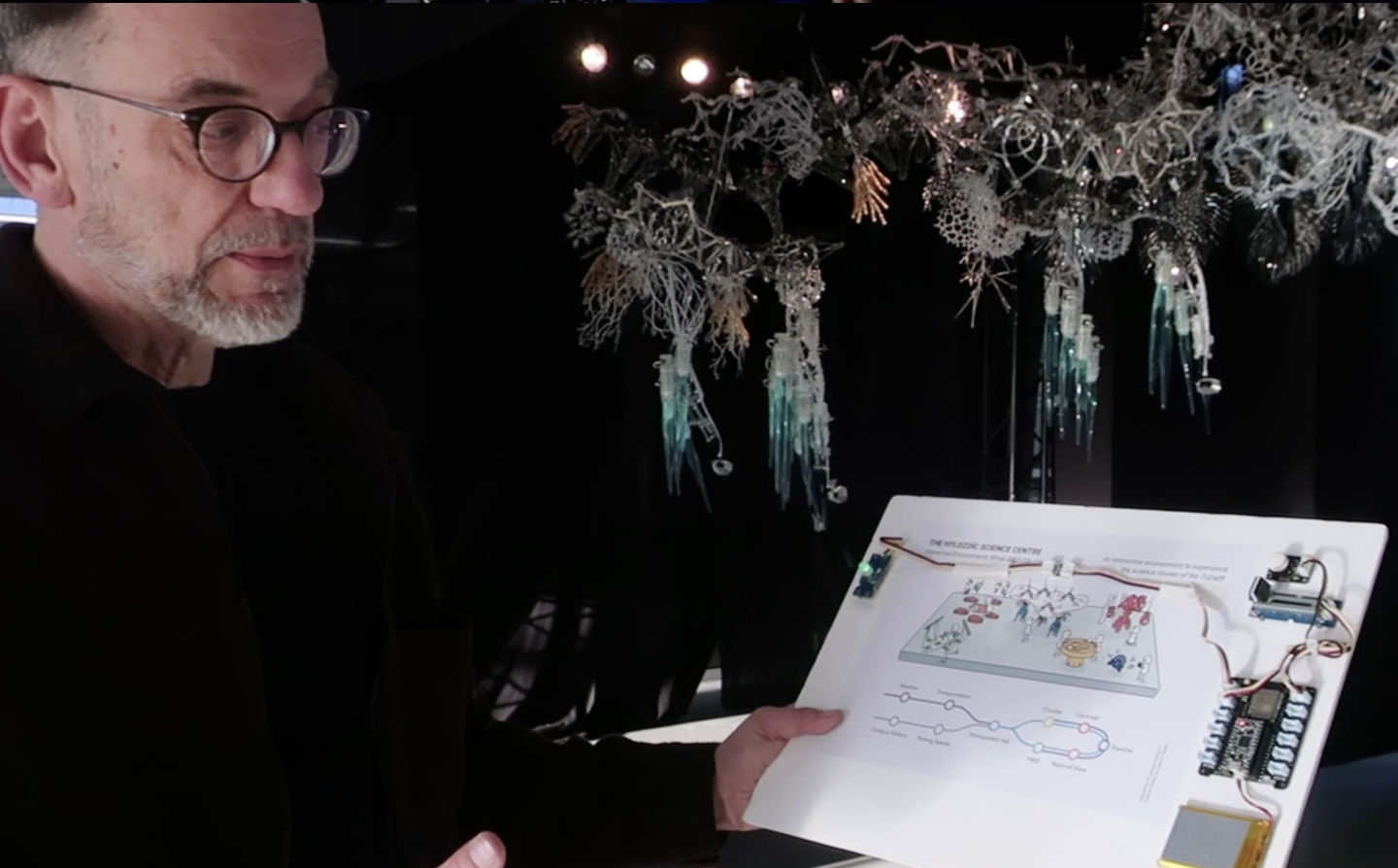
Working Methods

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Above: LASG Collaborator Matt Gorbet, PBSI, programming performance of Meander, Tapestry Hall, Cambridge, ON. The performance was composed by configuring behaviour using digital models linked to spatial data corresponding to the intermeshed physical systems of the sculpture

Below: LASG Collaborator Aadjan Van der Helm, TU Delft, demonstrating linked external and internal interactive systems within Poetic Veil, Interactive Environments Minor workshop, Delft Science Centre, 2022. The microprocessor units mounted on the demonstration board appearing within this image correspond to an external system of electronics communicating in real time with internal systems of the testbed.

The LASG is pioneering a efficient cyclical design method that integrates virtual digital media with physical mechanics and robust industrial design of physical components. In this new method, digital twins and virtual-reality components come at the very beginning of a design process. Kinetic mechanisms are explored in expressive digital media projections in early stages of project development, presented in the form of projections and shadow-plays. Following the same designs created for that digital media, robust physical mechanisms are tested and fabricated in later developments. Identical designs are used for both virtual and physical constructed versions of these mechanisms. This is a highly efficient process, creating flexibility for cycles of development alternating between virtual and physical constructions.





STEAM Education

Facing Page

Students and workshop leader Philip Beesley explore geometry meshworks in model form at CAST-LASG Workshop, Winnipeg, Canada, 2020

STEAM fields are the areas of science, technology, engineering, the arts, and mathematics. The Living Architecture Systems Group is actively engaged in STEAM education for a wide range of age groups, facilitated through coursework, workshops, open-access publications and even summer camps. The sculpture at Delft would provide participatory STEAM education opportunities during its assembly, and leverage findings and iterative work from past LASG STEAM workshops.



New Art Forms and New Audiences

New-media performances will be created within the environment of the sculpture, integrating experimental forms and expressive performances, surrounding audiences with evocative landscapes of movement, spatial sound, light, and immersive data projections. The immersive sculptural forms, sound, light, and motion of the Delft Science Centre Sculpture Testbed offer a new kind of art that invites development of new kinds of audiences.

Facing Page
Immersive performance of Meander at
Tapestry Hall, Cambridge, Ontario, 2024

Extraordinary interest from a wide range of public viewers has resulted in recent installations of this living architecture, with round-the-block lineups at Toronto’s Nuit Blanche and record attendance at locations including Futurium, Berlin, Royal Ontario Museum in Toronto, and Ars Electronica, Linz. Tapestry Hall in Cambridge, Ontario is now hosting sold-out dinner-and-performance evenings featuring a sound-and-light performance within the large-scale responsive environment of Meander.



Integration of Spatial Sound

The LASG has partnered with 4DSOUND Technologies, an Amsterdam-based studio focusing on spatial sound as a creative medium to create immersive experiences and sound design tools for sculptures of different sizes, characters, and contexts. The TU Delft test-bed will incorporate a cutting-edge spatial sound system, merging custom software and hardware innovations. The system features a modular spatial audio software framework designed to support the involvement of artists and technical collaborators. This spatial sound system creates a sculpture-like presence of sound in time and space. The physical installation functions like a spatial sound canvas, supporting sound holograms.

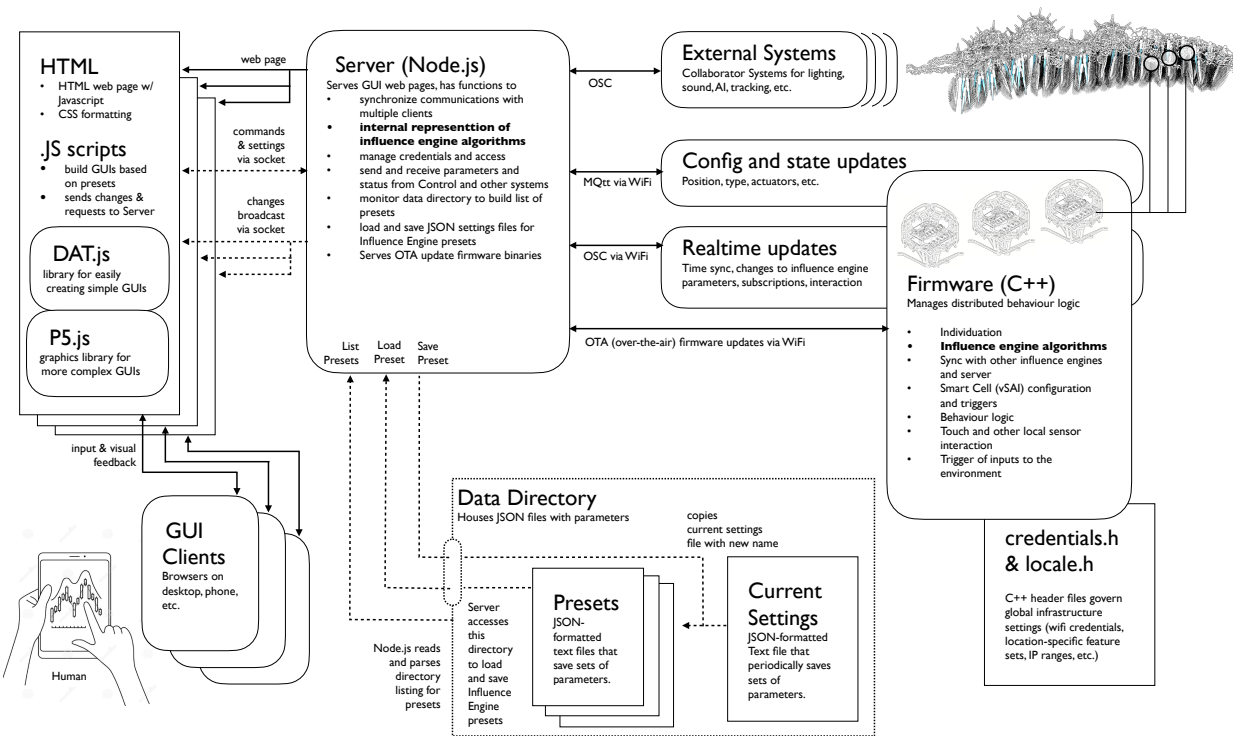
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Example of spatial sound arrangement at the Grove installation for the Venice Biennale, Venice, Italy, 2021



Electronic Controls and Behaviours

The behaviour systems of past LASG sculptures are divided into central and distributed parts. These two parts work together. Many dozens of interconnected microcontrollers are positioned throughout the sculpture environment, working in parallel with a central control computer. The distributed and central systems work together to choreograph a sculpture's expression. 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, while for distributed behaviour individual microcontrollers are decision makers. With more development, the behaviour systems of the testbed can have the potential for extension by visiting artists and collaborators.

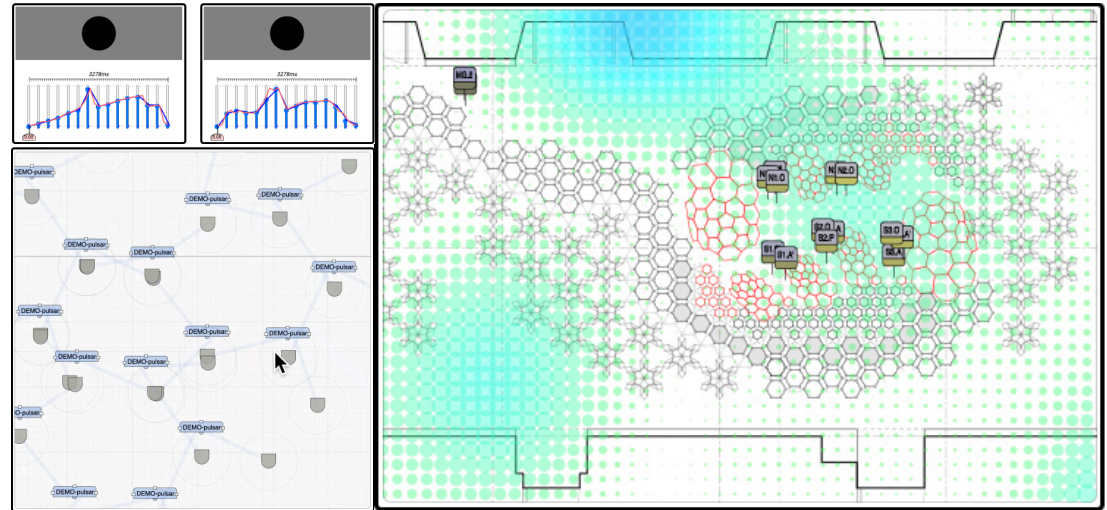


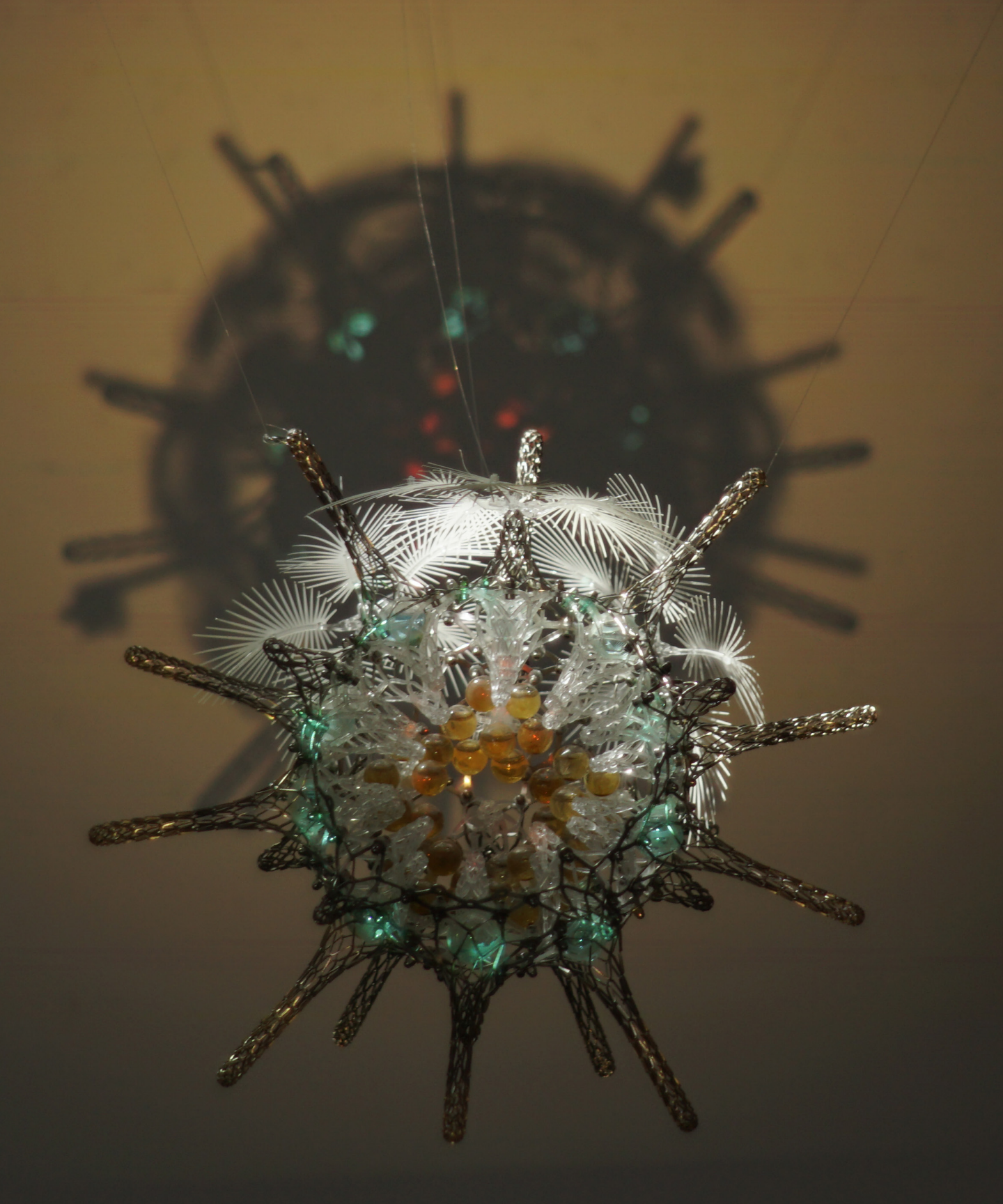
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Behaviour diagram for Meander in Cambridge, ON, 2022

Below

Examples of control software used for Meander in Cambridge, ON, 2022





Living Shadows

The Living Shadows project is an augmented reality experience that explores the intersection of physical and virtual worlds through the medium of shadowplay. It investigates how the shadows of a physical object might be augmented with the shadows of animated creatures and field conditions that exist within a virtual world. The aim of the Living Shadows project is to create a virtual world that is closely linked to its physical counterpart. In this virtual world, a digital twin takes on a life of its own, with actions and influences that are projected back out into the physical world and made visible through the interplay of light and shadow on objects and their surroundings. Overlaid on a physical work, this virtual world of living architecture evokes new dimensions for exploring the lives of virtual beings immersed within environments.

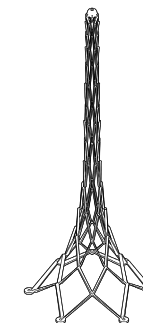
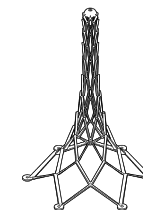
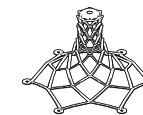
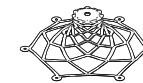


Living Shadows Video and
Virtual Object Demo

The creatures that inhabit this virtual world help develop the identity of a sculpture's static physical components. Action composed within the virtual environment is related to the particular components and organizations of physical fabrications within LASG sculptures. The Living Shadows project explores behaviours that these assemblies might manifest if they were given autonomy and set free within a virtual environment. This project represents an early step in the Living Architecture Systems Group's exploration of augmented reality environments.



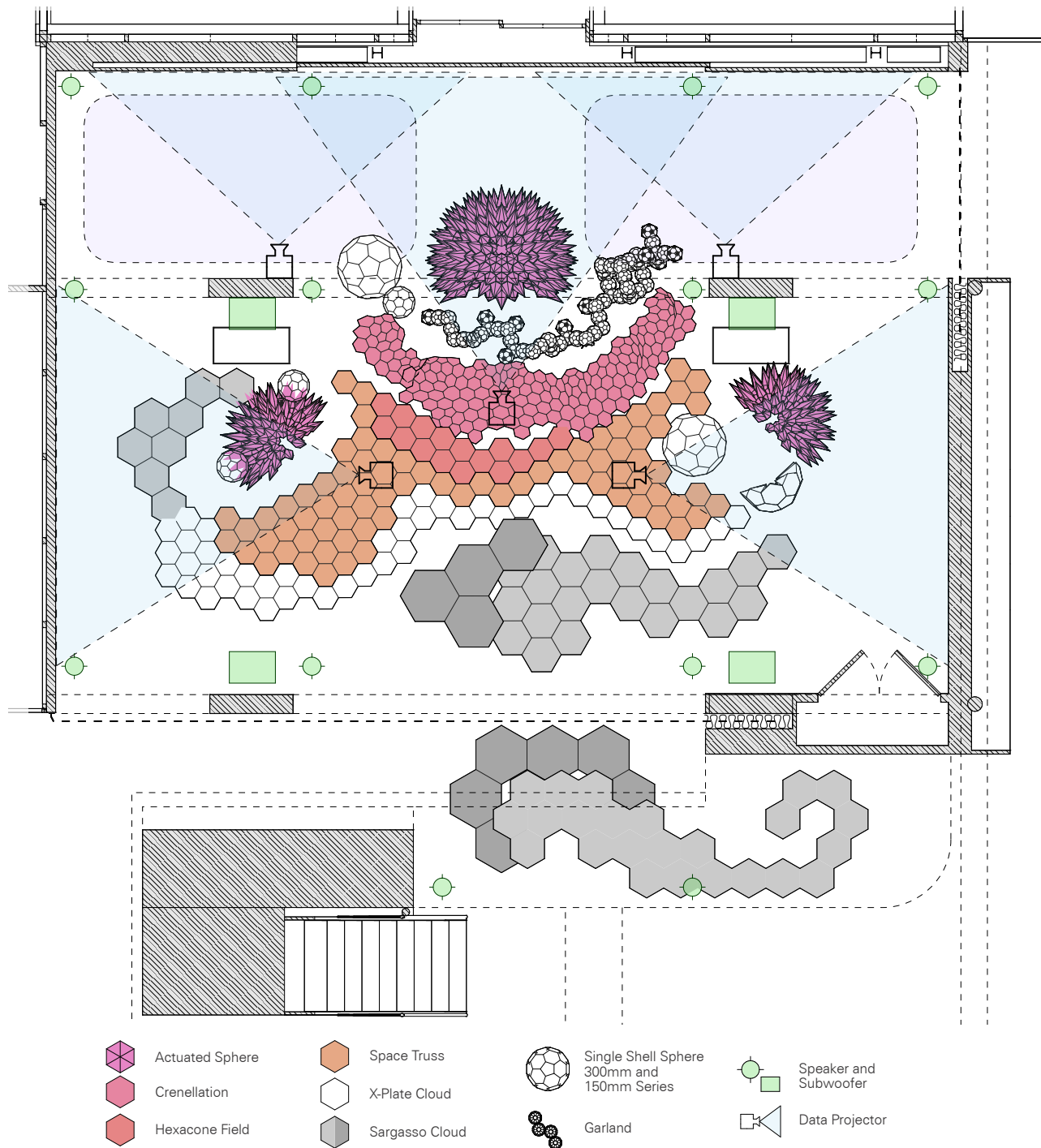
New Material



The interwoven structures of the Testbed 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.

The open mesh grid-like construction is composed of thin sheets of materials. Metal materials include stainless steel and aluminum. 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.

Materials in past sculptures have included impact-resilient polymer sheets, filaments and resins, combined with custom-fabricated aluminium and stainless steel components, and custom-printed circuit boards. The material was manufactured by the design team using laser cutters, photo-setting digital resin printers and mechanical stretching rigs. The sculpture at Delft is an opportunity to develop a brand-new material that is locally and sustainable sourced. Experiments with hemp sheets are already underway in the LASG's Toronto studio.



Full Project Scope

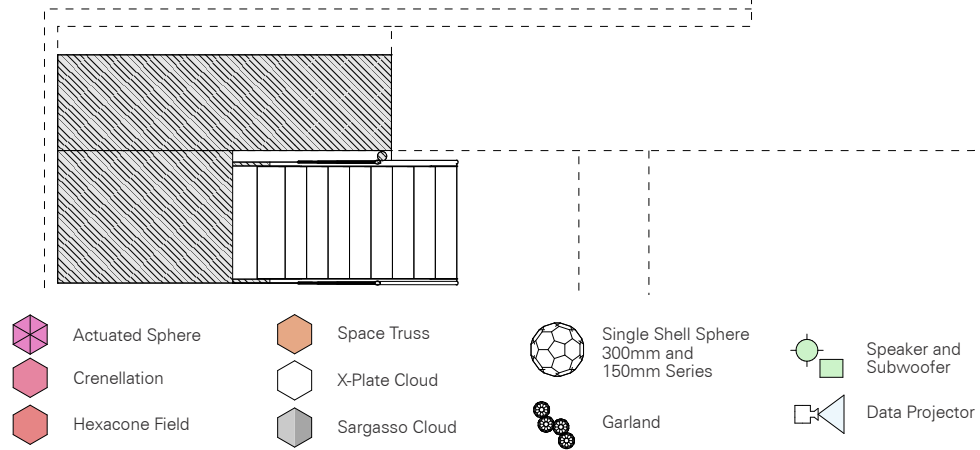
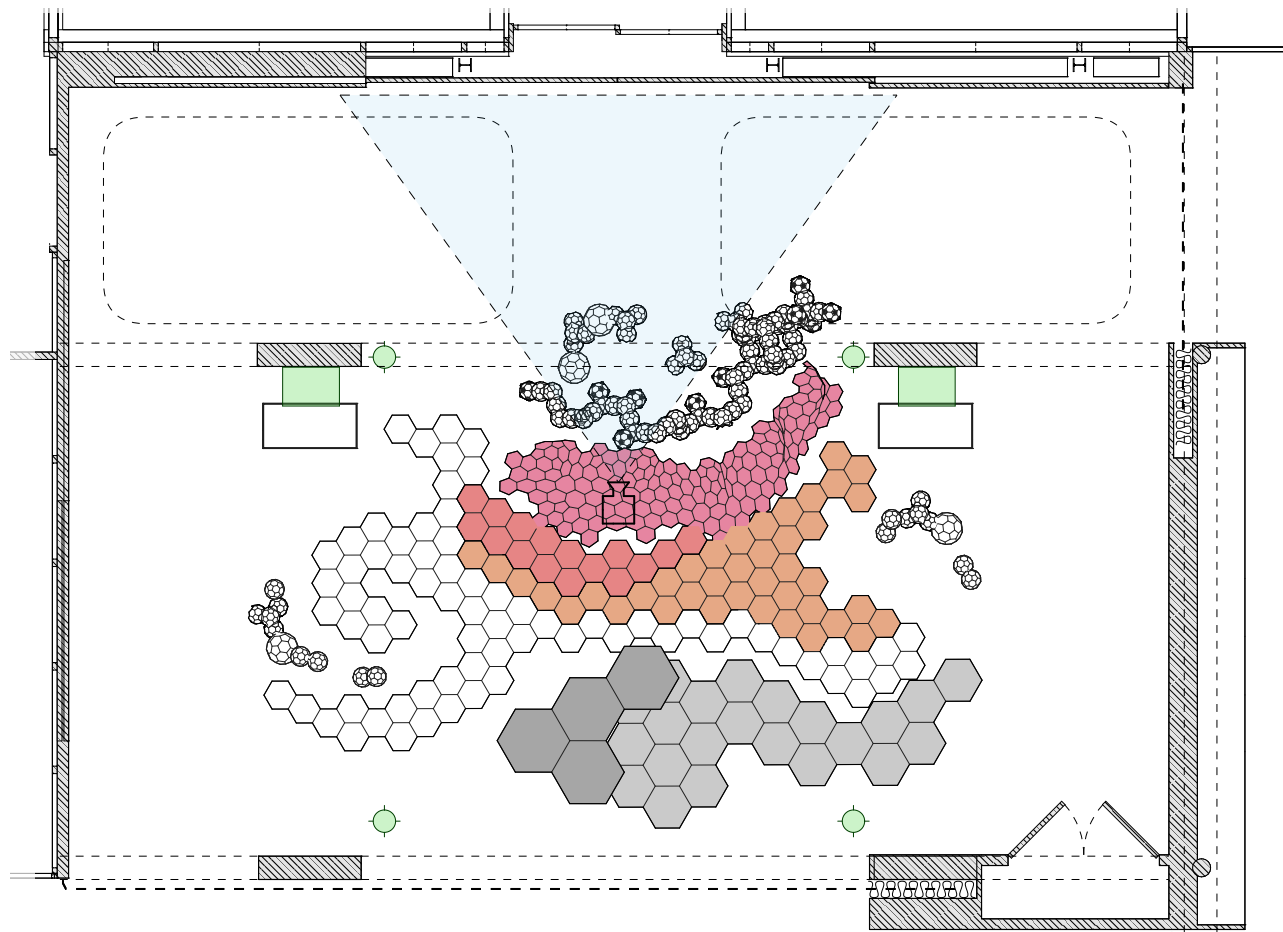
Sculpture Development Phases

The Living Architecture Testbed project is designed to support modular development, matching funding that is being confirmed in dialogue with community members and organizations. Plans entitled 'Minimum', 'Intermediate', and 'Full' scopes are illustrated within this publication, demonstrating the evolving components of the environment including the first phase scheduled for completion in late 2024. Additional components planned for integration in following periods.

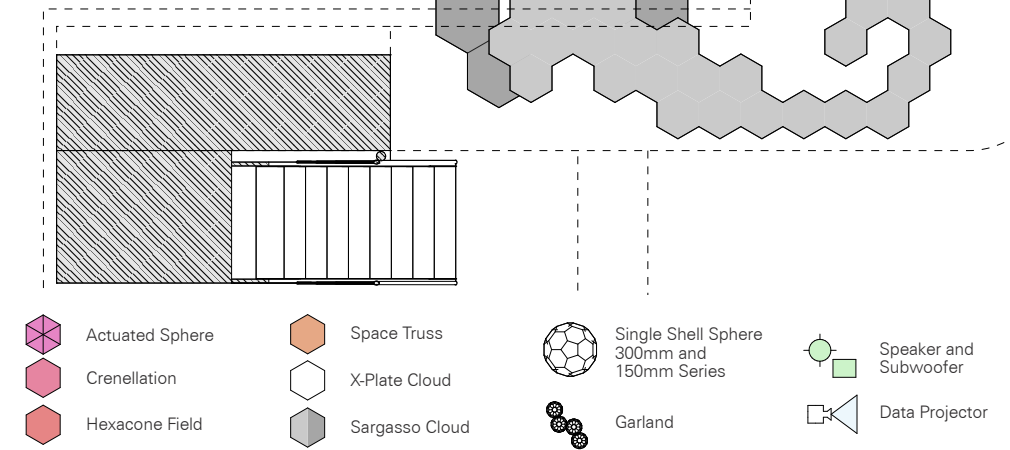
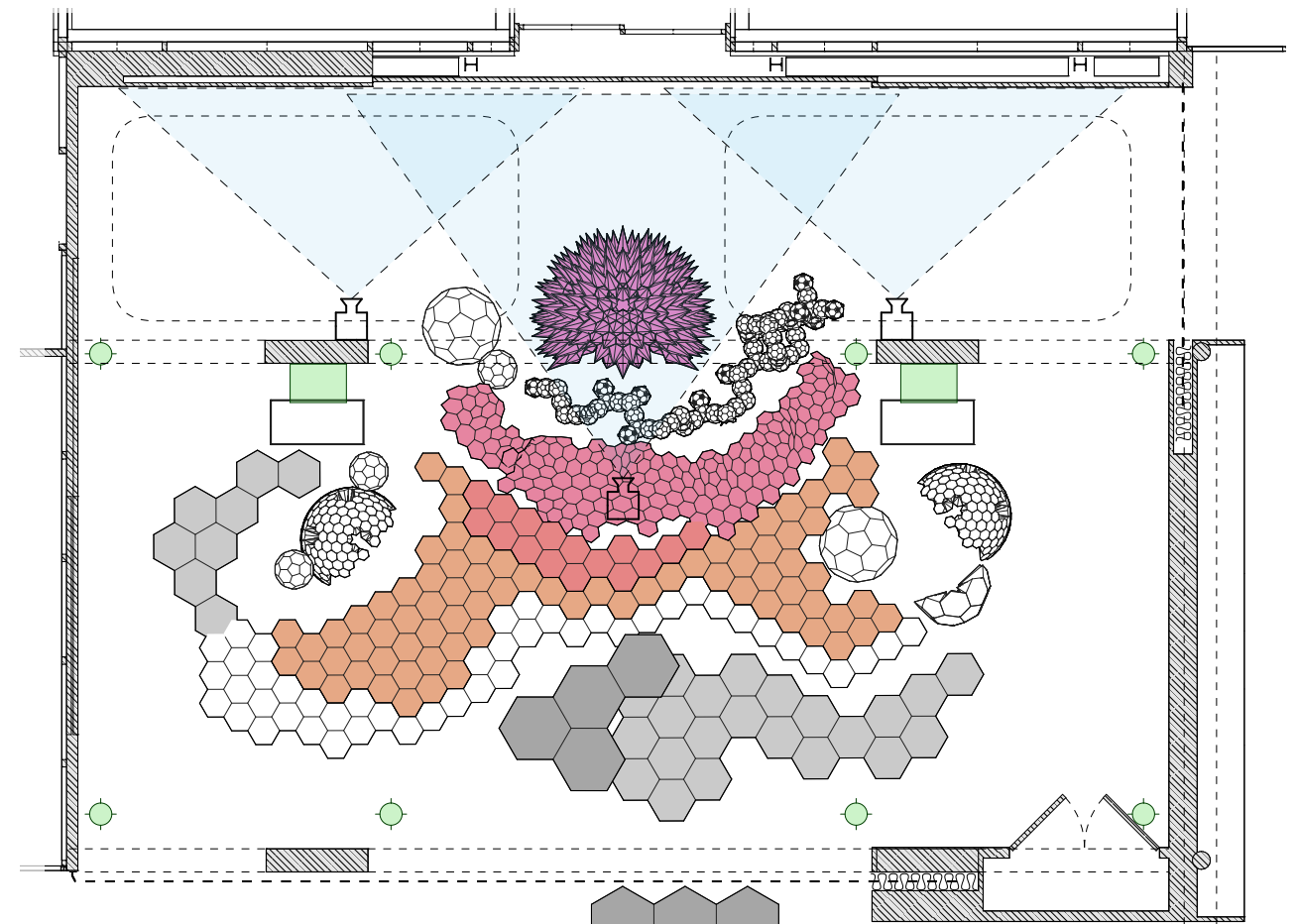
With additional support, features can include:

- Expanded software, allowing the inner workings of this interactive sculpture to be seen and experienced by the public, and supporting advanced research development
- Fields of kinetic mechanisms providing expressive motion
- STEAM kits, supporting exploration and learning by young people
- Publications and displays, sharing specialized knowledge and design patterns
- Immersive coupled projections, creating large-scale imaginary worlds
- Research kits, providing an ecosystem of exploration that permits researchers and creators to develop their own models and experimental structures

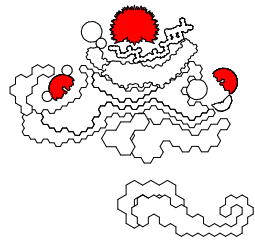
	Minimum Scope	Intermediate Scope	Full Scope
Software Interfaces	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
Living Shadows	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
Spatial Sound	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
Media & Displays	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
Programs & Events		<div><div>WORKSHOPS</div></div>	<div><div>WORKSHOPS</div></div>
		<div><div></div></div>	<div><div>KITS</div></div>
		<div><div></div></div>	<div><div>STEAM PROGRAMS</div></div>
		<div><div></div></div>	<div><div>PUBLICATIONS</div></div>



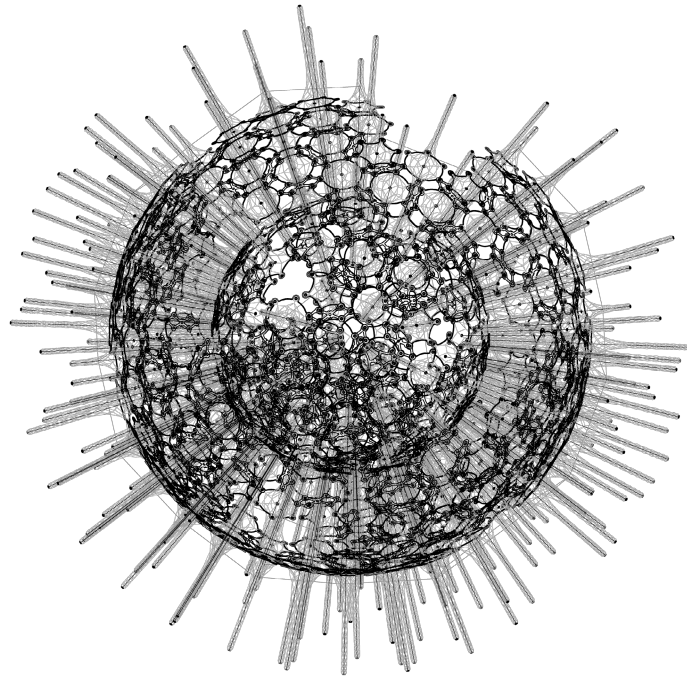
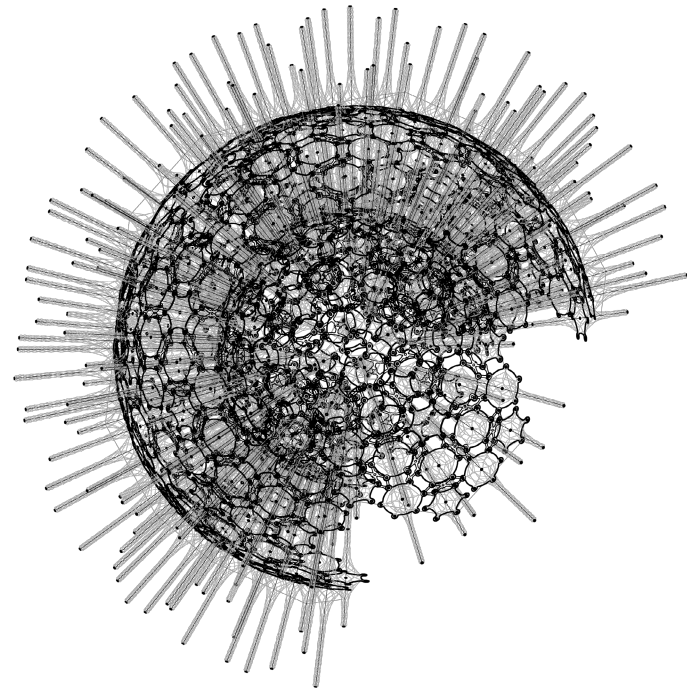
Minimum Project Scope



Intermediate Project Scope

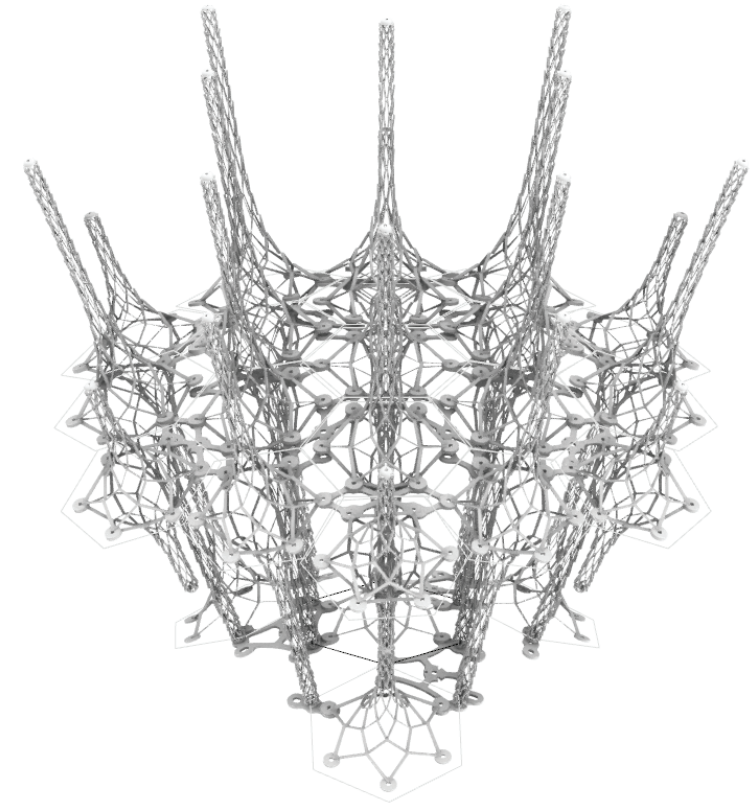


Region Elevation

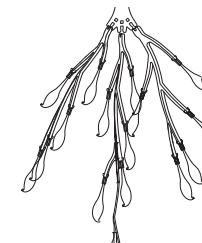


Region Plan

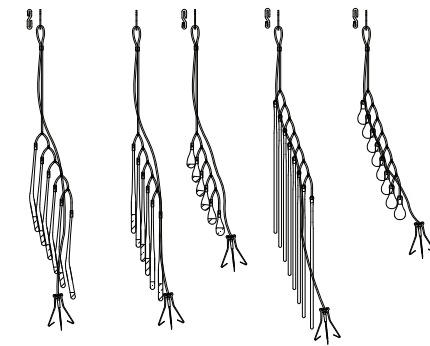
Aletheia Sphere Region Lexicon



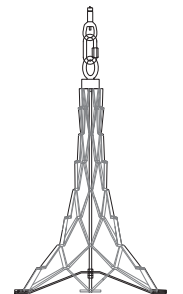
Hex Triad Assembly



Melted Tear Cluster

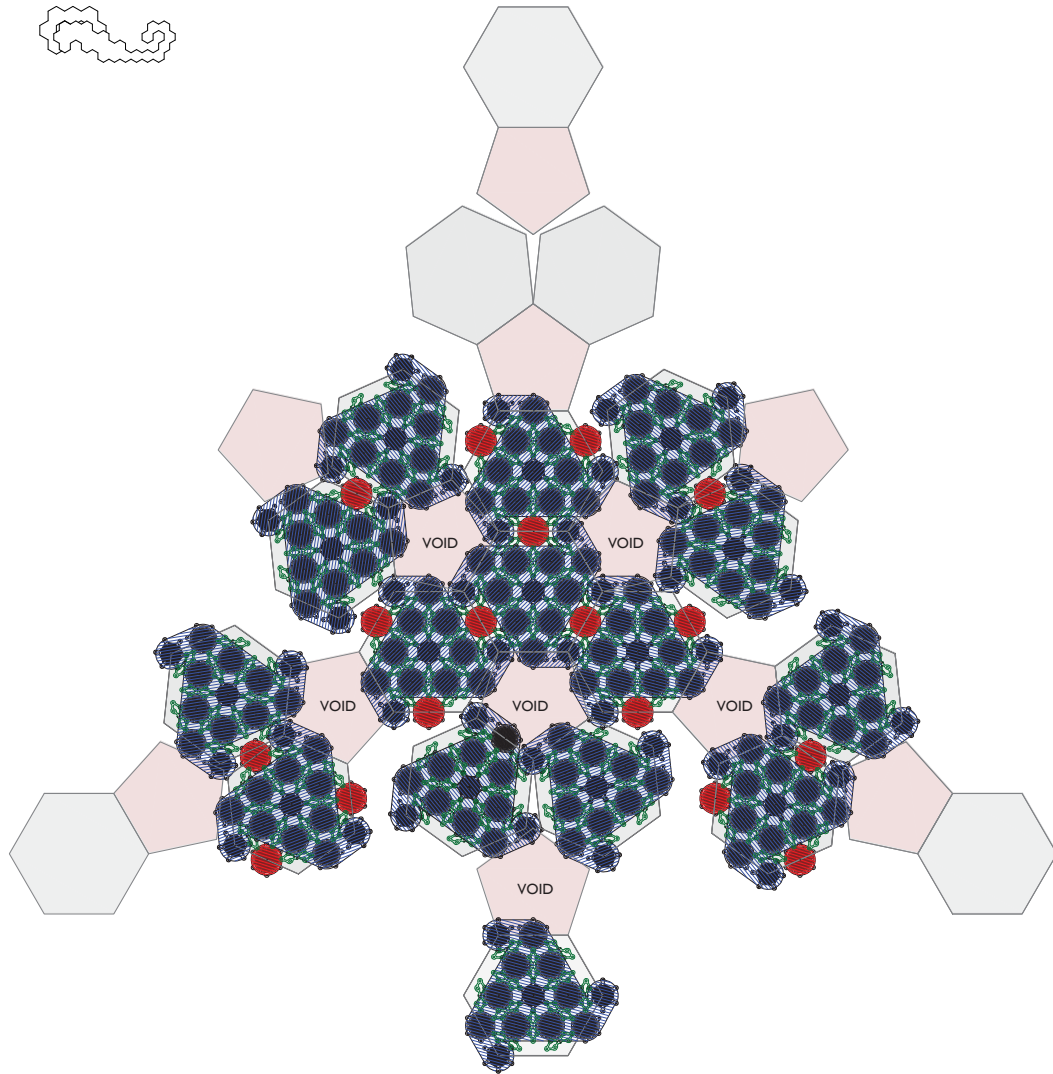
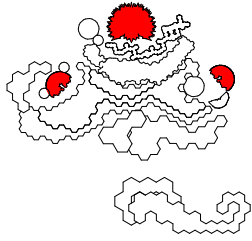


Glass Weeds Assemblies

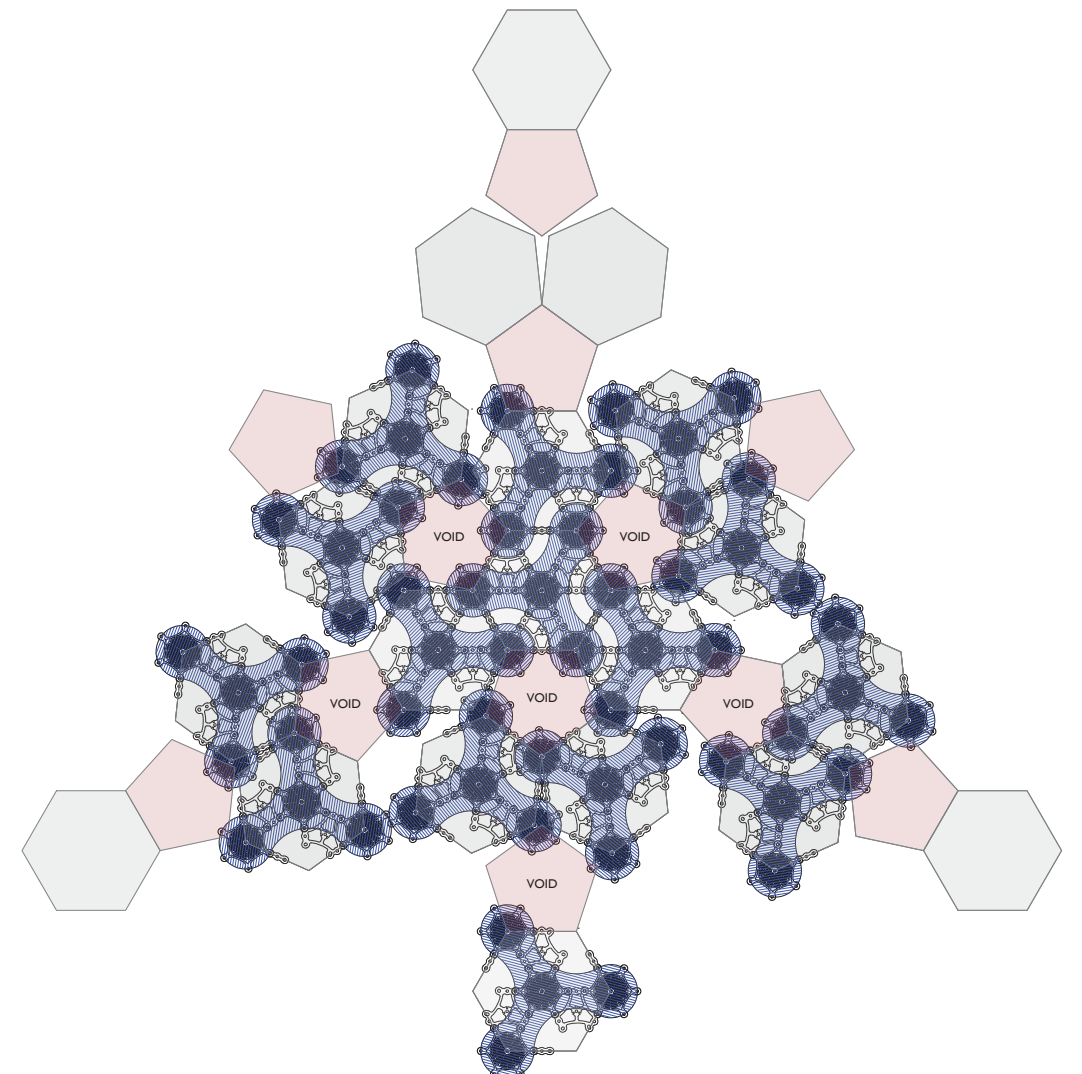


Structural Spar

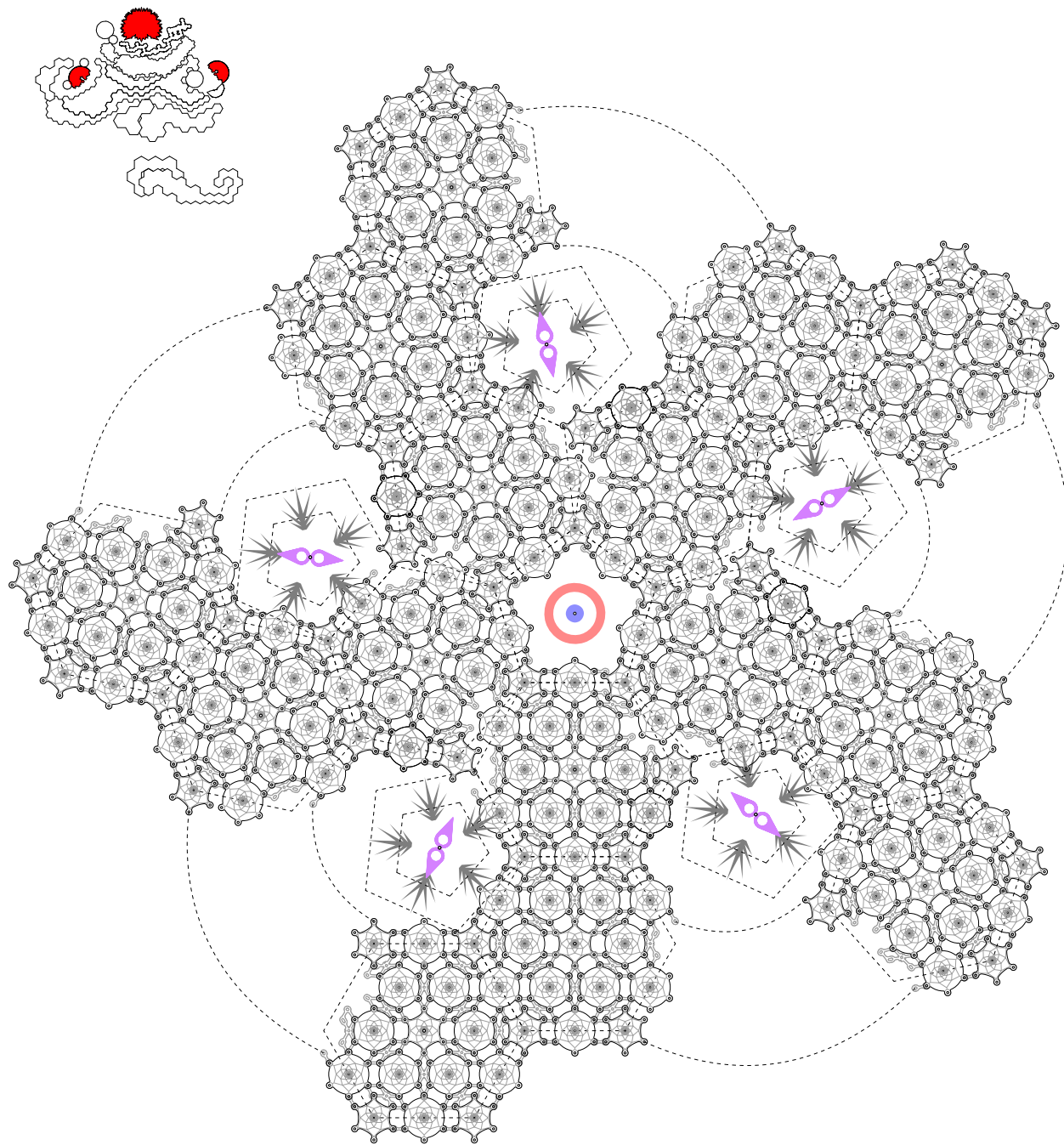
Aletheia Sphere Scaffold and Assembly Lexicon



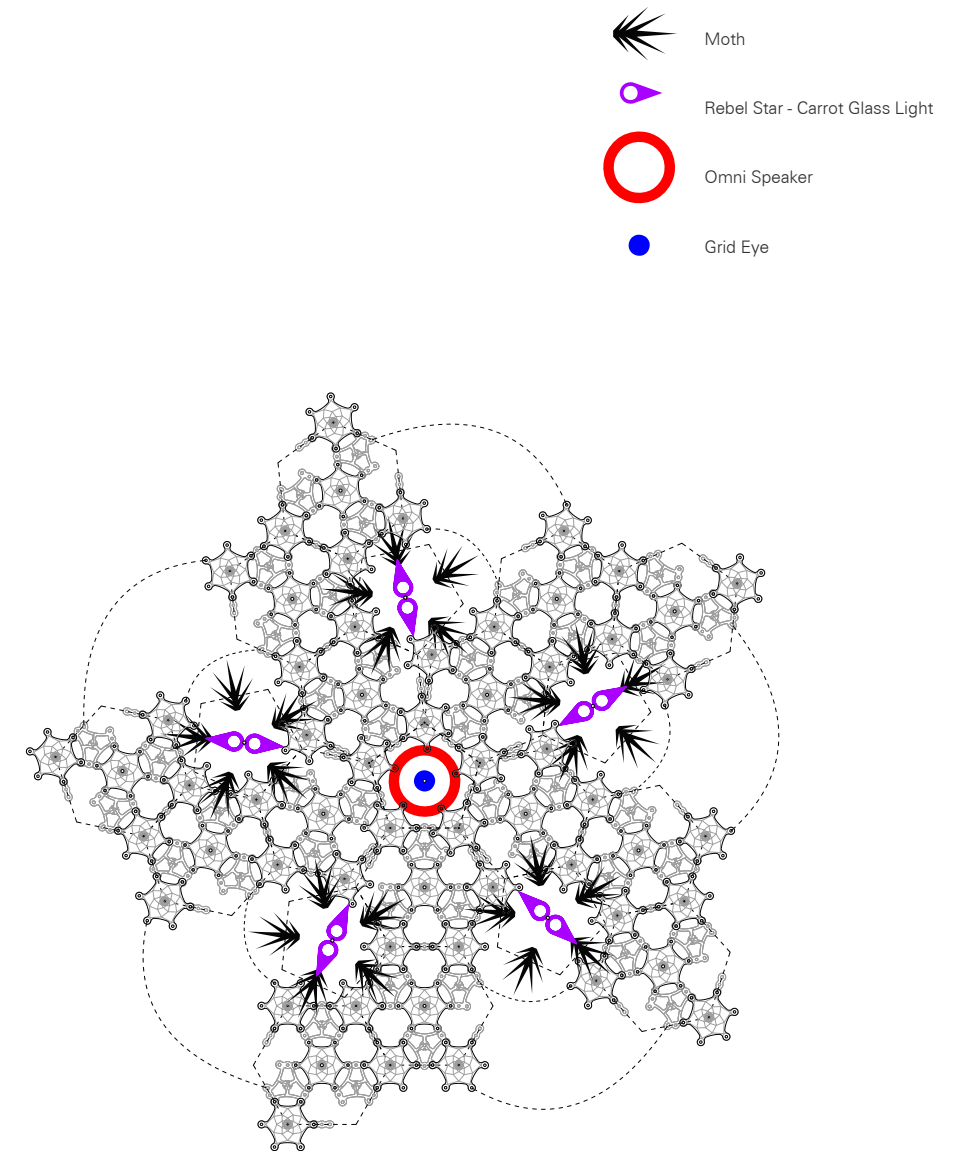
Aletheia Sphere Unfolded Plan - Exterior



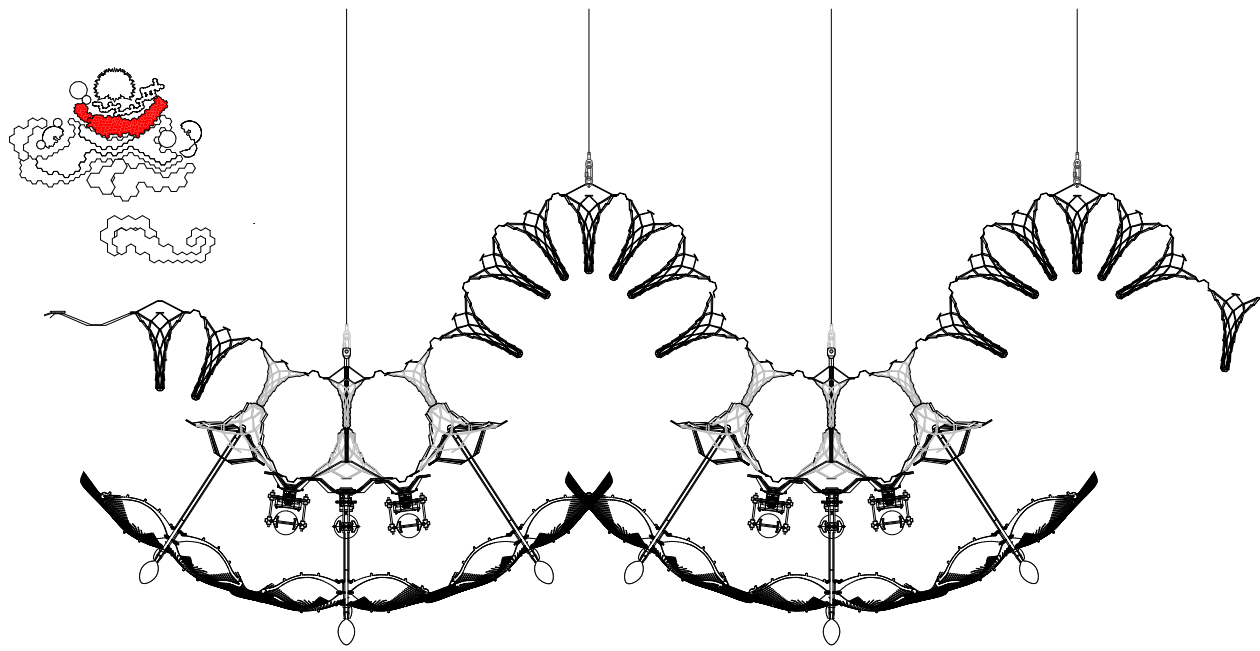
Aletheia Sphere Unfolded Plan - Interior



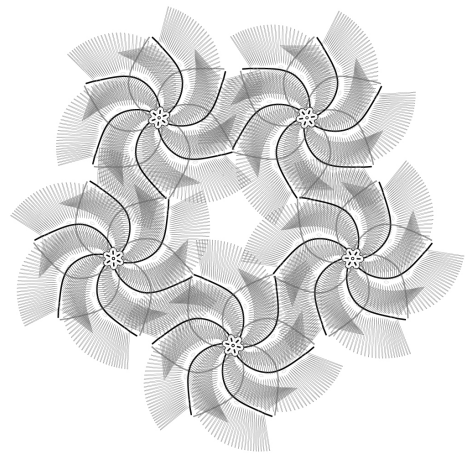
Aletheia Mini Sphere - Actuation Plan Exterior



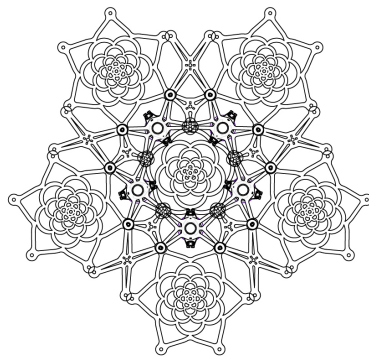
Aletheia Mini Sphere - Actuation Plan Interior



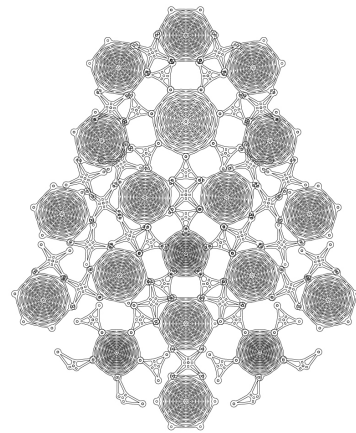
Region Elevation



Sargasso Cloud Layer



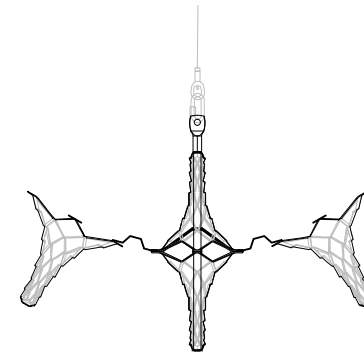
300mm Crenellation
Scaffold Layer



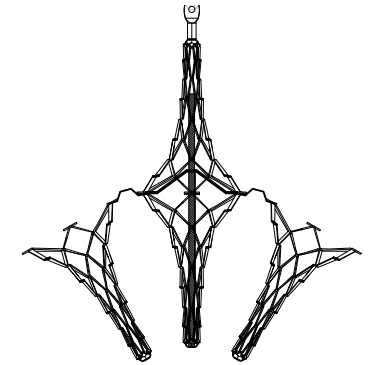
150mm Crenellation
Scaffold Layer

Region Plan

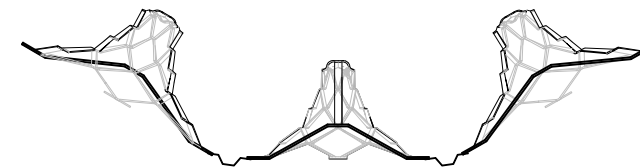
Crenellation Region Lexicon



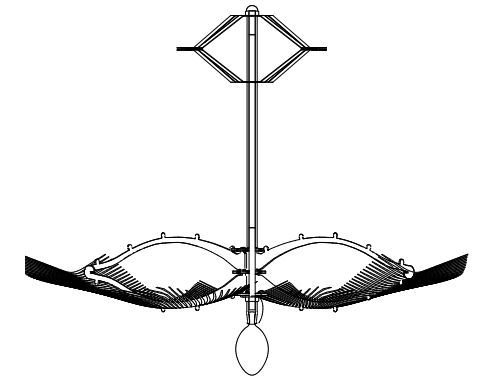
150mm Crenellation Scaffold Convex



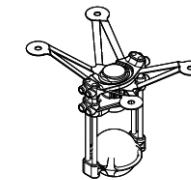
150mm Crenellation Scaffold Concave



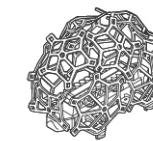
300mm Crenellation Scaffold



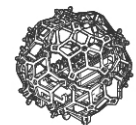
300mm Sargasso Cloud Unit



S4 LED Sphere Pinpoint with
Crenellation

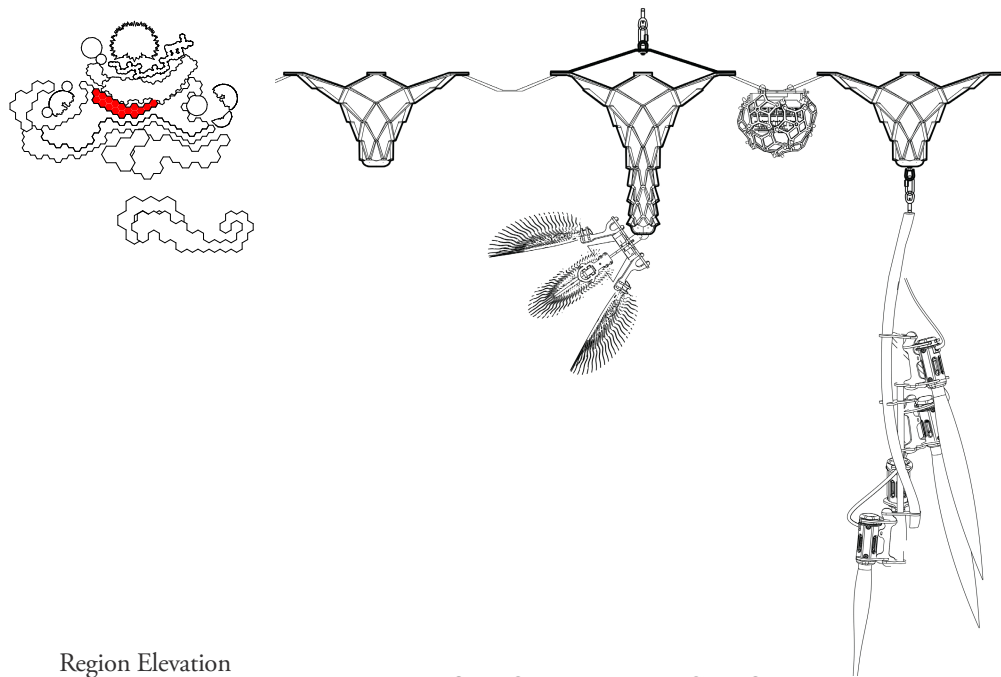


Power Distribution Nest
Assembly



Node Controller Nest
Assembly

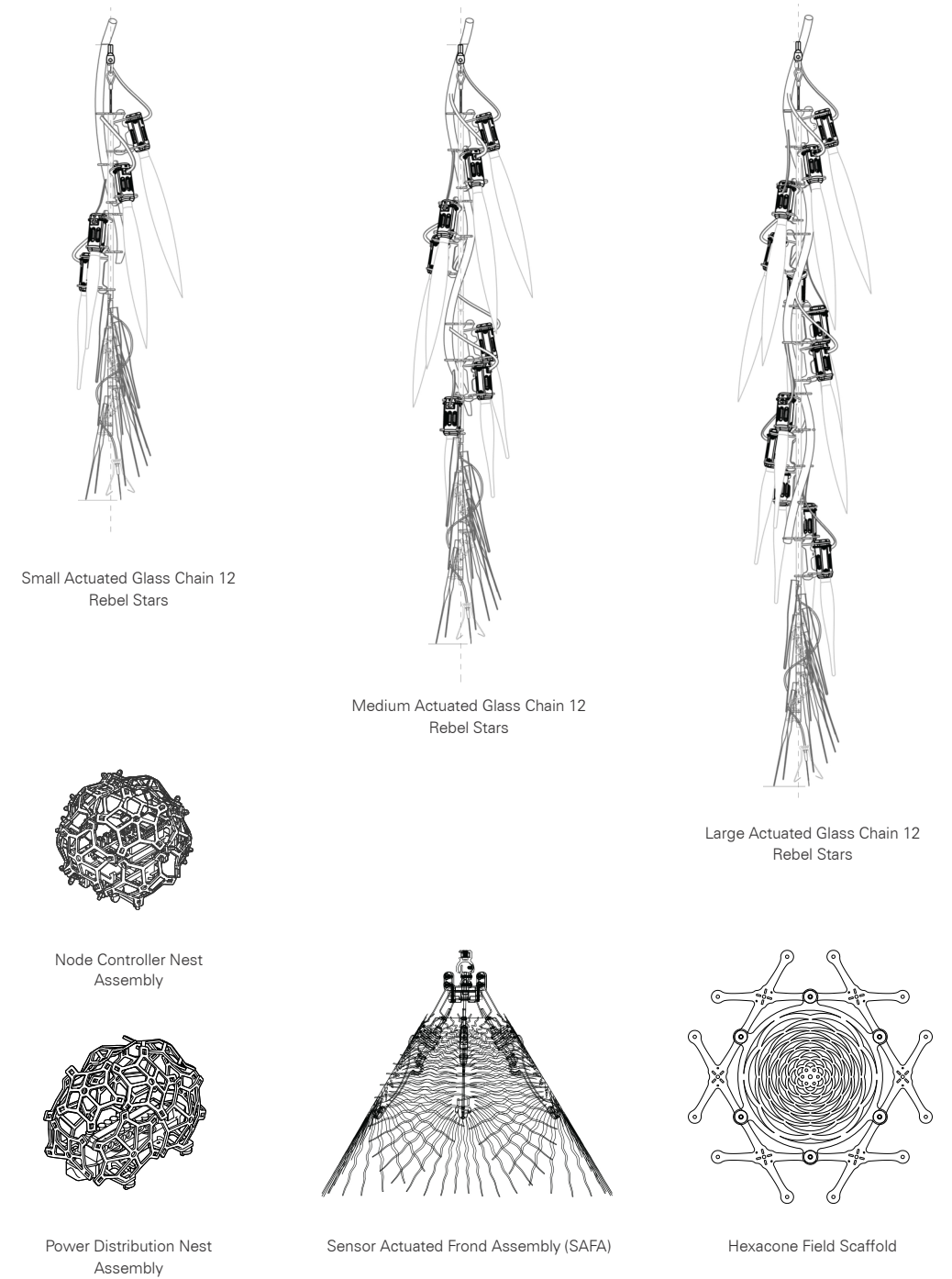
Crenellation Scaffold and Assembly Lexicon



Region Elevation

Region Plan

Hexacone Field Region Lexicon



Small Actuated Glass Chain 12
Rebel Stars

Medium Actuated Glass Chain 12
Rebel Stars

Large Actuated Glass Chain 12
Rebel Stars

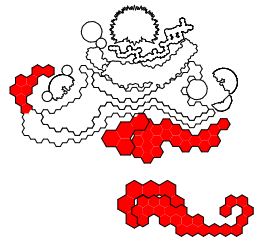
Node Controller Nest
Assembly

Power Distribution Nest
Assembly

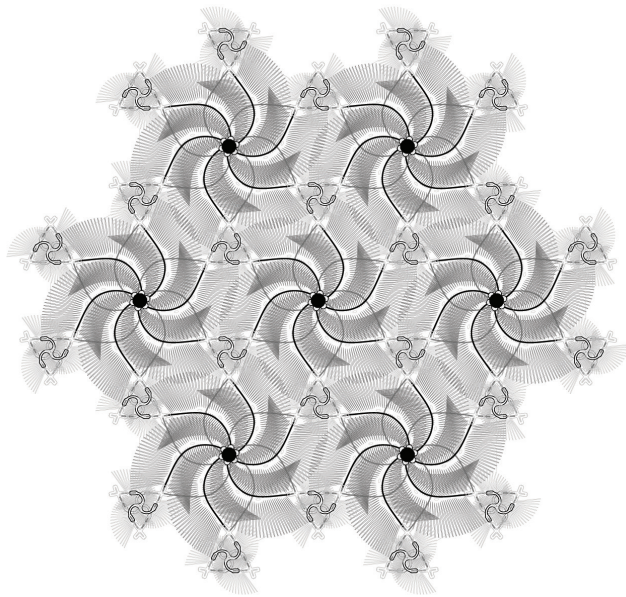
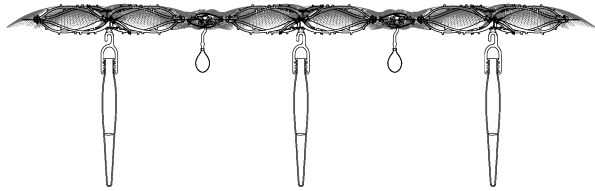
Sensor Actuated Frond Assembly (SAFA)

Hexacone Field Scaffold

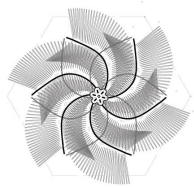
Hexacone Scaffold and Assembly Lexicon



Region Elevation



Region Plan



450mm Sargasso Hex



450mm Sargasso Tri



Tapered Glass Assembly



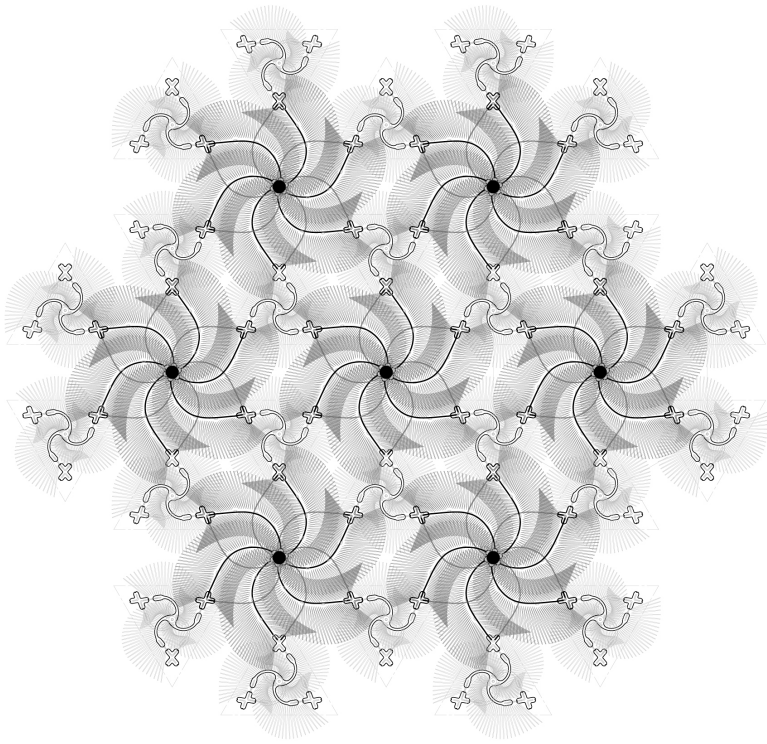
Fig Glass Assembly

Components

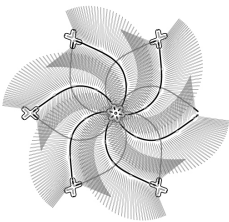
Sargasso Cloud 450mm Region Lexicon



Region Elevation



Region Plan



600mm Sargasso Hex



600mm Sargasso Tri



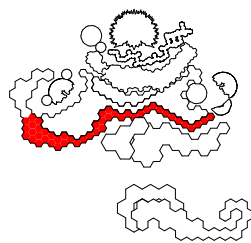
Tapered Glass Assembly



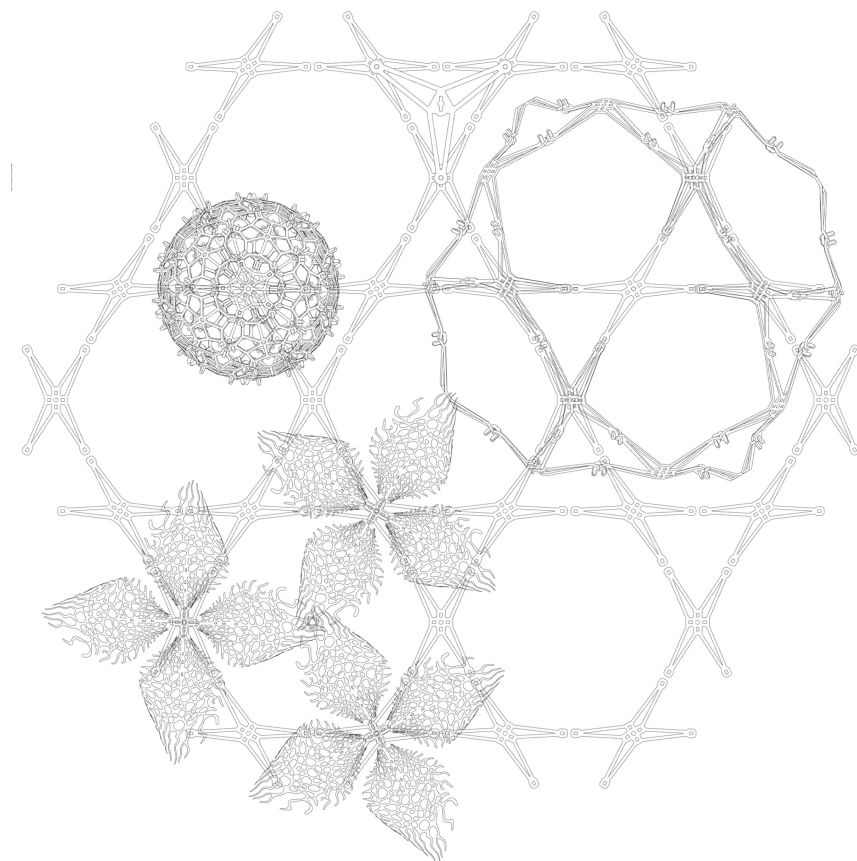
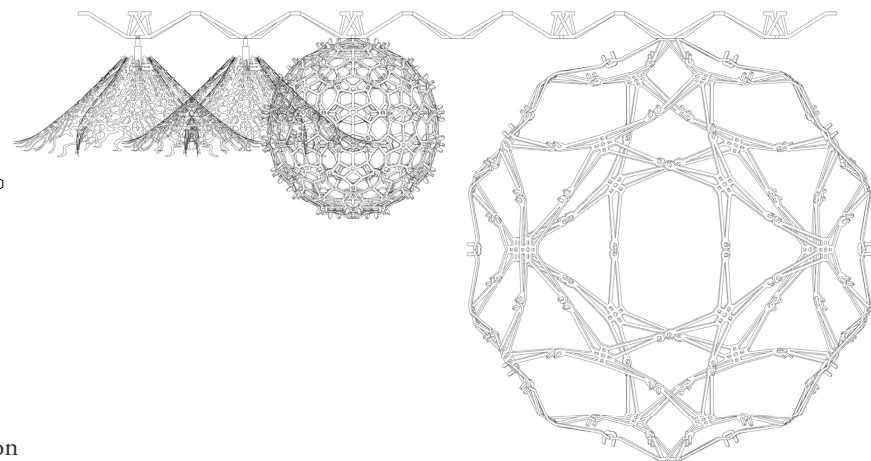
Fig Glass Assembly

Components

Sargasso Cloud 600mm Region Lexicon

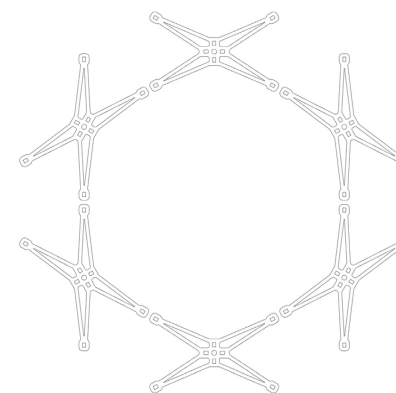


Region Elevation

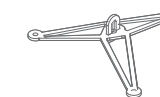


Region Plan

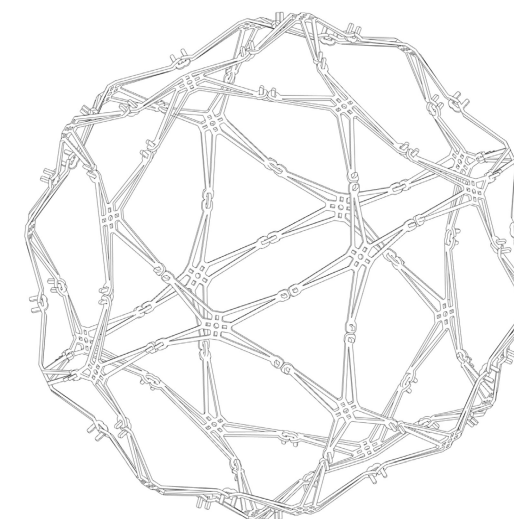
X-Plate Cloud Region Lexicon



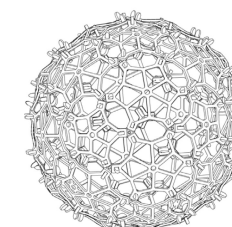
X-Plate Cloud Scaffold



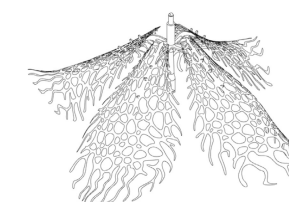
300 Hanging Point Tri-Plate



Truncated Icosahedron Sphere Dressing

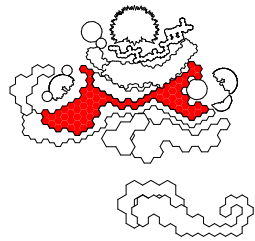


Dodecahedron Sphere Dressing

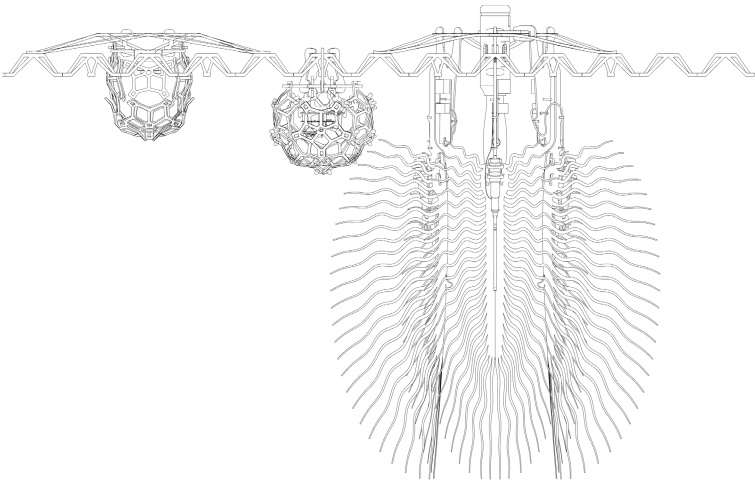


Quad Frond Dressing

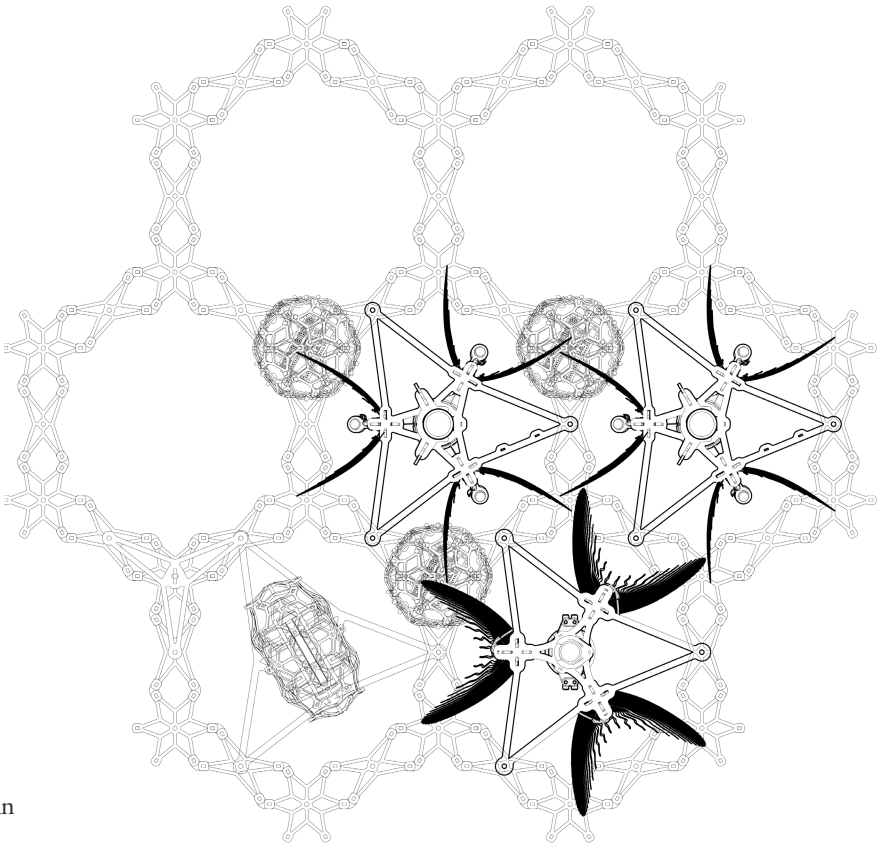
X-Plate Scaffold and Assembly Lexicon



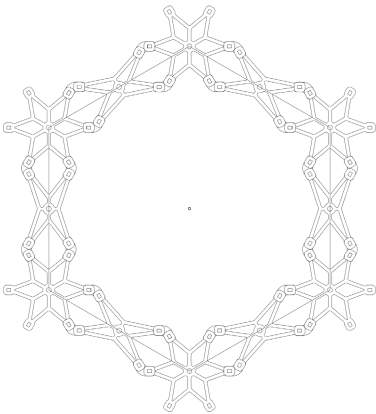
Region Elevation



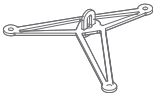
Region Plan



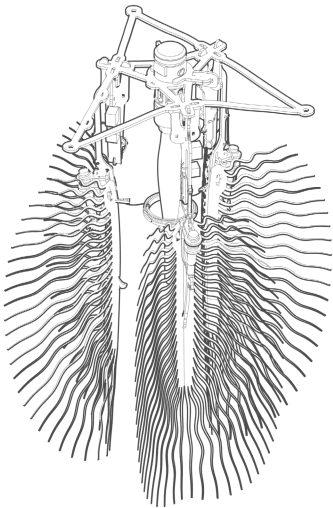
Space Truss Region Lexicon



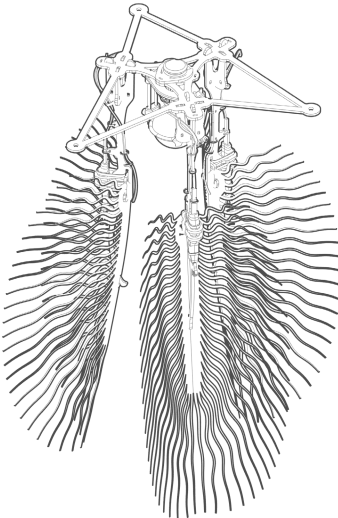
Space Truss Scaffold



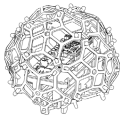
300mm Hanging Point Tri Plate



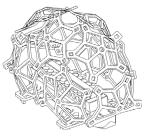
Series 3 Cloud Cell Assembly



Series 4 Cloud Cell Assembly

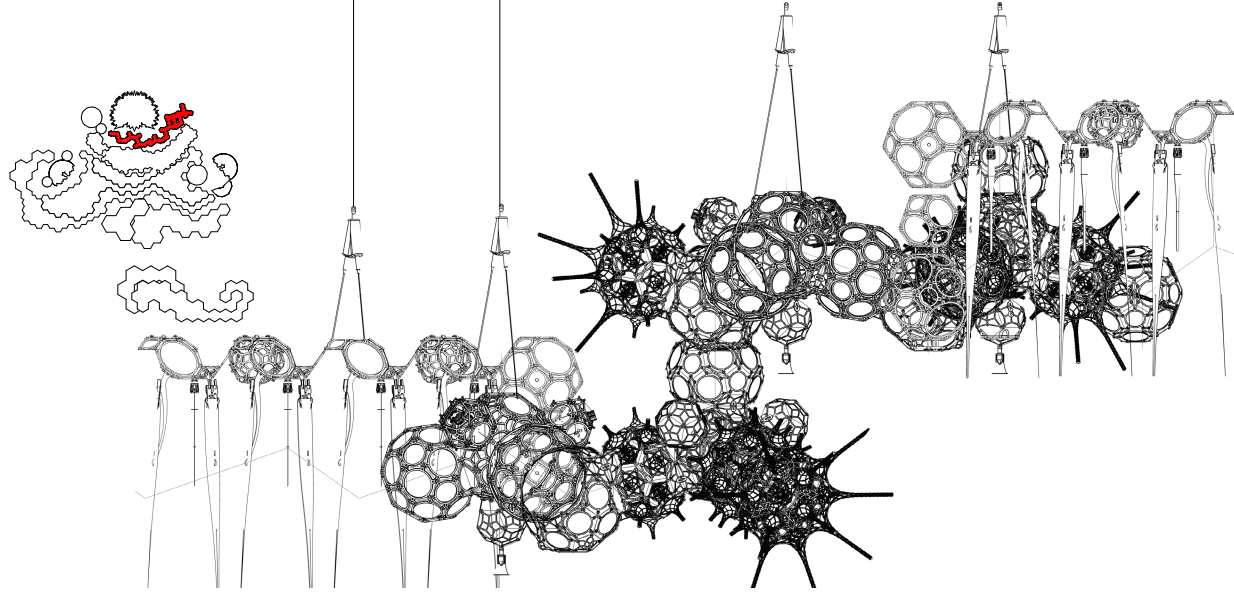


Node Controller Nest Assembly

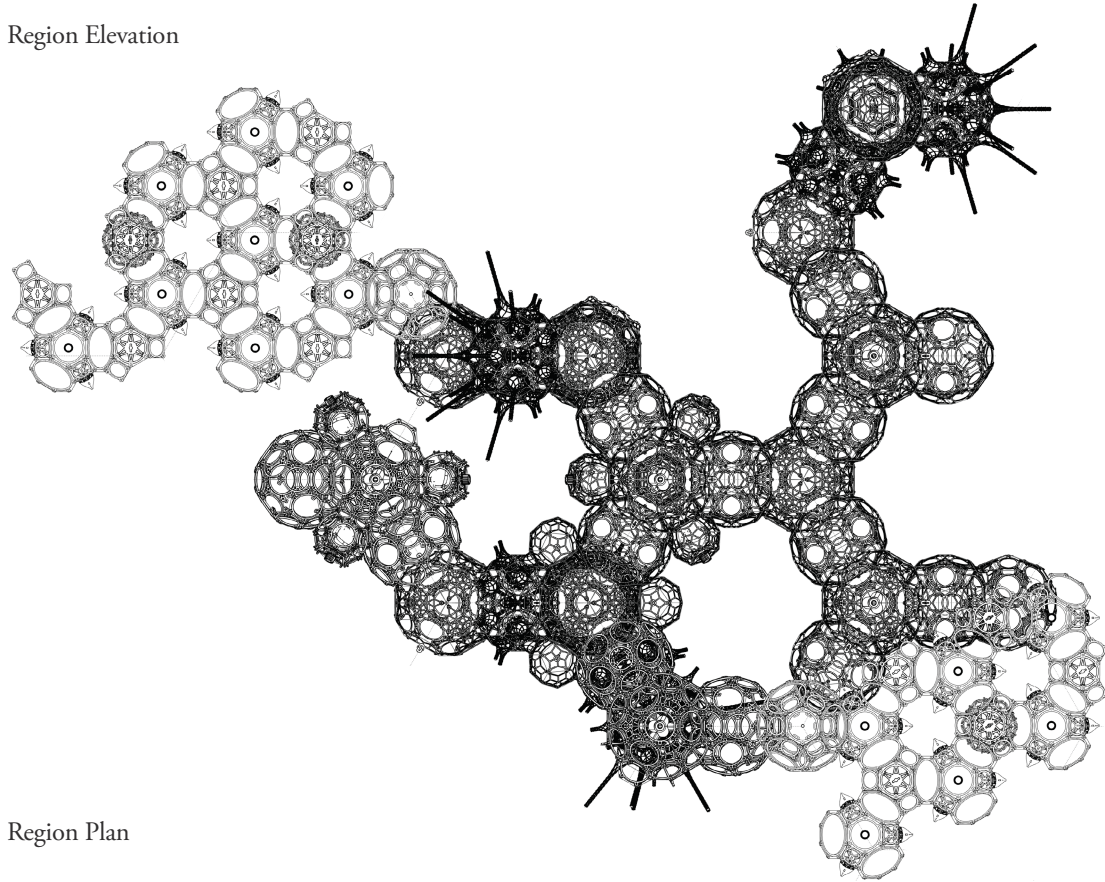


Power Distribution Nest Assembly

Space Truss Scaffold and Assembly Lexicon

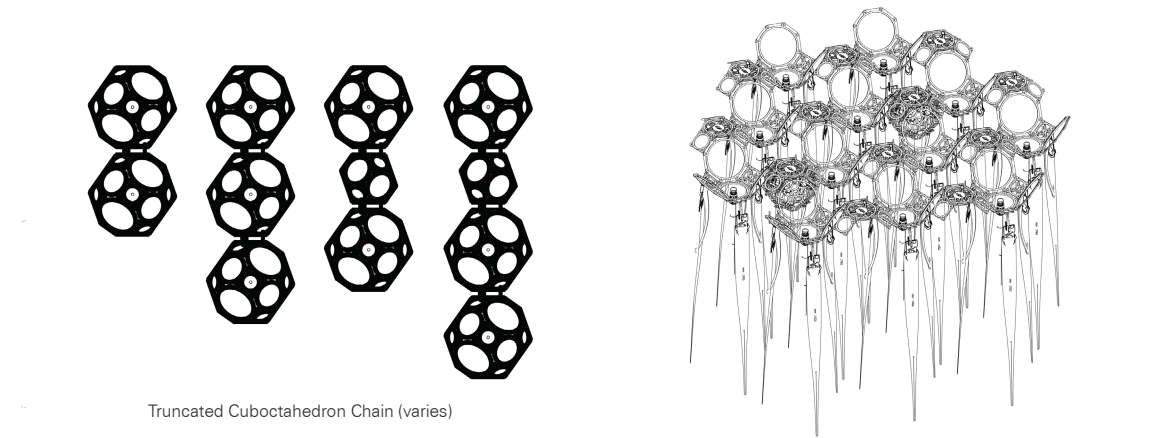


Region Elevation



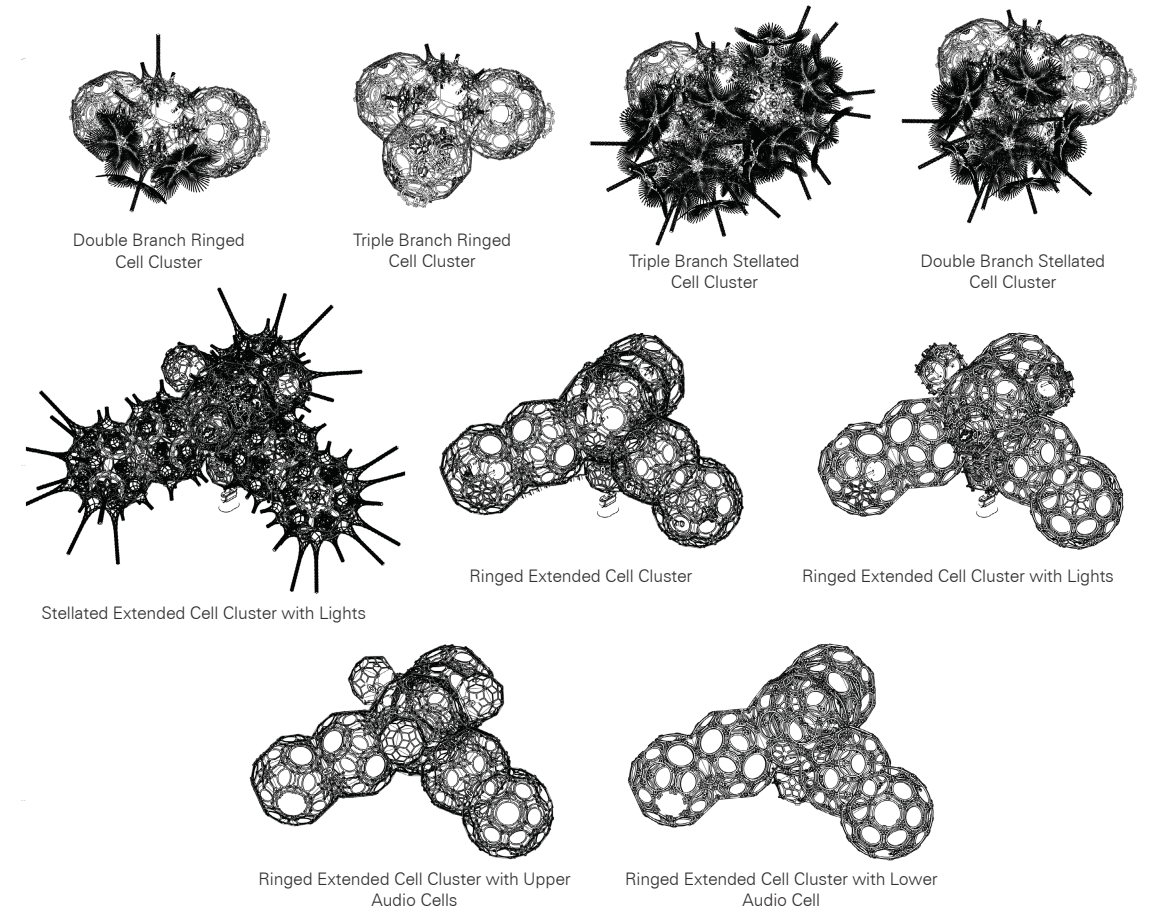
Region Plan

Garland Region Lexicon



Truncated Cuboctahedron Chain (varies)

Truncated Cuboctahedron Waffle



Double Branch Ringed
Cell Cluster

Triple Branch Ringed
Cell Cluster

Triple Branch Stellated
Cell Cluster

Double Branch Stellated
Cell Cluster

Stellated Extended Cell Cluster with Lights

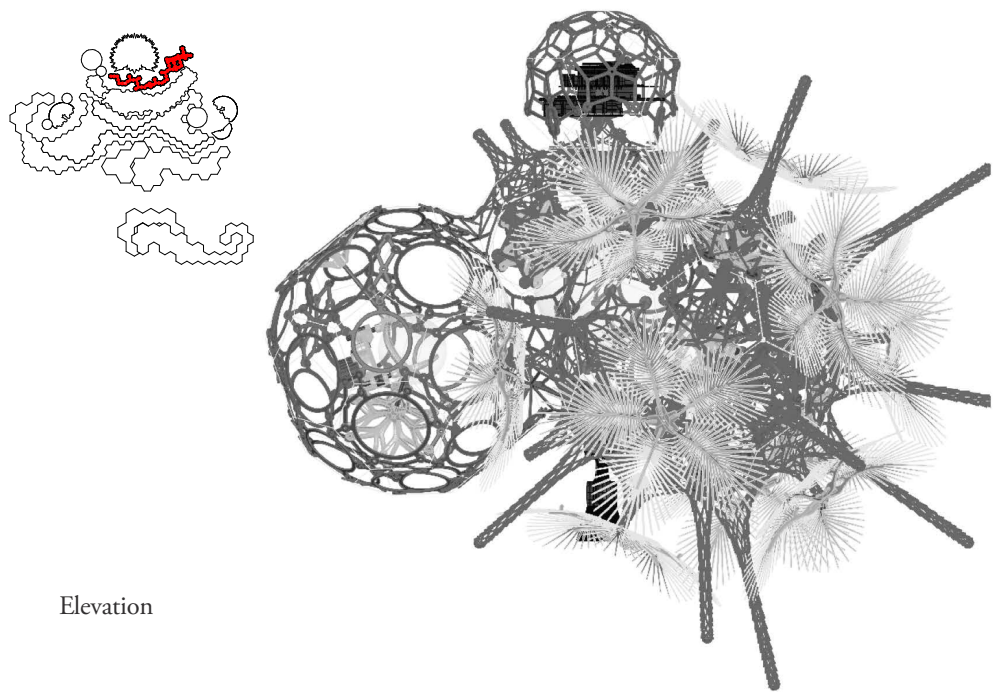
Ringed Extended Cell Cluster

Ringed Extended Cell Cluster with Lights

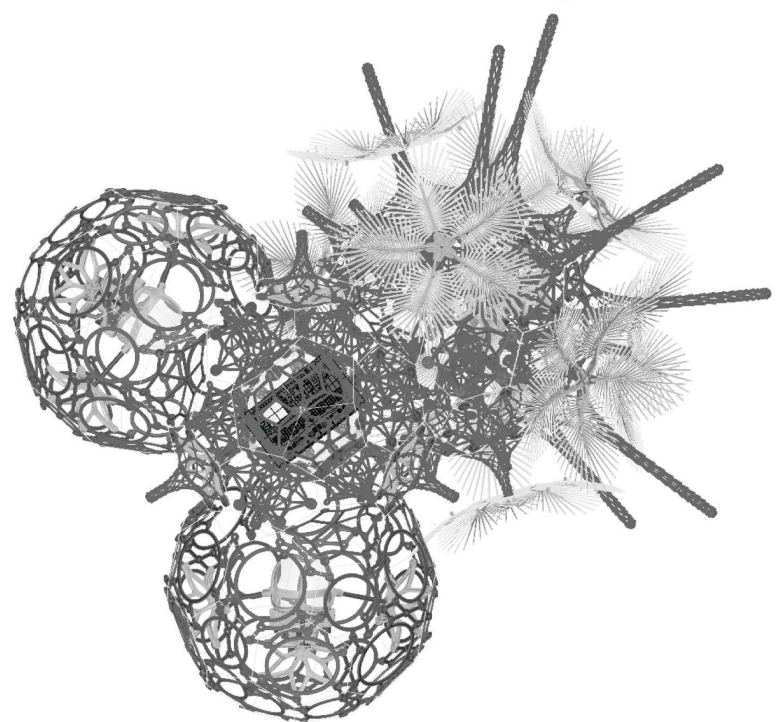
Ringed Extended Cell Cluster with Upper
Audio Cells

Ringed Extended Cell Cluster with Lower
Audio Cell

Garland Scaffold and Assembly Lexicon

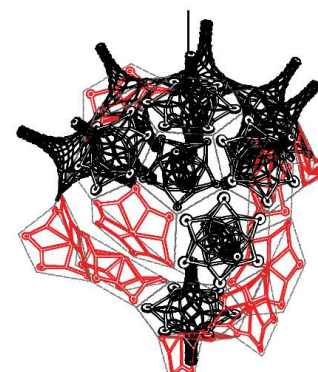


Elevation

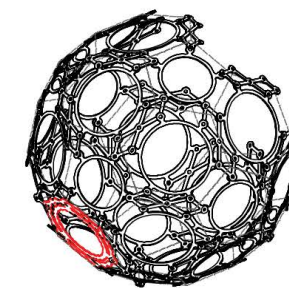


Plan

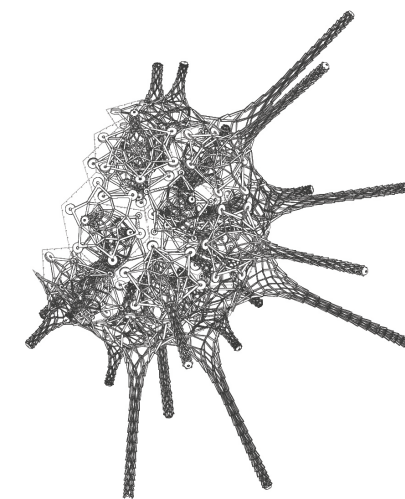
Double Branch Metal Cell Cluster with Terminal



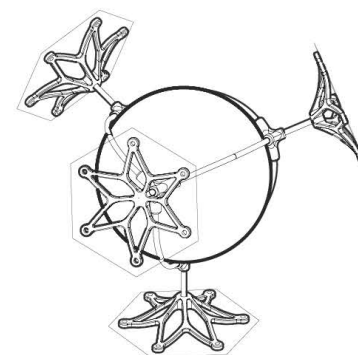
Truncated Icosahedron Structural Metal
3-way Hub



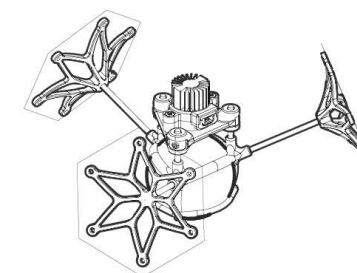
Truncated Icosahedron Metal Connector
Terminal



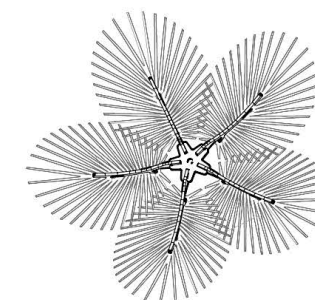
Truncated Icosahedron Metal
Terminal



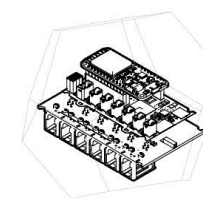
100mm Glass Sphere Centre



LED Sphere Pinspot



Penta Frond Dressing

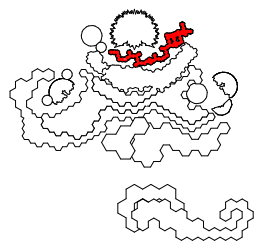


Node Controller Nest

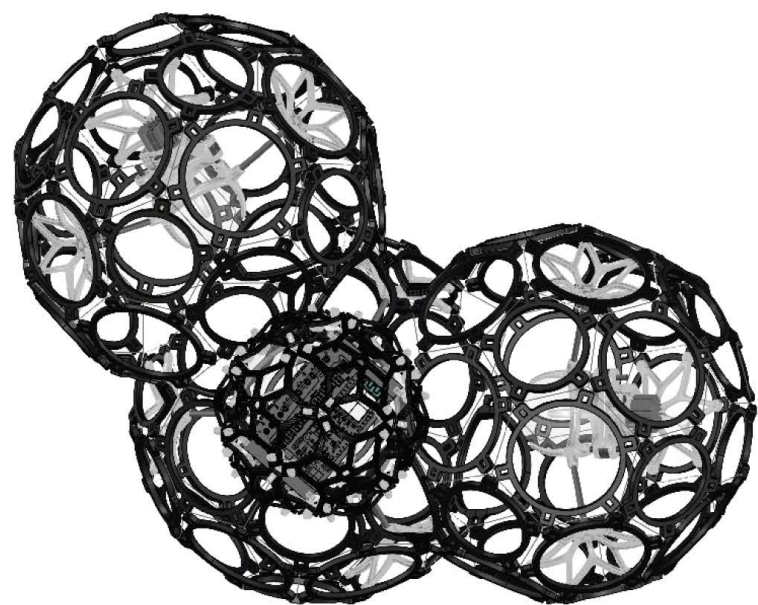


IR Sensor

Double Branch Cell Cluster Assembly Lexicon

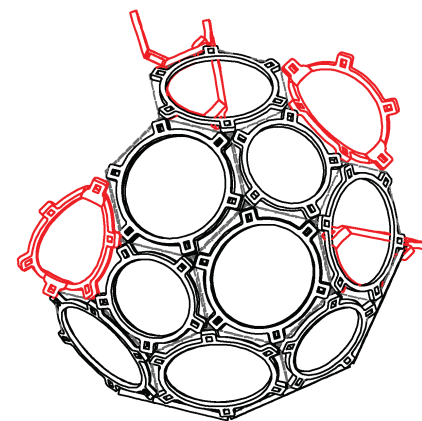


Elevation

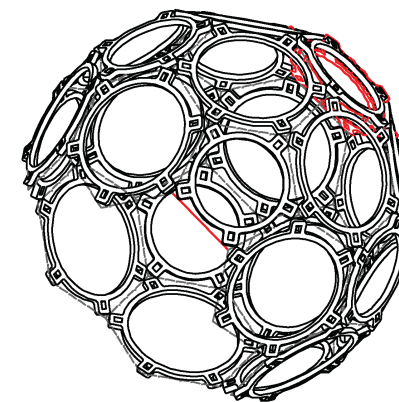


Plan

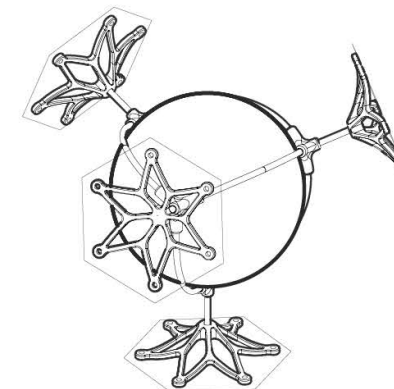
Double Branch FDM Cell Cluster



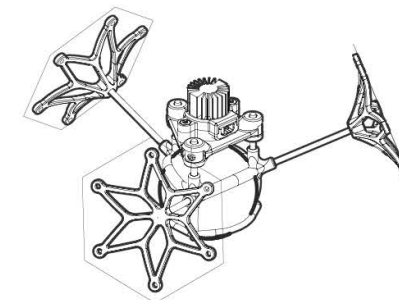
Truncated Icosahedron Structural FDM 2-way
Hub



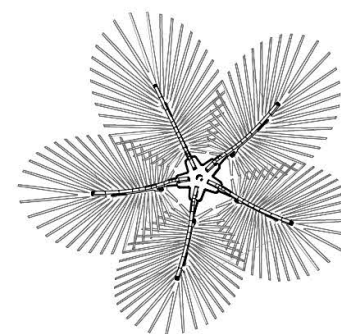
Truncated Icosahedron FDM Connector
Terminal



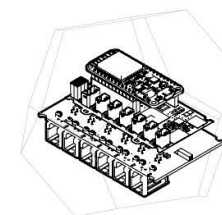
100mm Glass Sphere Centre



LED Sphere Pinspot



Penta Front Dressing

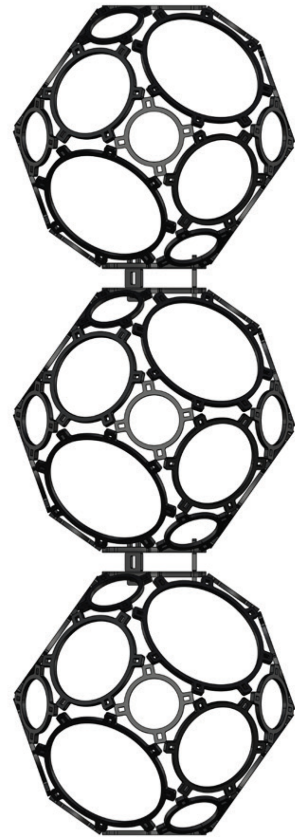
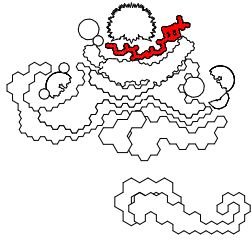


Node Controller Nest

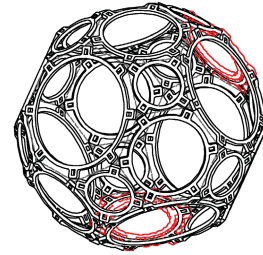


IR Sensor

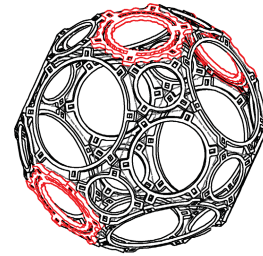
Double Branch FDM Cell Cluster Assembly Lexicon



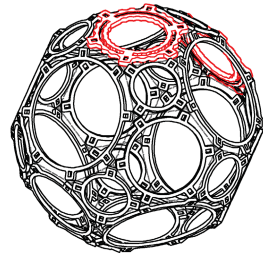
Elevation



2-way Hub Obtuse Variant FDM Truncated
Cuboctahedron Cell

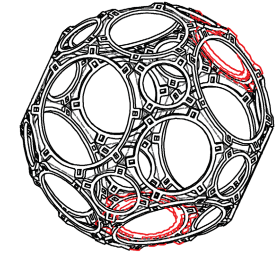
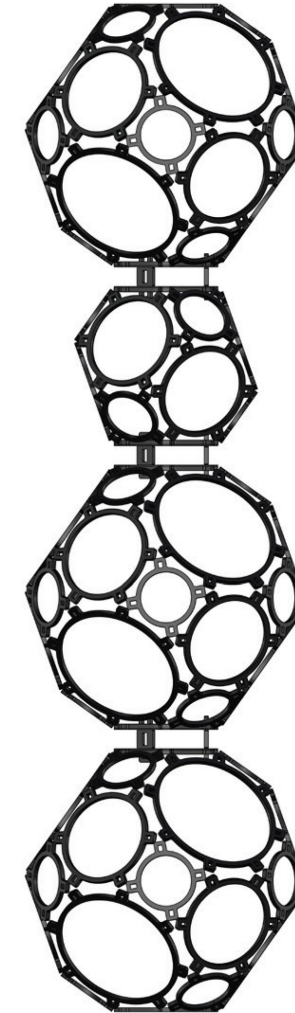


3-way Hub Obtuse Variant FDM Truncated
Cuboctahedron Cell x1

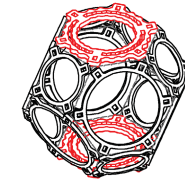


2-way Hub Acute Variant FDM Truncated
Cuboctahedron Cell x1

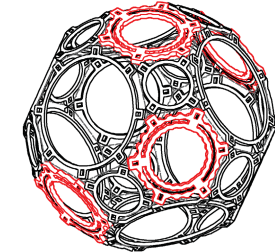
Hub Cuboctahedron Chain Elevation & Lexicon



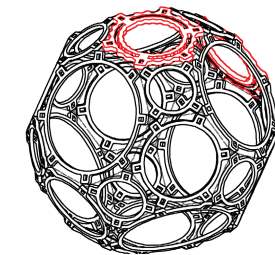
2-way Hub Obtuse Variant FDM Truncated
Cuboctahedron Cell x1



Spoke FDM Truncated
Octahedron Cell x1

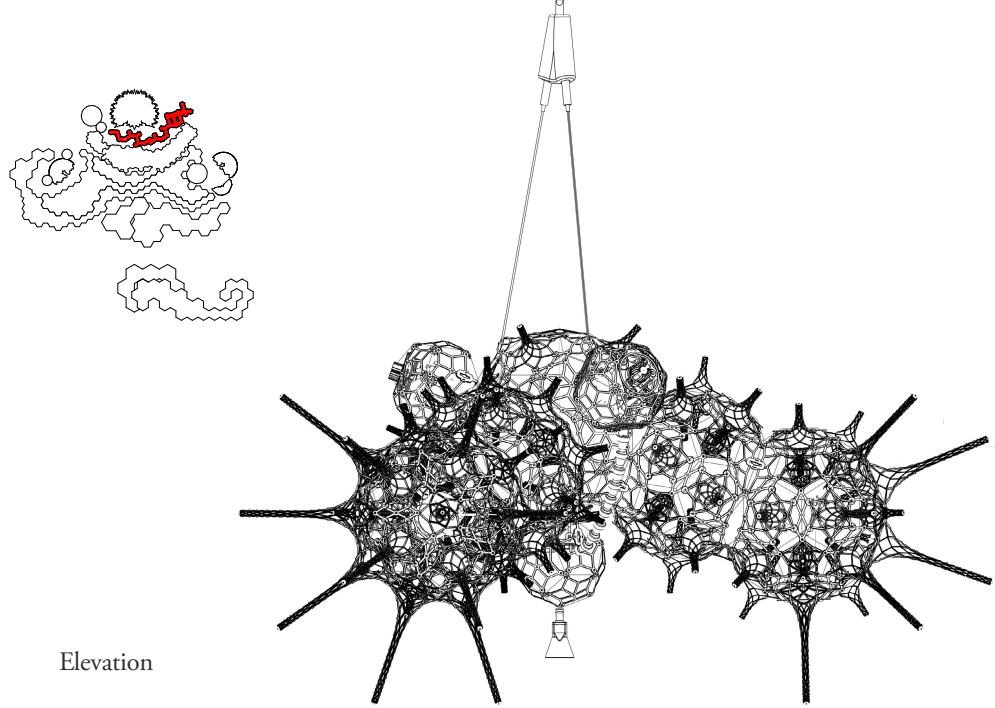


4-way Hub Acute Variant FDM Truncated
Cuboctahedron Cell x1

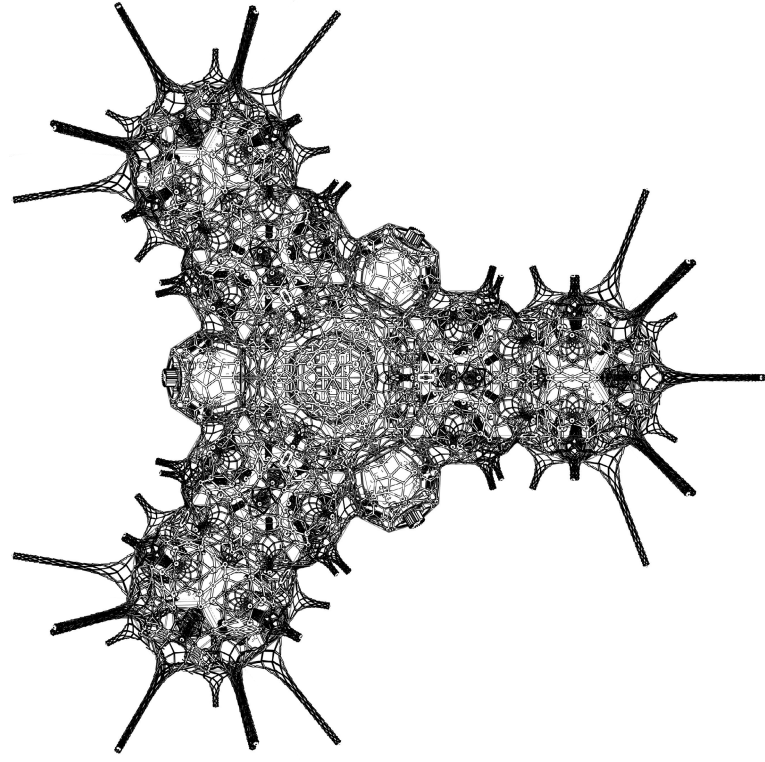


2-way Hub Acute Variant FDM Truncated
Cuboctahedron Cell x1

Hub & Spoke Cuboctahedron Chain Elevation & Lexicon

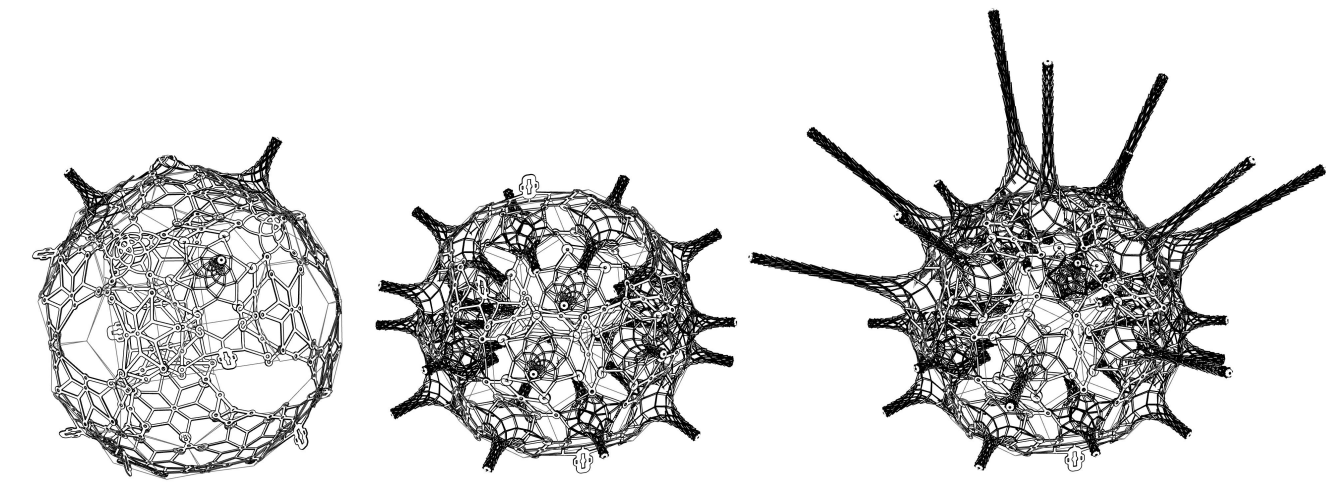


Elevation

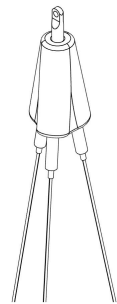


Plan

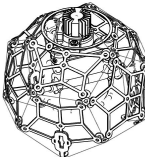
Stellated Metal Extended Cell Cluster



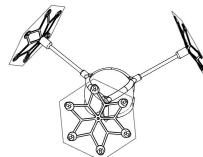
Tetrahedral Truncated Icosahedron Structural Metal 3-way Hub (Stellated) Truncated Icosahedron Metal Spoke (Stellated) Truncated Icosahedron Metal Terminal (Stellated)



Hanger



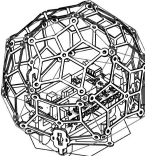
LED Sphere Pinpoint Metal Nest Assembly



50mm Glass Sphere



IR Sensor

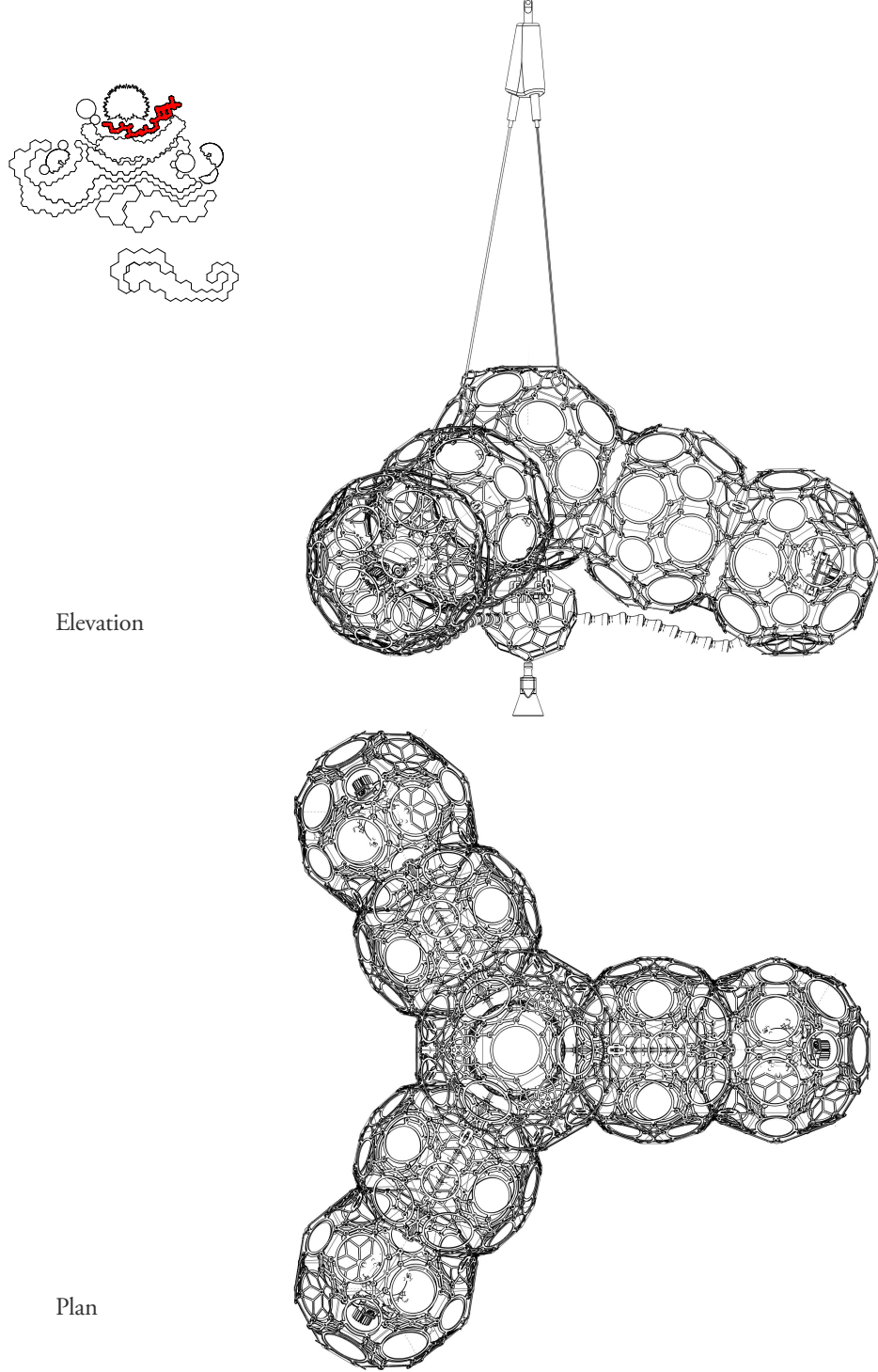


Node Controller Metal Nest Assembly



Cable Shell Assemblies

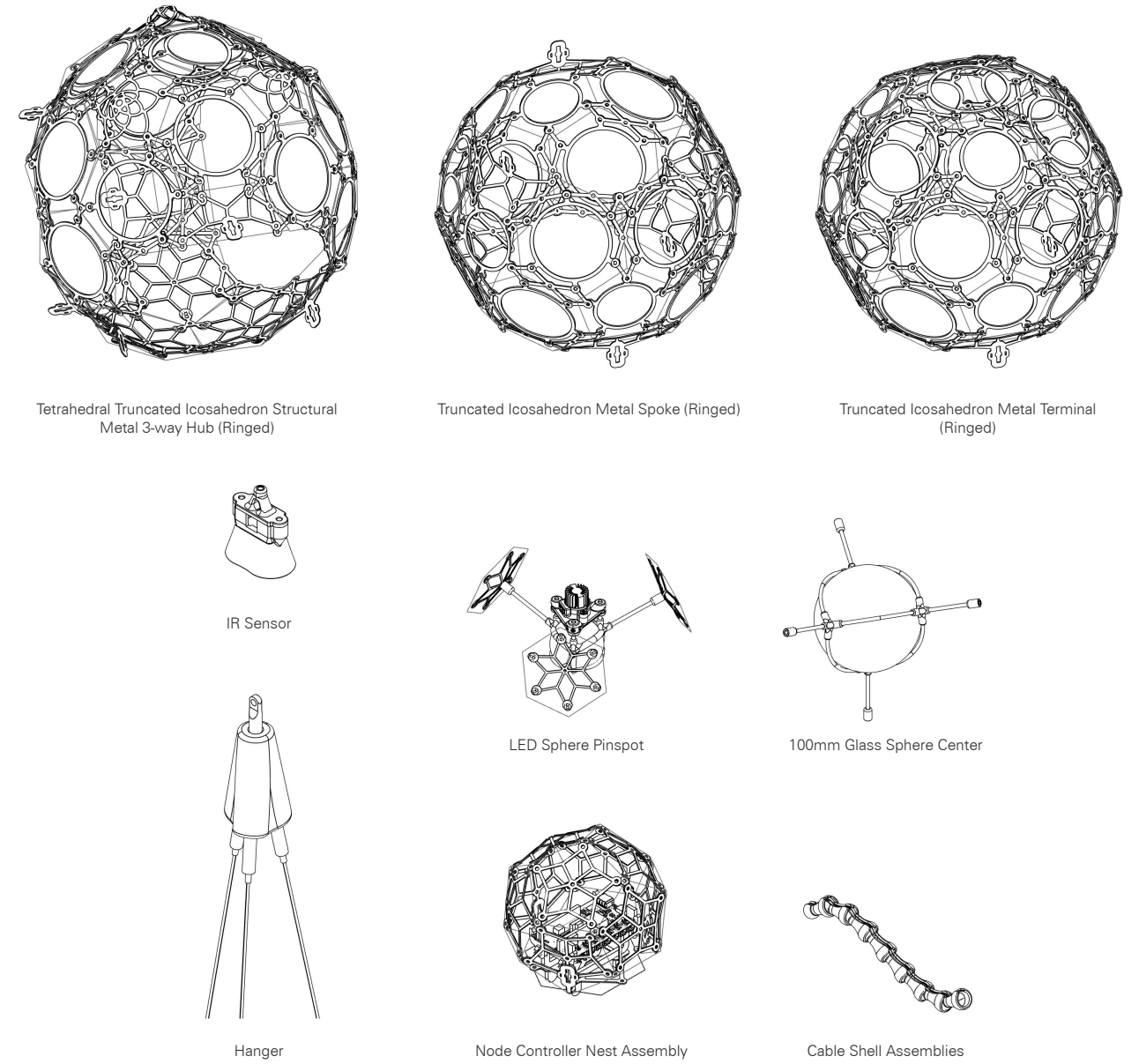
Stellated Metal Cell Cluster Lexicon



Elevation

Plan

Ringed Metal Extended Cell Cluster



Tetrahedral Truncated Icosahedron Structural
Metal 3-way Hub (Ringed)

Truncated Icosahedron Metal Spoke (Ringed)

Truncated Icosahedron Metal Terminal
(Ringed)

IR Sensor

LED Sphere Pinpoint

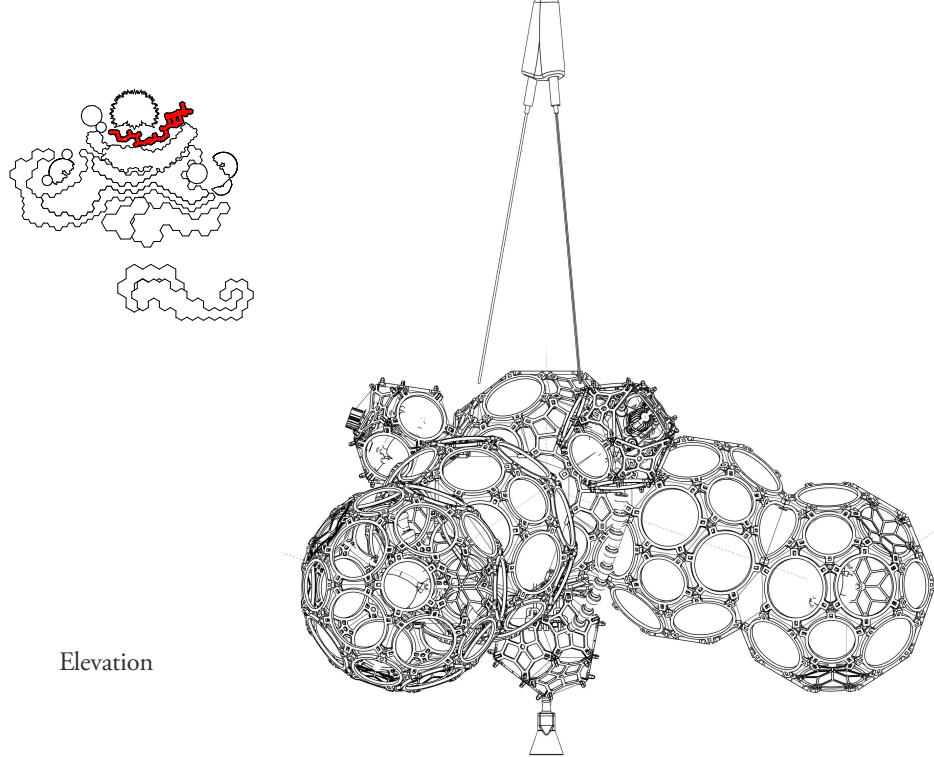
100mm Glass Sphere Center

Hanger

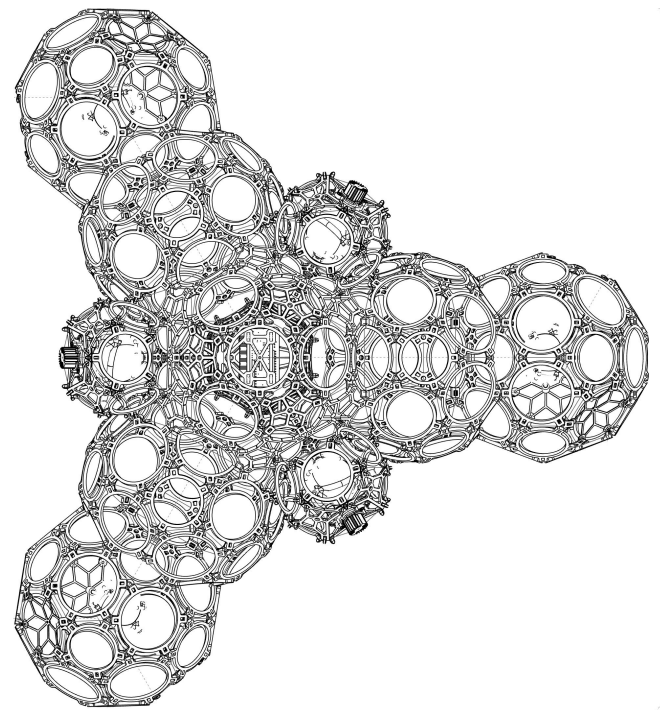
Node Controller Nest Assembly

Cable Shell Assemblies

Ringed Metal Extended Cell Cluster Lexicon

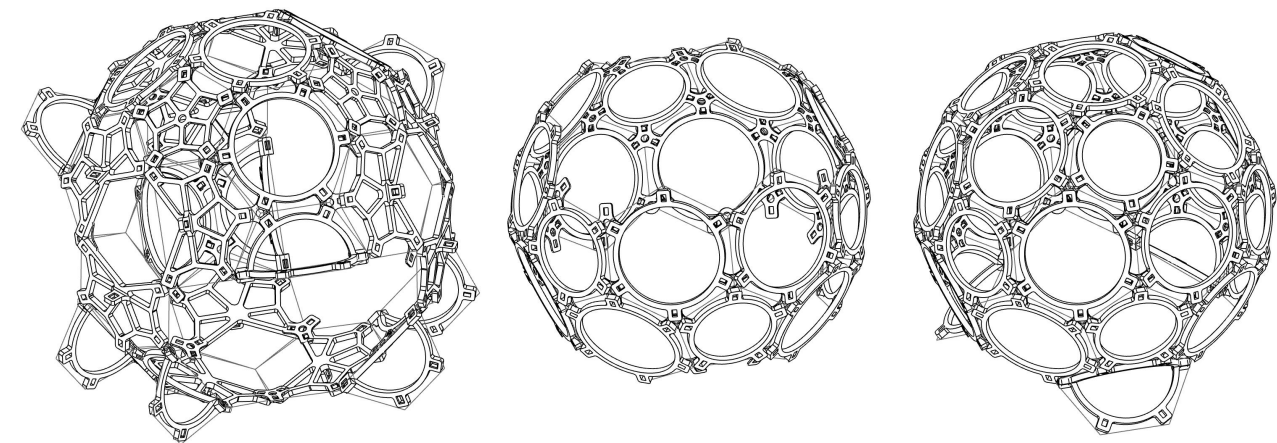


Elevation



Plan

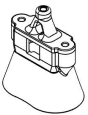
Ringed FDM Extended Cell Cluster



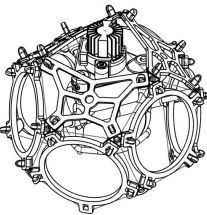
Tetrahedral Truncated Icosahedron Structural FDM 3-way Hub (Ringed)

Truncated Icosahedron FDM Spoke (Ringed)

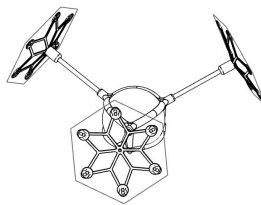
Truncated Icosahedron FDM Terminal (Ringed)



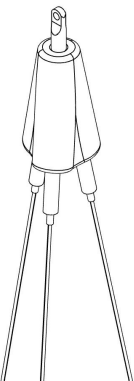
IR Sensor



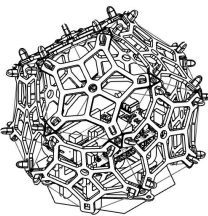
LED Sphere Pinpoint FDM Nest Assembly



50mm Glass Sphere



Hanger

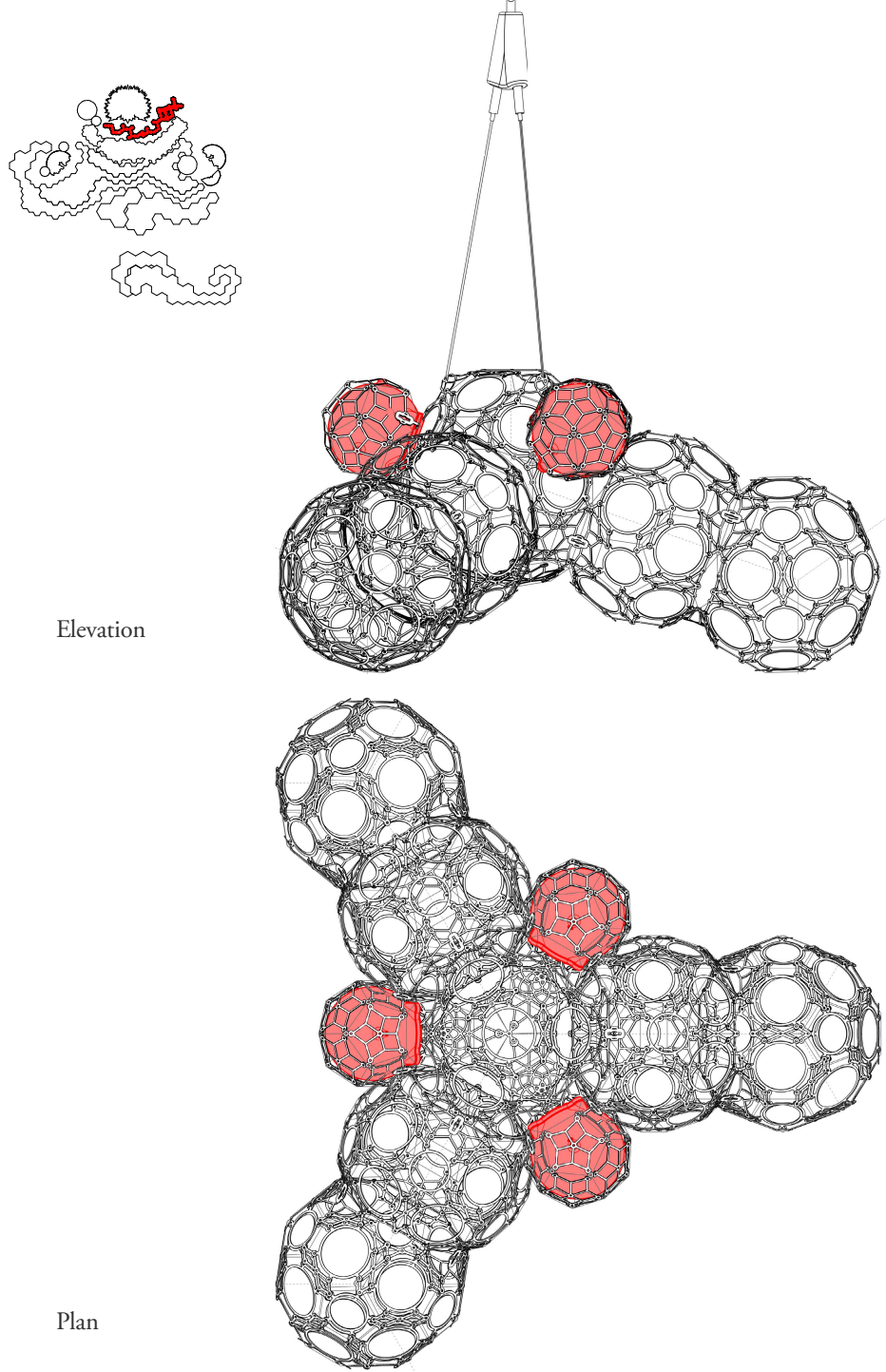


Node Controller FDM Nest Assembly



Cable Shell Assemblies

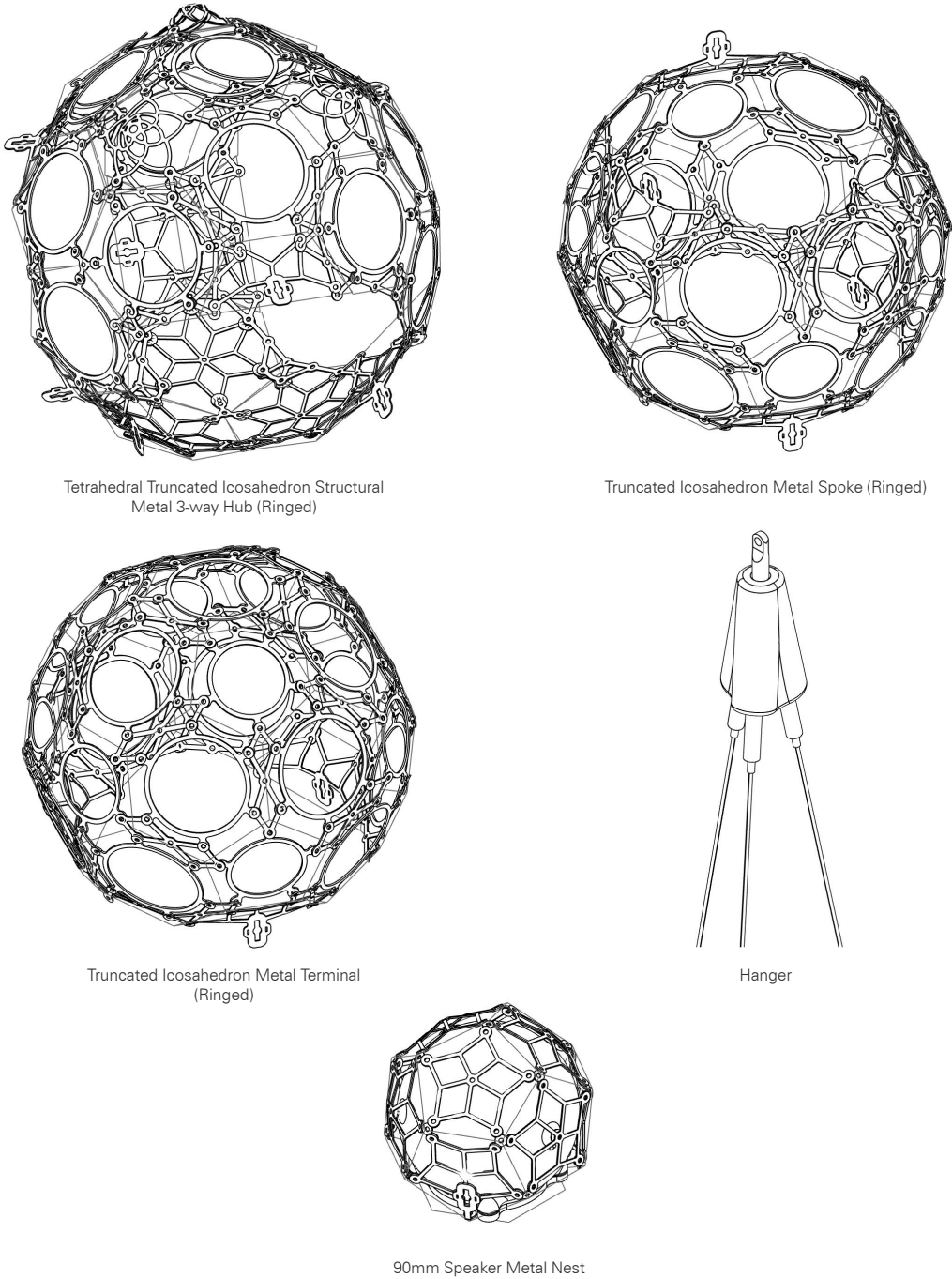
Ringed FDM Extended Cell Cluster Lexicon



Elevation

Plan

Ringed Metal Audio Extended Cell Cluster



Tetrahedral Truncated Icosahedron Structural Metal 3-way Hub (Ringed)

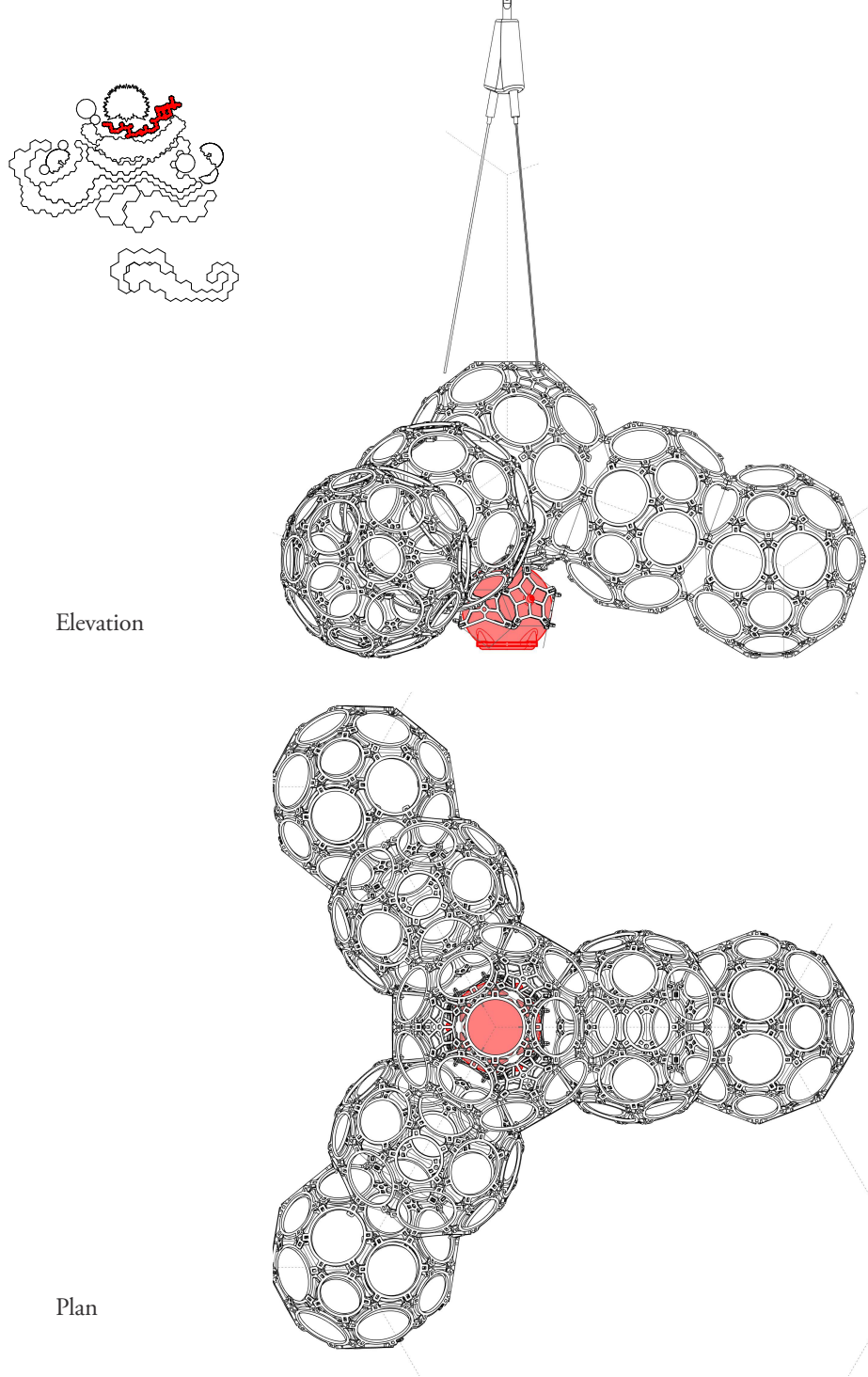
Truncated Icosahedron Metal Spoke (Ringed)

Truncated Icosahedron Metal Terminal (Ringed)

Hanger

90mm Speaker Metal Nest

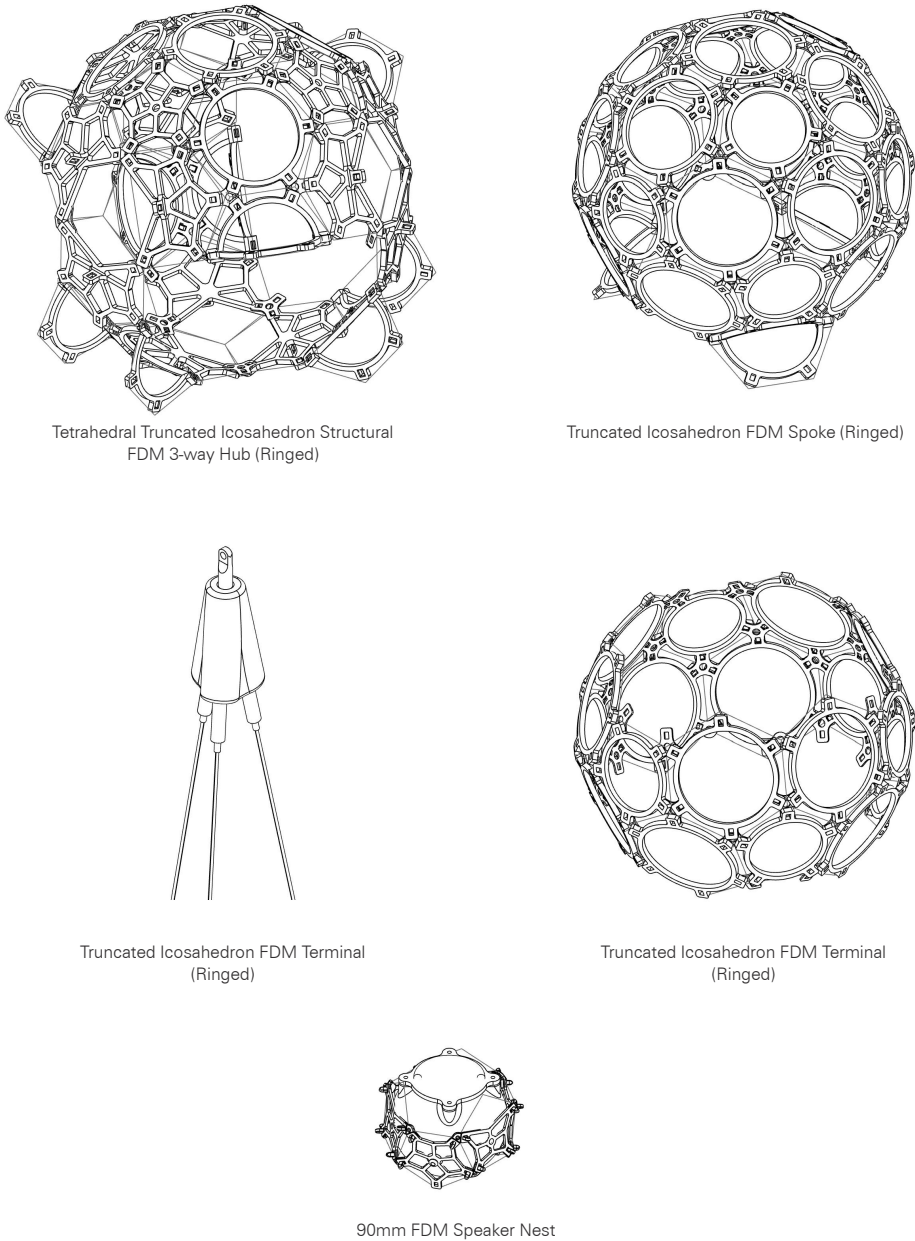
Ringed Metal Audio Extended Cell Cluster Lexicon



Elevation

Plan

Ringed FDM Audio Extended Cell Cluster



Tetrahedral Truncated Icosahedron Structural
FDM 3-way Hub (Ringed)

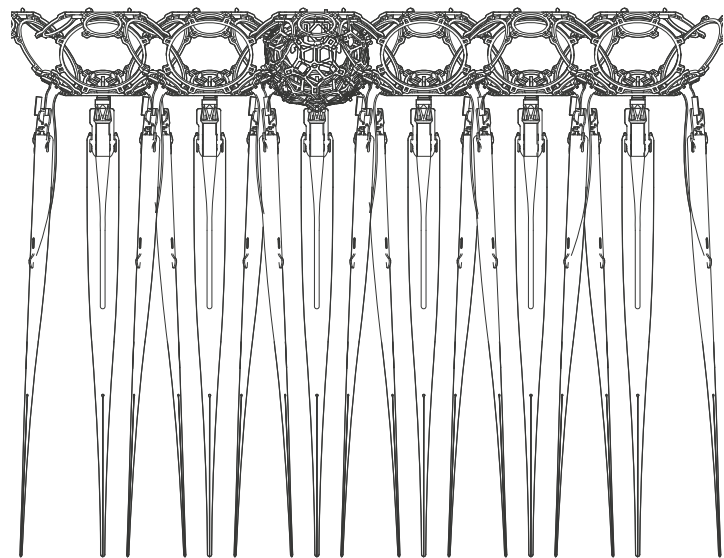
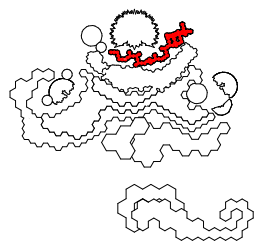
Truncated Icosahedron FDM Spoke (Ringed)

Truncated Icosahedron FDM Terminal
(Ringed)

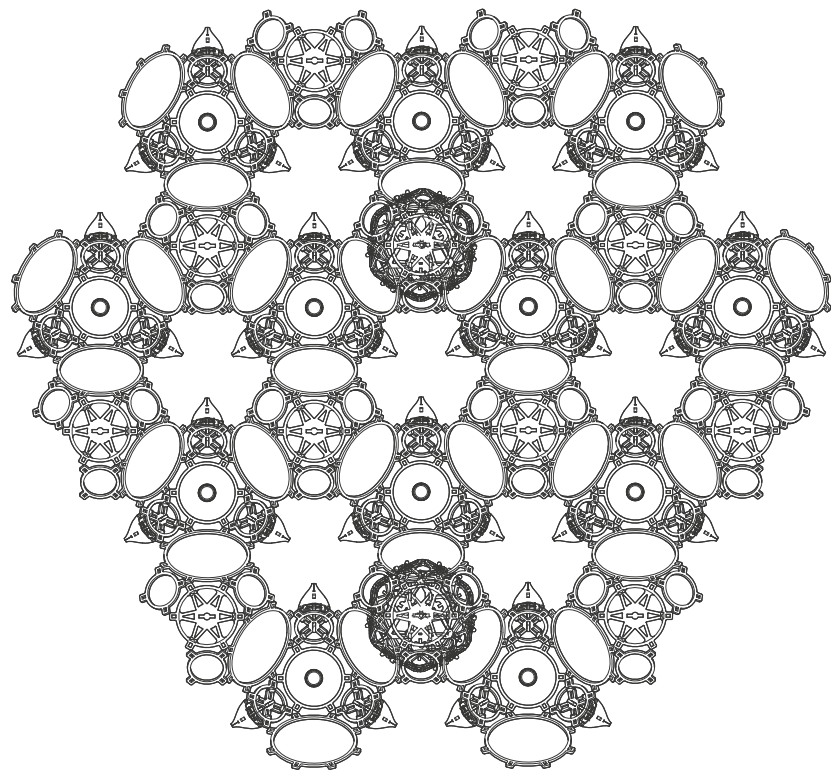
Truncated Icosahedron FDM Terminal
(Ringed)

90mm FDM Speaker Nest

FDM Audio Extended Cell Cluster Lexicon

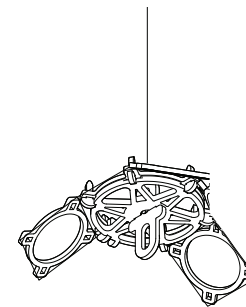


Elevation

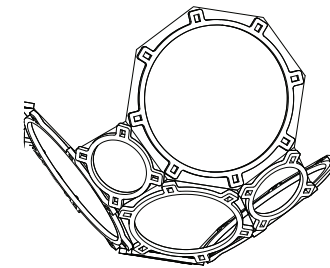


Plan

Garland Waffle



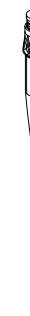
Concave Waffle Scaffold



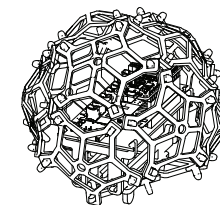
Convex Waffle Scaffold



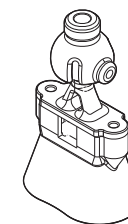
Vibrating Blade of Grass



Carrot LED



Node Controller Nest Assembly



IR Sensor

Garland Waffle Scaffold and Assembly Lexicon

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Living Architecture Testbed

Delft Science Centre

Delft University of Technology
Living Architecture Systems Group
Philip Beesley Studio

A Living Architecture testbed sculpture is now in development for the Delft Science Centre. This publication describes the multi-year project bringing this visionary, immersive environment to TU Delft.

A new testbed sculpture will be installed at the entry of the new Science Centre facility. The project will act as a public beacon that gathers the public, expressing a sustainable, inclusive vision of future design. Delft Science Centre is working in collaboration with Living Architecture Systems Group and Philip Beesley Studio, combining contributions by the TU Delft community, the municipality of Delft, TodaysArt, and numerous artists and educators from the Netherlands and Canada. The project is affiliated with TU Delft's Architecture and Engineering departments and multiple Canadian research contributions.



<https://media.lasg.ca/dsc-testbed>

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