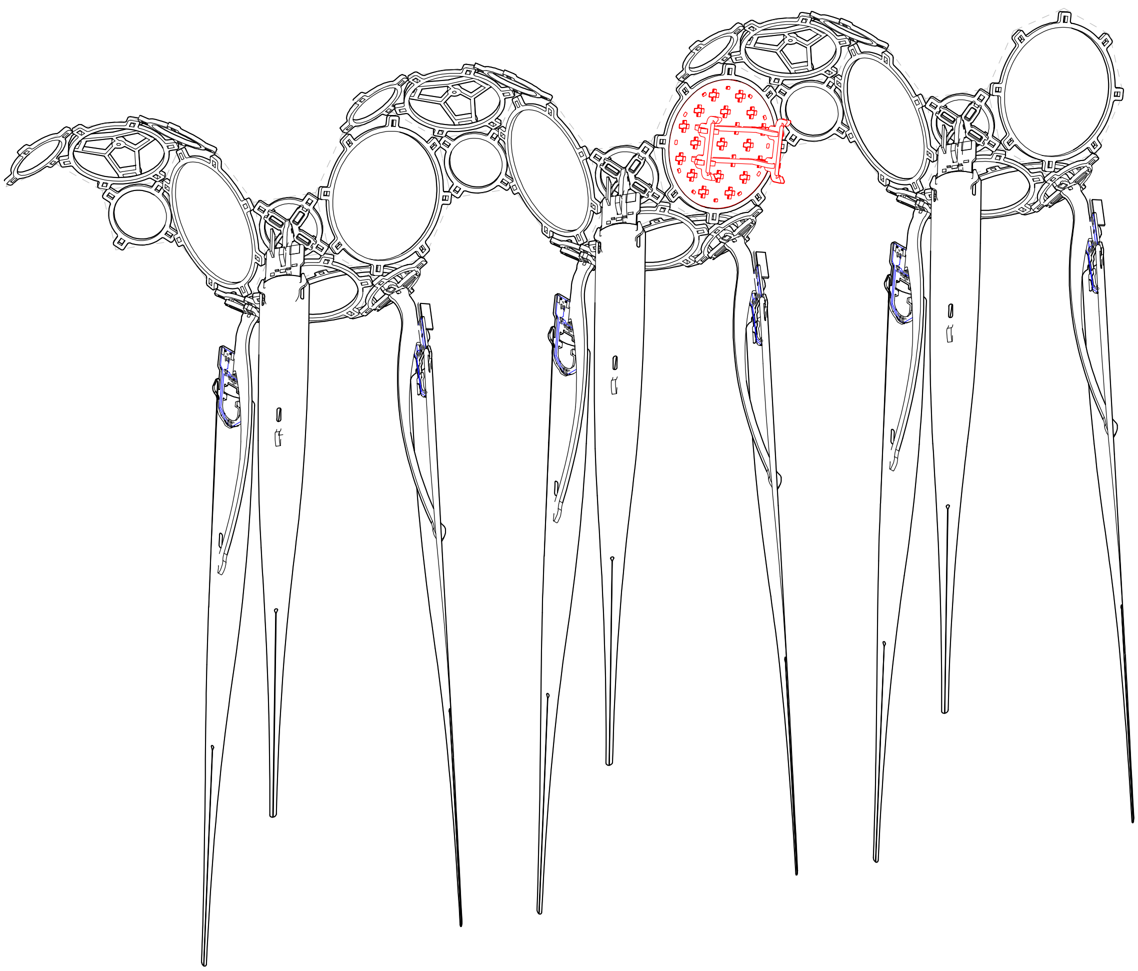


INTERACTIVE ENVIRONMENTS
MINOR WORKSHOP 2023

MANUAL

Contents

2023 Interactive Environments Minor: Workshop Manual |

Introduction

This manual is presented by the Living Architecture Systems Group (LASG) in collaboration with Science Centre Delft and the Interactive Environments Minor of TU Delft on the occasion of the 2023 Living Architecture Interactive Environments Workshop, Oct. 30-Nov.30, 2023. The manual provides download links that provide access to multiple components for fabrication, software and behaviour control systems developed by members of the Living Architecture Systems Group. The compressed print version of this manual supports introductory material. The digital version of the manual is expanded and includes extensive additional resources.

The web-based software and the physical kit components that have been included within this set are part of an evolving collection of tools and component designs that have been developed by the Living Architecture Systems Group under Creative Commons licensing. Large-scale interconnected arrays in both virtual and physical forms can be easily constructed by extending the system components that are provided in these kits. These patterns can be duplicated for personal non-commercial use, conditional on preserving credit for authorship and on preserving the original license within material that you copy or adapt.

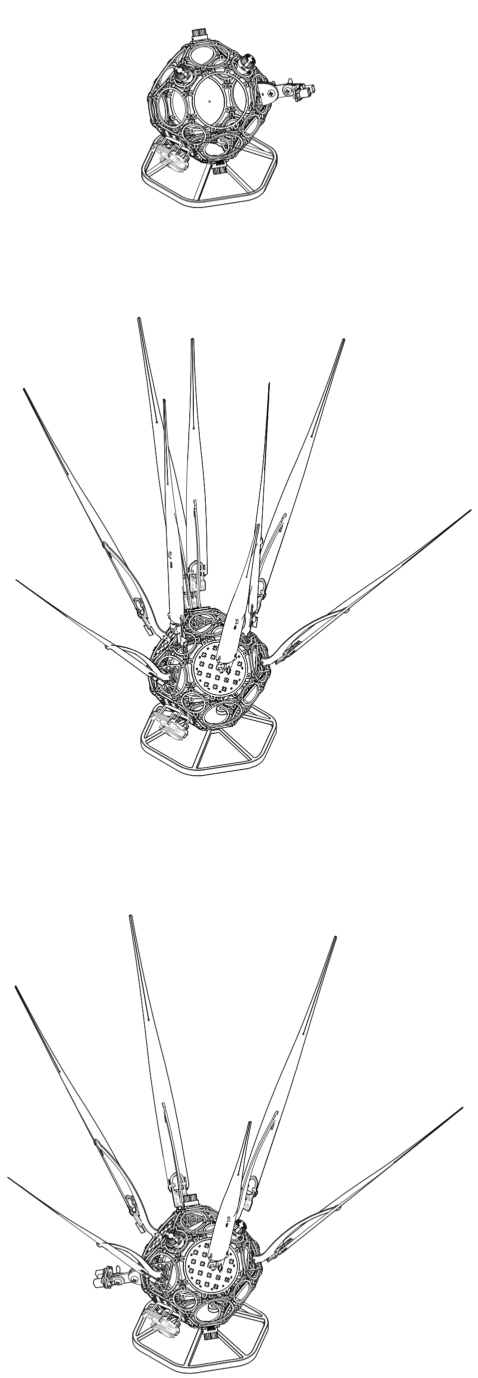
The component designs have been developed as part of a research and creation initiative that is seeking to develop architecture that approaches the qualities of living systems. Qualities within the kit scaffold designs support minimal material use and compliant structures that are capable of accommodating multiple components and evolving functions. The structures that are documented here include filamentary triangulated skeletal frameworks for highly efficient waffle, shell and spherical envelopes.

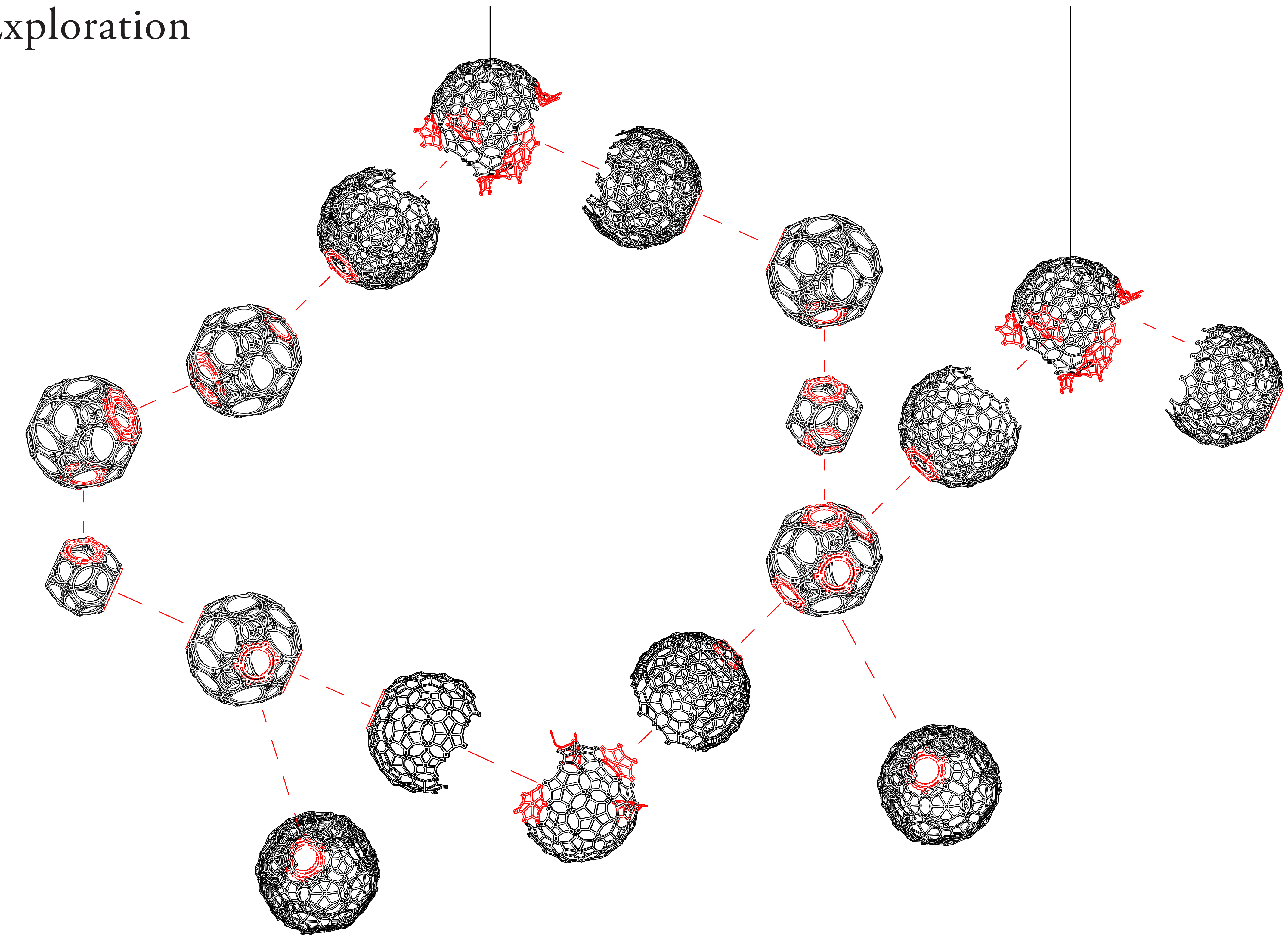
This manual describes the electronic components and software used in this kit. It demonstrates recommended connections between the "control" boards, and the actuators (motors, lights) and sensors. By following the recommended connections, the electronic components can be flexibly arranged in a wide variety of different configurations.

This flexible mounting system can support development of composite mechanisms, creating a diverse range of actuator and sensor components. This mount system includes cable-tie attachments that support precisely angled locations within the skeletal scaffold. A slotted tray design is included that accommodates a range of component mounts employing simple pegs, securable with locking washers.

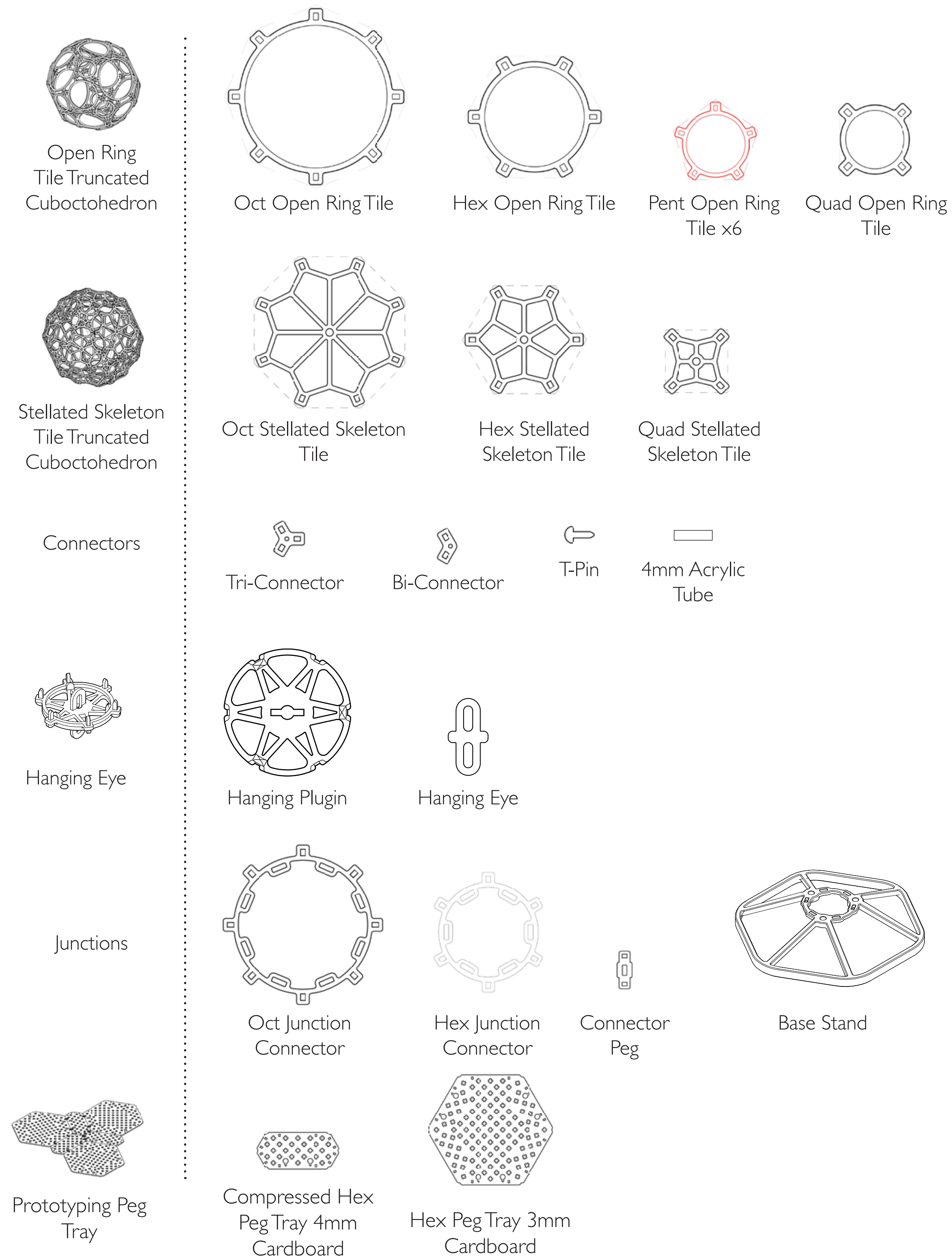
Descriptions of software include the "profile" configurations used to customize how the physical electronics behave. This software will allow you to finely tune the output of individual mechanisms, how they respond to external stimuli, and how they propagate through a system. It will also allow you to then plan out physical configurations and simulate larger systems on a virtual canvas.

Ecosystem of Exploration

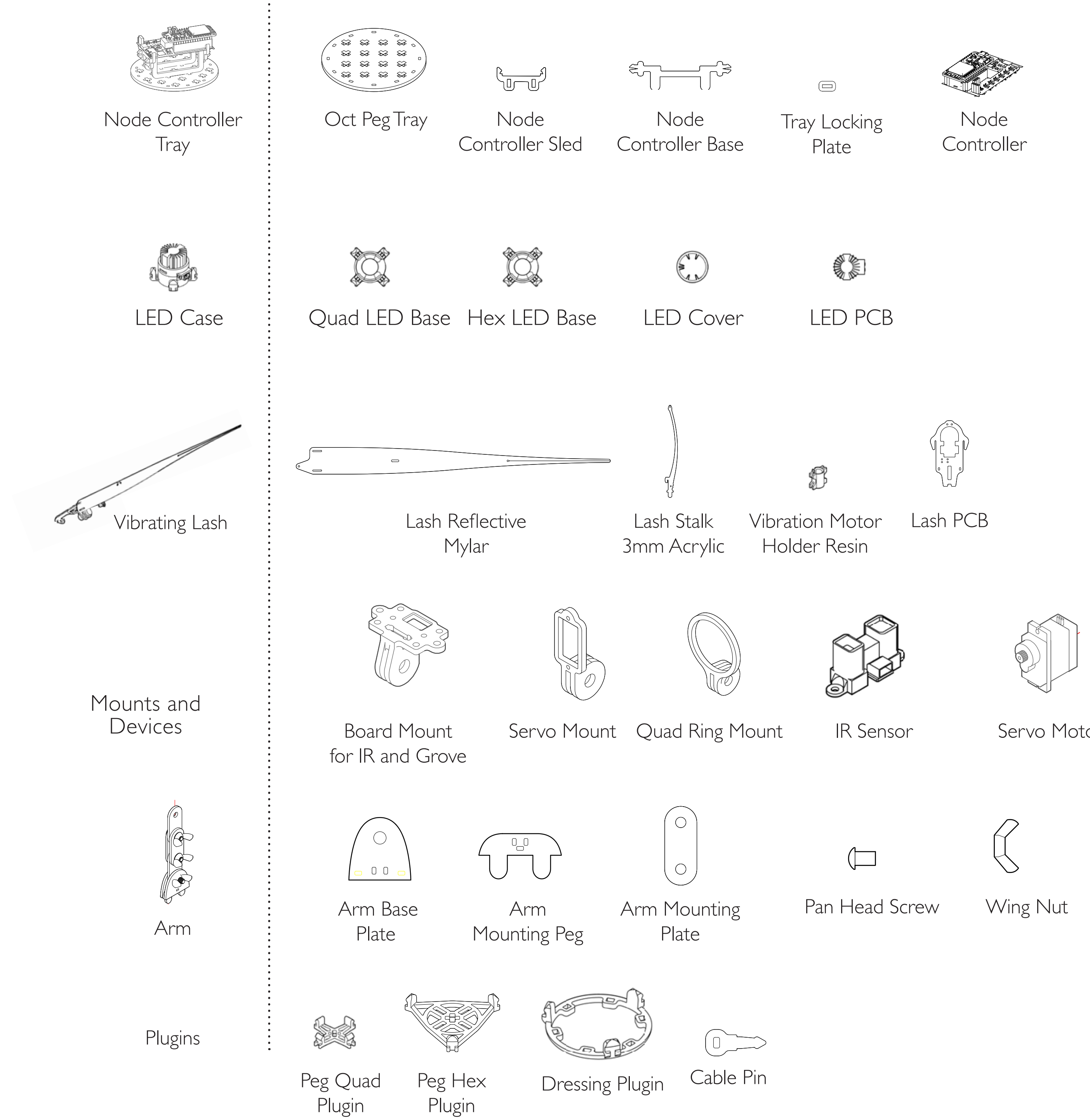




Scaffold Components

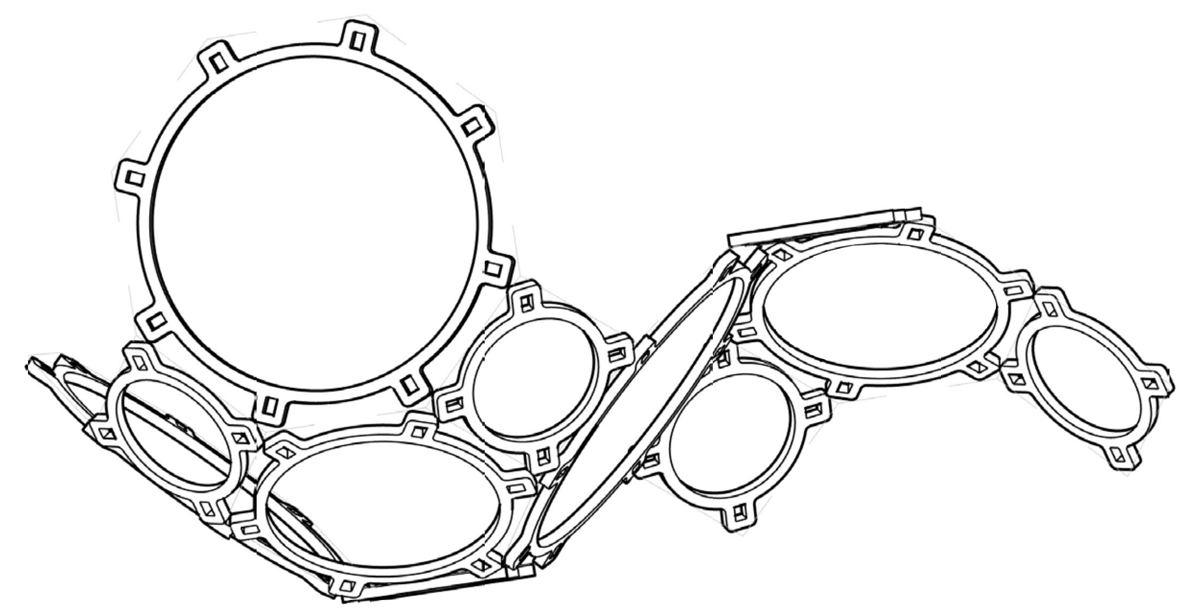


Actuator and Sensor Components



1

Scaffolds

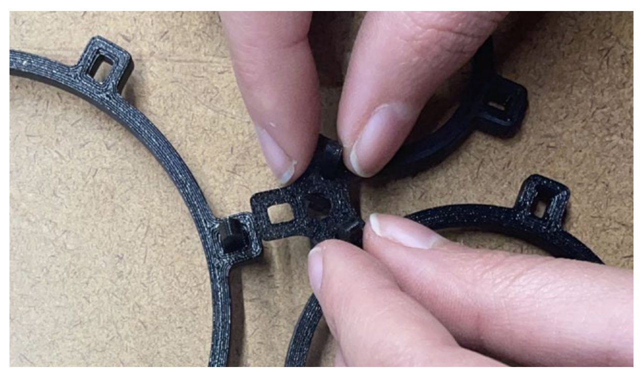


Ring Assembly Instructions

Step 1
Place T-pins into ring holes



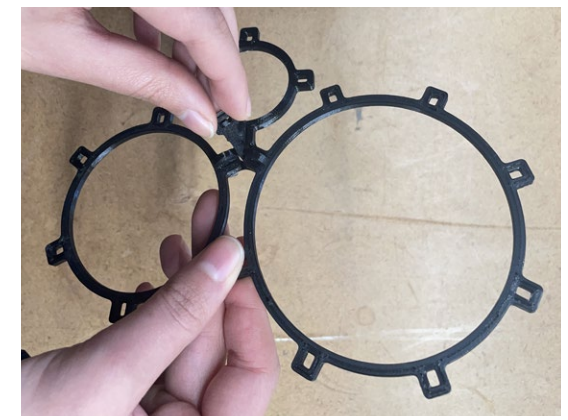
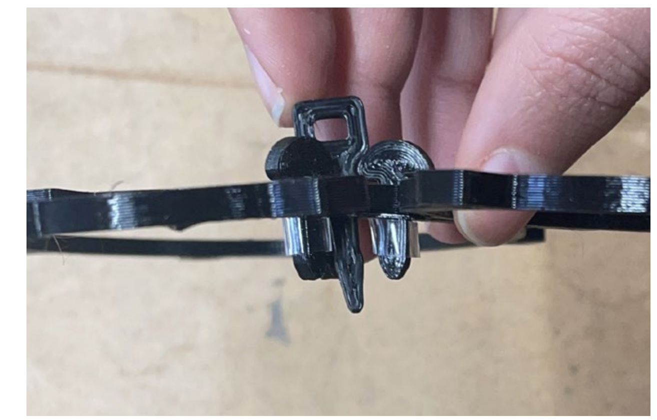

Step 2
Attach the rings together by placing a tri-connector over the t-pins

Step 3
Place a 4mm acrylic tube over the end of each T-pin to secure it in place

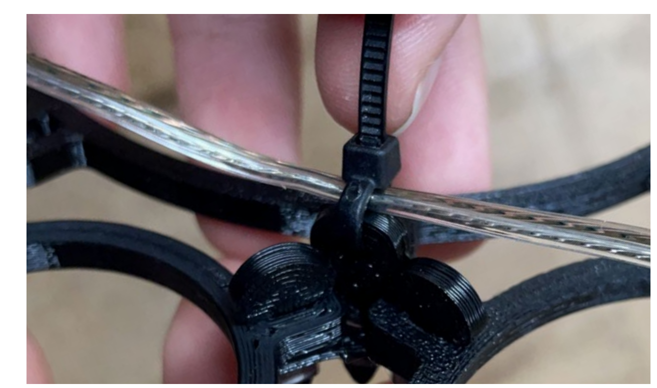

Cable Management

Step 1
If wiring is desired at this location, a Cable Pin can be added to the center hole of the Tri-connector, providing additional attachment capabilities at that junction

Step 2
Place a 4mm acrylic tube over the end of the Cable Pin to secure it in place

Step 3
Insert a zip tie into the hole of the Cable Pin and use it to attach a wire on top of the Cable Pin



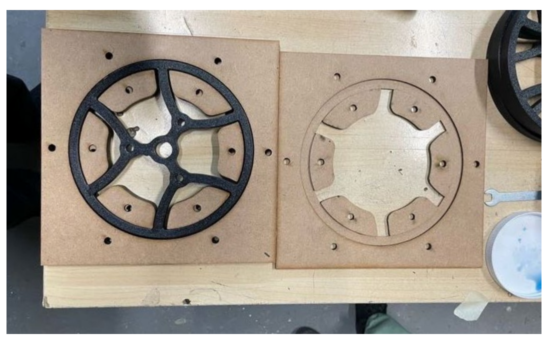
Introduction to Thermal Forming

Thermal Forming is the process of using heat to reshape a material. It is commonly used to give an object a more 3 dimensional shape when its manufacturing process would otherwise struggle to produce that shape.

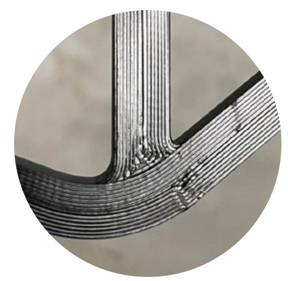
Thermal Forming Instructions (Uniform Heating)

Step 1
Place the object to be formed (in this case a base ring) into a containment jig made of less malleable material. This helps to localize the heat to areas that need to be stretched, while protecting the areas that need to remain flat.

Each 3d printed face usually has a unique texture, a 'flat and smooth' side, and a side with more visible extrusions. For consistency, keep the 'flat & smooth' side facing up

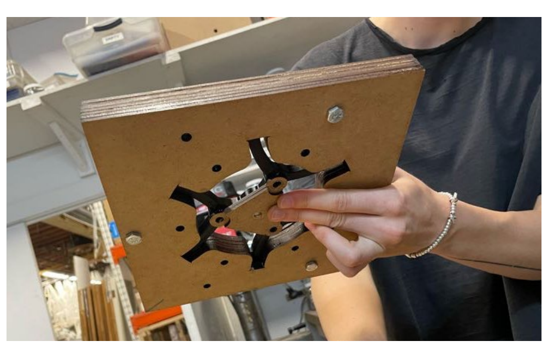


Flat & Smooth

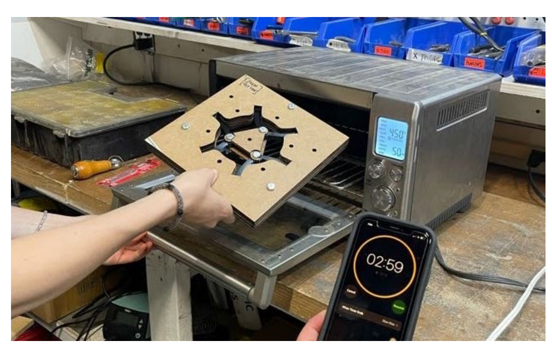


Visible Extrusions

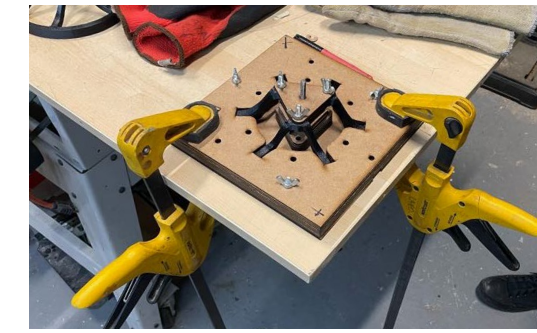
Step 2
Attach the top pieces of the jig using screws and nuts in a triangle formation to ensure its stability.



Step 3
Have oven set at 450 - place jig into the oven for 3 minutes (heat and time may vary based on material size and required malleability)

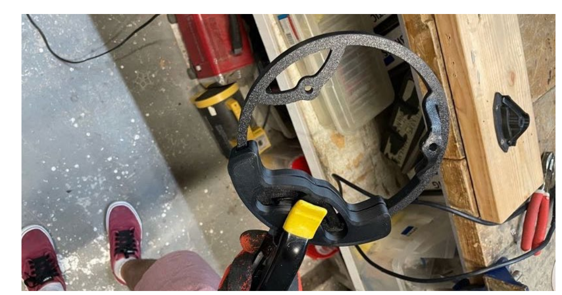


Step 4
Remove the jig from the oven, and keeping the 'Flat & Smooth' side up, align the containment jig with the base jig, slowly and uniformly press down on the sides. Use center screw to guide the alignment of the jigs. Use clamps to keep the jigs aligned while the object cools.

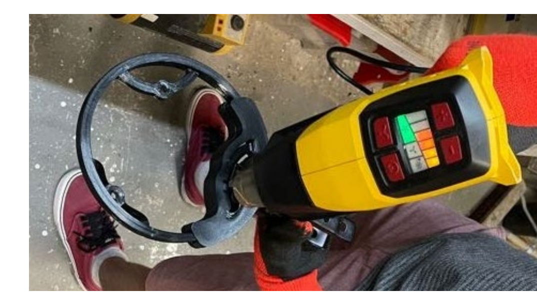


Thermal Forming Instructions (Localized Heating)

Step 1
Place the Base Ring into a containment jig made of less malleable material. Keep the 'flat and smooth' side up (for more detailed process description: see step 1 of Thermal Forming Instructions - Uniform Heating)

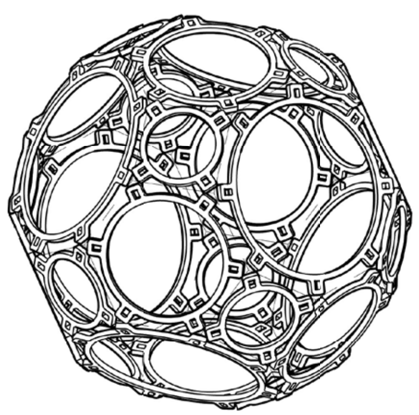


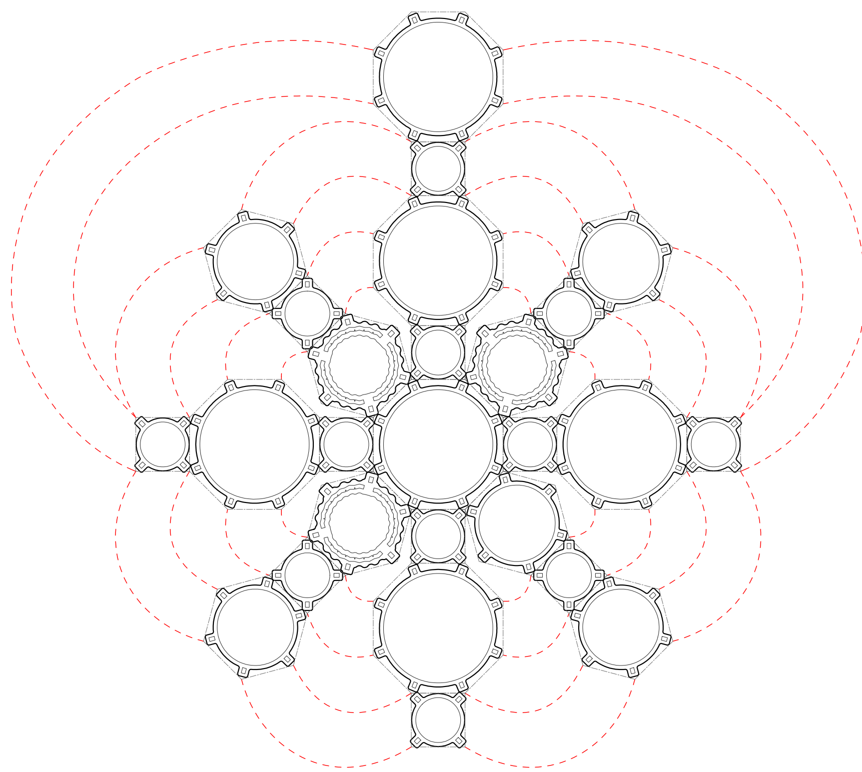
Step 2
Apply heat to the area that will be stretched using a heat gun. Make sure the heat gun is at least 10cm away from the object at all times to avoid overheating the jig. Heat until the Base Ring has a rubber-like consistency.

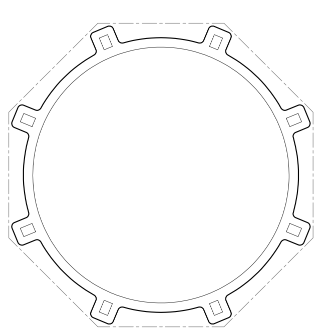


Step 3
Remove the Base Ring from the jig, and use the center screw to guide the alignment of the object to the base jig. Slowly and uniformly press down on the sides. Use clamps to keep the jigs aligned while the object cools.

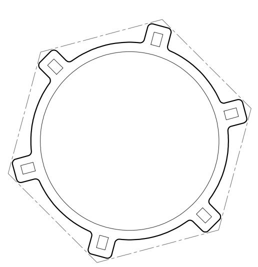
Truncated Cuboctahedron Assembly



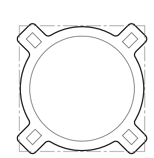




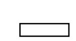
Oct Open Ring
Tile x6



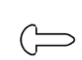
Hex Open Ring
Tile x8



Quad Open
Ring Tile x12



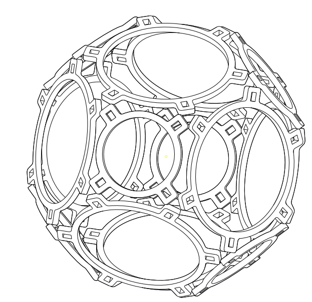
4mm Acrylic Tube
x144

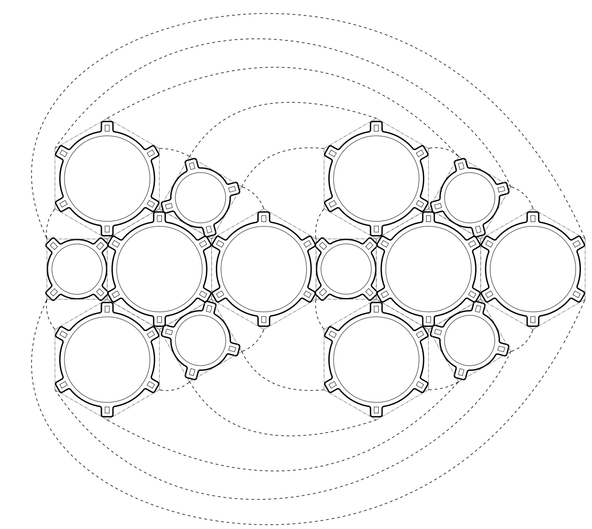


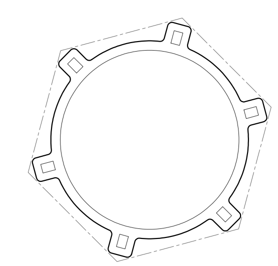
T-Pin
x144

Tri-Connector
x48

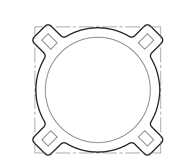
Truncated Cuboctahedron Assembly



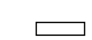




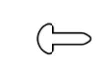
Hex Open Ring
Tile x8



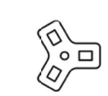
Quad Open
Ring Tile x6



4mm Acrylic Tube
x108



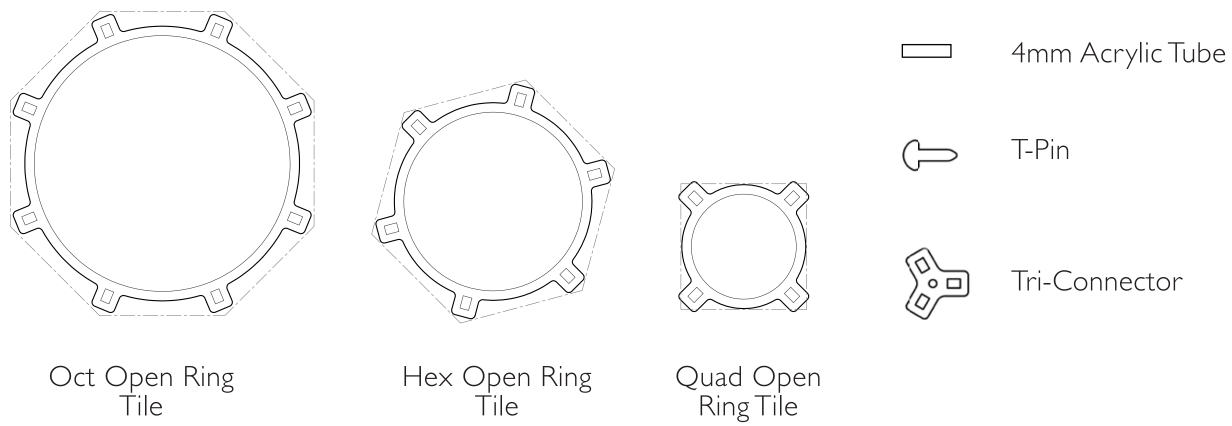
T-Pin
x108

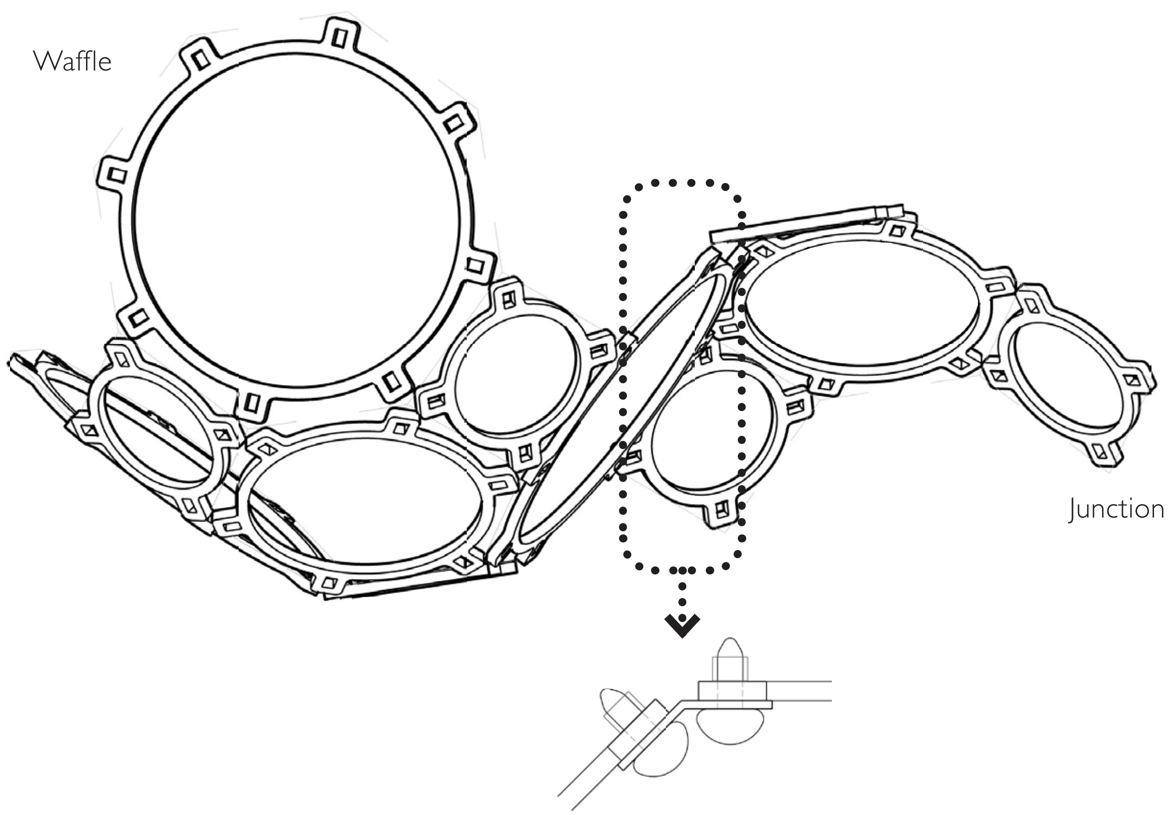


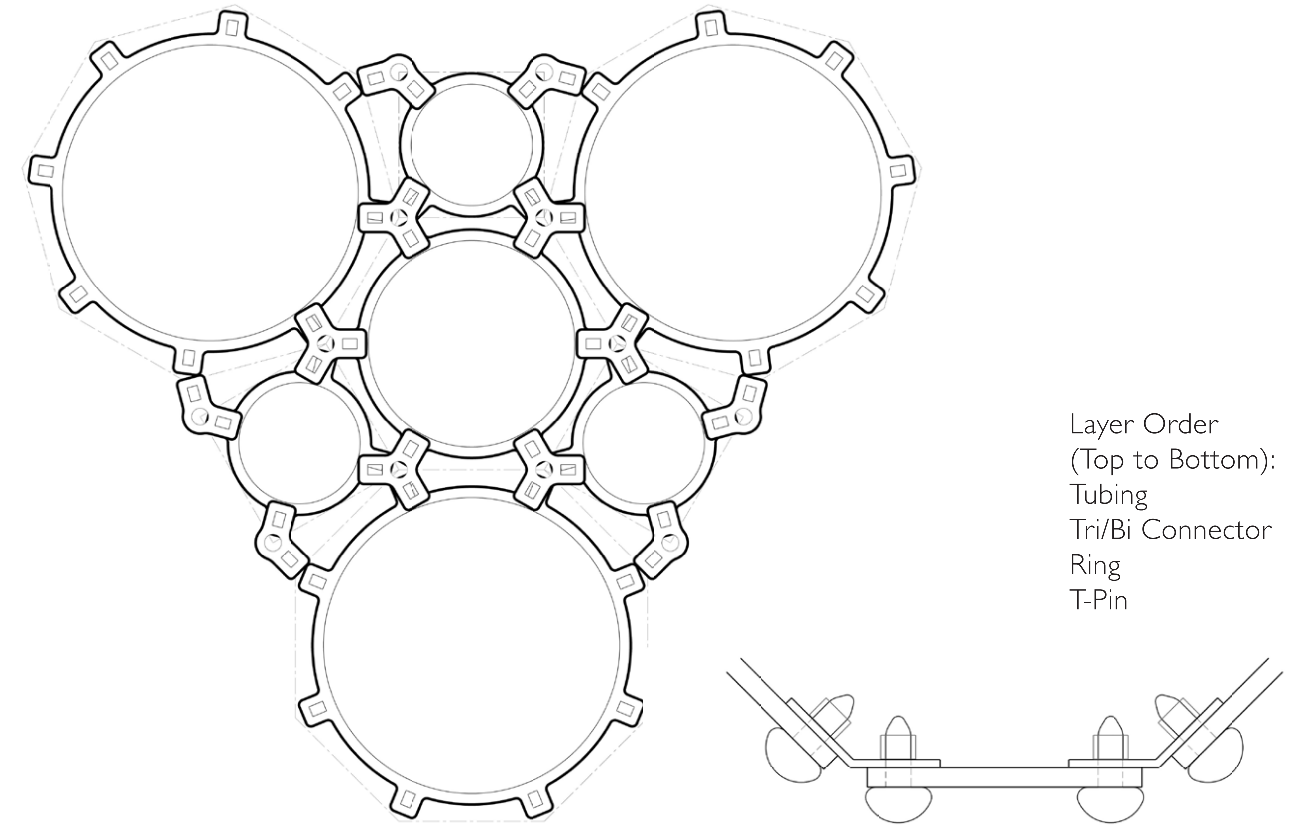
Tri-Connector
x36

Truncated Cuboctahedron Net

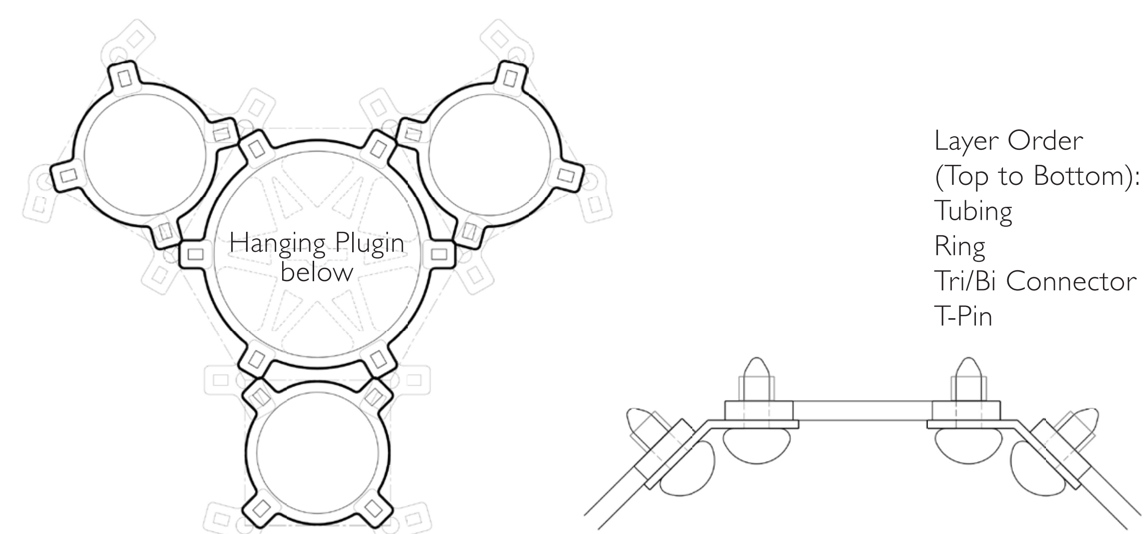
Waffle Assembly







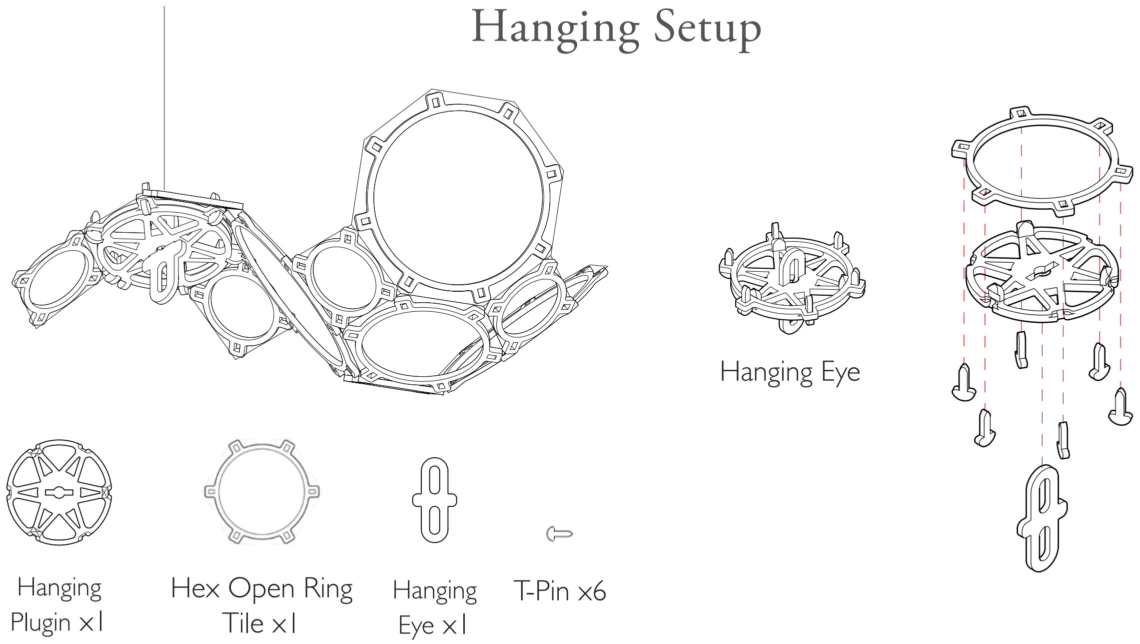
Canopy Waffle Net



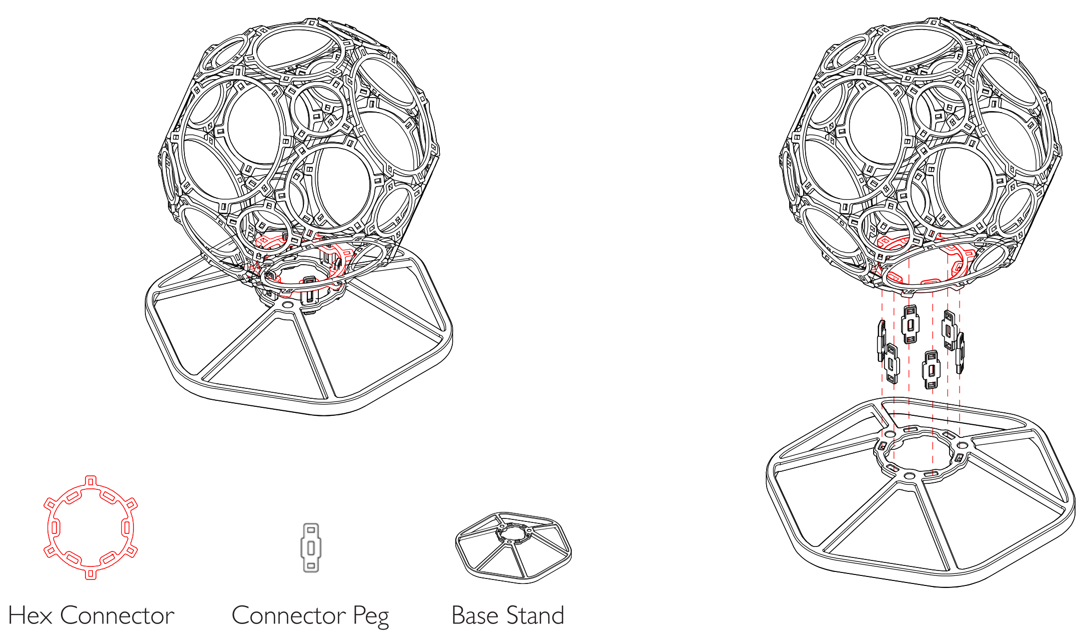
Canopy Junction Net

Hanging and Base Setup

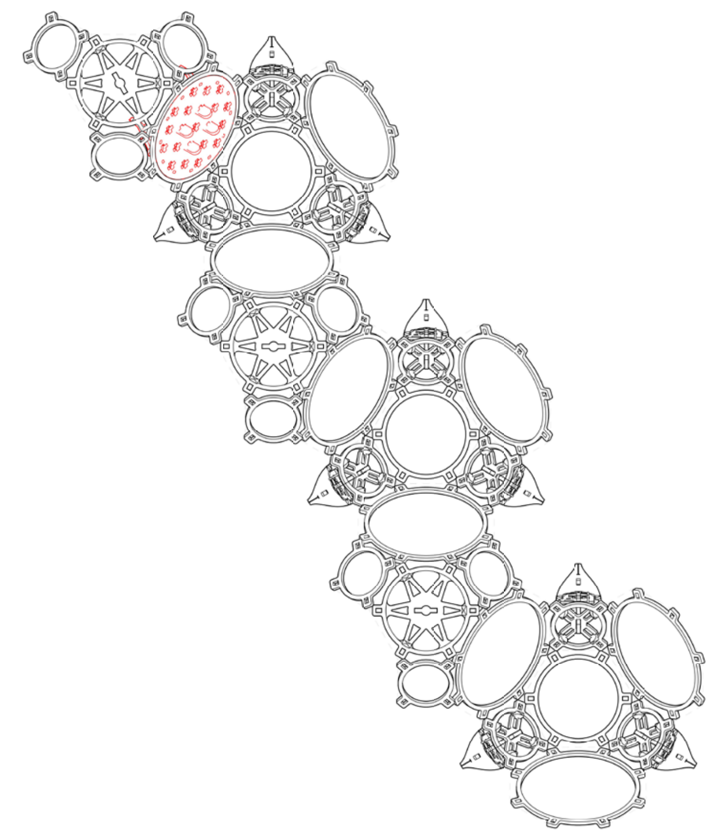
Hanging Setup

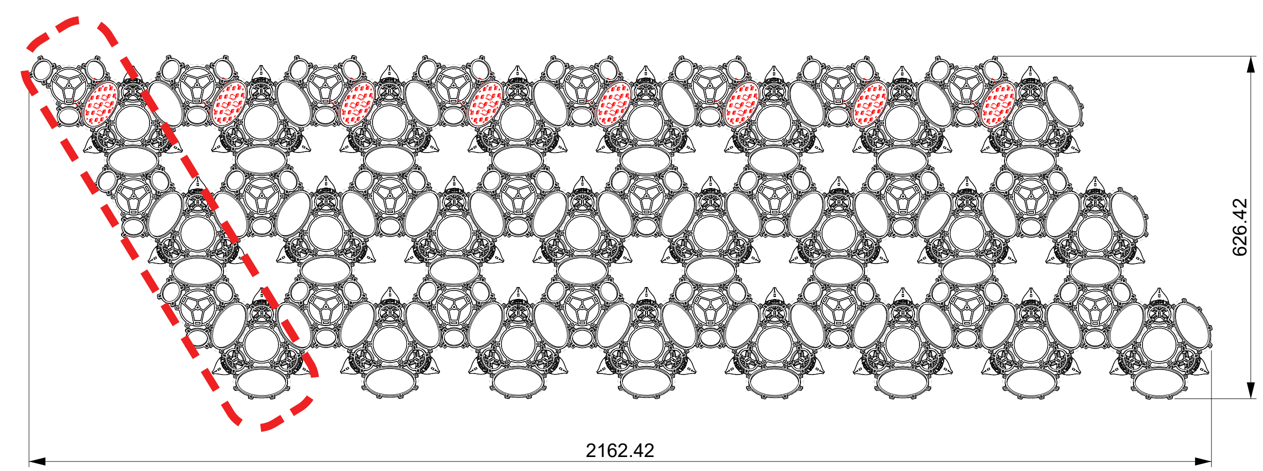


Base Setup



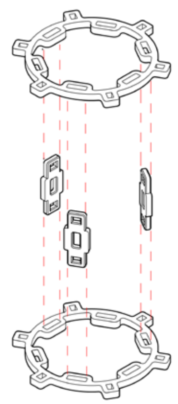
Canopy Segment Plan



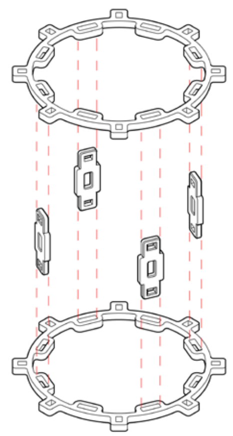


Connections Between Spheres

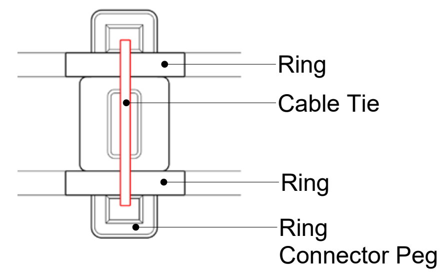
Ring Connector Junctions Assembly

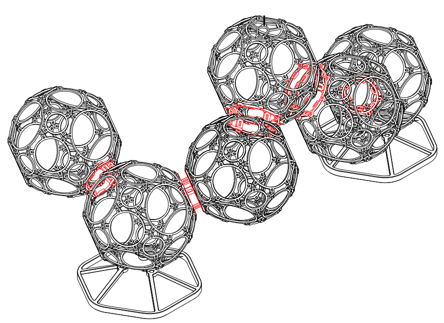


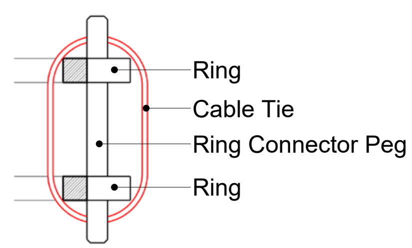
Truncated Cuboctohedron or Truncated Octohedron



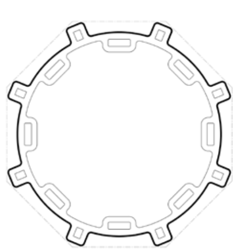
Truncated Cuboctohedron Octagon Connector Variant



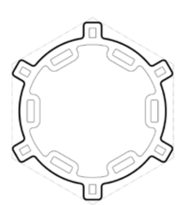




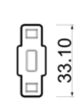
Ring Connector Junctions Materials



Oct Connector

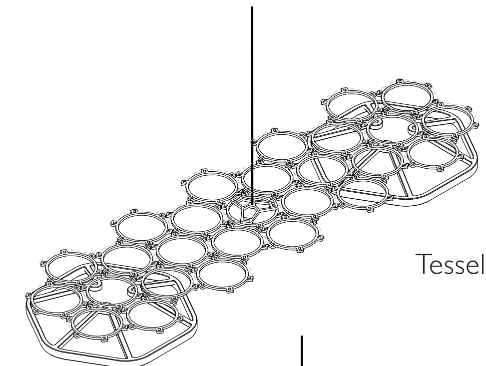


Hex Connector

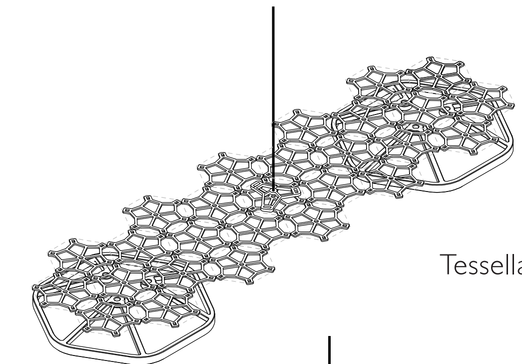


Ring Connector Peg

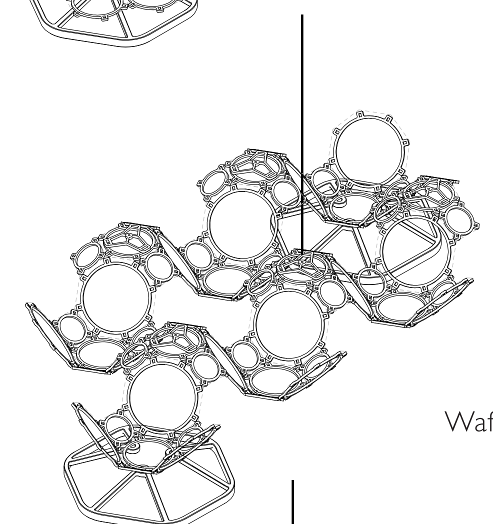
Tile Configurations



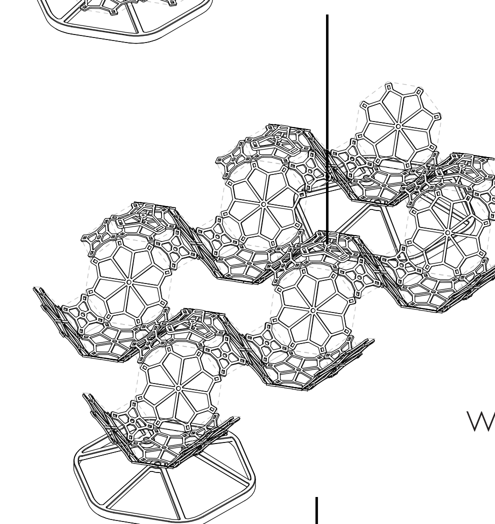
Tessellation



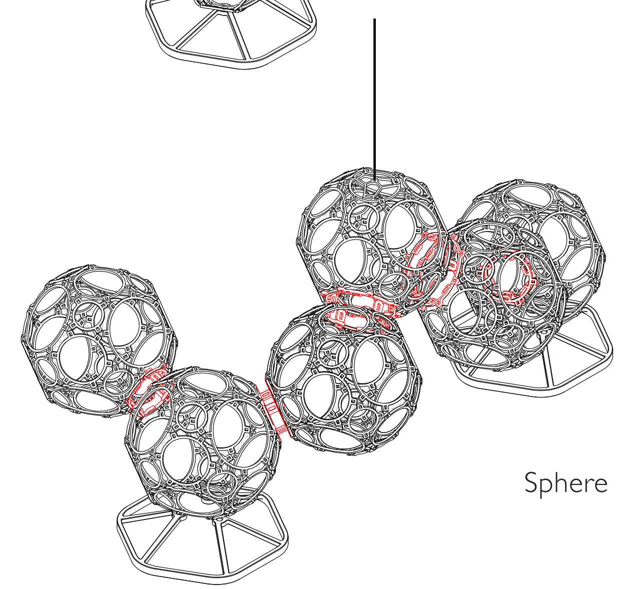
Tessellation



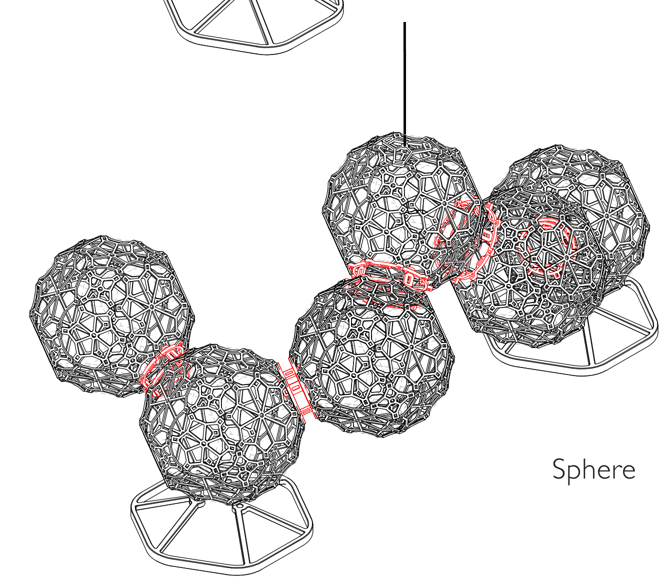
Waffle



Waffle



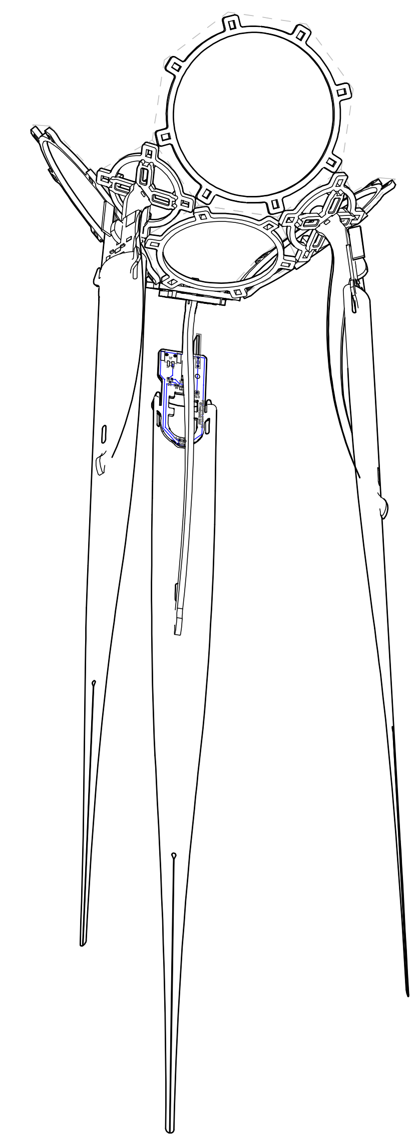
Sphere



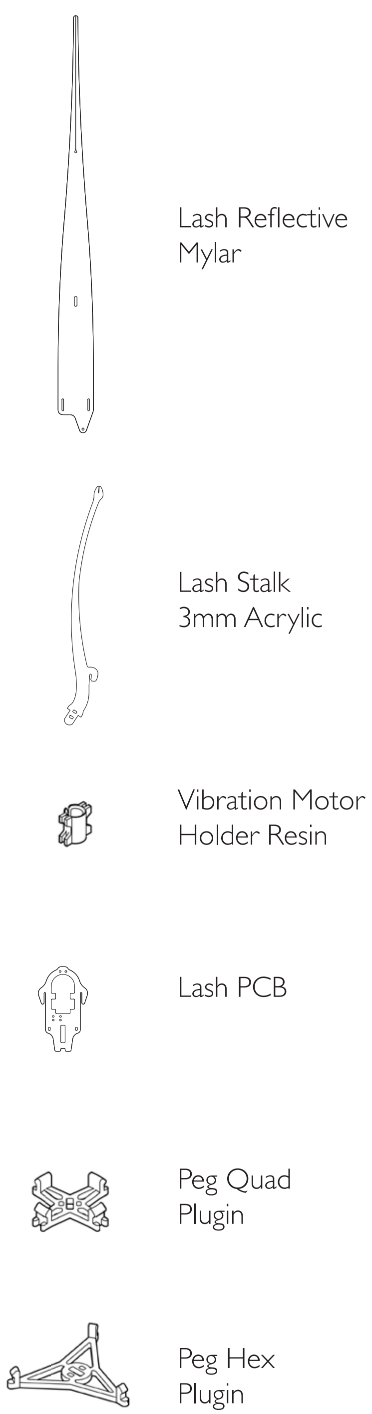
Sphere

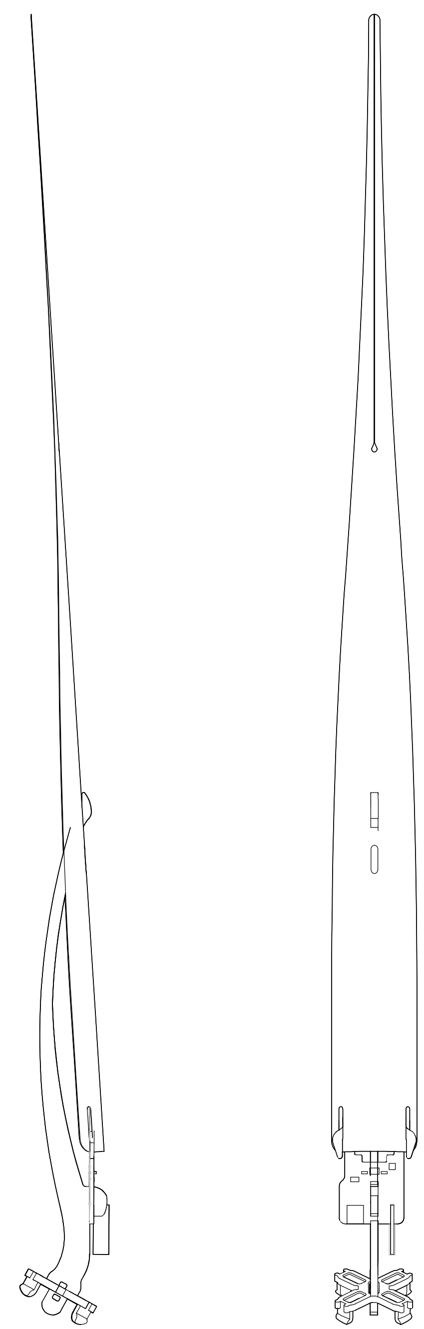
2

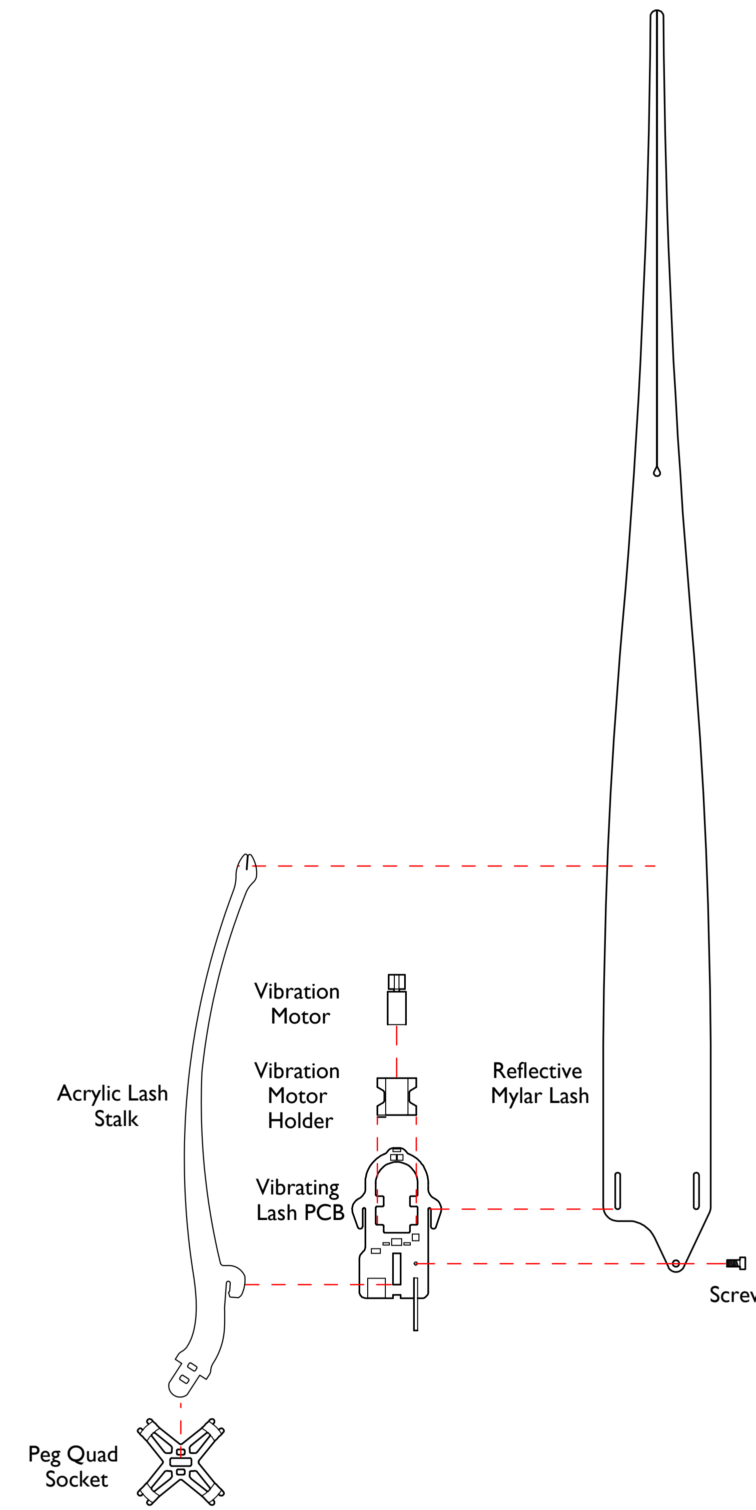
Actuators and Sensors



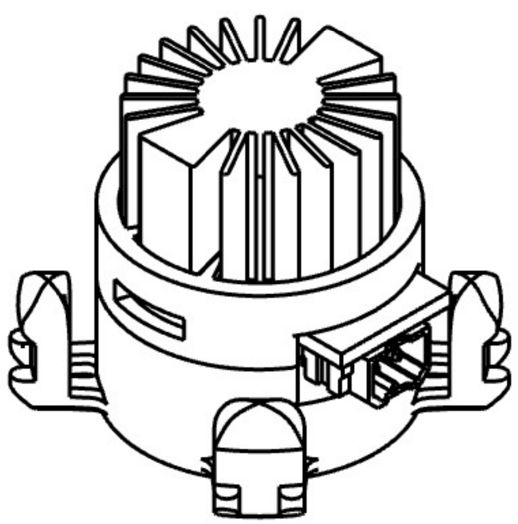
Vibrating Lash Assembly Instructions

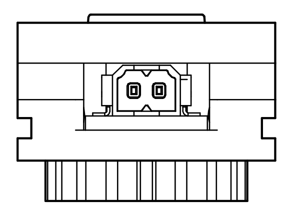


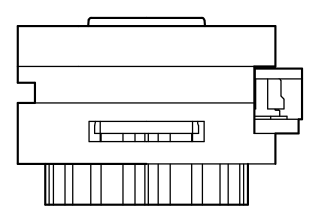


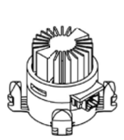


LED Light Assembly Instructions





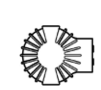




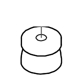
LED Case

LED Base

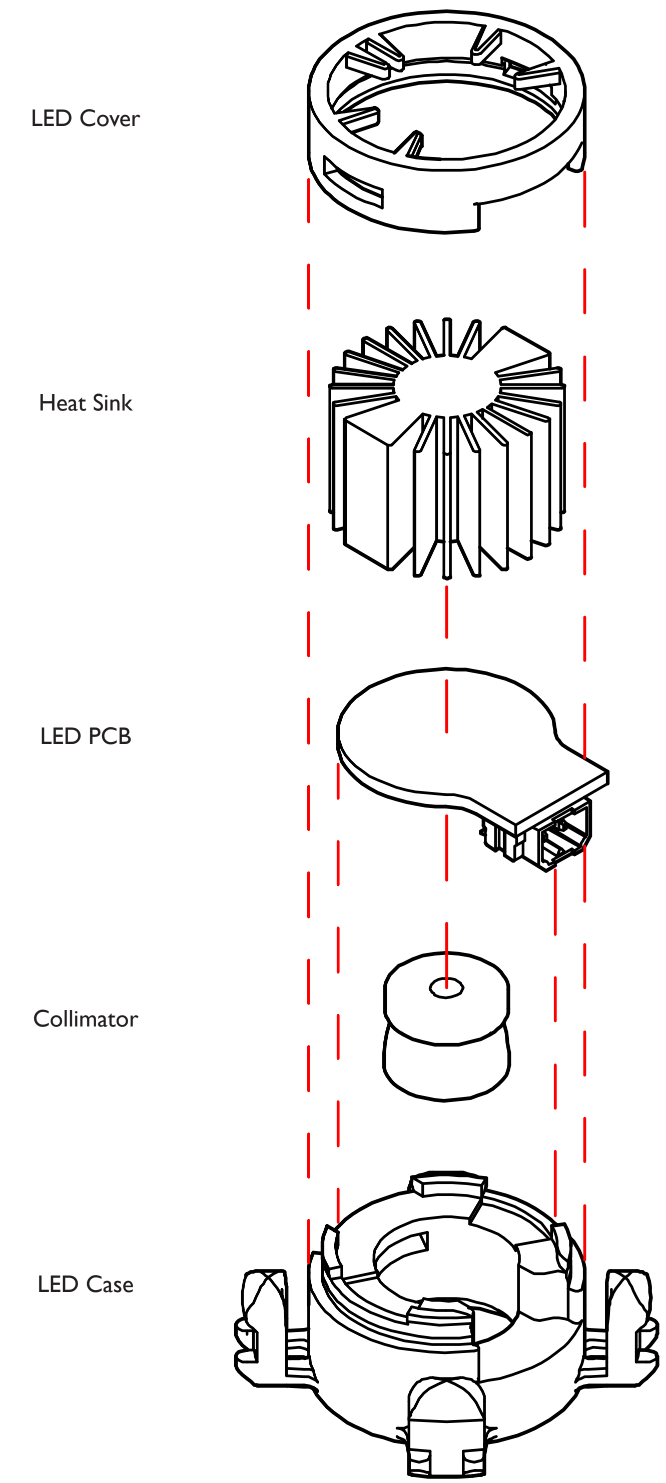
LED Cover



LED PCB +
Heast sink

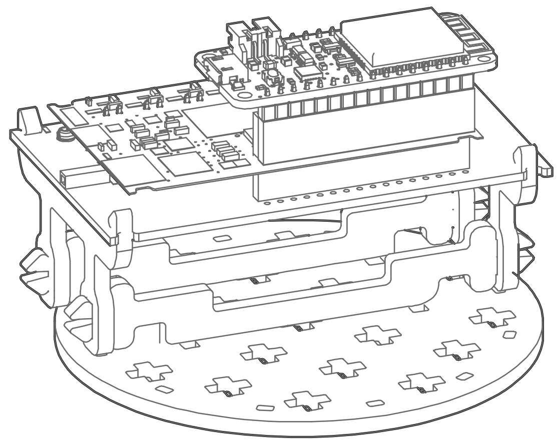


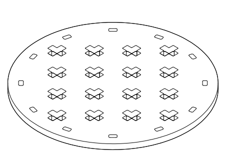
Collimator



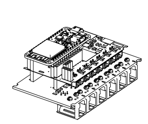
Node Controller Tray Assembly Instructions

With Expansion Board

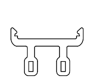




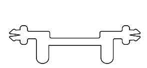
Peg Tray 3mm Acrylic x1



Expansion Board + Node Controller x1



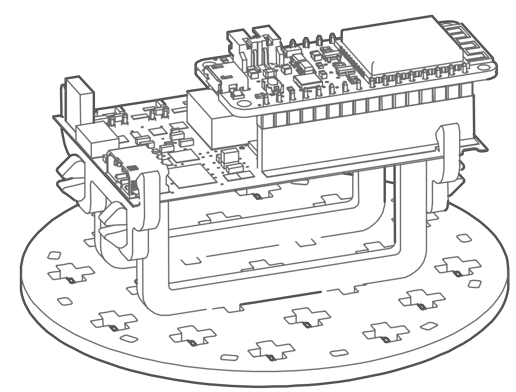
Node Controller Sled 3mm Acrylic x2

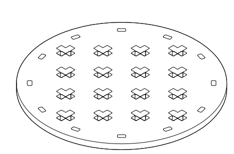


Node Controller Base 3mm Acrylic x2

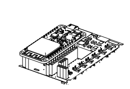
Tray Locking Plate x4

Without Expansion Board

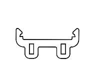




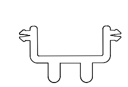
Peg Tray 3mm Acrylic x1



Node Controller x1



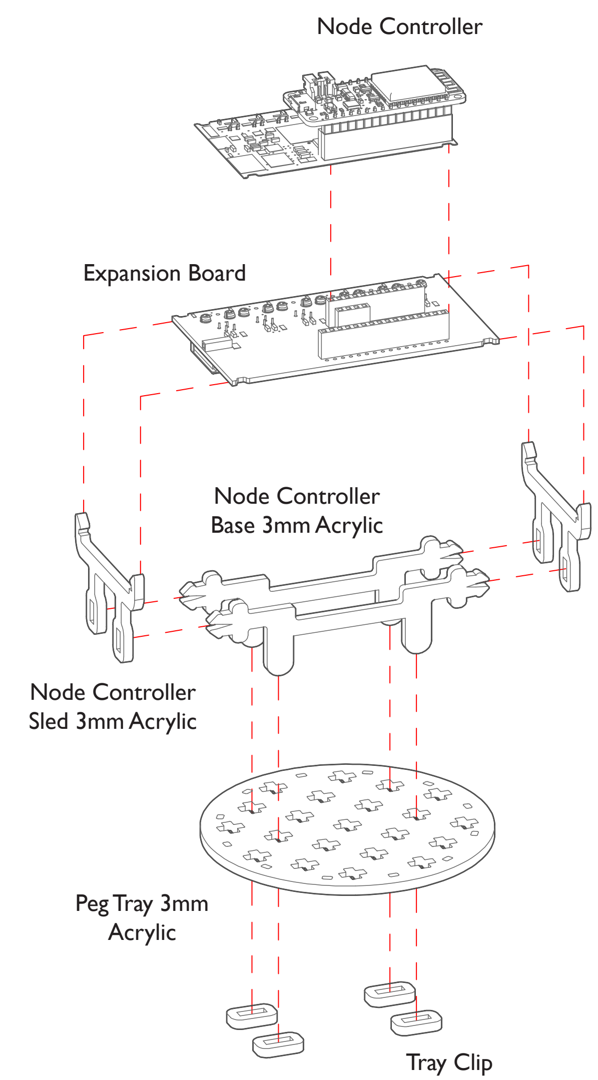
Node Controller Sled 3mm Acrylic x2



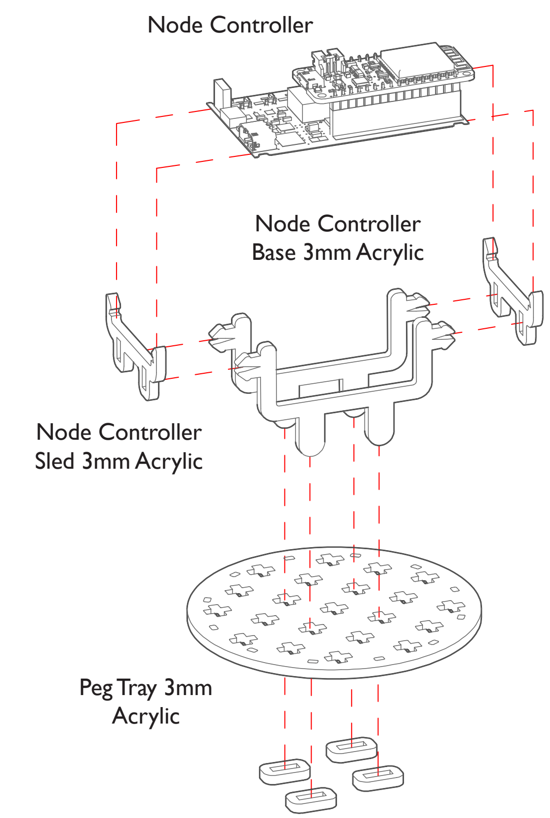
Node Controller Base 3mm Acrylic x2

Tray Locking Plate x4

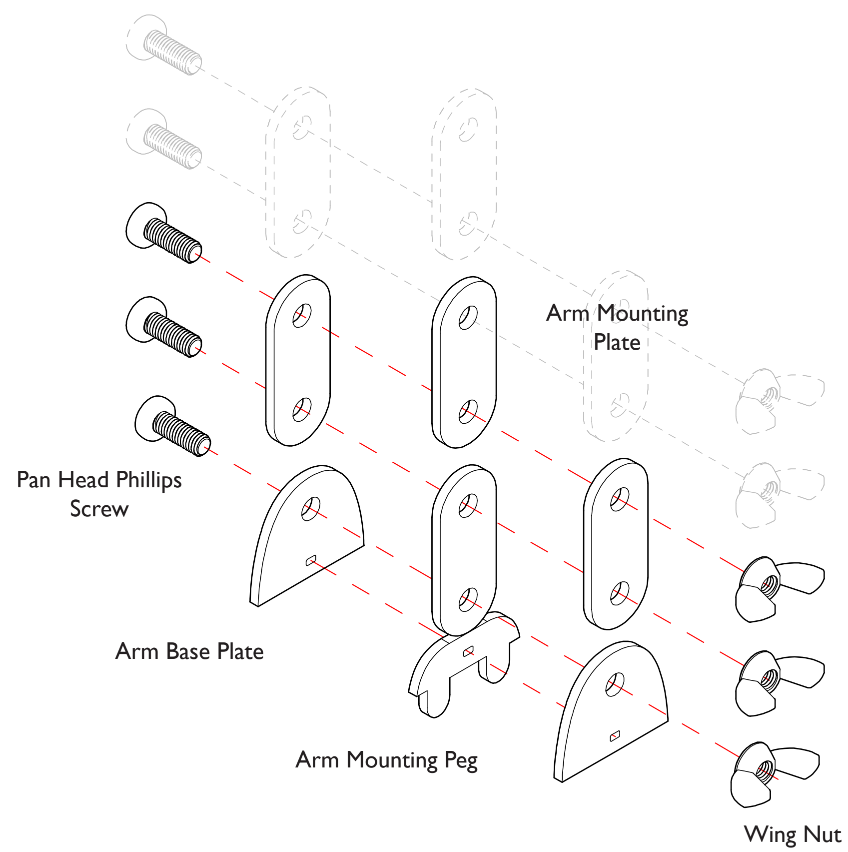
With Expansion Board

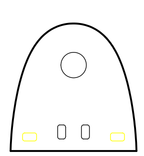


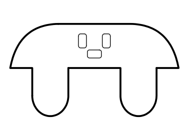
Without Expansion Board

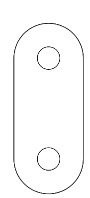


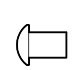
Arm Assembly Instructions

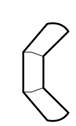


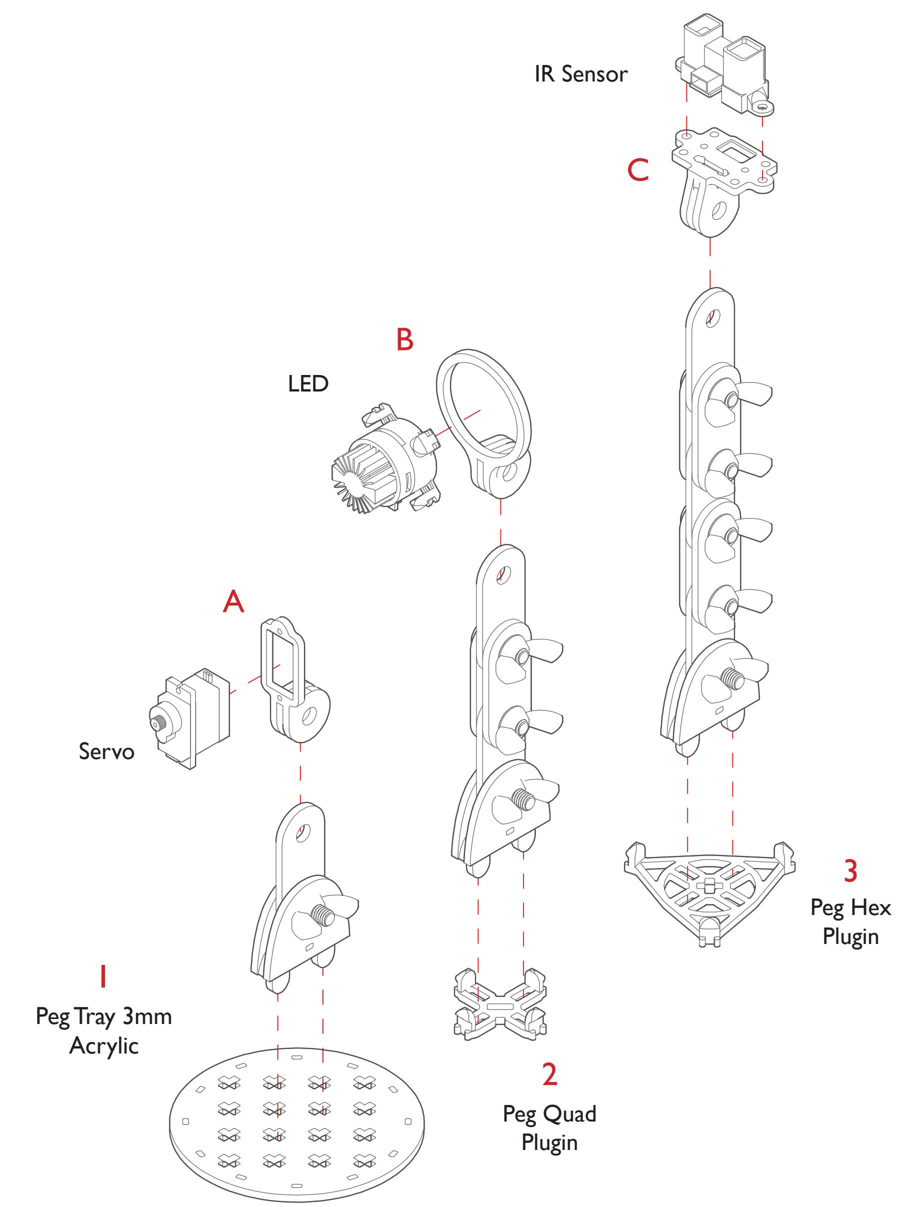

Arm Base Plate


Arm Mounting Peg


Arm Mounting Plate


Pan Head Phillips Screw


Wing Nut

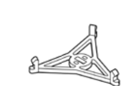


Base Attachment Options

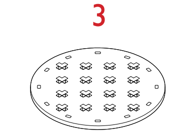
1


Peg Quad Plugin

2

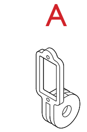

Peg Hex Plugin

3

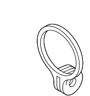

Peg Tray 3mm Acrylic

Top Attachment Options

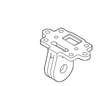
A


Servo Mount

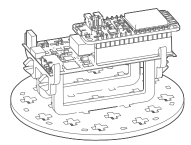
B

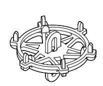

Quad Ring Mount

C

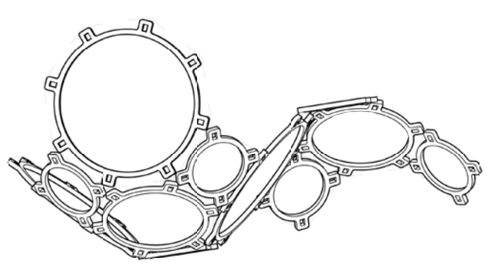

Board Mount

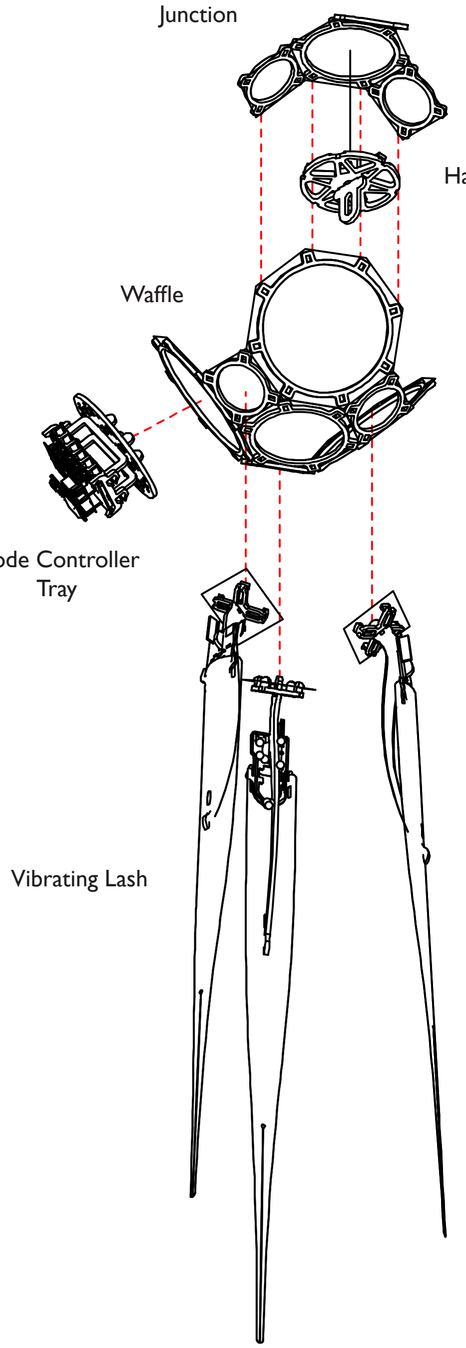
Canopy System Assembly

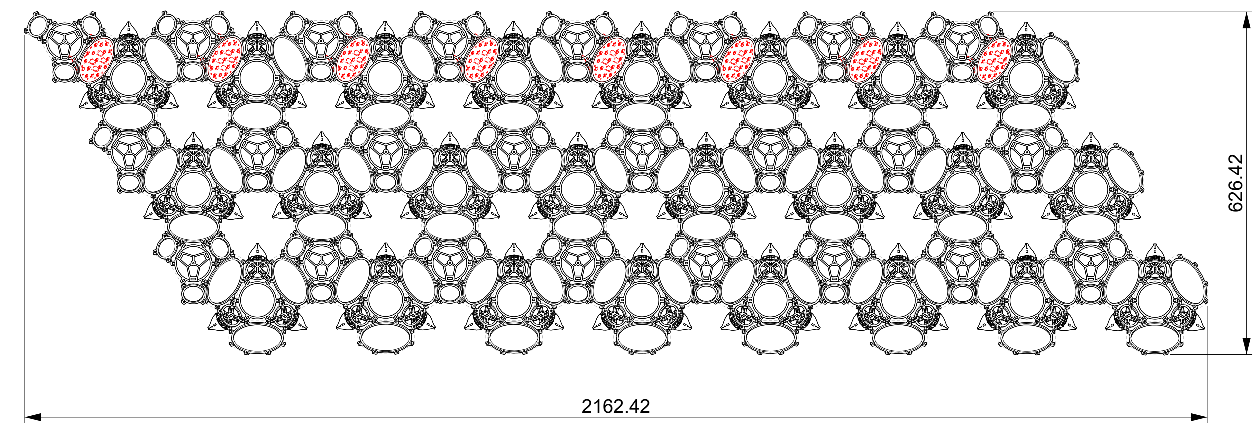

Node
Controller Tray

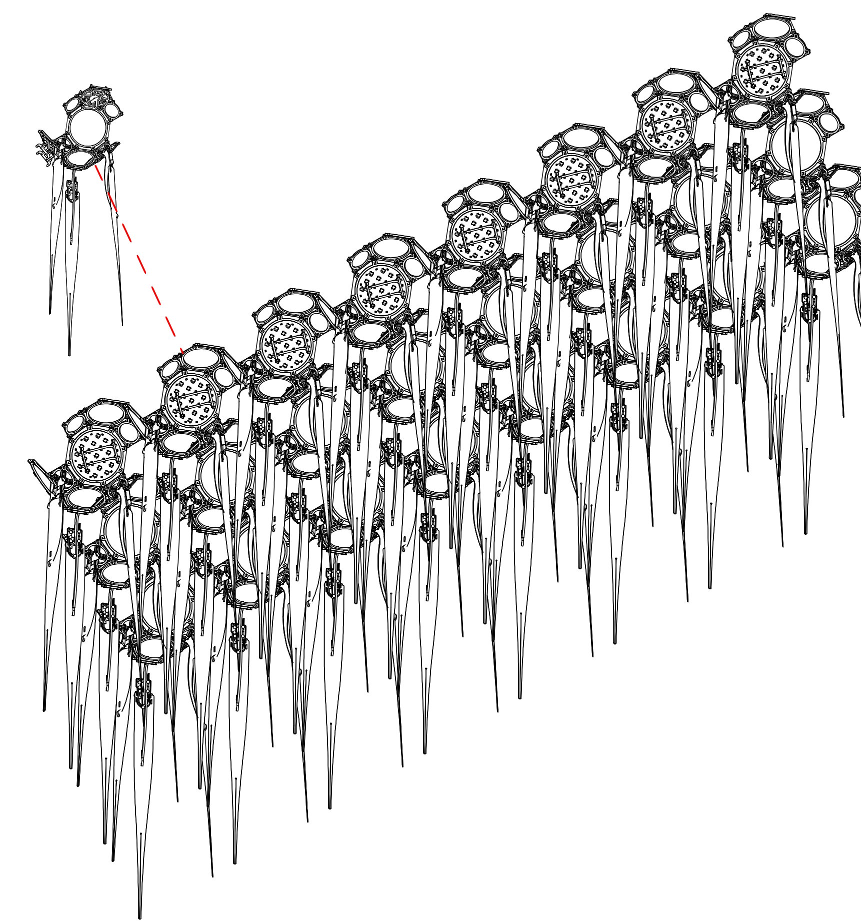

Hanging Eye


Vibrating Lash


Waffle + Junction





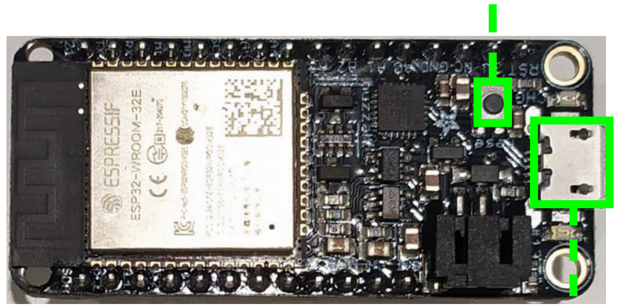


3

Electronics Hardware

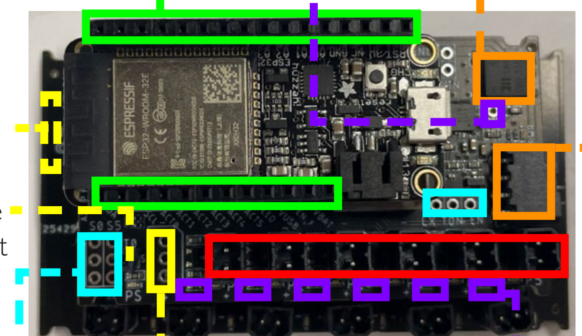
Node Controller

The Node Controller is a custom printed circuit board (PCB) that acts as a bridge between the microcontroller and the actuators and sensors. The microcontroller is the black board sitting on top. Connect its USB port to a USB power supply (any phone power supply or battery pack), or a laptop/computer port to give the board power. Connecting it to a laptop will also allow you to upload SAI profiles to it. It has on-board yellow LEDs that tell you when it is supplying power to an actuator through one of its 6 output ports (or servo ports, which use the same actuation channel as P0 and P5). It also has one LED that comes on to confirm that the board is receiving power. It has one sensor port, and a header for selecting the sensor channel. Channel A1 does not modify the sensor signal. Channel A0 applies a 2.4kHz low pass filter to the sensor signal before it reaches the microcontroller. The actuator, servo, and sensor ports all accommodate the dupont cables included in the kit.

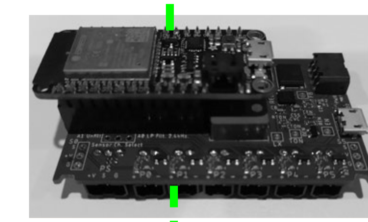


ESP32 Microcontroller

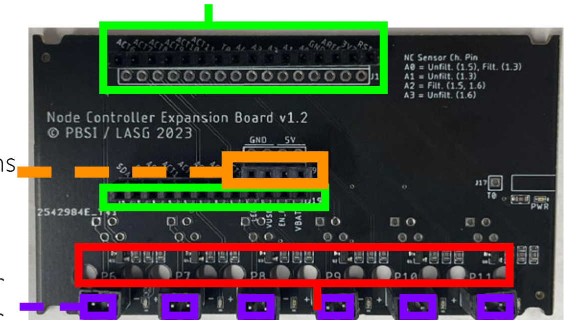
Node Controller Configurations



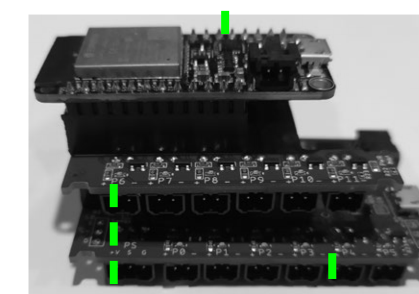
Node Controller Base Board



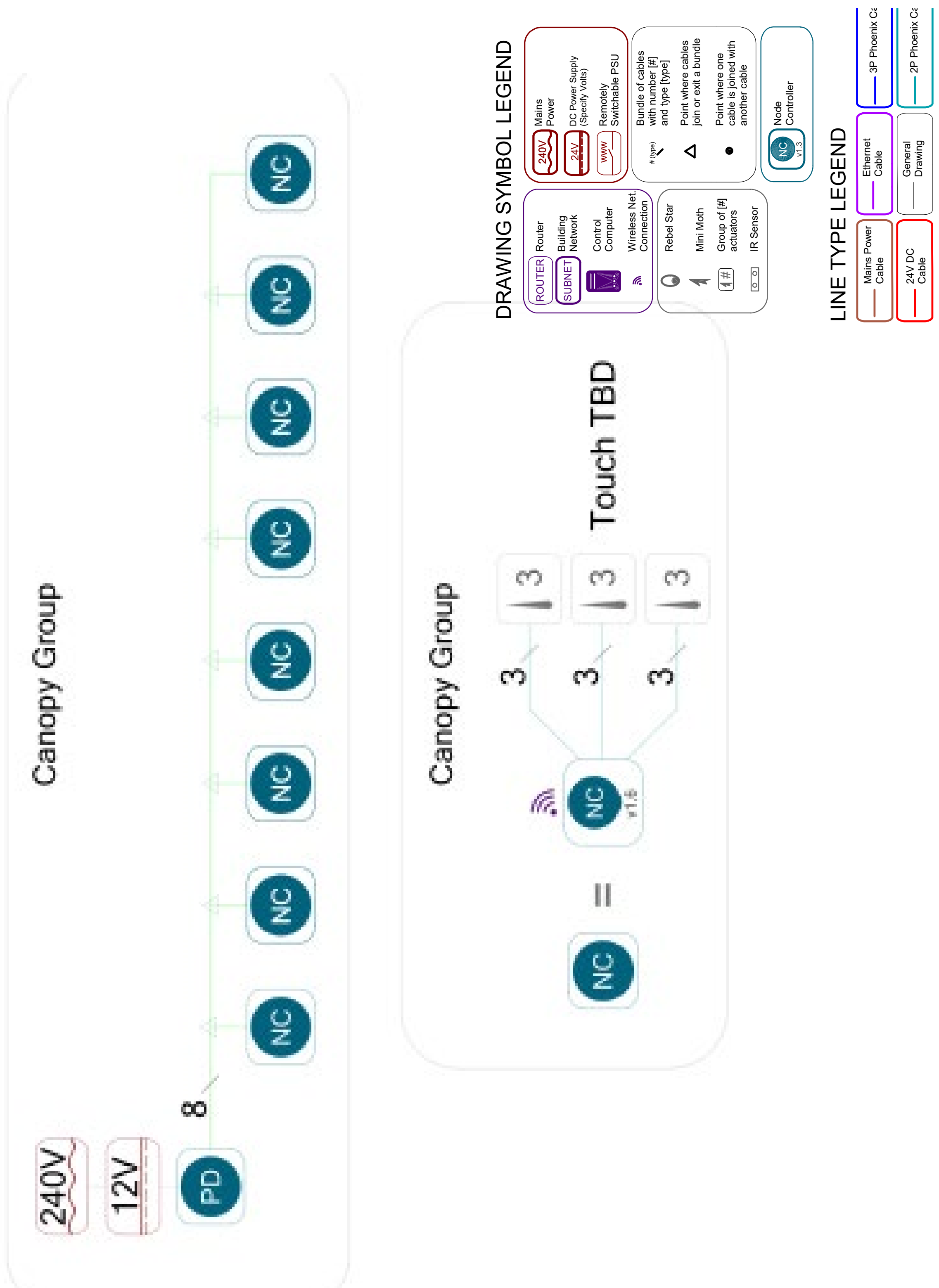
Base Configuration



Node Controller Expansion Board



Expansion Configuration

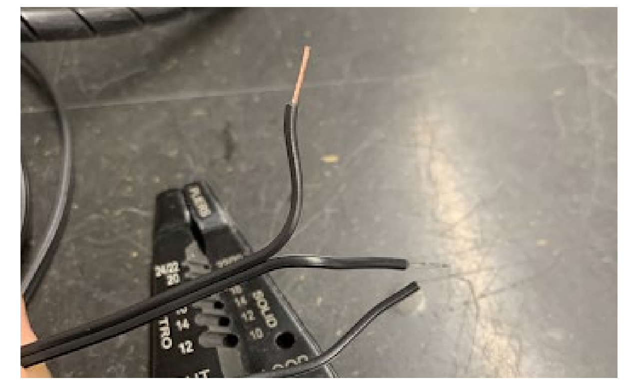


Electronics Block Diagram

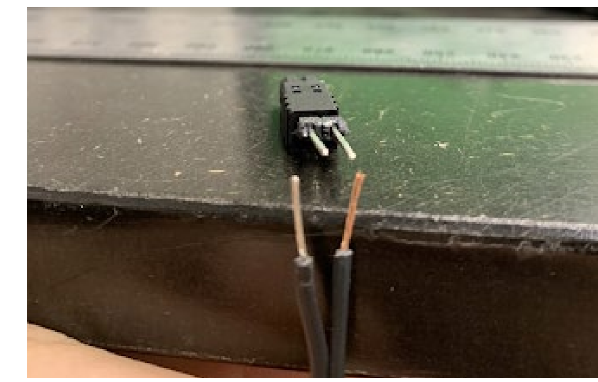
Cable Assembly Guide

Step 1
Separate the cable about 2-3 cm

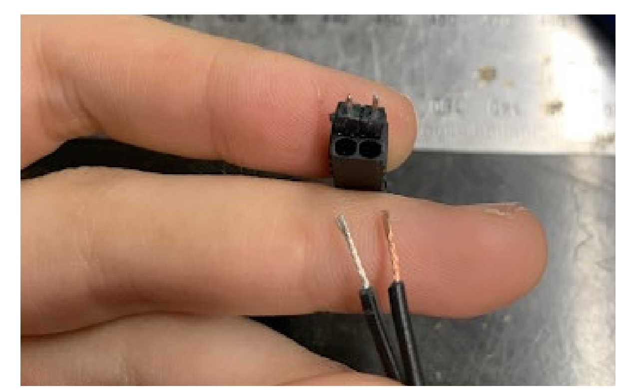
Step 2
Strip the ends of the 24AWG cable by 6mm



Step 3
Put the header pin into the top openings of the 2P Phoenix plug



Step 4
In the openings below the header pin, place copper wire on right side, silver on left



Step 5
Remove the header pin to secure the wires in place.

Step 6
Cut 1.5cm of adhesive heat shrink (0.43" D) and shrink onto ridges of connector

Step 7
Allow to cool and use needle nose pliers to peel off squeeze out (glue)

Capacitive Touch Wire

Step 1
Separate the two wires from the 2C cable - Strip 3mm using the self-adjusting orange wire strippers at 34cm from one side and 37cm from the other side on the 91mm wire. Strip 5mm from both ends of each of the three wires

Step 2
Tin all wire ends and middles

Step 3
Fold the tinned end in half, on both 20cm pieces

Step 4
Add 1.5cm of 1/8" black heat shrink between the 3mm tinned bits

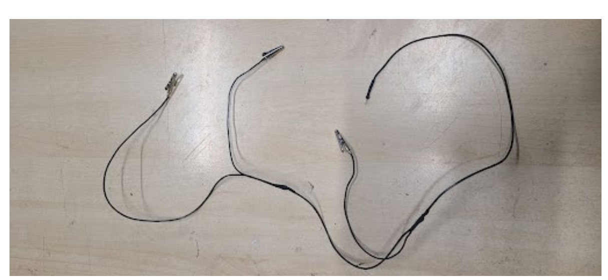
Step 5
Hook it onto the 3mm tinned wire

Step 6
Solder the T join with the 20cm piece angled away from the 34cm end of the long wire

Step 7
Tin and solder one pin to the final remaining tinned wire end

Step 8
Head shrink 1.5cm long and 1/8" diameter heat shrink over all connections

The finished wire should look like this:



Combining Cables & Wires

Step 1
Use a node controller to align the cable. The cables exit opposite the power cable and the longest cable should plug into P0

Note: The cables should not be twisted. Start wrapping the spiral wrap around the cable bundle allowing the 2P Phoenix cables to exit with the shortest alligator clip wire at the location of the T-joint

Note: wire insulation should extend all the way to the edge of the connector, none of the metal should be exposed.

Pin Terminal 24 AWG

Step 1: Strip wire 8mm
Step 2: Push wire firmly into the terminal
Step 3: Crimp wire with crimper

Pin Terminal 12 AWG

Step 1: Strip wire 10mm then twist
Step 2: Push wire firmly into the terminal
Step 3: Crimp wire with crimper

Servo Motor Wiring

4

Behaviour

The behaviour systems of LASG sculptures are divided into global (centralized) and local (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 microcontroller (or in some cases, a Raspberry Pi embedded computer) is the decision maker. These two systems work together to choreograph a sculpture's expression.

The Science Centre Prototype at TUDelft represents a major step in the evolution of LASG behaviour systems, in that the logic of expression -- that is, under what circumstances the sculptural elements generate behaviour -- is far more decentralized than ever before. The microcontrollers distributed throughout the fabric of the sculptural canopy are responsible for their own outputs, based on shared information, parameters, and algorithms. Working in this way, they can create coordinated and responsive movements without needing constant flow of high-bandwidth information. Unlike a display screen, the individual units within the sculpture are only given information about high level environmental changes, and generate their own moment-to-moment output internally.

Global Behaviour: Influence Engines

At the heart of LASG's global behaviour system is the concept of Influence Engines. An influence engine is a piece of software that algorithmically generates 'influences' on the various spatially distributed parts of the sculpture. For example, a simple influence engine might create waveforms that move through the sculpture by determining the amplitude of a wave at various physical locations in the space. A different Influence Engine might use particle dynamics to calculate the trajectory of virtual objects which influence elements within the sculpture.

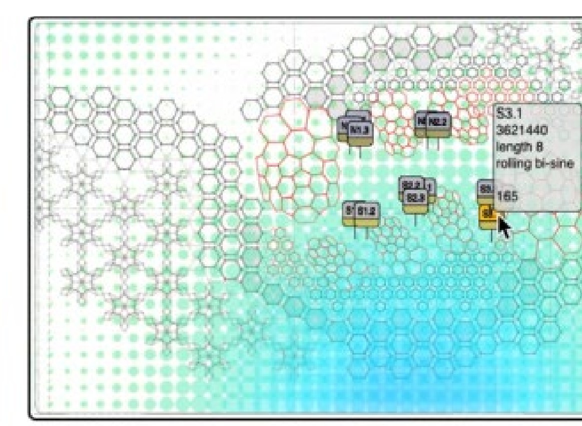
Key to the concept of Influence Engines is that they are not directly determining what each part of the sculpture should do, but rather 'influencing' the behaviour of the local computational elements. Elements can respond in many ways to the influences they are exposed to. For example, an actuator might glow in the presence of a virtual particle, or, that influence might dampen an already existing glow. This local logic of whether to respond to certain influences, how strong their impact becomes, and how exactly it becomes visible as part of the behaviour of the sculpture is inspired by independent natural lifeforms in a changing environment. Coordinated behaviour might occur if all the elements within an environment are similar (think about fireflies or crickets or ants) but the potential also exists for parts of the sculpture to respond independently as influences shift.

In the Science Centre Prototype at TUDelft, there are three main Influence Engines at work:
SkyGen, a distributed parametric "weather system",
Tendency, a probabilistic trigger system for local behaviour
TouchPoint, a system for generating one-to-one impulses within the sculpture

These Influence Engines run simultaneously, and their parameters can be adjusted using simple web-browser-based controls. The responses of elements of the sculpture to the influences can be adjusted as well via a browser interface.

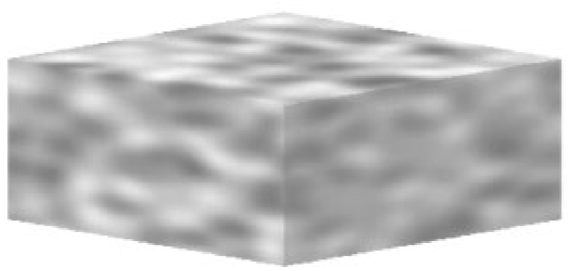
SkyGen

SkyGen is an Influence Engine that produces variable naturalistic 'cloud' behaviour within the testbed. Accessible via a web browser interface, a few simple control parameters enable a wide variety of patterns, evoking a spectrum of attitudes within the space.



Technically, the SkyGen system uses a well-known 'noise' algorithm called Simplex Noise, which generates a coherent 3D volume of 3D noise according to known parameters. Any point within this volume can be queried at any time, resulting in a spatially coordinated influence that feels like clouds. Each of the 40 microcontrollers that make up the testbed knows the location of the actuators within the space that it controls, and they are synchronized via a clock signal sent from the server. Using a shared 'seed' value, shared algorithm and clock, each microcontroller efficiently manages the influence of SkyGen on its own actuators to keep them coordinated.

SkyGen provides an example of the scalability and efficiency of distributed processing vs. centrally choreographed behaviour.



Simplex Noise Function (Perlin, Gustavson, etc.)

$$P = (x, y)\ ,\ i = floor(x)\ ,\ j = floor(y)$$

$$g_{00} = gradient\ at\ (i, j),\ g_{10} = gradient\ at\ (i+1, j)$$

$$g_{01} = gradient\ at(i, j+1),\ g_{11} = gradient\ at(i+1, j+1)$$

$$u = x - i,\ v = y - j$$

$$n_{00} = g_{00} \cdot \begin{bmatrix} u \\ v \end{bmatrix},\ n_{10} = g_{10} \cdot \begin{bmatrix} u-1 \\ v \end{bmatrix},\ n_{01} = g_{01} \begin{bmatrix} u \\ v-1 \end{bmatrix} \cdot\ ,\ n_{11} = g_{11} \cdot \begin{bmatrix} u-1 \\ v-1 \end{bmatrix}$$

$$f(t) = 6t^5 - 15t^4 + 10t^3$$

$$n_{x0} = n_{00}(1 - f(u)) + n_{10} f(u),\quad n_{x1} = n_{01}(1 - f(u)) + n_{11} f(u)$$

$$n_{xy} = n_{x0}(1 - f(v)) + n_{x1} f(v)$$

Tendency

Tendency is a simple Influence Engine based on probability, with three parameters:

- Likelihood: How often a Smart Cell chain within the sculpture that is subscribed to this influence engine will trigger its local behaviour
- Strength Variation: How varied will be the strength of the trigger (with zero Strength Variation it will always be 100%, but it may be less as this parameter is increased.
- Time Variation: How fast will the Smart Cell profiles play out. Zero Time Variation will result in precise execution of defined profiles, and as this parameter is increased the runtime of triggered patterns will develop more variety, stretching or compressing to a greater degree.

These parameters can be controlled by a series of sliders on a browser-based interface, or linked to data feeds generated by other systems.

TouchPoint

The TouchPoint Influence Engine simply reports impulses generated by an external interface to all elements within the sculpture, with the following parameters:
X,Y and Z location of 'touch' impulse

- Core Size in mm
- Full Size in mm
- Speed in mm/s

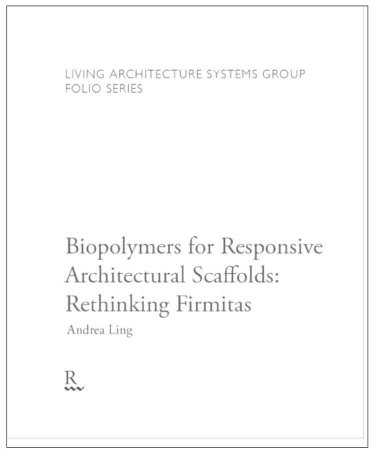
These parameters are received and acted on simultaneously by every element of the sculpture. The elements then calculate how to react. If their distance from the impulse location is greater than 'full size' range, the impulse will be ignored. If their distance is within the 'core size' the influence will be 100%. In between 'core size' and 'full size' there will be a linear decrease in the influence. Also, the response to this influence will be delayed in inverse proportion to the 'speed' parameter. That is, if the speed is slow, elements that are further from the impulse location will respond later than elements that are closer.

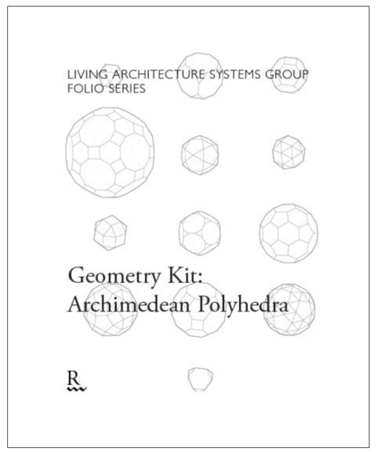
Though simple, this influence engine is capable of generating complex and varied behaviour such as ripples, waves and real-time 'paintbrush' effects.

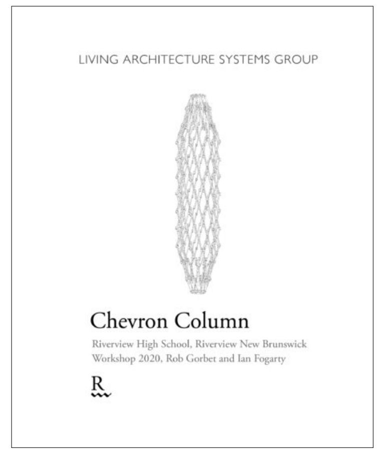
A variety of interfaces can be imagined to control the four input parameters listed above, from a very direct manipulation of the sculptural map with a touch-screen GUI to a responsive system that generates impulse parameters based on the movement of individuals within a space, to a system for mapping impulses to external datasets for visualization.

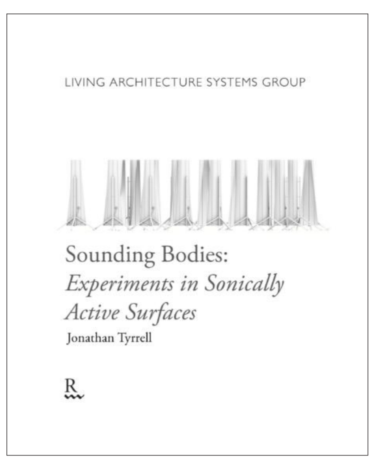
6

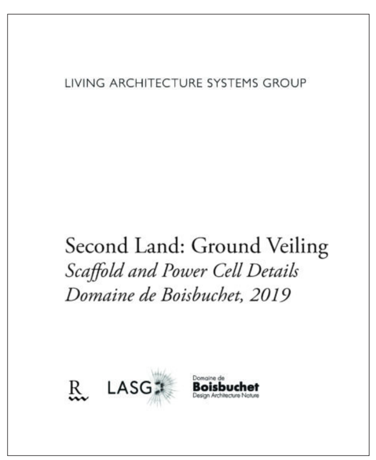
Additional References

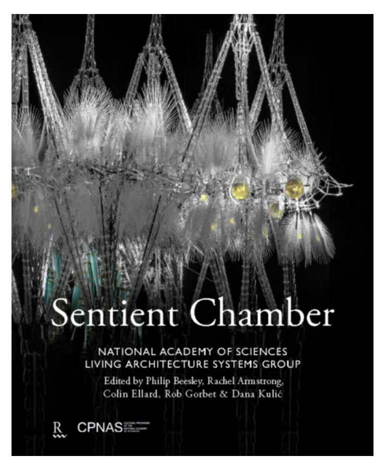












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Support is gratefully acknowledged from Social Sciences and Humanities Research Council of Canada, Canada Council for the Arts, Delft University of Technology, University of Waterloo, Art on Camps, Philip Beesley Studio Inc., Gorbett Design Inc.

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