Deployable Architecture: A Seasonal Theatre for the Halifax Commons

by

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Submitted in partial fulfilment of the requirements
for the degree of Master of Architecture

at

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DALHOUSIE UNIVERSITY

SCHOOL OF ARCHITECTURE

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "Deployable Architecture: A Seasonal Theatre for the Halifax Commons" by Jen Earle in partial fulf lment of the requirements for the degree of Master of Architecture.

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ABSTRACT

This thesis is an exploration in deployable architecture, focusing on long span structural design. The application for the design will be a summer theatre for the Halifax Commons. The deployment of the structure will be for a five month duration, therefore important design considerations will be durability, waterproofing, as well as assembly, disassembly and storage.

ACKNOWLEDGEMENTS

Thank you:

Susan Molesky for your continual support, guidance and patience throughout this process.

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To my family for all your support.

CHAPTER 1: INTRODUCTION

Thesis Question

How might an architecture of impermanence facilitate a cyclical pattern of seasonal activities on the Halifax Commons?

Deployable Architecture

> Our present task is to unfreeze architecture, to make it a fluid, vibrating, changeable backdrop for the varied and constantly changing modes of life. An expanding, contracting, pulsating, changing architecture would reflect life as it is today and therefore be part of it (Fox 2009, 27).

Deployable architecture is a system that allows for the deconstruction and reconstruction of a load bearing structure and affords impermanence to place. Deployable architecture has its roots in nomadic dwellings; structures that were designed to be lightweight and durable as well as collapsible and compact for easy transportation. Pragmatism was a main driver for development (Fox 2007, 48).

Designs are developed and constructed with an imminent disassembly in mind. The consideration of the life cycle is important when making decisions concerning programmatic and building demands such as lighting, thermal performance, acoustics and waterproofing. Innovation within this field is largely driven by the mechanics of assembly and disassembly to increase the time and efficiency of deployment (Fox 2007, 31).

This thesis will investigate the construction challenges and precedents of deployable geometries as an impermanent architectural response to an environment with a continually shifting pattern of use, but will consider the phenomenological aesthetics of geometrical transformation as an event itself outside of the pragmatics of functional deployment and use.

Dynamically Self Erecting Structures

William Zuk, author of *Kinetic Architecture*, proposes that there are two types of dynamically self erecting processes, pneumatic erection and articulated erection, this thesis will consider the latter. In articulated erection there is a stable base or core to which an expandable number of rigid elements are attached. To be automatic these expandable elements must also be linked by pins, pulleys, slides, cables etc., so that through the introduction of an energy source, a turn of a crank, pull of a cord, the entire assemblage undergoes its predetermined transformation (Zuk 1970, 51).

The Hoberman expanding geodesic dome is an example of a self erecting structure. Developed by inventor and architect Chuck Hoberman, the dome expands from 4.5 feet (1.37 meters) to 18 feet (5.48 meters). The structure achieves expansion by a pulley system at the base of the dome and increases in size from the enlargement of the hexagons and pentagons in the geometry of the dome. Its shape, connectivity and stability remain the same throughout the transformation and the structure reverts to its compact size through a reversal of the erection process (Baldwin 1996, 149).

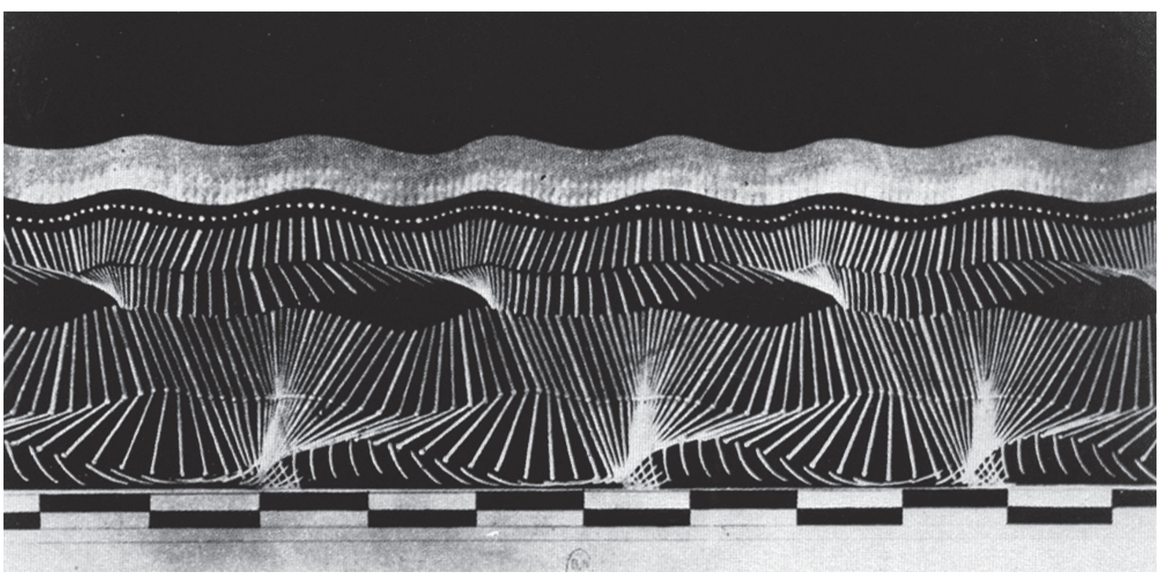
A sequential image of the erection Hoberman's expanding geodesic dome, 1991 (Hoberman Associates 2012).

Movement

Within human culture there has always been an interest and appreciation for the study of motion, one that lies in the interpretation of complexity derived from simplicity, from E.J. Marey's chronophotographic studies to Duchamp's Nude Descending a Staircase" (Fox 2009, 30). Within the f eld of architecture the historic advancement of kinetics has been one that is based in pragmatic innovation. However, the study and implementation of motion speak to both the pragmatics of optimizing solutions for building performance as well as an aesthetic phenomenology (Fox 2009, 30).

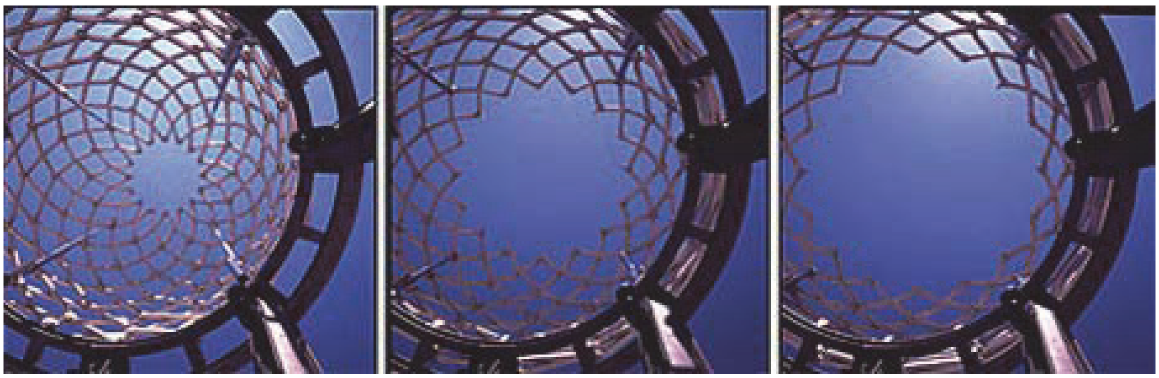
One of the architects on the forefront of kinematics is Chuck Hoberman, whose work explores transformable geometries that def ne space and structure. He suggests that:

> There is a psychological association between transformation and life, which everyone perceives at an emotional level. When one sees the special behaviour of transformation, one feel's it in one's body-perhaps a physiological connection, because there is a sensation, a physical sensation and a mental and perceptual sensation (Fox 2009, 31).

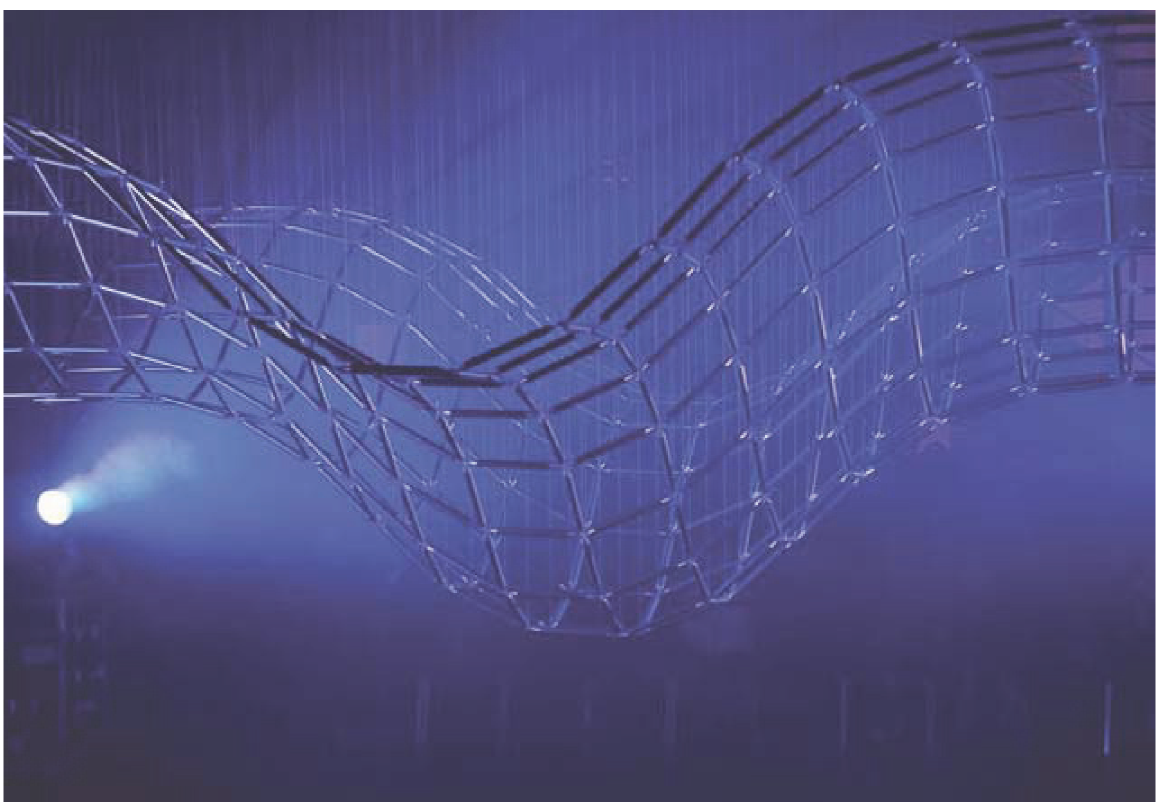


E.J. Marey's geometric chronophotographic study of the man in the black suit, 1883 (UC Berkeley 2012).

As described by Hoberman, dynamic components that allow for a physical transformation in structure, skin or volume can provide both an innovative solution to a pragmatic problem such as mobility and adaptability but can also transcend pragmatism in design of their movement to provide an aesthetic phenomenological experience of transformation.



The Iris Dome was created by Hoberman Associates for Expo 2000 in Hannover, Germany and illustrates the event of deployment (Hoberman Associates 2012).



Reuben Margolin's kinetic wave sculptures illicit a hypnotic memorization of the complexity of movement derived from the multiplication of a simple mechanism (Bruyn 2012).

Atomism and Structure

The methodology of this thesis will be to investigate kinetic building blocks; base units that can undergo a geometric transformation. The arrangement and repetition of these units will form the pattern of the overall structure.

Robert Le Ricolais describes the search for structure as two opposing attitudes: “One is to start with a block and work by means of excisions, the other is to start with a germinal cell in order to arrive at the def nitive form by means of addition, as in some arrangement of repetitive elements” (Bryan 1973, 31).

Lancelot L. Whyte describes the latter as *atomism*, which he def nes as a “reduction of complex data to f nite numbers of f xed unit factors. They are the ultimate material units that have no internal structure which can undergo change” (Whyte 1965, 20). These individual units constitute the patterning of the whole, or structure. He argues that there cannot be an understanding of the whole without an understanding of the interactions of the individual components.

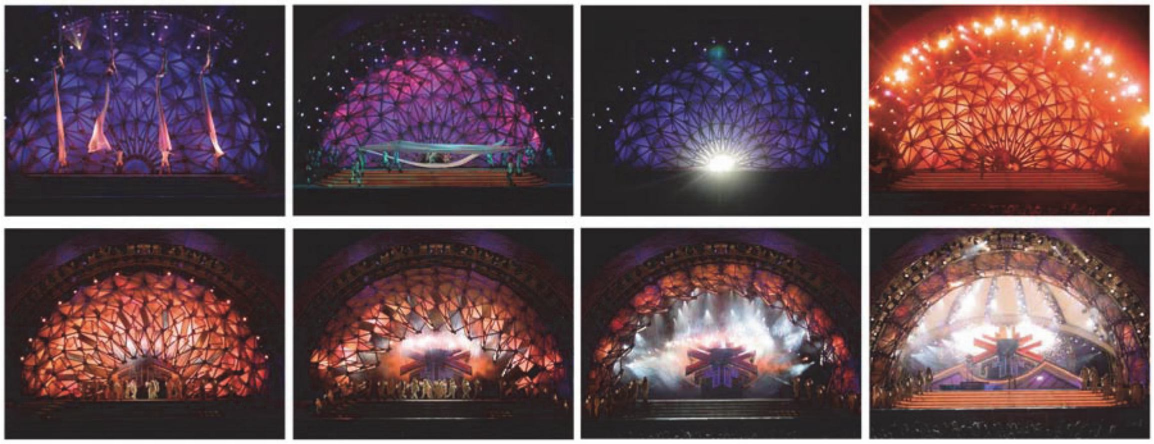
Whyte continues by def ning structure as “an arrangement, def nite or changing, of these localized parts, such as patterns or points.” He argues that structure is the antithesis of matter, that structure is a system of relations, and that within the changing pattern of those relations are discreet points obeying atomic law (Whyte 1965, 21). This def nition of structure is similar to the writings of Buckminster Fuller who does not describe structure as a solid or object, but as a process; “a pattern of energy events” (Fuller 1965, 66). The union of atomism and structure comprise form.

Precedents

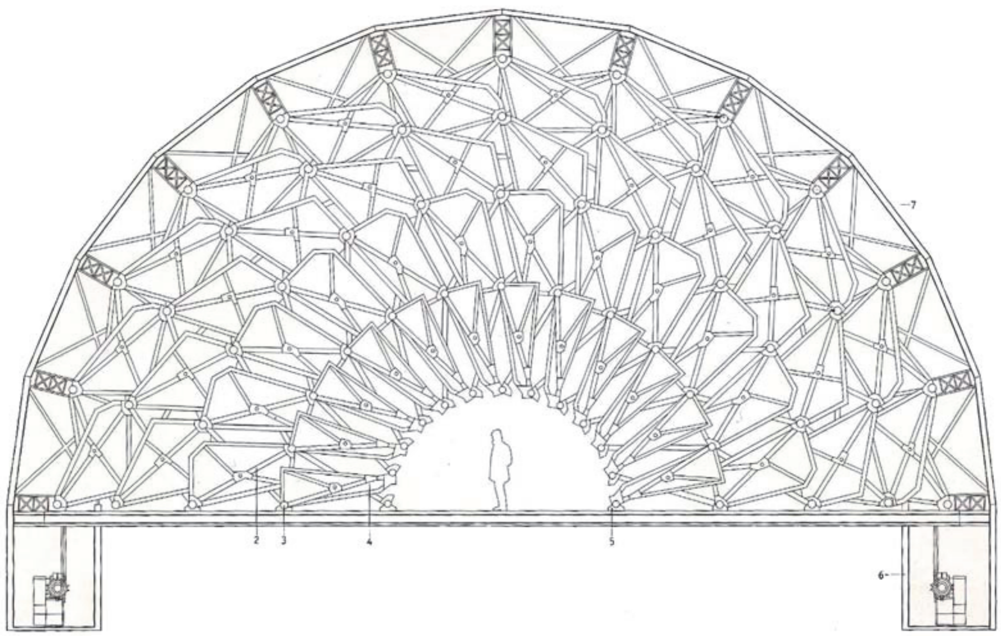
Another example of the work of Chuck Hoberman is a temporary performance stage curtain called the Hoberman Arch. The arch is an expanding and contracting stage curtain that was designed and created for the 2002 Olympic Winter Games in Salt Lake City, Utah. Hoberman's f rm created a 72' (22m) wide mechanical curtain for the opening and closing events at the games. The arch is a retractable semi-circular iris structure, 36' (11m) in radius, and when fully opened the stack can compact to a 5.9' (1.8m) band. The arch is constructed from sand-blasted aluminum and 96 translucent, f bre reinforced panels. The curtain was operated by two 30HP electric motors controlling tension cables that both opened the structure and supported its weight. More than 500 computer controlled lights were integrated into the curtain's opening and closing action so that its appearance could be dramatically altered as it moved (Kronenburg 2007, 154).

This design is based on the concept of kinetic building blocks that connect to make a network that transfers force, which is converted into motion. The critical factor in this assembly is how to maintain stability, something that Hoberman def nes as a process rather than a state. His f rm resolved this challenge by restricting def ections in the structure's components (Kronenburg 2007, 153).

Opening sequence of the Hoberman Arch. The deployment is accomplished by the arch acting as a stable base that the kinetic units are attached (*CrossLab Yuki Blog* 2012).

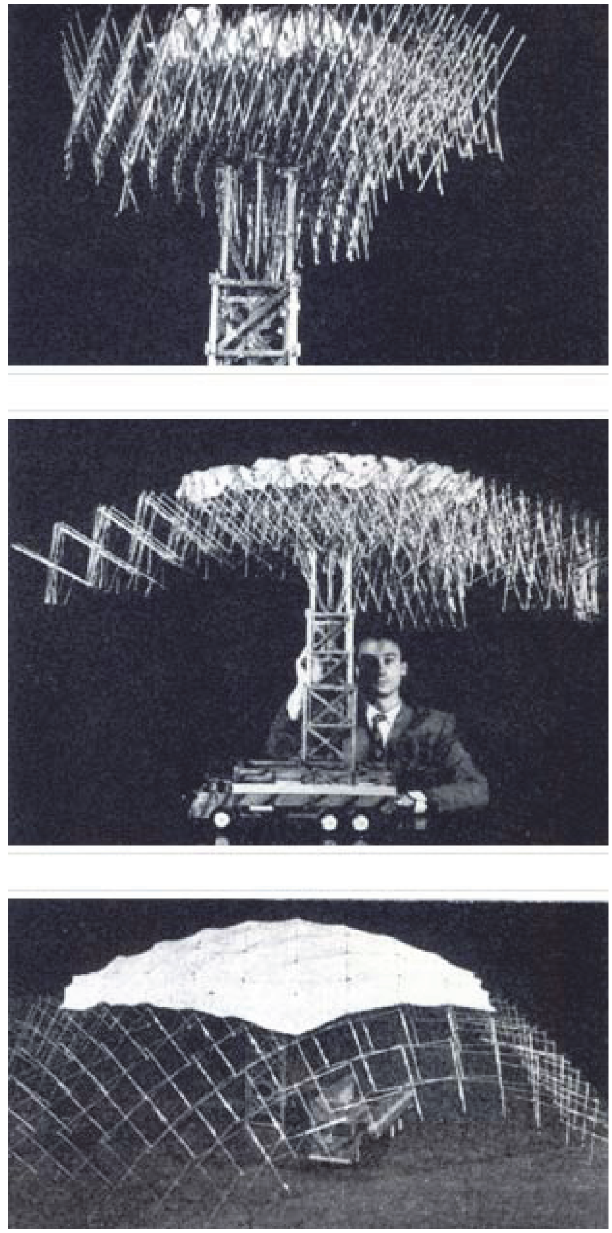


Sequence of the Hoberman Arch during the opening of the 2002 Winter Olympic Games (Poucke 2012).



Section showing the placement of the motors used to control the opening of the curtain (Schumacher 2010).

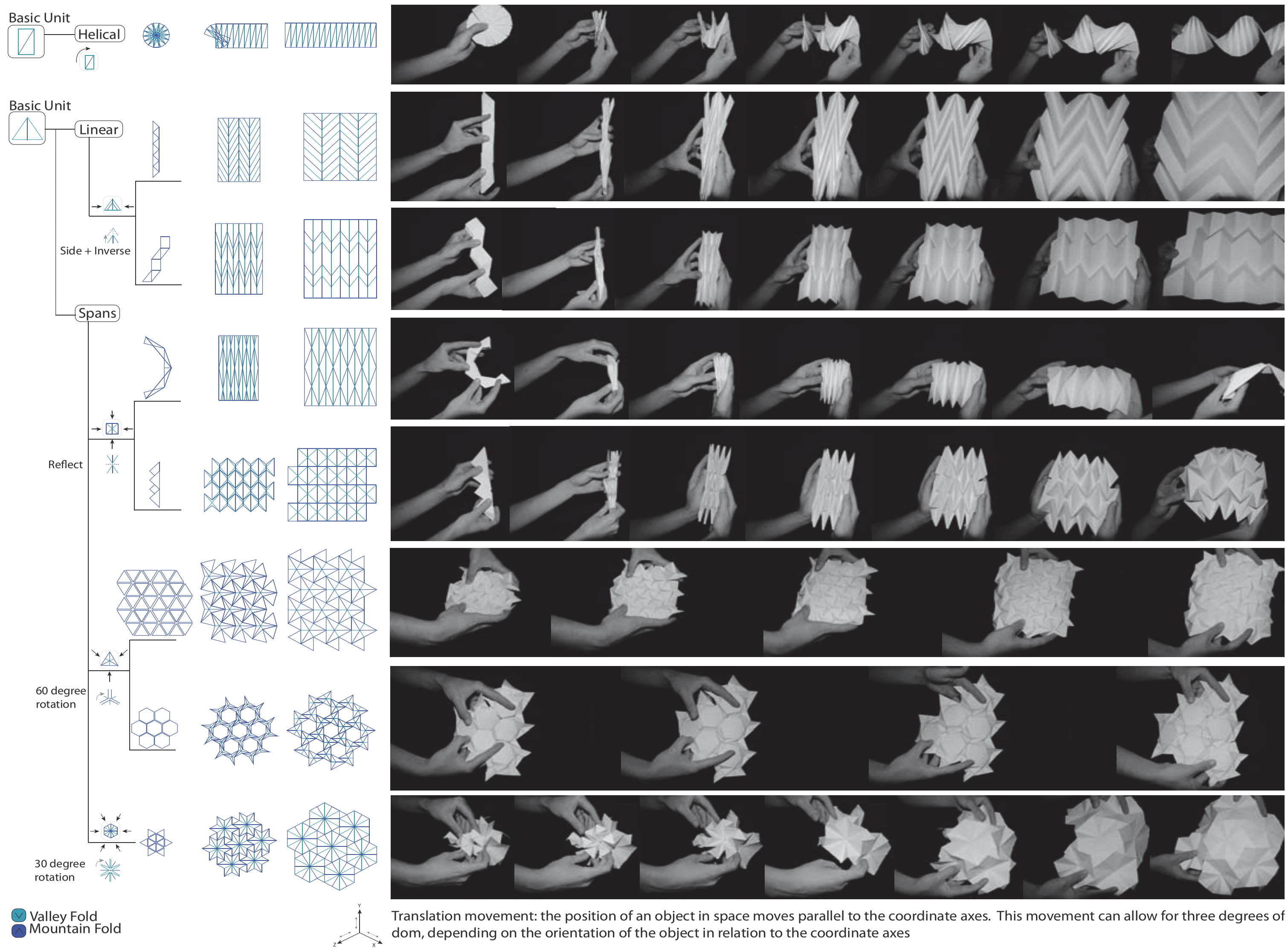
Another example is a design by Emilio Perez Pinero created in 1961 as a self-erecting mobile theatre. The entire structure is capable of being launched from a tower attached to the back of a truck. This control tower supports a dome constructed of a three dimensional lattice geometry. During erection the bundles unfold, forming the domed shaped roof. Pinero also experimented with a membrane that would be integrated with the structure to further simply the construction process (Zuk 1970, 50).



Working study model for a traveling deployable theatre (*Emilio Perez Pinero Foundation* 2012).

Studies in Collapsible Geometry

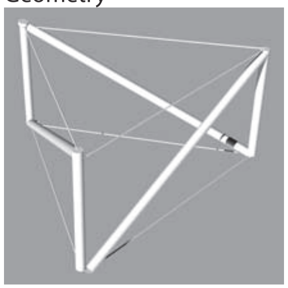
The initial studies were created from paper folded origami used to understand the base cell of collapsible design and their accompanying archetype patterns. The base cell of a triangle that undergoes a geometric transformation was extracted from this study and turned into a three dimensional unit to become the germinating cell for a double layer grid structure.

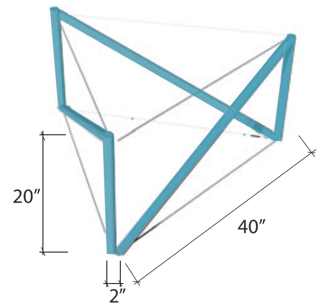


Translation movement: the position of an object in space moves parallel to the coordinate axes. This movement can allow for three degrees of dom, depending on the orientation of the object in relation to the coordinate axes

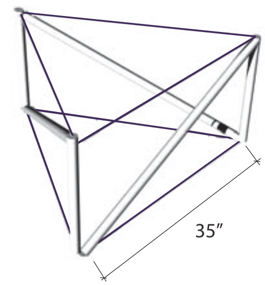
This study is organized from the base cell and what geometric transformation the cell undergoes to create the deployable pattern.

Geometry



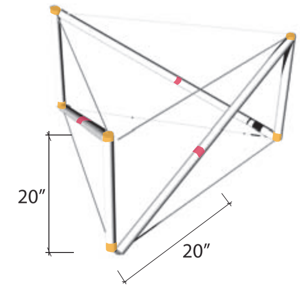


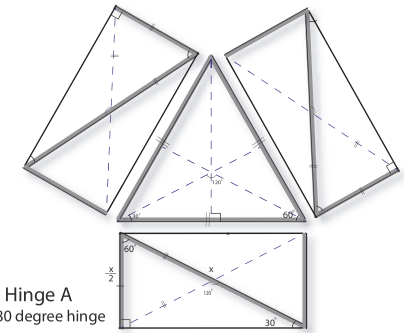
Aluminum Round HSS Struts



Tension Cable

The tension cable allows the cell to fold together by becoming slack when the vertices are moved toward the center of the triangle.



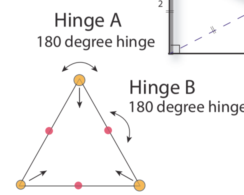


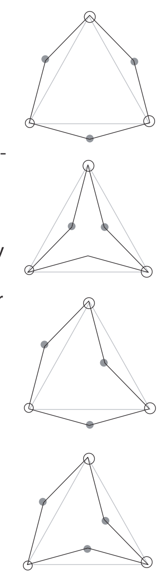
Hinge Joints

Movement of the vertices toward the center of the triangle allow the hinge joints in the center of the strut to fold to the interior or exterior of the geometry.

The equilateral triangle only has four possible configurations of folding.

The most successful configurations involved a combination of both interior and exterior folds, this allowed the three dimensional geometry to fold into a two dimensional form which is ideal for collapsing and storage.





All sides of the triangle hinge to the exterior of the geometry

All sides of the triangle hinge to the interior of the geometry

One side hinges to the interior, two sides to the exterior

One side hinges to the exterior, two sides to the interior

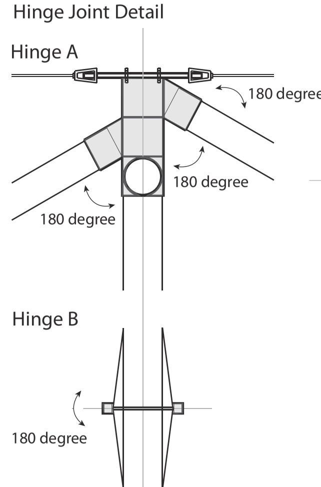
Hinge Joint Detail

Welded plate
Steel cable
Cable clips
Rotating sleeve

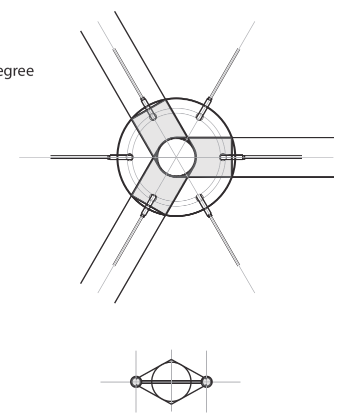
Aluminum round HSS
Diagonal strut

Aluminum round HSS
Spacer strut

Gusset plate
Hinge pin



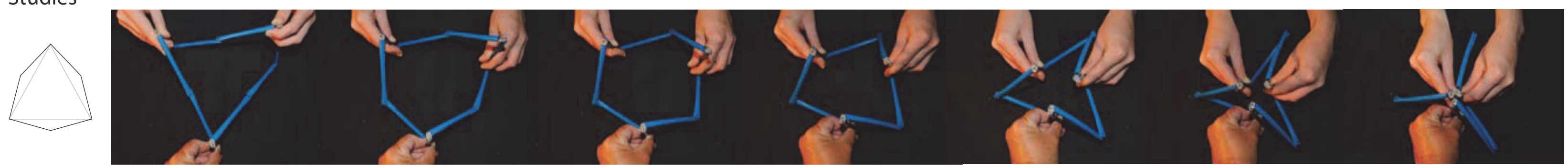
Elevation

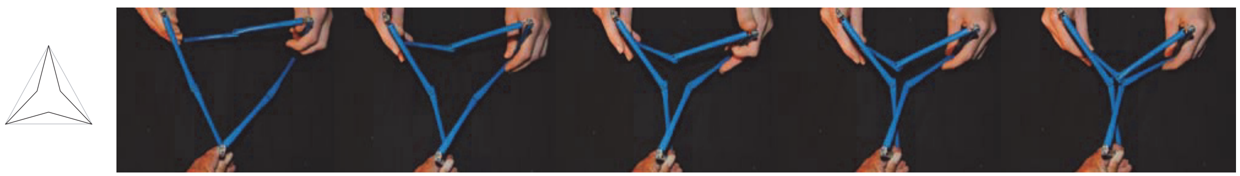


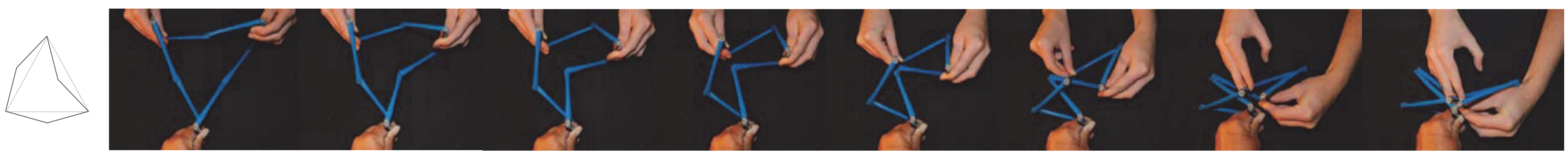
Plan

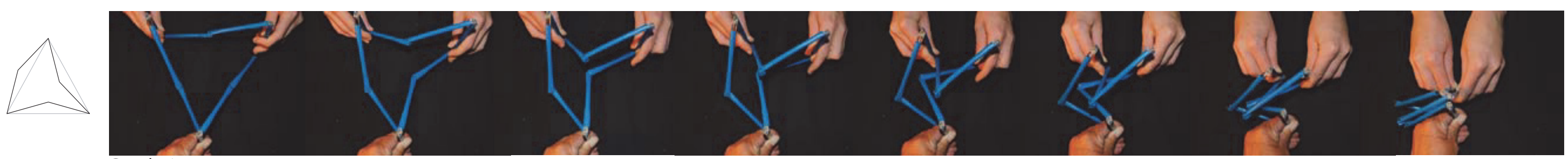
Studies in the geometry of the germinating base cell, as well as the hinge joints to allow the geometry to collapse.

Studies









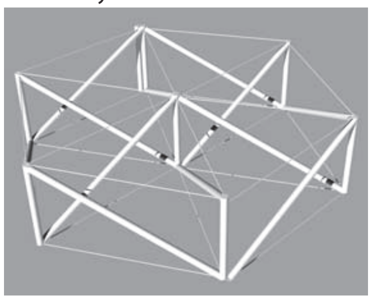
Conclusions

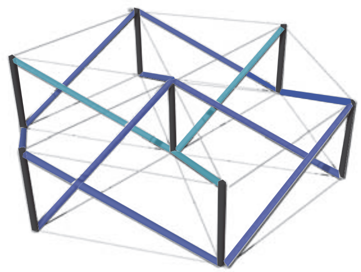
The exterior hinge is ideal because it is independent in its movement; it does not cross paths with another strut. However the geometry folded in three different directions making it difficult to add additional cells that could collapse in this same manner. As well, the geometry collapsed in volume but not in diameter making it an unsuccessful collapsing pattern.

The interior hinge had the most limited movement, the sides of the triangle folded into each other at the hinging point. This geometry also collapsed in volume but not in diameter.

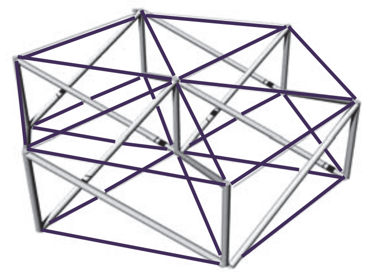
The combination geometry was the most successful. Each transformation was able to fold into two dimensions, forming equilateral triangles in section. A possible concern is the triangle with the two interior folds as they cross paths, however within a larger field of cells the direction that the vertices move might allow for one interior fold to move first and the other to follow.

Geometry

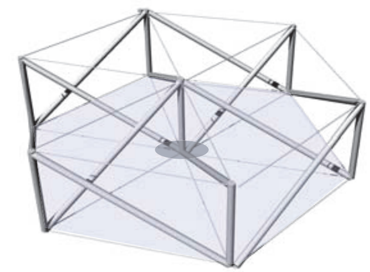




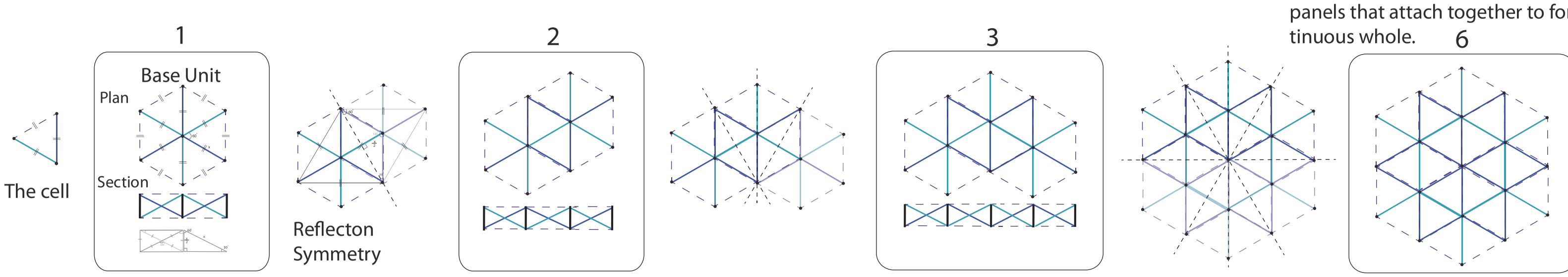
Aluminum Round HSS Struts



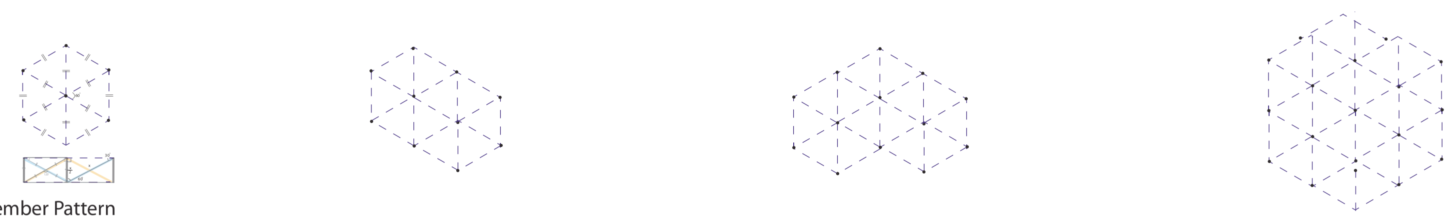
Tension Cables



Fabric Membrane
The membrane is attached to the interior structure and consists of multiple fabric panels that attach together to form a continuous whole.

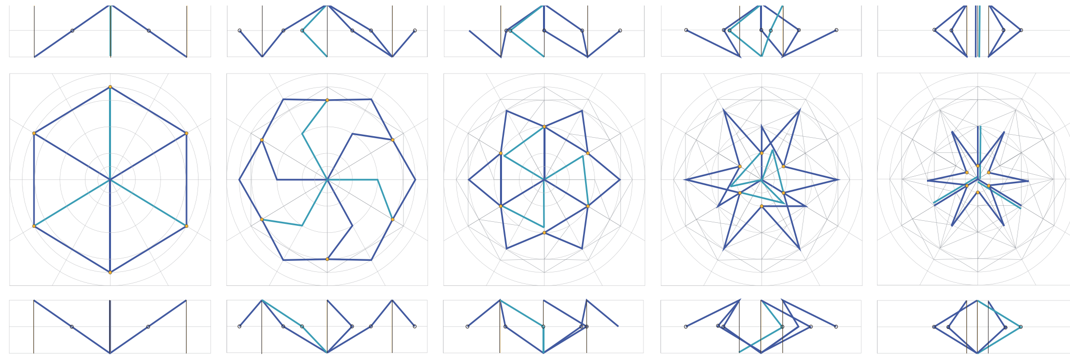


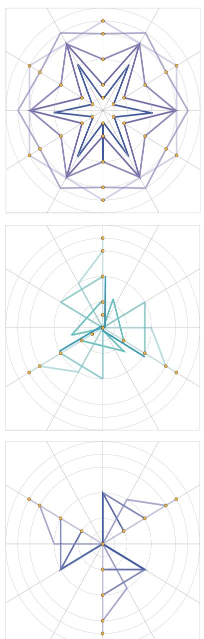
Compression Member Pattern

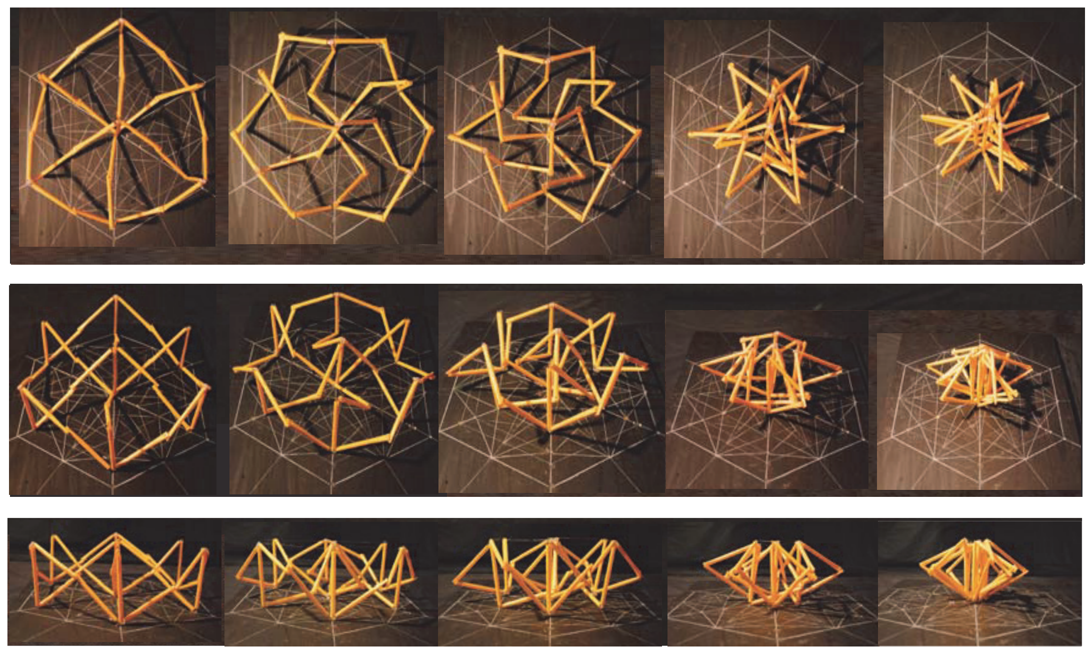


Tension Member Pattern

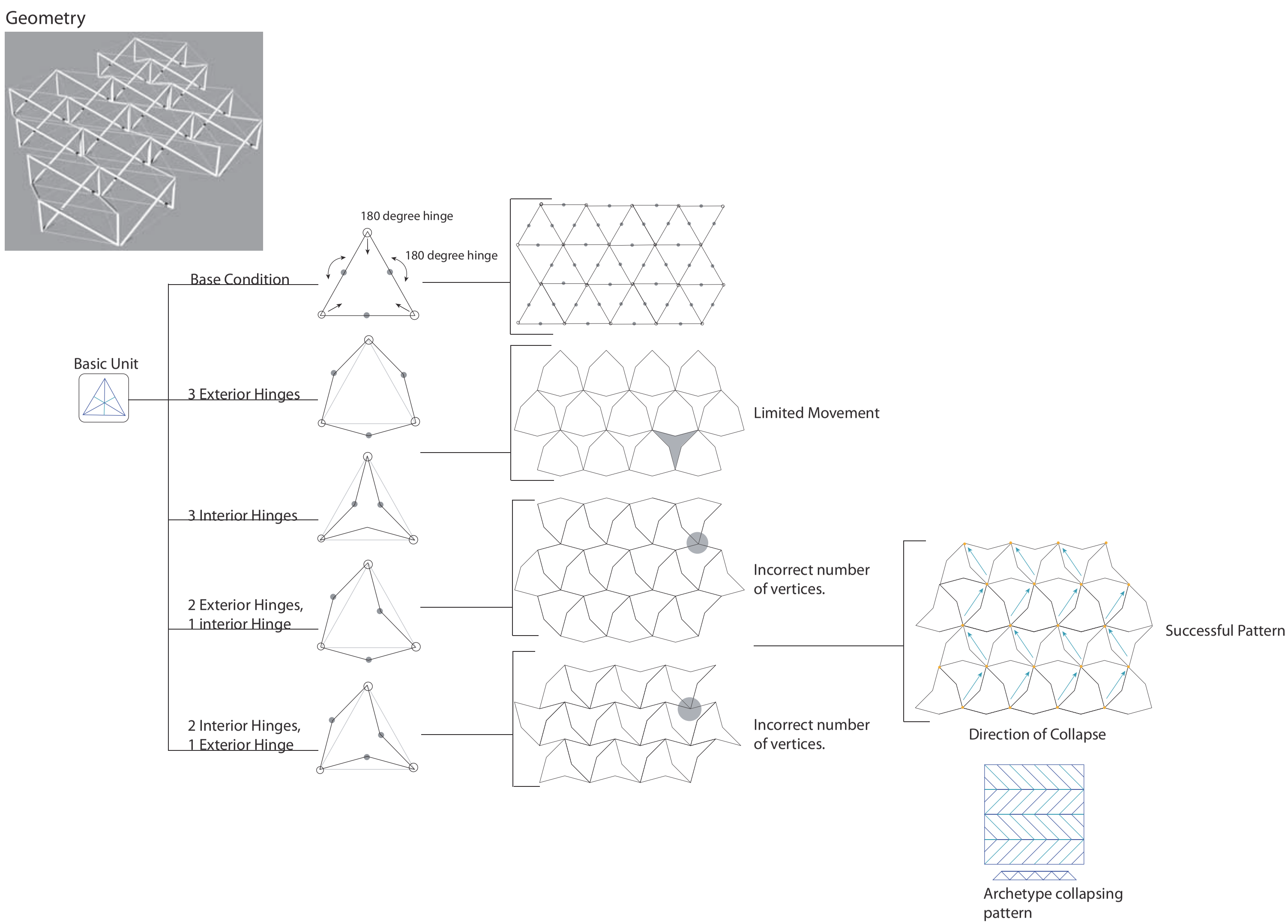
Studies in the geometry of the base unit of the structural geometric pattern. Within the hierarchy of structure the base unit consists of six cells forming a hexagon, the hexagon would then become the germinating unit from which the structural form is achieved.





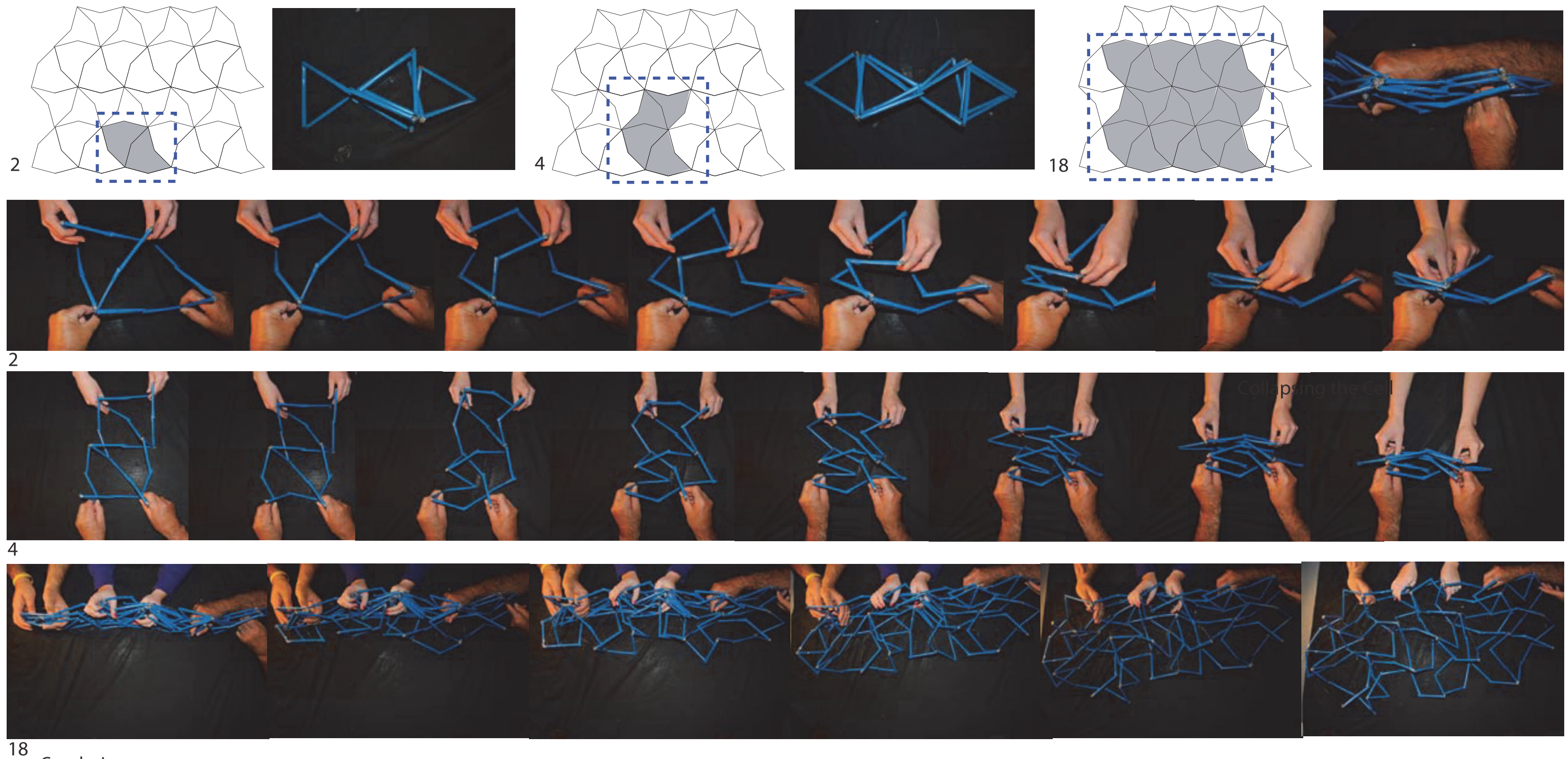


This study was unsuccessful because of the nature of the collapsing geometry. This collapsing unit could not make a continuous surface with the addition of more units that would collapse in the same manner. As well, the unit could only collapse to half the dimension of its diameter.



This study, like the initial study, looked at the collapsible base cell and its geometric transformations to create a deployable pattern.

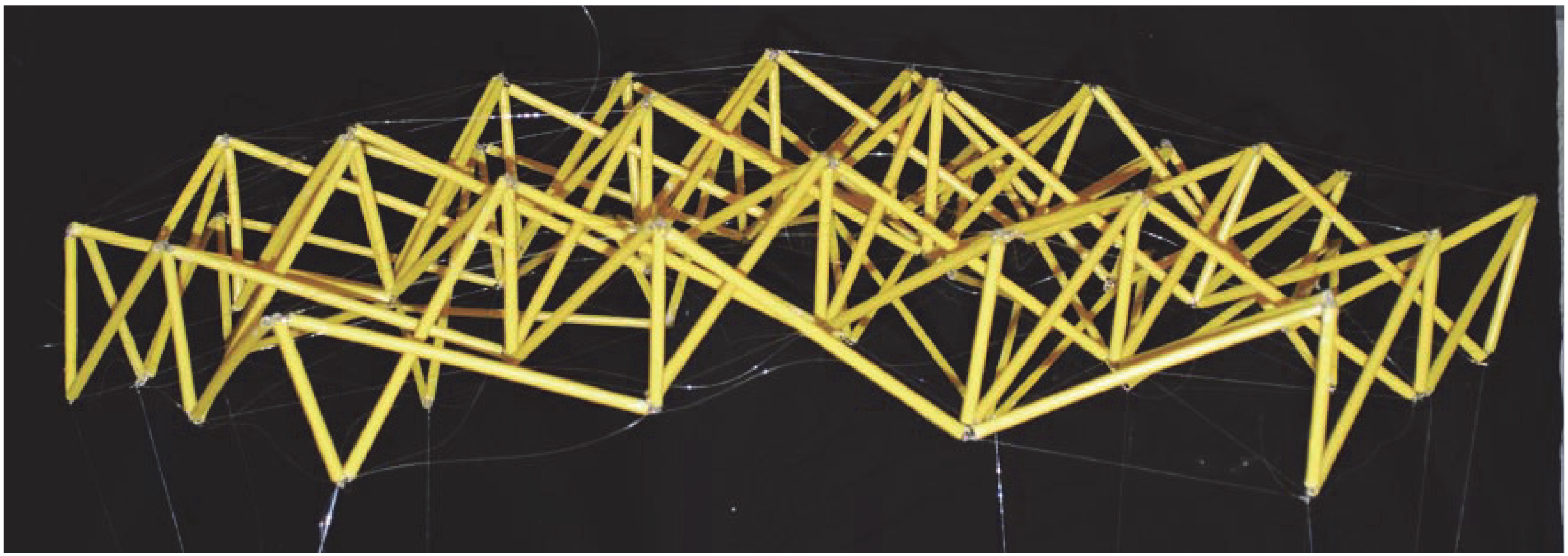
Studies



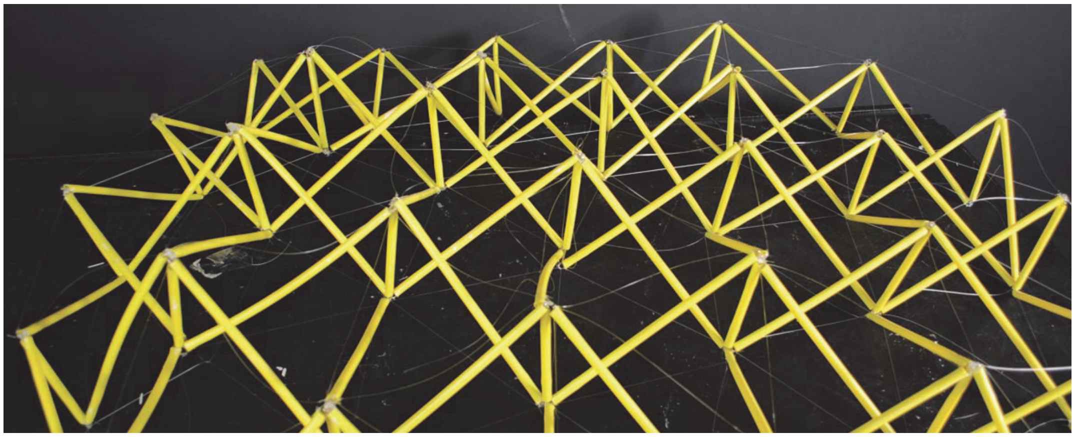
Conclusions

The tessellation of the base cell will collapse in a linear movement pattern. This pattern is successful because of the repetition without variation of the base cell, allowing the unit to collapse into equilateral triangles. However, this might become problematic in translating to a spanning structure without altering the dimensions of the structural tessellation pattern.

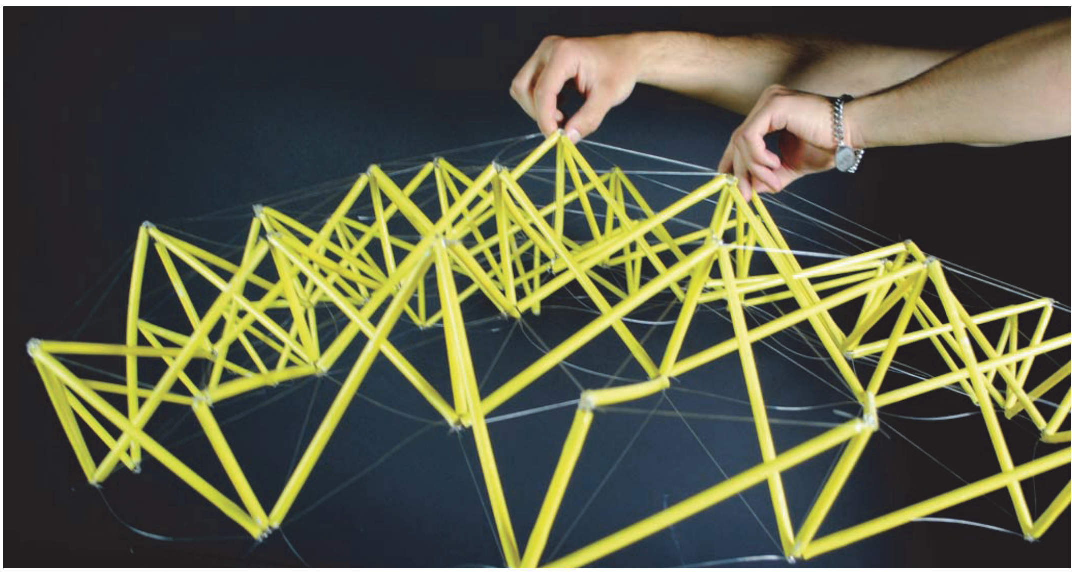
This study demonstrates the testing of the deployable geometry. This was accomplished by incrementally collapsing several cells until a suff cient number was reached to be conf dent of the success of the deployable pattern.



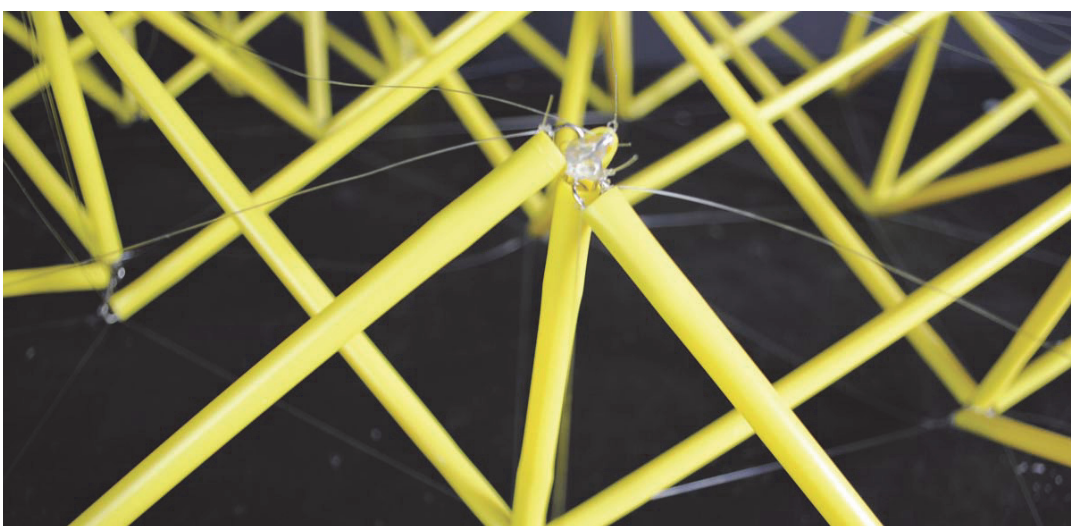
1:10 Structural model hung to determine the placement and length of the tension wire, which would determine the degree of curvature.



This image was taken before the tension wires were pulled tight to show the strut pattern of the structure.



This image was taken after the tension wires were pulled tight to show the curvature.



This image is a closer detail showing the repeating strut pattern, as well as the sketch model connection detail.

CHAPTER 2: DESIGN

Application Context

Site

In 2011 a permanent 400 metre speed skating oval was constructed on the southeast corner of the North Common after the success of a temporary oval that was constructed in the same location for the Canada Games the previous winter. The Emera Oval has become a popular social gathering space during the winter months, hosting 3500-5000 public skating participants each day. The Oval is free and open to the public from December to March, 7 days a week and offers skate rentals to the public free of charge. (Halifax Regional Municipality 2012)

The program for the Oval during the winter months includes public skating, skating lessons, speed skating clinics, competitions as well as winter festivals. (Halifax Regional Municipality 2012)

Permanent facilities for the Oval include six refrigeration units to artif cially freeze the ice during the more temperate winter months in Halifax. As well, a maintenance and power building is located directly adjacent to the units.

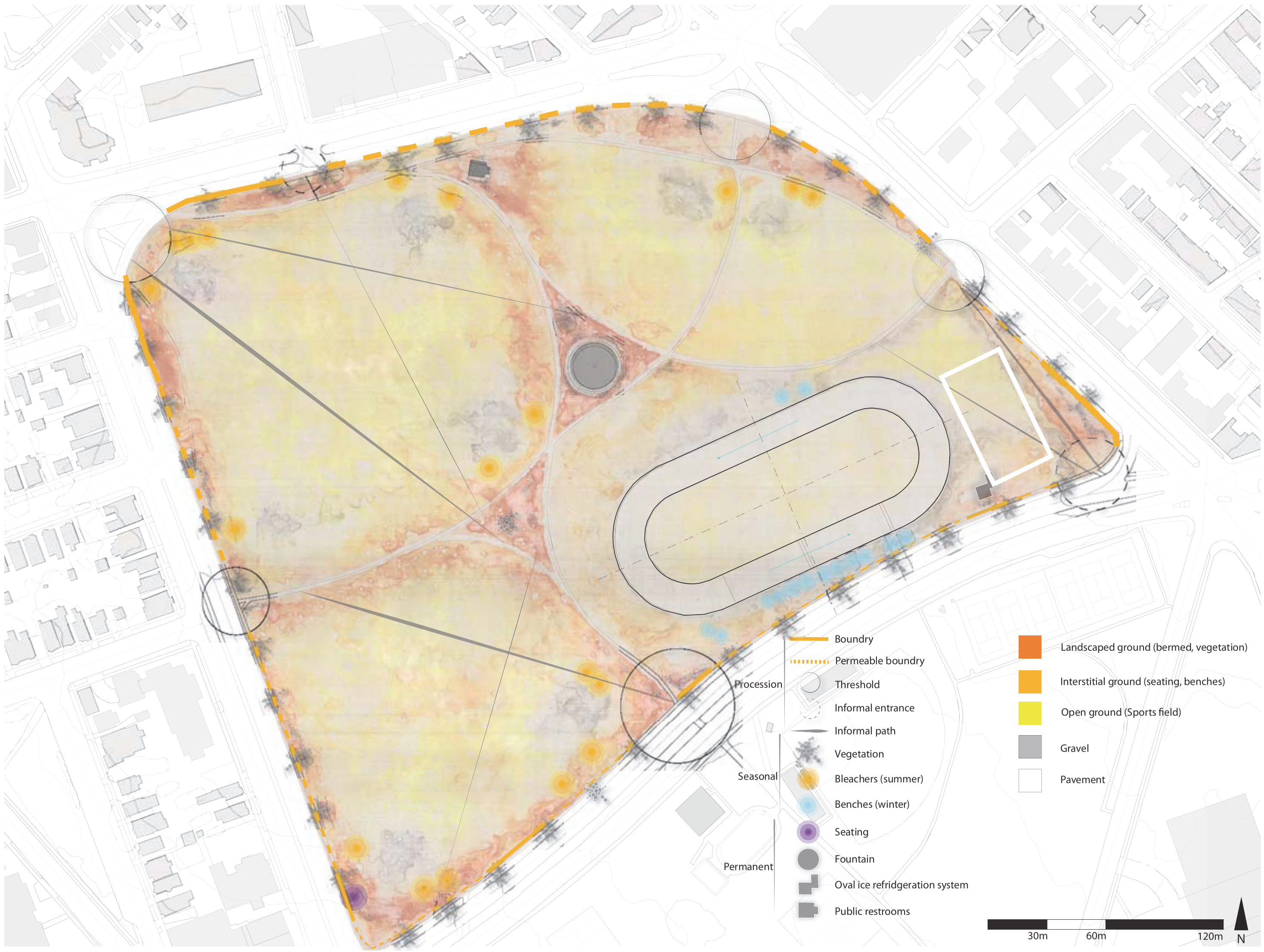
The Oval has seasonal structures to facilitate the inf ux of winter program. Three temporary site trailers to house the skate rental facilities, staff off ces and a staff breakroom are located on the southern side of the Oval. A mobile stage for music festivals is trucked in during the winter months. Benches and space heaters also line the southern edge of the Oval where participants can change footwear, sit and socialize as well as grab food from one of the on site food vendors. Portable toilets and the Zamboni storage shed are temporary facilities set up for the winter months. After the month of March all of these facilities are removed from the site and all that remains is the concrete pad of the Oval.

Site Analysis/Existing Conditions

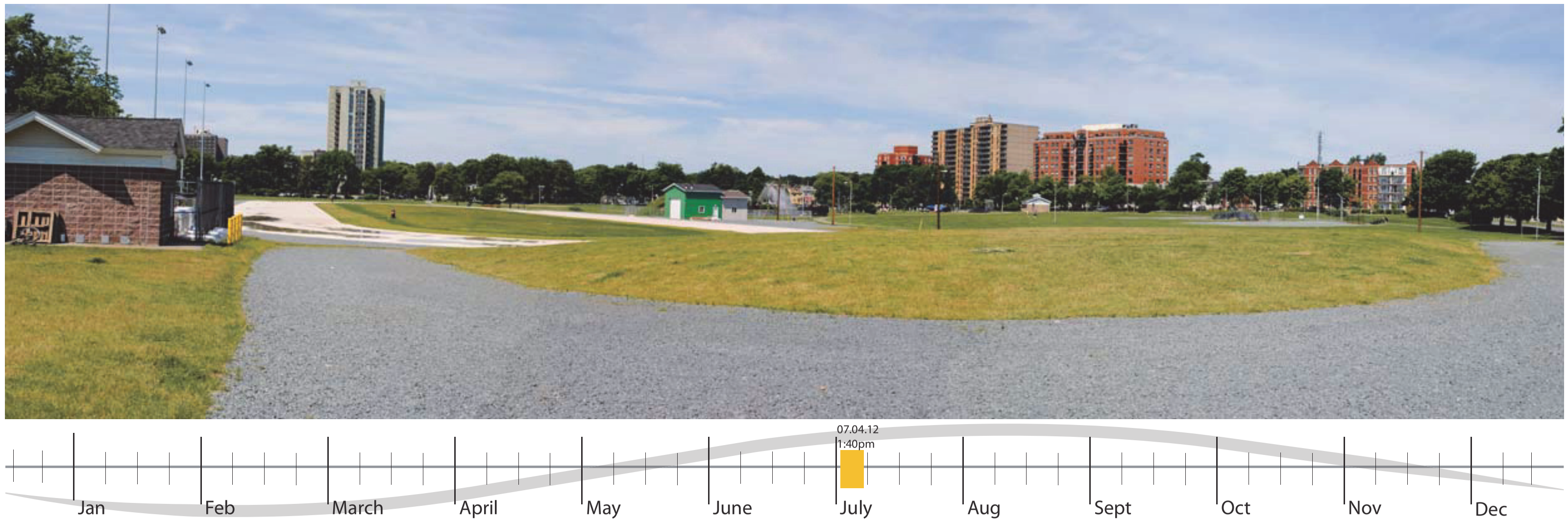
Outlined in this section are the current site conditions of the Oval, showing the programmatic occupation of the site throughout the year. The analysis shows a lack of programmatic use during the summer months (May-October). This thesis will address the inf ux of seasonal use with a temporary theatre that will consist of both permanent and impermanent elements.

Southwest aerial view of the North Common, 1969. Outlined is the area currently occupied by the Emera Oval (Oostveen 2011).

The existing site conditions and temporary winter infrastructure for the 2011-2012 season.



Site analysis of the existing conditions of the North Common prior to the design intervention. The map shows boundary conditions, temporary interventions, permanent structures and ground conditions. Outlined in white is the location of the temporary theatre.



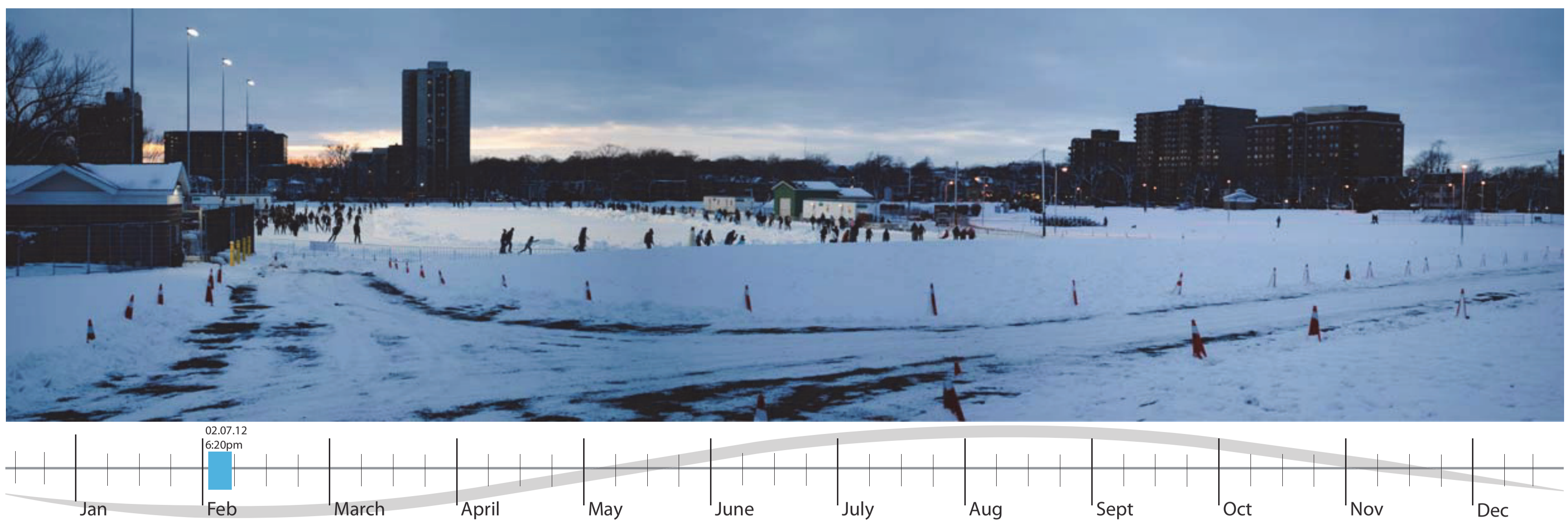
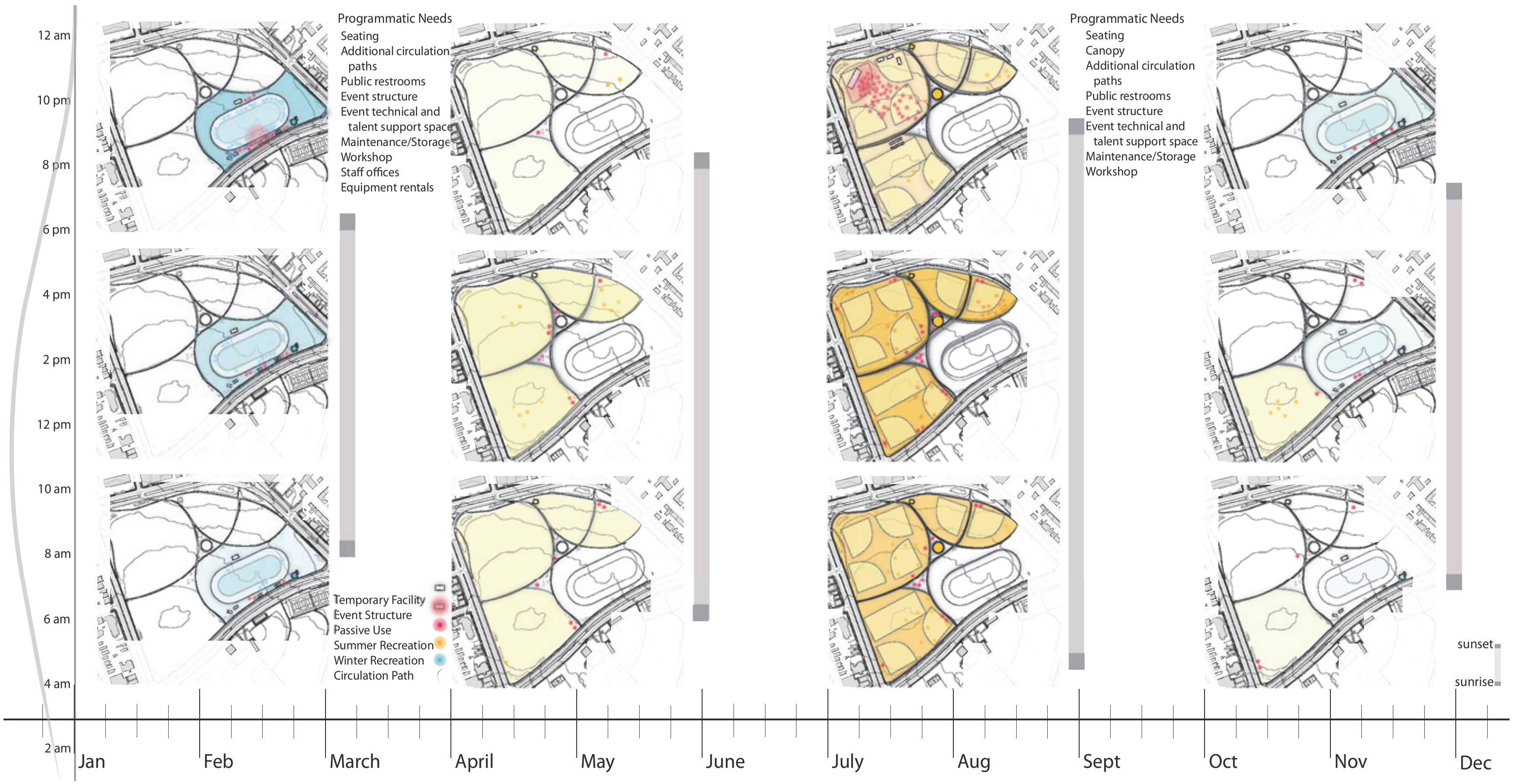
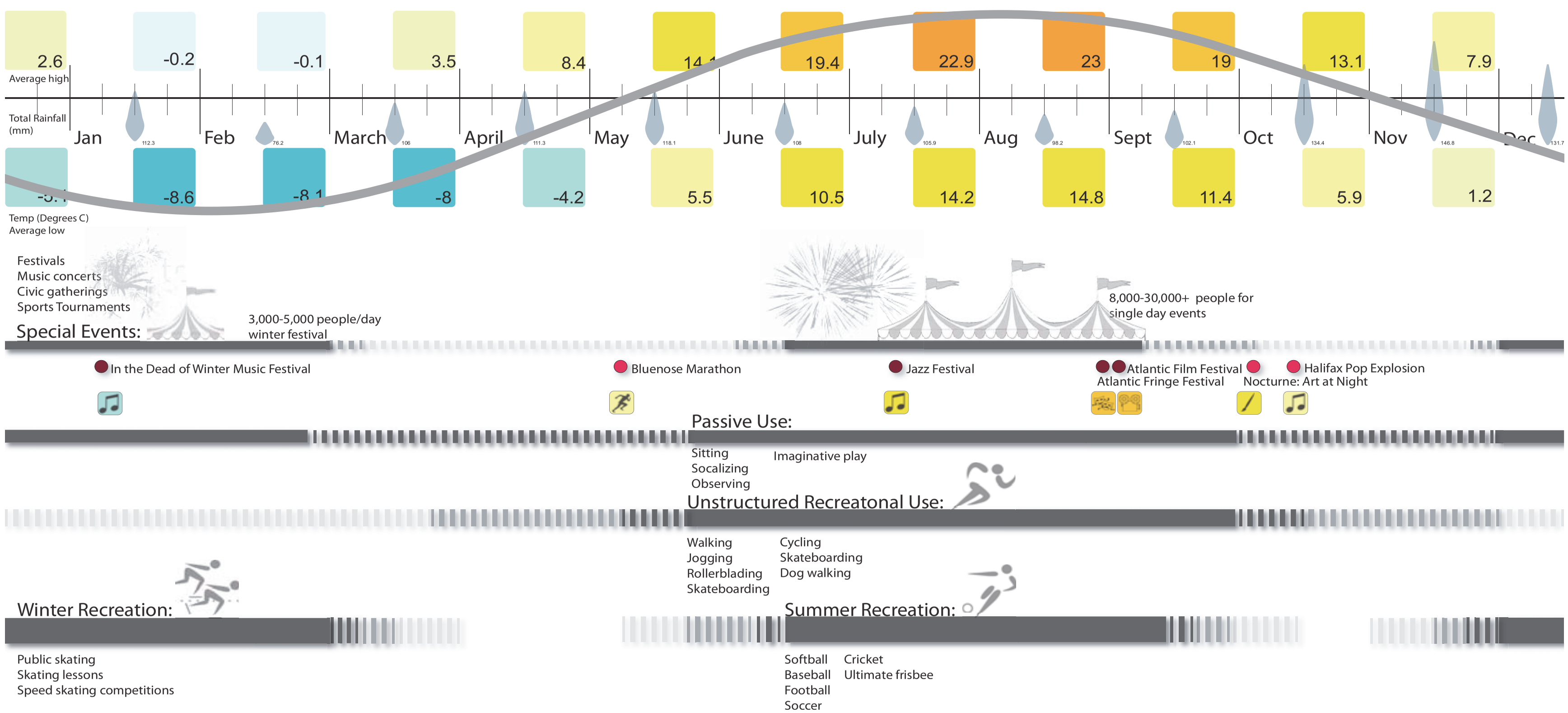


Image taken from the east side of Oval, showing lack of programmatic use during the summer



Study of activity level and occupation of the North Commons throughout the year.



A program diagram of the events that take place during the year on the North Common

Final Design Work

Program

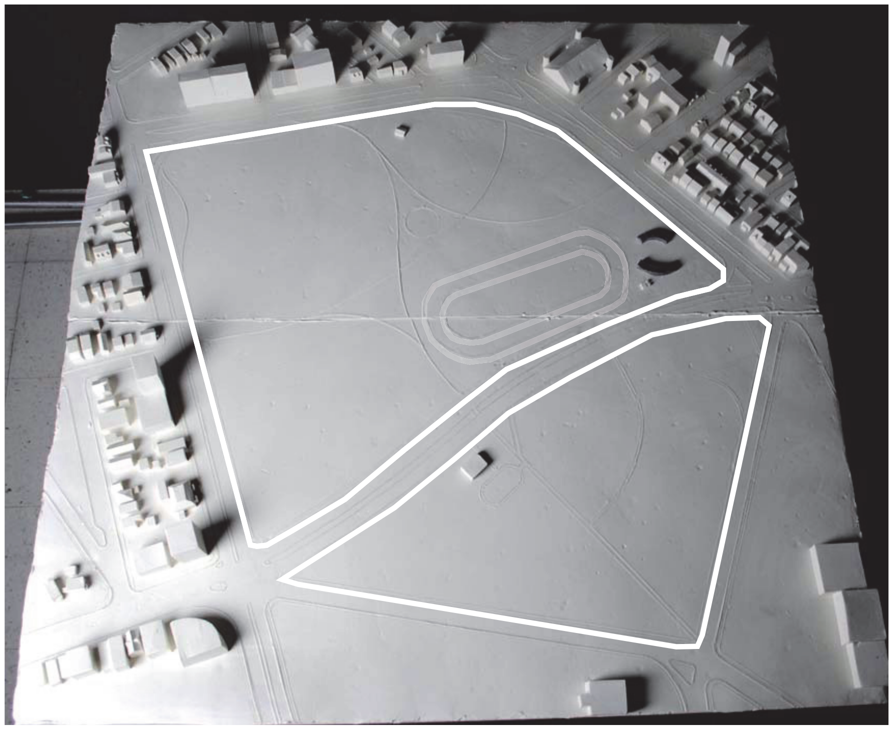
To facilitate the use of the Oval throughout the year as a gathering space this thesis proposes a program of a 200 person theatre located on the east side of the Oval that is capable of hosting a variety of festival events from May - October. The theatre will be comprised of two parts: a temporary deployable canopy and permanent seating and facilities for the Oval.

The theatre will become a venue for traveling festivals, as well local talent that otherwise do not have the facilities to hold outdoor public performances. The seating of the theatre will become a permanent place-making insertion on the North Common, and will function as an amphitheatre for traveling festivals during the summer months and transition into stadium seating for the Oval during the winter months. The main challenge of the seating will be to study the views of the audience towards the stage as well as towards the Oval.

The support facilities for the theatre that require enclosure include administration off ces, a ticket booth, dressing rooms, a green room and storage. The support program for the theatre will also be permanent, but will be designed so that in the winter months these spaces might transition in programmatic use to support facilities for the Oval. The support spaces for the winter months include equipment rentals, staff off ces, a staff breakroom, and a storage and maintenance space.

The theatre enclosure will be a deployable long span structure that will be erected for a duration of f ve months, therefore important design considerations will be durability, waterproof ng, as well as assembly, disassembly and storage.

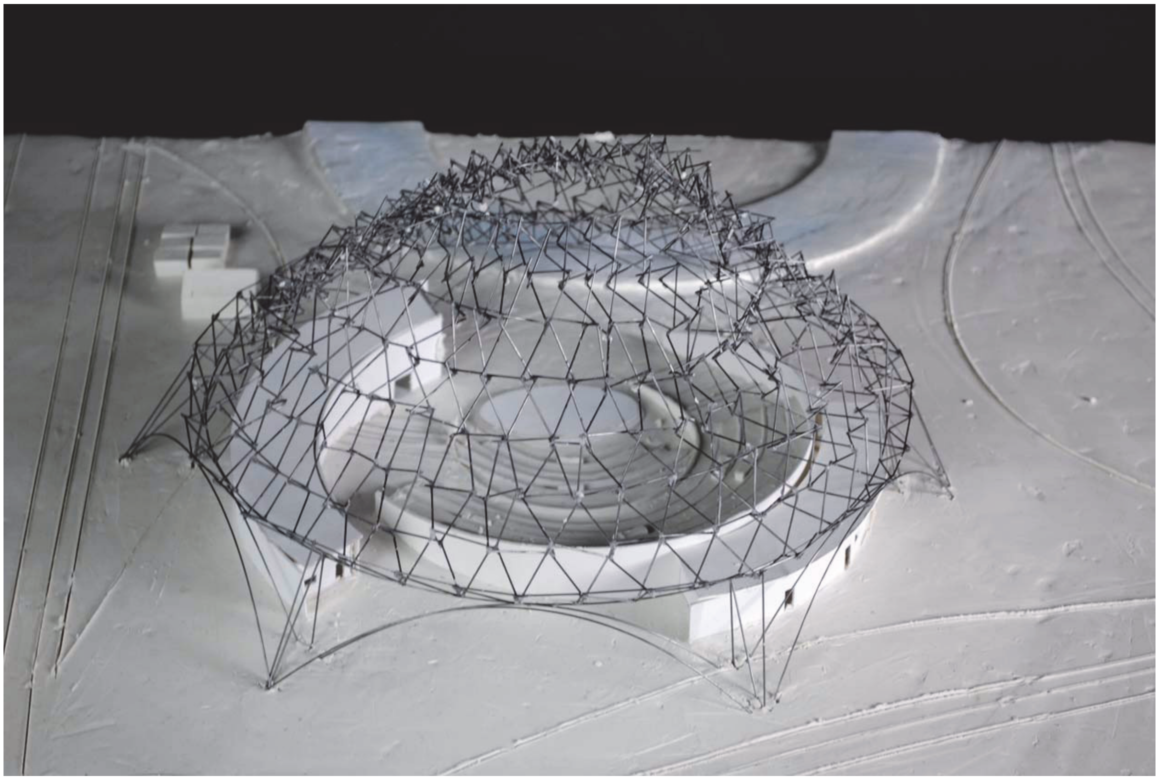
The placement of the structure on the east side of the Oval was optimal because of the direct connection to the downtown area as well as the existing site being the maintenance entrance, which is ideal for the trucking in of infrastructure to deploy the canopy.



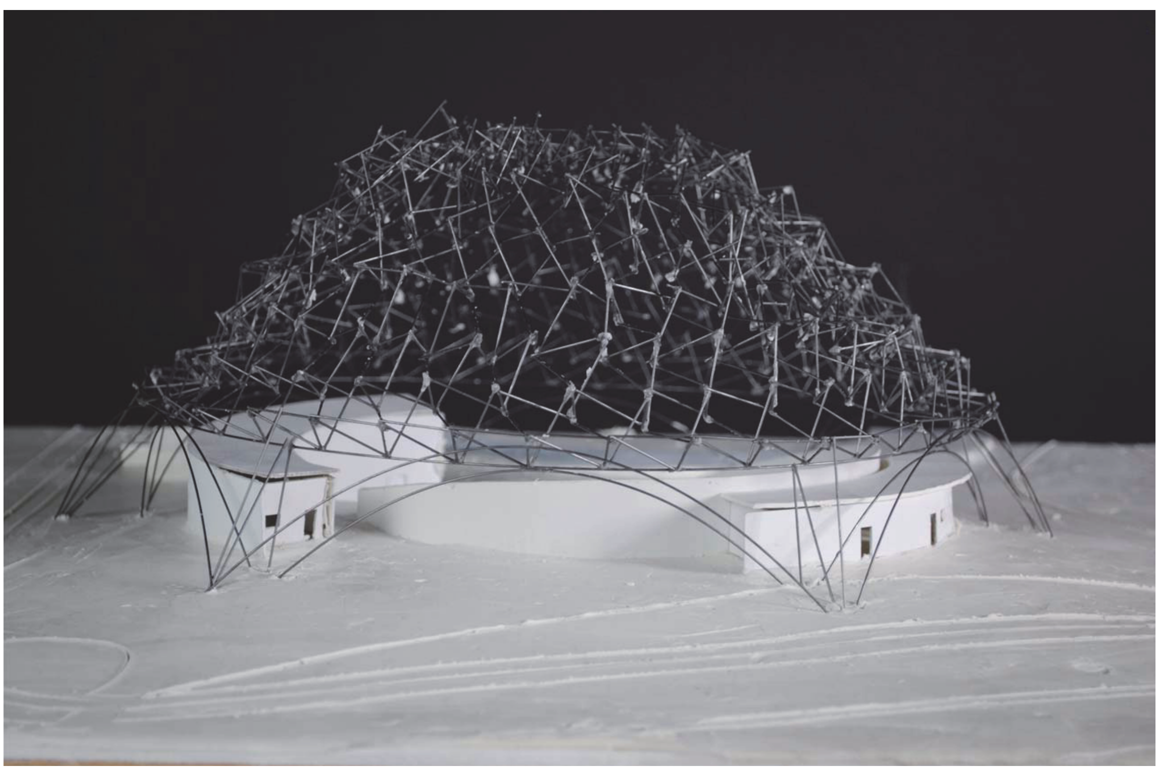
Massing model showing both the North and Central Commons with the location of the permanent theatre elements.

A closer image of the massing model showing the east side of the Oval and the surrounding area.

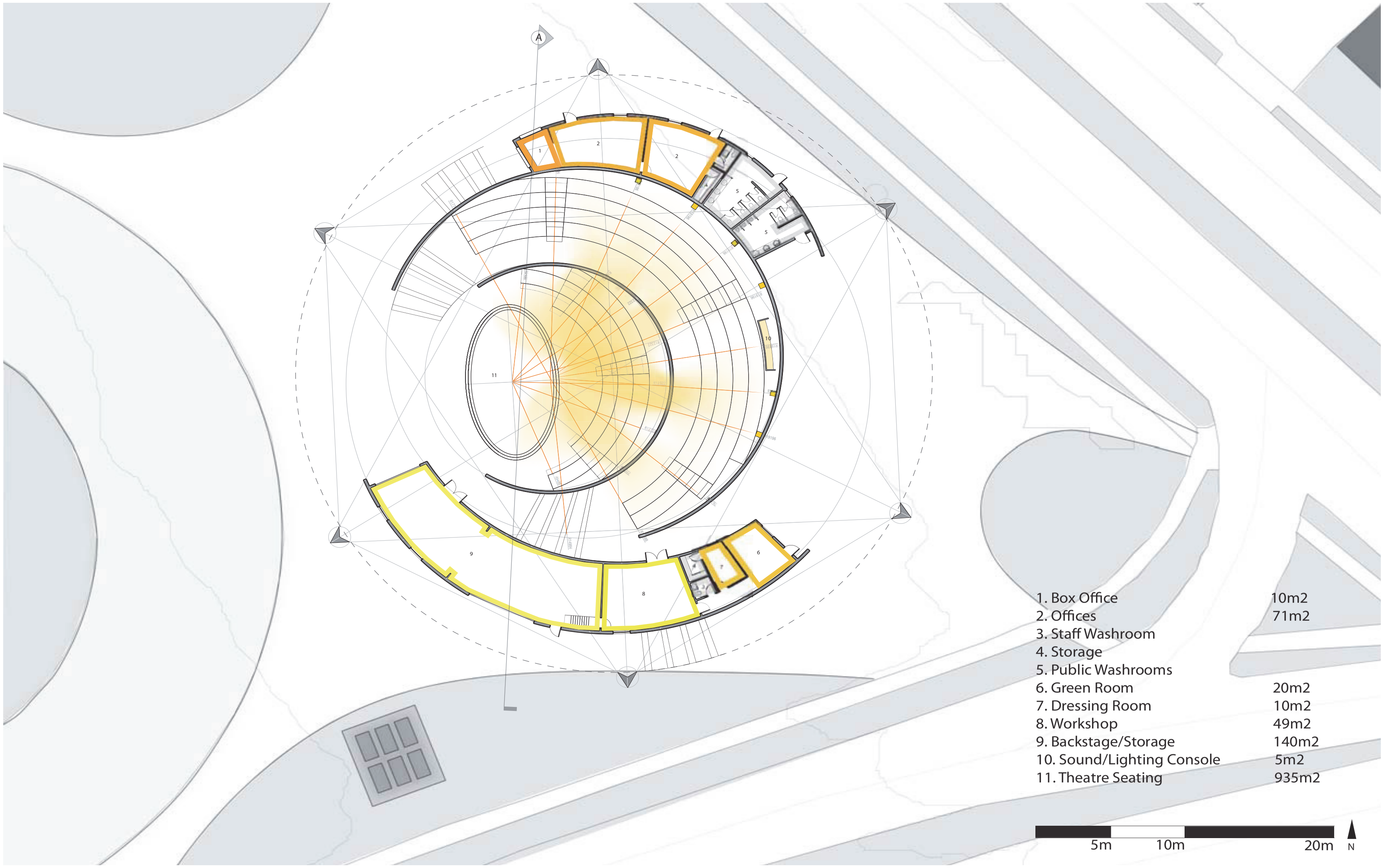
1:200 Model showing the theatre in relation to the Oval, as well as the permanent existing refrigeration units and maintenance building.



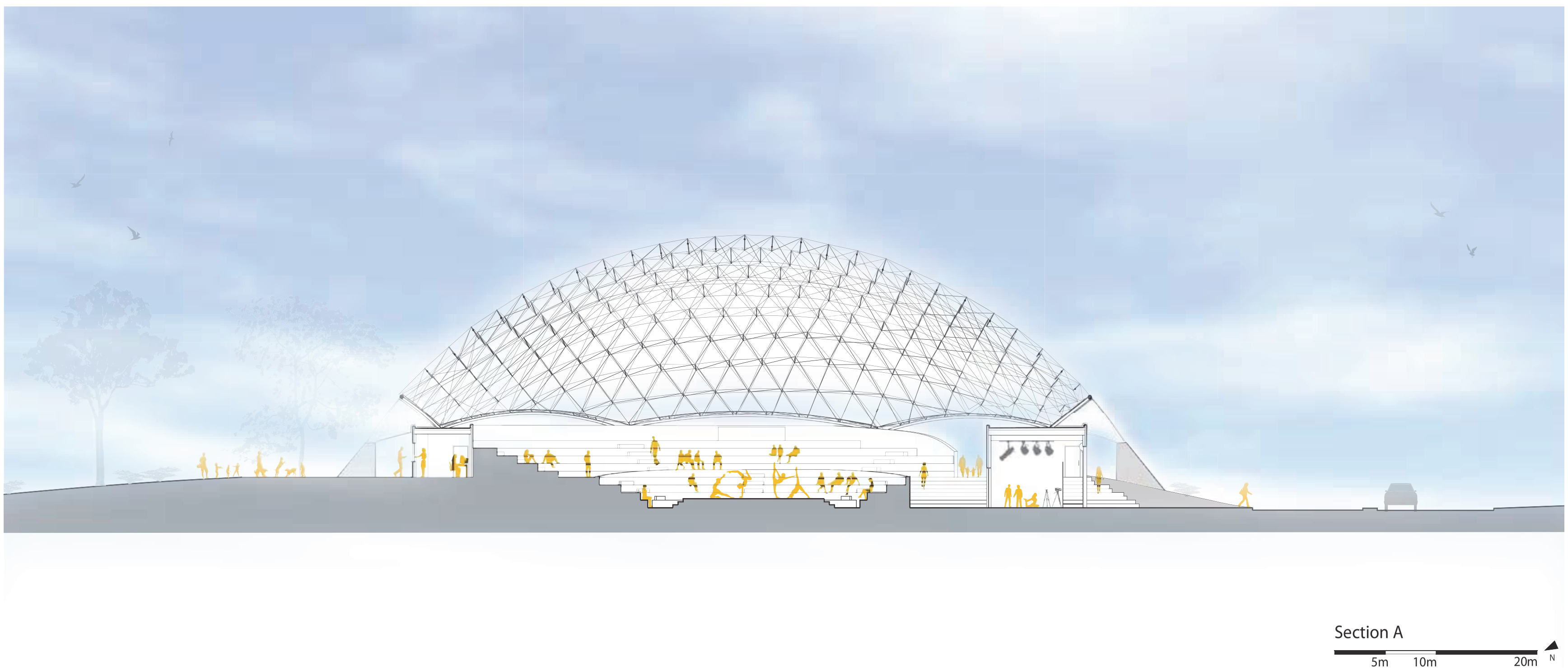
The materiality of the model differentiates between permanent and impermanent structure.



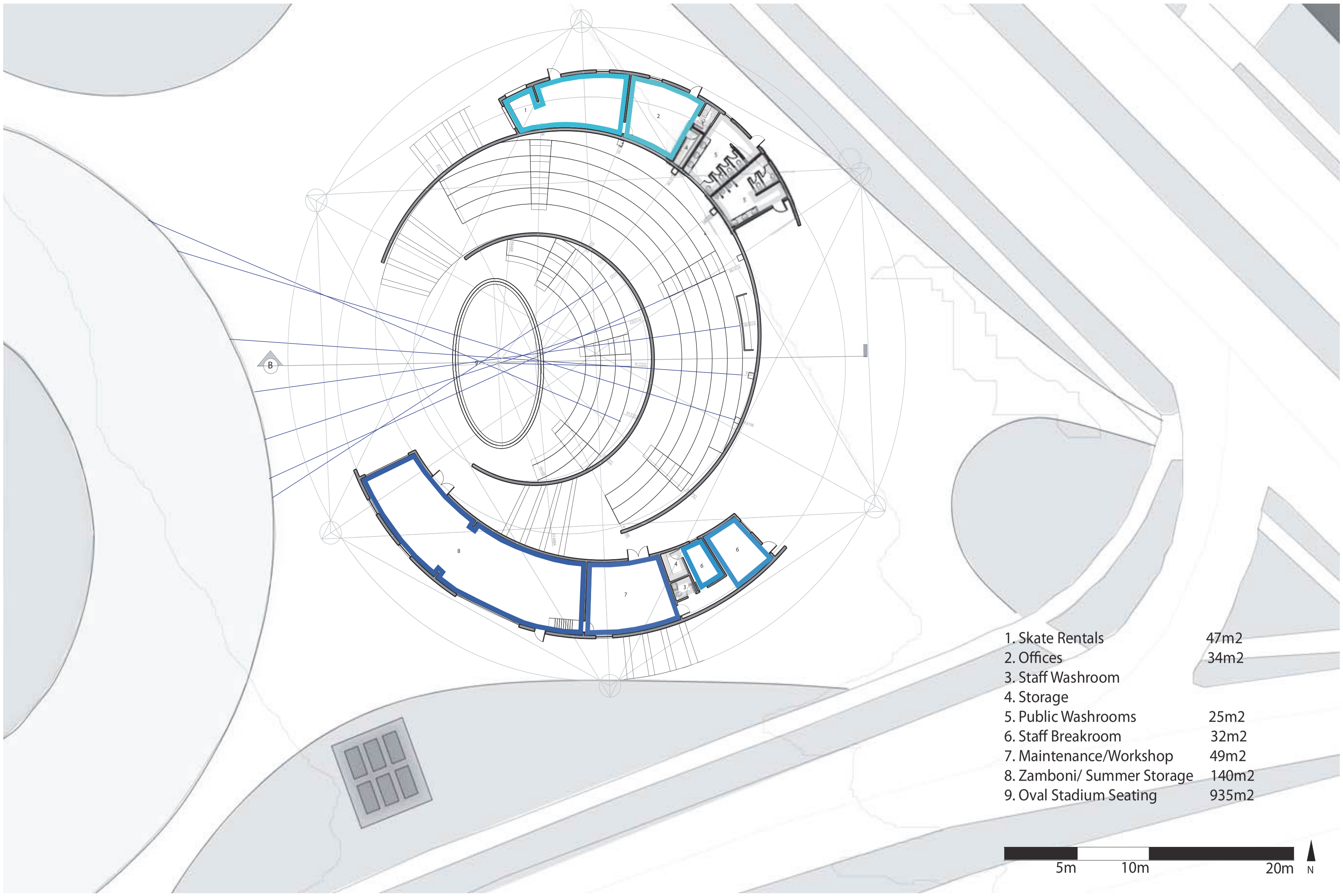
An image of the east elevation of the structure looking toward the oval.



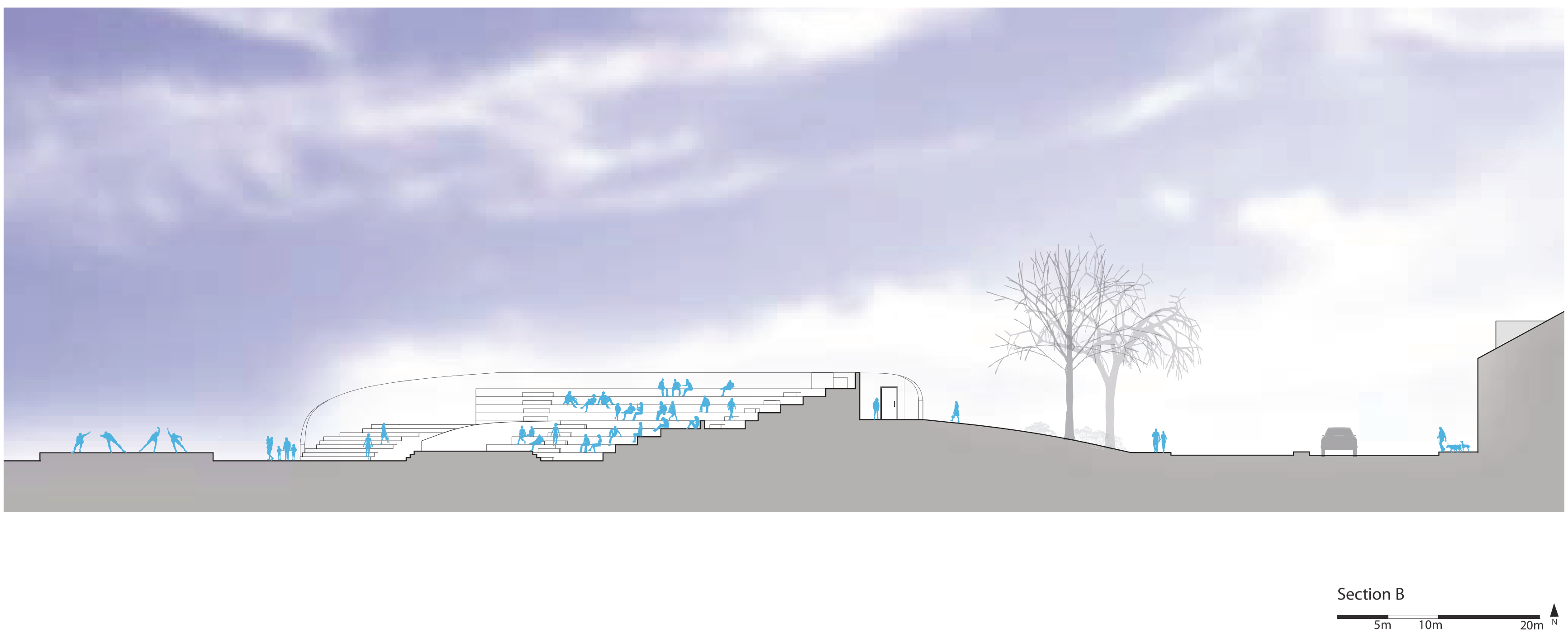
Plan showing summer programmatic use.



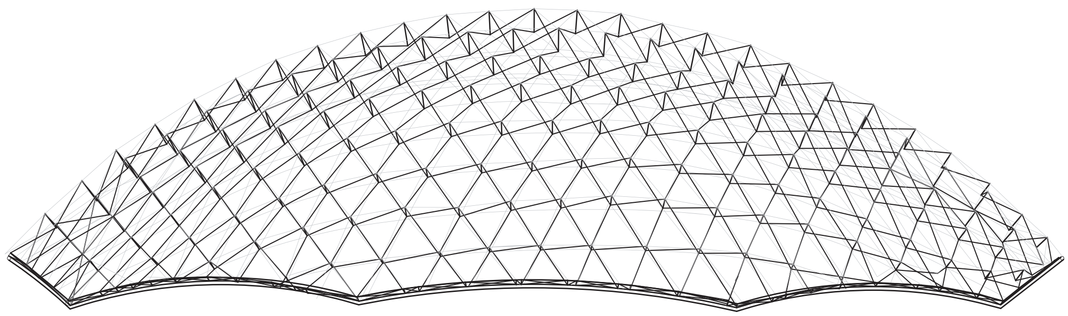
Section showing summer programmatic use.



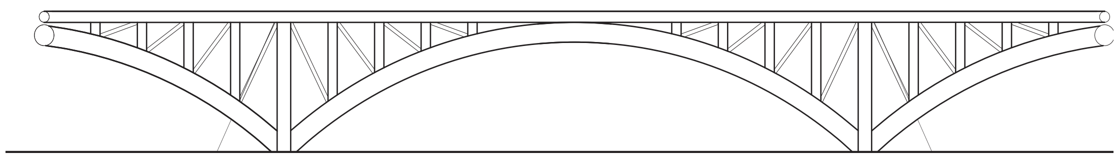
Plan showing winter programmatic use.



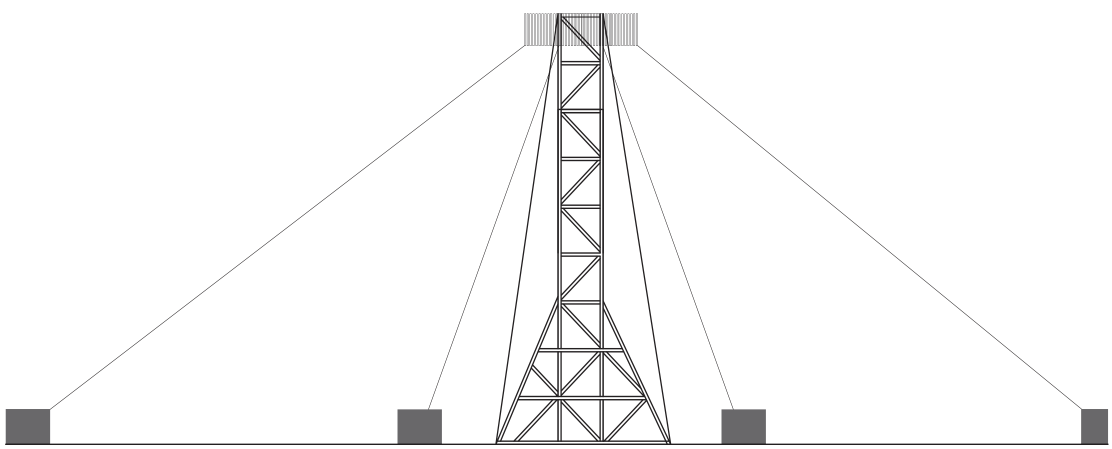
Section showing winter programmatic use.



1. Lightweight deployable dome constructed from aluminum pipe and tension cables with a fabric membrane.



2. Impermanent structural base consisting of buttressed compression arches that the dome is secured to and transfers the weight and force of the dome into the ground. The base also acts as a tension ring to keep the dome from falling outward to its exterior edge.



3. Space frame tower that is constructed for the deployment of the dome and deconstructed after the dome to secured to the base. The collapsed dome is held at the top of the tower and pulled into its predetermined geometry by cables attached to winches on the ground.

Diagram showing the different structural elements of the deployable dome.

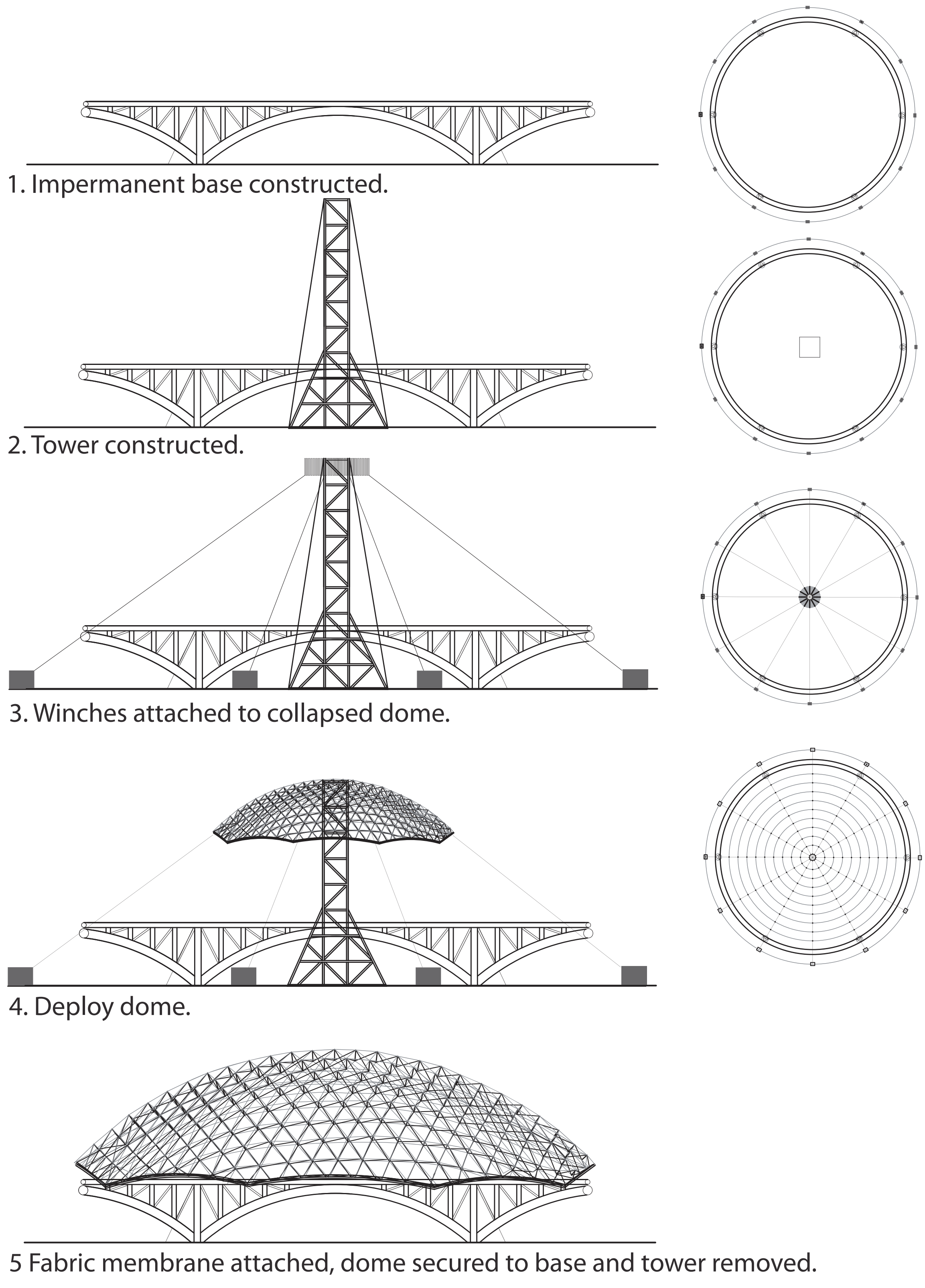
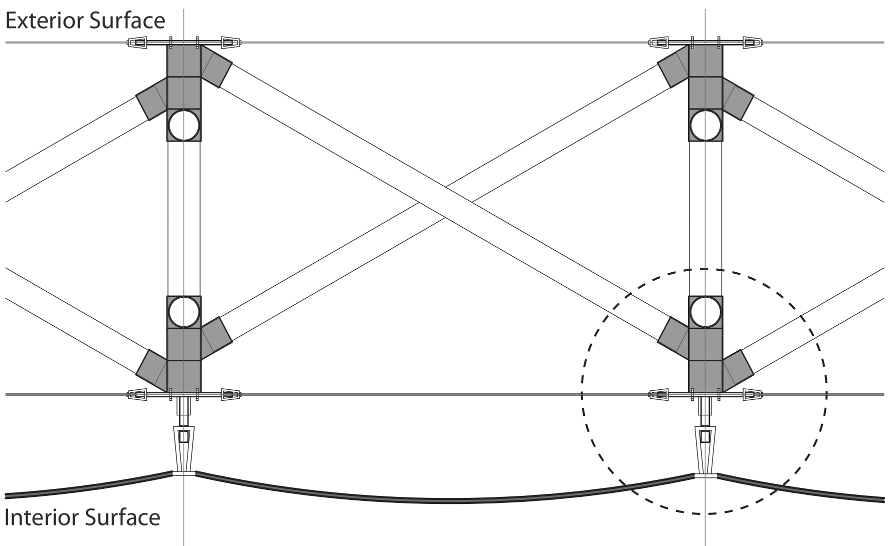
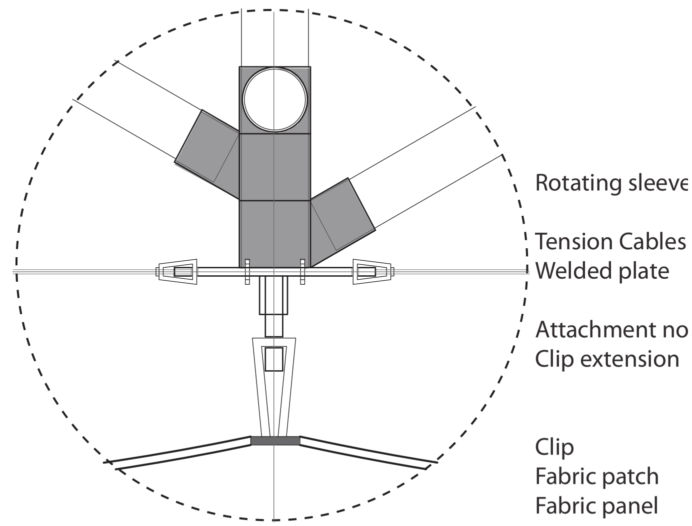
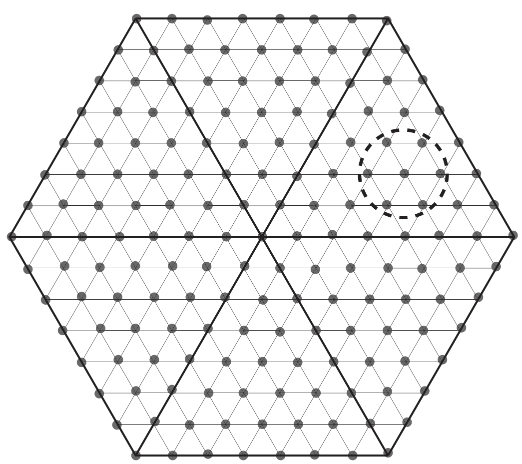


Diagram showing the sequence of construction to deploy the dome.



Structural Section with fabric attachment detail

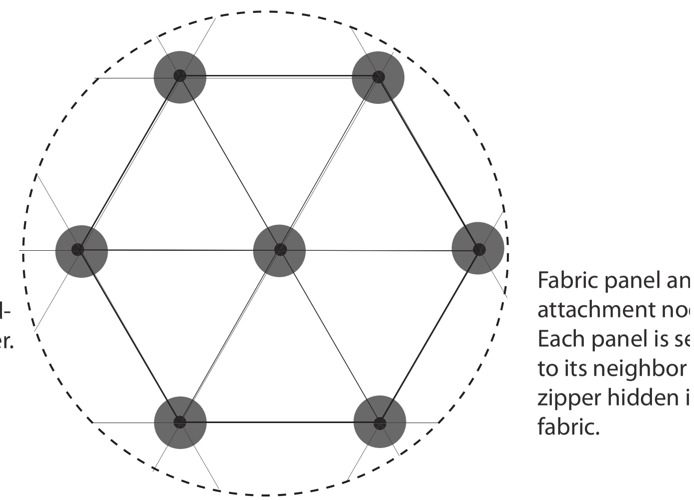




Plan view of the fabric pannel pattern and attachment nodes

Fabric skin pulled into a taut curve at each hub to prevent flapping and catching the wind.

Assembly involves attachment of individual panels that are clipped to the structural frame and then attached to adjacent panels by a zipper. The end result will look like one continuous membrane



Detail of skin attachment and fabric panel pattern in plan view.

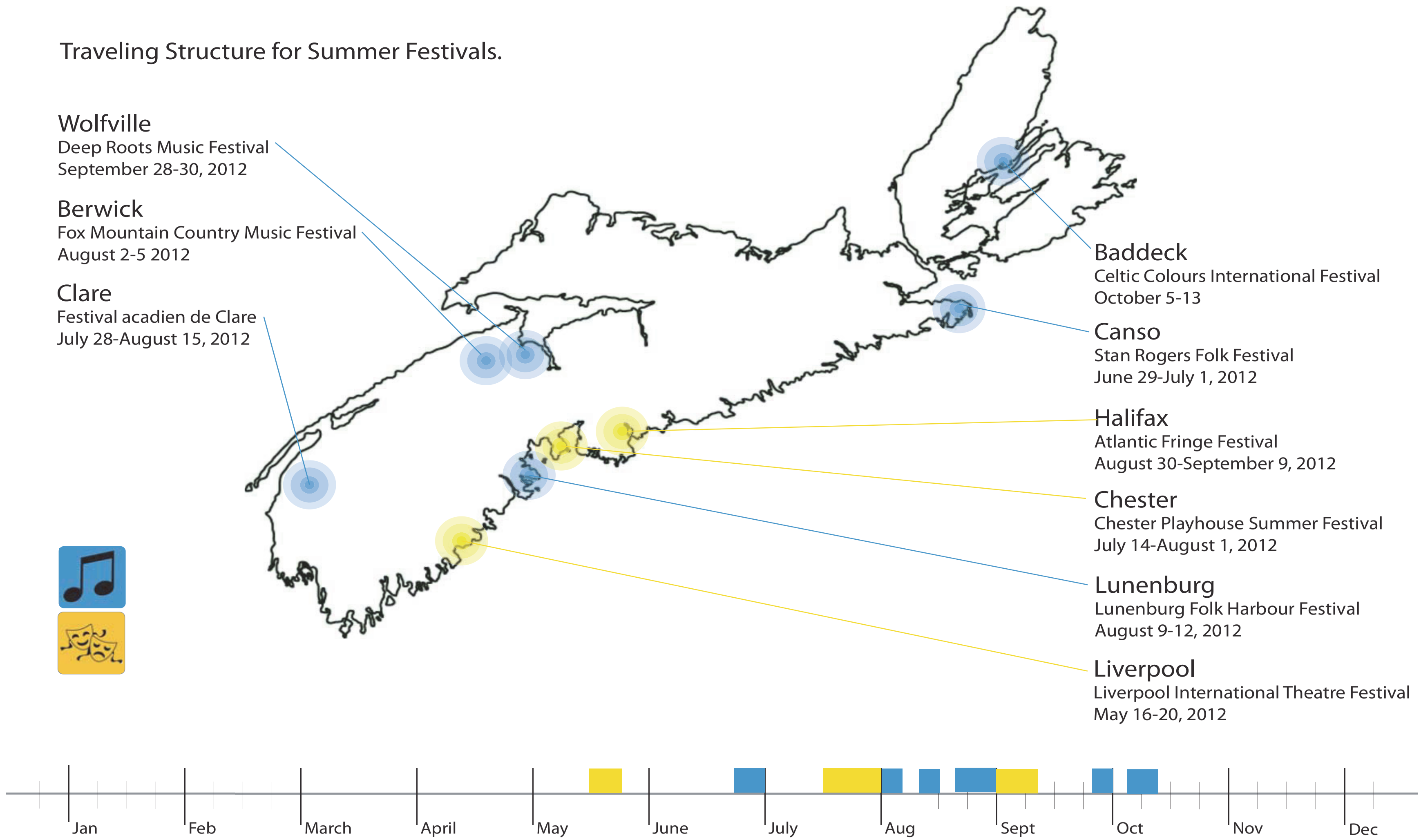


Diagram showing the expanded use of the structure as a traveling deployable pavilion for summer festivals throughout the Province of Nova Scotia.

CHAPTER 3: CONCLUSION

The goal of this thesis was to develop a long span deployable structure. Throughout the thesis the investigation was focused on collapsible geometry and the joints to achieve deployment. This was a crucial initial development of the design that could answer the initial thesis inquiry of assembly and disassembly. However, materiality was not addressed in this thesis to the degree needed to answer the questions of durability, structural stability, waterproof ng and storage.

The next stage in the development of this project would be to address the question of materiality of the structure to be able to construct a larger working model of the design. This would enable a more engaging consultation with a structural engineer to discuss issues of structural stability, limits and weaknesses to then modify the design accordingly.

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