ARCHITECTURAL CONNECTIONS:
Movement at Play

by:

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THANK YOU,

To my parents and sister for their continuing love and support.

To all my friends for their constant guidance and encouragement.

ABSTRACT

Architectural structure, ornamentation, space, and other elements are generated by different types of physical connections and materials. It is generally recognized that the conventional method of connecting is based on rigidity and statics. However, we know that the introduction of movement in architecture offers the possibility of making building more energy-efficient, user-friendly, experiential, and functional. This thesis investigates movement in connections and their relationship with space. A further step will be to explore how the incorporation of movement in architecture can alter the user's experience of space, interactions with space and understanding of space. As an architectural and constructional approach, this is then explored further for the framework of playground structures; an assemblage that provides an array of changing elements, encouraging users to reconfigure their environment and to stimulate curiosity and delight.

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INTRODUCTION

> If a building could mediate our needs and the environment outside:
>
> Its demand on physical resources could be slashed
>
> If it could transform to facilitate multi-uses:
>
> Its function would be optimized
>
> If a building could adapt to our desires:
>
> It would shape our experience. Michael Fox[1]

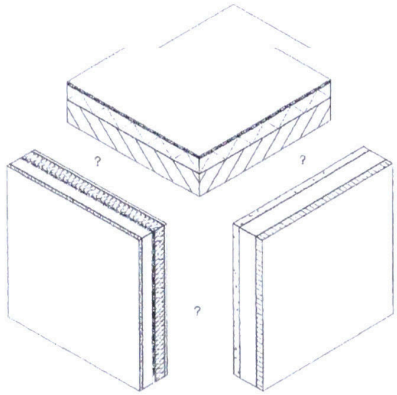
Materials and their connection to one another is what creates the functional aspect of architecture. Architecture that is capable of mediating, transforming and adapting could greatly enhance the architectural industry. In aspiring to attain these attributes, we are led to explore ways in which buildings can more energy-efficient, user-friendly, experiential, and functional. Can this be achieved by incorporating movement into architecture?

The construction industry has traditionally strived to create static structures. However, even within this stasis, a tolerance for movement is required in order for buildings to endure over time. Movement in architecture offers much more than an extended lifecycle, it offers options and change. It has the capabilities of adjusting to and for the environment and individuals. But what does movement in architecture mean for architectural space?

The effects that movement can have on space will be explored and categorized with the help of existing architectural precedents. Furthermore, the investigation of the users as activators of movement in space and how they can manipulate, reconfigure, experience, explore, and play with the possibilities of space will also be examined.

Architecture at its core consists of materials and their connections to one another. Changing the way materials are joined together, could change the way in which architecture is used, experienced, and functions. Therefore, in order to explore the possibility of movement in architecture, it is first necessary to examine the building joint.

1 Robotecture. "MIT Kinetic Design Group." Accessed January 17, 2012. http://www.robotecture.com/kdg/index.html



Connection of Functional Layers
Maarten Meijs and Ulrich Knaack. Components and Connections: Principles of Construction. Berlin: Birkhausen, 2009. P61

A . JOINTS

A.1 Intro

A.1.1 Definition

The Merriam-Webster dictionary defines 'joint' as "–a place where two things or parts are joined –a space between the adjacent surfaces of two bodies joined and held together."[1] The 'joint' is the place or part at which two or more things are put or brought together so as to make continuous or form a unit. Individual parts are joined to form components, which are then joined over and over again with other components in varying methods to eventually create a building.

For our purpose in this study there are two main applications for 'joints': to join similar materials or to join distinct materials/parts. This first application is based on the size of the component. For instance, due to manufacturing options, limitations on transport, space on the construction site, material characteristics, etc., several pieces of the same material may be required in order to form a larger entity. The second application is based on the functions of the components. It can be argued that joining different functions is much more critical because it is the start of 'functioning architecture'; how floors and walls are connected, windows in walls, building to site, etc. It is explained in *Components and Connections: Principles of Construction* that "[i]n a connection, a transition is made from one building

1 Merriam-Webster Online – Dictionary and Thesaurus. http://www.merriam-webster.com/dictionary/joint

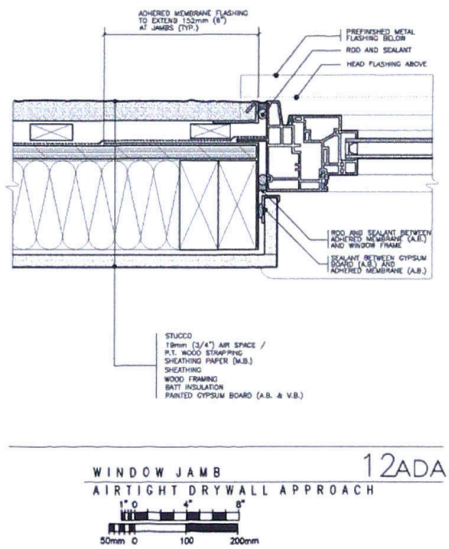
component with a specific set of functions and characteristics to another, also with its own functions and characteristics."[2] Greater importance is placed on connecting different functional components because their method of connection must ensure that the individual components still perform their designate functions.

*

Detail:

Specification or description of the work to be performed in the execution of a building[3]

It is worth noting that the current standard for representing joints is the architectural detail. These details explain graphically how components are attached together. The graphics are accompanied by text to ensure the understanding of the relationship between the materials, their methods of connection and any other valuable information needed for construction. In order to understand the purpose of details we must first understand the importance of joints.

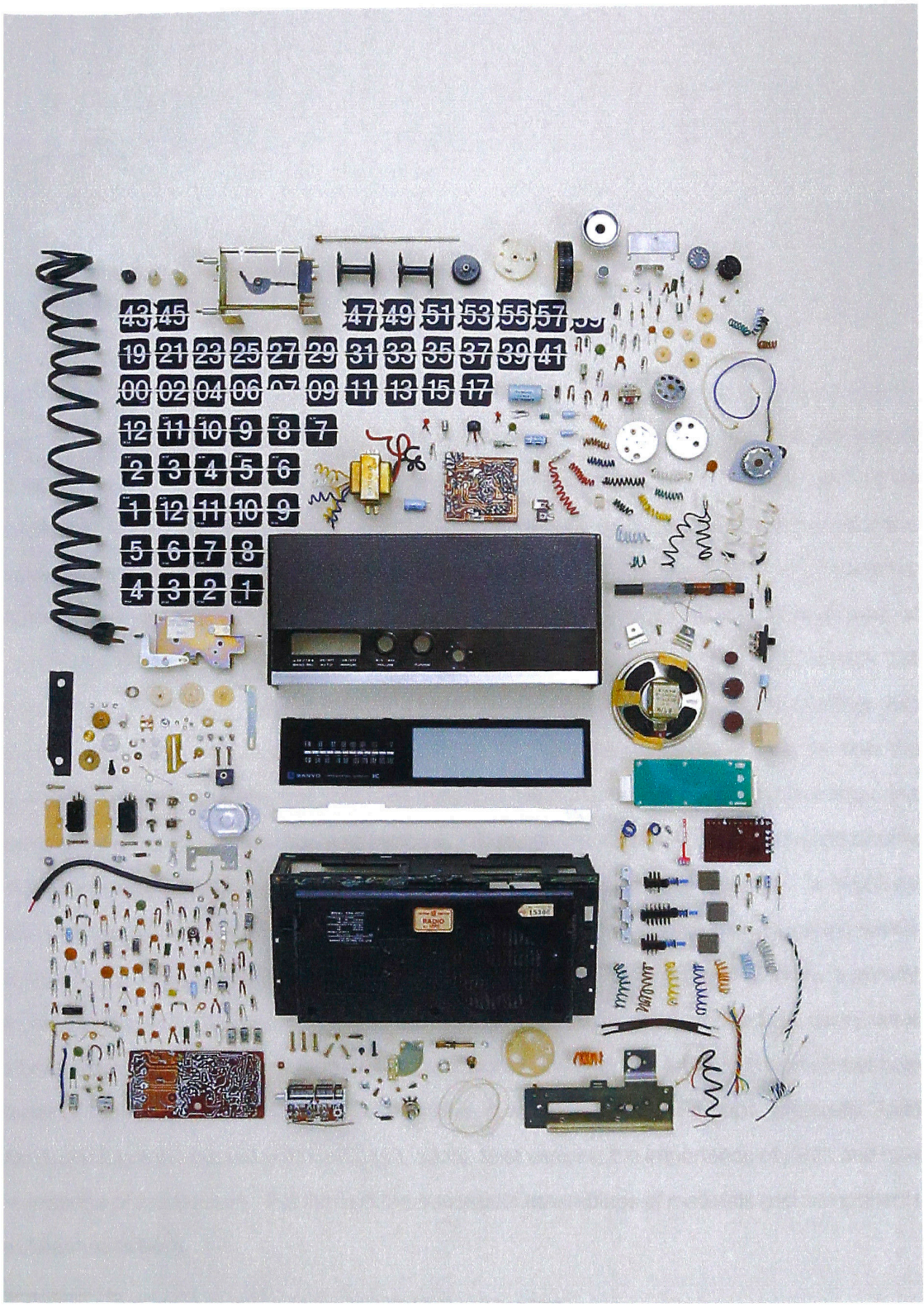


Sample Detail

Google Images. First appropriate image when searching for "Detail".

2 Maarten Meijs and Ulrich Knaack. *Components and Connections: Principles of Construction.* Berlin: Birkhausen, 2009. P61

3 Daniel Ramée. *Dictionnaire Général des Termes d'Architecture.* Paris: 1868. Sourced from Marco Frascari. "The Tell-The-Tale Detail." Via (1984). P25



Todd McLellan . Flip Clock

Todd McLellan. *Motion/Stills - New Work*. http://toddmclellan.com/

A.1.2 The Importance of Joints

Canadian photographer Todd McLellan's newest photography series "Disassembly," demonstrates the dismantling of old technological relics and exhibits all their parts. The photographs are an unusual way to demonstrate the complexity found in everyday functioning objects. If buildings were to be 'disassembled', they would not only be broken down into structure, floors, walls, doors, windows, heating system, etc., but these components could then be 'disassembled' even further into sheathing, insulation, fasteners, metal studs, and so forth. What would be left is an unimaginable amount of parts, which like the photograph, would clearly expose the intricacies that make up its entirety but would not explain much else. Rapper Ice Cube (who has an education in Architectural Drafting) said it best when describing the Eames House Case Study #5, "[i]t's not about the pieces, it's how the pieces work together."[4] The physical joining of materials, elements, components and building parts are essential for a building to function and perform. "Through this individual act, dead components are transformed into a living, subjectively designed building"[5], explains Jörg Schlaich – a structural engineer and the founder of Schlaich Bergermann und Partner. Thus, how well a building works comes down to how well its pieces are joined together. Architect Meinhard von Gerkan, a partner at gmp Architeckten von Gerkan, Marg und Partner, says "[t]o create good architecture, every detail has to be an integral part of the whole."[6] As a comparison, in clothing, the fabric is important but how the pieces of fabric are sewn together is what makes a wearable t-shirt. Perhaps, unusually, Todd McLellan's photograph coupled with Ice Cube's quote, best explains the importance of joints and how it is the essence of architecture. It is through the successful assemblage of materials and components that architecture is born.

4 Ice Cube. "Ice Cube Celebrates The Eames." Filmed December 2011 for Pacific Standard Time, 02:16. http://www.youtube.com/watch?feature=player_embedded&v=FRWatw_ZEQI#!
5 Christian Schittich, "Detail(s)." in *Detail: The Purpose of Details,* Iss. 8 (2000). P1437
6 Schittich. P1435

In the context of buildings, joints also have another use. In addition to making parts function, they also ensure buildings last. Due to natural/environmental forces acting on a building, such as wind, movement of the earth, temperature change, etc., a certain degree of tolerance is needed in joints in order to absorb such pressures. Without these tolerances the forces applied will harm the performance, durability and life of the building.[7]

Given the importance of joints, they are liable to become primary areas of weakness. As the joining of parts serves to make things work, it can also, more easily, make things fail. If not constructed or designed properly, the connection between pieces is where failure within an assemblage is most likely to occur. If pieces are joined too tightly, they can break apart. If joined too loosely, they can separate. "For me," stated architect Alvaro Siza, "detailing means exercising the utmost care at the junctions between different materials or different elements of a building."[8] More attention is required in guaranteeing that connections perform satisfactory, which includes, if any, the durability of the properties of additional materials used in the method of connection. "The mortar in brickwork, for example" stated in *Components and Connections: Principles of Construction*, "is less waterproof and mechanically weaker than the bricks."[9] If nails are used as fasteners, it must be ensured that the nails don't rust. Therefore the connecting pieces, the method of connection and any additional elements that contribute to the connection, must be very consciously considered. These choices not only affect the performance of that connection but can also affect the total performance of the building. Mies van der Rohe's famous expression, 'God lies in the details'[10] holds true.

7 This notion of tolerances will be discussed further in 'A.2.1 Static Connections'.
8 Schittich, P1438
9 Meijs and Knaack. P63
10 Philip Johnson. "Architectural Details." *Architectural Record* 135 (April 1964). P137

A.2 Type of Joints

There are two main categories that joints can be divided into: static or dynamic. Static joints are the most commonly used method of connection, whereas dynamic joints are typically only used for doors, windows, furnishings, and deployable structures. These two types will be further discussed.

A.2.1 Static Connections

Static joints are designed to remain rigid and are at equilibrium. Architect, researcher and author Alexander Tzonis explains that "[i]ntuition tells us that structures are stationary. They give us the impression of solidity, of being able to resist forces, and channel loads to the ground."[11] Buildings are meant to protect us from the environment, be rigid and strong enough to withstand all forces, be durable enough to last and to satisfy our psychological need for shelter. This is seen in buildings throughout history, from early medieval churches to more contemporary office buildings. "The components that make up a building should not move or rotate in relation to the earth,"[12] as stated in *Components and Connection: Principles of Construction*. This predominance in rigidity is widely accepted and has made static the norm method of connection in both traditional and conventional buildings.

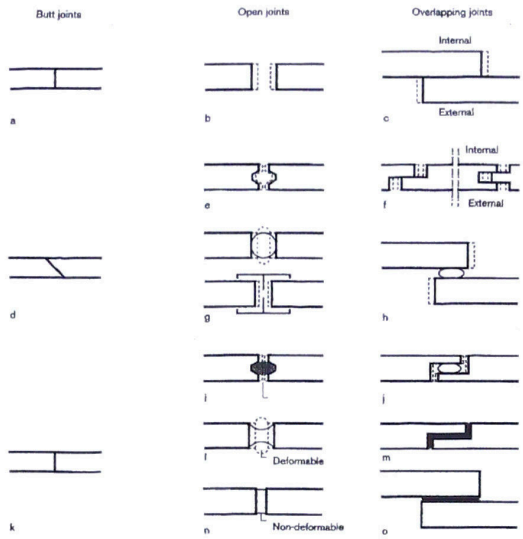
There are two main types of static joints: direct and indirect. Direct joints occur when two elements are directly attached to each other, whereas indirect joints refer to cases wherein a third element is used to act as the bonding agent in the connection. ***Butt joints, open joints, overlapping joints,*** and crossing joints are all examples of types of direct joints. Soldering, gluing, and bolting are examples of indirect joints. The image on the following page demonstrates a selection of static joints.

Butt joints: The parts being connected fit very closely together.
Maarten Meijs and Ulrich Knaack. *Components and Connections: Principles of Construction.* Berlin: Birkhausen, 2009. P65

Open joints: The parts being connected do not touch each other.
Meijs and Knaack. P65

Overlapping joints: The parts do not need to touch each other – the joint remains open for certain functions, such as air circulation, but closed for others, like rain or prying eyes. If the parts do touch each other, the surface unevenness of the materials will mean that the joint will not be completely sealed.
Meijs and Knaack. P65

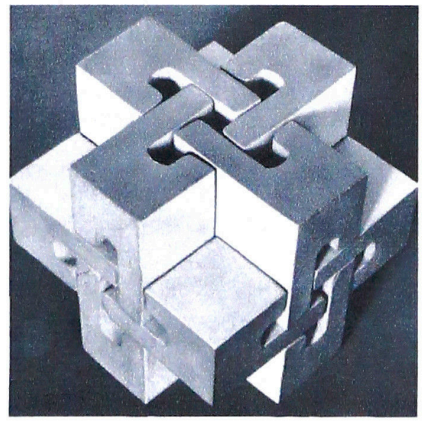
11 Alexander Tzonis and Liane Lefaivre. *Movement, Structure and the Wonder of Santiago Calatrava*. Basel: Birkhauser, 1995. P10
12 Meijs and Knaack. P77-78



Overview of the different types of joints

Maarten Meijs and Ulrich Knaack. Components and Connections: Principles of Construction. Berlin: Birkhausen, 2009. P64

Architect Konrad Wachsmann understood the importance of the connection between elements and, as a result of industrialization, utilized mass production to create a standardized static joint. His 'universal partition wall system' joint did not use any mechanical connectors and could attach as many as 12 individual elements together, from walls, ceiling and floors. This method of standardized attachment was intended to change the way buildings were constructed and to offer "almost unlimited possibilities of harmoniously connecting the various parts and elements of a structure."[13] This is an example of an attempt at a universal static direct joint.



Universal Partition Wall System - 12 panels in three planes meeting at the centre of an imaginary cube

Konrad Wachsmann. *Turning Point of Building: Structure and Design*. Translated by Thomas Burton. United States of America: Reinhold Publishing Corporation, 1961. P137

13 Konrad Wachsmann. *Turning Point of Building: Structure and Design*. Translated by Thomas Burton. United States of America: Reinhold Publishing Corporation, 1961. P10

Even though buildings are perceived as being rigid and solid, as mentioned in 'A.1.2 The Importance of Joints', we know that a tolerance for movement needs to be incorporated. Some connections are truly static (non-movement joints), as presented in the diagrams on the previous page, but others, primarily the connections between functioning components, must allow for some degree of movement. Edward Allen explains in *Architectural Detailing: Function, Construction, Aesthetics*, that "[a] building is never at rest. Its movements, though seemingly small, are extremely powerful and can cause irreparable damage unless the building is detailed to accommodate them."[14] In addition to the environmental forces (wind, earthquakes, etc.), other sources of movement affect buildings, "**temperature movement, moisture movement, phase change movement, chemical change movement, structural deflections, structural creep**, and **foundation settlement.**"[15] Most of these forces and pressures are unpreventable and are beyond our control. Given these external loads, movement joints are provided between building components in specific locations and in specific methods to absorb the designated applied forces without harming the components, the connection, or the building. These movement joints are form containing, meaning they absorb the movement to insure that the component's shape remains the same and is not affected by the forces. "If we did not provide movement joints, the forces that cause movement in a building would create their own joints by cracking and crushing components until the building's internal stresses were relieved. At best, the result would be unsightly; at worst, the result would be a leaky, unstable, unsafe building."[16]

Temperature Movement is cause by the expansion and contraction of building materials with rising and falling temperatures.
Edward Allen. *Architectural Detailing: Function, Construction, Aesthetics*. New York: John Wiley & Sons, Inc., 1993. P75

Moisture Movement occurs in porous materials such as wood, plaster, masonry, and concrete. These materials swell as they absorb moisture from water or humid air and shrink as they dry.
Allen. P75

Phase Change Movement accompanies a change in the physical state of a material. The phase change movement that is of primary interest to the detailer is the expansion of water as it freezes.
Allen. P75

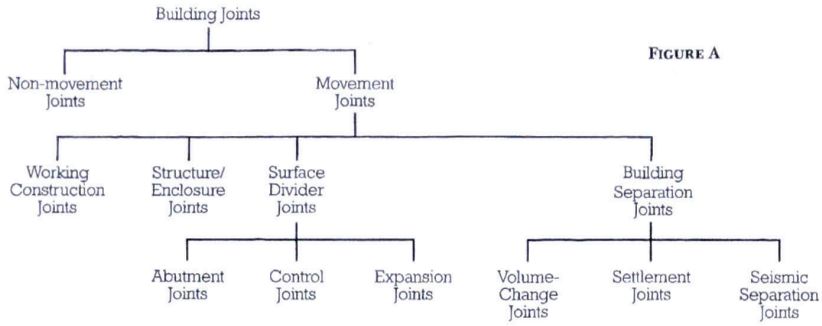
Chemical Change Movement takes place in certain construction materials as they cure or age. Gypsum plaster expands slightly as it changes from a slurry to a solid. Solvent-release coatings and sealants shrink as they cure. Reinforcing bars that rust expand and can crack the masonry or concrete in which they are embedded.
Allen. P75

Structural Deflections: Floors, roofs, walls and columns change their form elastically under the influence of increased loads. After the loads have gone, they return to their original shape.
Maarten Meijs and Ulrich Knaack. *Components and Connections: Principles of Construction*. Berlin: Birkhausen, 2009. P72

Structural Creep is characteristic of wood and concrete, both of which sag permanently by small amounts during the first several years of a building's life and then stabilize.
Allen. P75

Foundation Settlement occurs when the soil beneath a building deflects or creeps under loading. All foundations settle; if the settlement is small and is uniform across the entire building, little movement occurs within the components of the building itself. If settlement is nonuniform from one wall or column to another, considerable movement must be accommodated.
Allen. P75

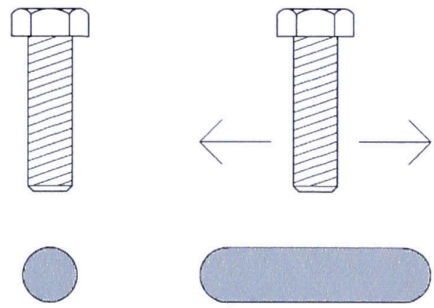
14 Edward Allen. *Architectural Detailing: Function, Construction, Aesthetics*. New York: John Wiley & Sons, Inc., 1993. P75
15 Allen. P75
16 Allen. P75



Movement Joints in Buildings – Types of Building Joints

Edward Allen and Joseph Iano. Fundamentals of Building Construction: Materials and Methods - Fourth Edition. New Jersey: John Wiley & Sons, Inc., 2004. P349

Depending on the component's properties, size, location and the type of movement it is absorbing, different types of movement joints are used. The chart above introduces these types. The principles behind static movement joints are simple: to provide space in between connecting elements allowing movement to occur. The specifics on the type and size of space vary per joint. The drawing below is a very simple example used to demonstrate this idea.



NON-MOVEMENT vs. MOVEMENT

Drawing of static non-movement vs. static movement joints

The purpose for this static movement joint is not only to allow for tolerances during installation (construction inconsistencies) but also to allow for the expansion and contraction of materials. This drawing demonstrates how movement is allowed to be absorbed.

Buildings have typically been constructed and designed with solidity and durability as their goal. Even though movement has traditionally been discouraged, its effects are known and taken into account. The allowance of movement in connections has more to offer than just increased durability.

Non-Movement Joints: A connection between materials or elements that is not designed to allow for movement.
Edward Allen and Joseph Iano. *Fundamentals of Building Construction: Materials and Methods - Fourth Edition*. New Jersey: John Wiley & Sons, Inc., 2004. P885

Movement Joints: A line or plane along which movement is allowed to take place in a building or a surface of a building in response to such forces as moisture expansion and contraction, thermal expansion and contraction, foundation settling, and seismic forces.
Allen and Iano. P884

Working Construction Joints: A connection that is designed to allow for small amounts of relative movement between two pieces of a building assembly.
Allen and Iano. P893

Structure/Enclosure Joints: A connection designed to allow the structure of a building and its cladding or partitions to move independently.
Allen and Iano. P890

Surface Divider Joints: A line along which a surface may expand and/or contract without damage.
Allen and Iano. P890

Building Separation Joints: A plane along which a building is divided into separate structures that may move independently of one another.
Allen and Iano. P875

Abutment Joints: A surface divider joint designed to allow free movement between new and existing construction or between different materials.
Allen and Iano. P873

Control Joints: An intentional, linear discontinuity in a structure or component, designed to form a plane of weakness where cracking can occur in response to various forces so as to minimize or eliminate cracking elsewhere in the structure.
Allen and Iano. P877

Expansion Joints: A surface divider joint that provides space for the surface to expand.
Allen and Iano. P879

Volume Change Joints: A building separation joint that allows for expansion and contraction of adjacent portions of a building without distress.
Allen and Iano. P892

Settlement Joints: A building separation joint that allows the foundations of adjacent building masses to settle at different rates."
Allen and Iano. P888

Seismic Separation Joints: A building separation joint that allows adjacent building masses to oscillate independently during an earthquake."
Allen and Iano. P888

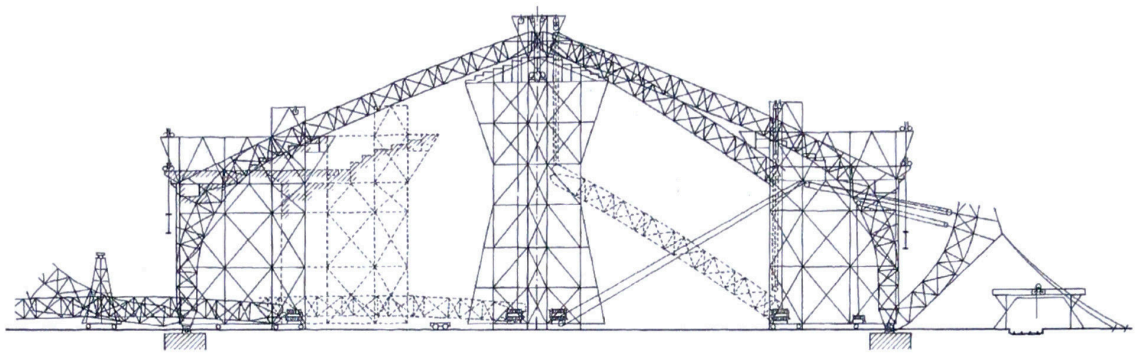
*

Before moving onto the topic of dynamic joints, demountable joints are worth mentioning for they are a sub-category of static joints. Demountable joints are a type of static connection which rather than focusing on being connected for longevity, they are connected with the intention of being deconstructed and reassembled. These joints have the capabilities of dismantling back into a collection of pieces. The current primary use for this type of system is in temporary structures where the structure can be taken apart, moved to a new location and then reassembled. These can include constructions such as scaffolding and concert stages. This method is mentioned as it aids in understanding the ways in which pieces can be statically connected together.

A.2.2 Dynamic Connections

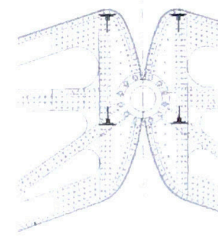
Dynamic connections are a method of connection that allow for change and motion. It is through this type of joint that movement has been incorporated into architecture. As suggested earlier, buildings typically try to resist movement rather than encouraging and developing it. In *Move: Architecture in Motion*, we read that "[t]he most common use of movement in architecture is in the form of individual moving elements: opening doors, windows and gates which have long been part of the basic architectural repertoire."[17] The method in which a door leaf is attached to a wall allows the leaf to rotate, opening and closing space. Elevators and escalators use dynamic connections to help users move between floors. This method of connection is traditionally used at a smaller scale and is found more in everyday objects and accessories: cupboards, curtains, blinds, drawers, door handles, gates, shutters, etc. These objects are not highly influential towards building functionality but are intended rather as part of the users' quality of living. With that said, there are some buildings which use dynamic connections for more functional applications (examples will be provided further on), but based on current construction conventions, they appear to be rare exceptions as the majority of new buildings are still conventionally and primarily static. The advantages and benefits of utilizing movement in connections will be addressed in the next chapter.

17 Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, *Move: Architecture in Motion - Dynamic Components and Elements*. Basel: Birkhäuser, 2010. P40-41

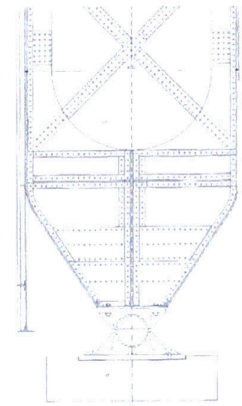


The method of erecting the trusses of the Palais des Machines
Stuart Durant. Palais des Machines: Ferdinand Dutert. London: Phaidon Press Ltd., 1994. P42

Nevertheless, not all dynamic connections have a final outcome of movement. The structural truss system, constructed by the Five-Lille Company in the Palais de Machines in 1889, was assembled with the help of dynamic connections. A hinged base joint (similar to a hinge, which allows for rotational movement) attached the trusses to the ground, which were then rotated and raised into their final position. When each end of the trusses were raised, they were connected to each other at the top with another hinge joint.[18] The main role for these hinged joints were for its assembly, which upon erection, no longer acted dynamically but acted instead as a static movement joint. While dynamic connections can be beneficial to the method of assembly, their main quality and benefit is with the introduction of change.



Truss Head Detail
Durant. P52



Truss Base Detail
Durant. P53

Change introduces the possibility of reactions, interactions, modifications, and options into static architecture. It allows the users and the environment to alter the current building components for an improved alternative. In his book, *Flexible: Architecture that Responds to Change*, Robert Kronenburg explains how "[a]rchitecture that is designed for adaptation recognized that the future is not finite, that change is inevitable, but that a framework is an important element in allowing that change to happen. Adaptable buildings are intended to respond readily to different functions, patterns of use and specific users'

18 Stuart Durant. *Palais des Machines: Ferdinand Dutert*. London: Phaidon Press Ltd., 1994.

requirements."[19] The ability of a building to change and adapt is an important quality to possess. According to Kronenburg, movement provides a "new set of design principles that actively support[s] the probability of change."[20] Change is the result of accepting and utilizing movement.

19 Robert Kronenburg. *Flexible: Architecture that Responds to Change*. London: Laurence King Publishings Ltd, 2007. P115
20 Kronenburg. P58

B . MOVEMENT

B.1 Intro: Movement in Joints

B.1.1 Definition

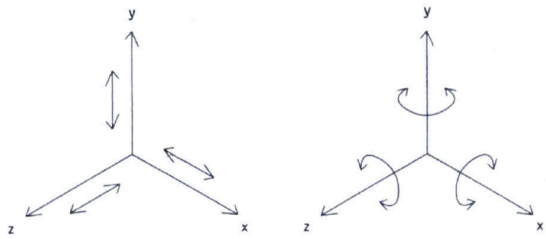
The Merriam-Webster dictionary defines 'movement' as "-the act or process of moving, especially: change of place or position or posture."[1] Movement is the act of physically changing in location or in volume. In the context of this investigation, movement refers to its application at the level of connections. Physical movement at a connections level means that there are certain restrictions on what can be considered 'movement'. If a material were to inflate, theoretically the material is physically changing in volume and by definition moving. However, this occurs due to material characteristics and not because of its method of connection. The same can be said about rolling; a ball that rolls around a table is moving solely as a result of gravity on its shape. A final example of what cannot be deemed 'movement' is demountable joints; as introduced earlier, individual pieces can separate and move location, but the physical joining of the pieces does not encourage movement. This is the reason why mobile architecture – architecture that is capable of being moved to different locations – will not be considered in this thesis.

The way in which architectural elements move as a whole, at a macro scale, is the result of the specific application of movement incorporated in the method of connection at a detail level. However, in order to incorporate movement into architecture, we must try and understand how movement works. The principles behind each type of movement are fairly simple but can easily become more complicated depending on the final desired function. The next section will look at the principles that allow objects to move.

1 Merriam-Webster Online – Dictionary and Thesaurus. http://www.merriam-webster.com/dictionary/movement

B.1.2 Types of Movement

There are two different kinds of movement: translation and rotation. Linear movement, also known as 'translation,' is the motion of an object as it moves along an axis. Rotation is the motion of an object as it changes its orientation by circulating around an axis. Each of these kinds of movement can occur on any of the three axis on a coordinate system: x-axis, y-axis, and z-axis. As explained in *Move: Architecture in Motion,* "[t]he ability of an object to move around in space is therefore defined by a maximum of six degrees of freedom."[2] The image below represents this.



The Principles of Mechanics
Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P36

With this understanding, movement can be incorporated in a variety of different ways to create distinct outcomes. Some examples of existing and, to a certain degree, standard types of movement are: swivel, rotate, flap, slide, fold, and expand and contract. These types of movement, which can be found in everyday objects, work by translation, rotation or a combination of the two. The book, *Collapsible: The Genius of Space-Saving Design,* showcases examples for these different types of movement from the folding of tents, the hinging of an umbrella, the sliding of a telescope, etc.

Examples from Collapsible: The Genius of Space-Saving Design
Per Mollerup. Collapsible: The Genius of Space-Saving Design. San Francisco: Chronicle Books, 2001. P93, 98, 170

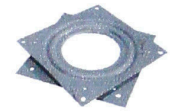
2 Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, *Move: Architecture in Motion - Dynamic Components and Elements*. Basel: Birkhäuser, 2010. P37

The easiest way of incorporating movement into connections is through the utilization of standard, off-the-shelf hardware. This includes items such as hinges, swivel plates, sliding tracks, ball bearings, ball-and-sockets, etc. These mechanisms help in understanding how movement can be incorporated into connections. Rather than directly attaching two pieces of wood together, if you were to 'indirectly' attach them to a hinge, then these two pieces become dynamic and rotatable.

Ball-and-Socket

Hinge

Track



Swivel Plate
Google Images

The type of movement incorporated into a connection defines how the connecting elements will move. In *Move: Architecture in Motion*, again it is mentioned that in addition to the type of movement, "[g]eometric constraints can be applied to limit an object's degree of freedom. A door leaf, for example, has precisely one degree of freedom of rotation."[3] The image below is of two conceptual models exploring this idea of constraining movement. The rotation of the stick is constraint, to up and down for the model on the left, and diagonally for the model on the right. The path in the ball is restricting the stick from rotating freely. Understanding the principles of movement, how it can be incorporated, and how it can be constraint is necessary in exploring its possibilities and taking advantage of its benefits to architecture. These benefits will be addressed next.

Constraining the path of rotation

3 Schumacher, Schaeffer and Vogt. P37

B.1.3 Reasons for Movement

Building elements that can rotate, swivel and move in all sorts of ways has a lot to offer architecture. Michael Fox, founder of the Kinetic Design Group at MIT, states that movement offers "adaptability, transportability, deployability, connectability and producibility", which are all "ideally suited to accommodate and respond to changing needs."[4] The fact that movement can accommodate change is its greatest means for benefiting architecture. After all Charles Darwin once said, "[i]t is not the strongest of the species that survives, nor the most intelligent; it is the one that is most adaptable to change."[5]

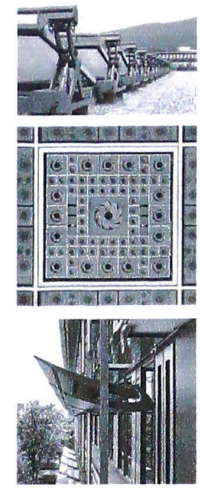
As explained in, *Collapsible: The Genius of Space-Saving Design*, "[t]he world is in a state of flux. Change is happening all the time, all around us. We try to hang on by continually adapting ourselves and our belongings to our shifting circumstances."[6] Conventional buildings are designed to resist change, stand permanently and hope for longevity. Eventually, when buildings can no longer satisfy their requirements, whether due to performance or functionally, they get demolished and replaced with buildings that could, or at least, last longer until they too need replacing. This cycle of seemingly disposable buildings is being diminished with the rethinking of conventional architecture. The incorporation of dynamic connections into buildings is better accommodating and adapting to changing external pressures.

Demolished Building
http://en.beijing2008.cn/52/71/article214007152.shtml

Decaying Building
http://squidgemag.com/2009/05/interview-kevin-bauman-100-abandoned-houses/

4 Michael Fox, "Kinetic Architectural Systems Design." In *Transportable Environments 2*, edited by Robert Kronenberg. London: Spon Press, 2003. P122
5 Per Mollerup. *Collapsible: The Genius of Space-Saving Design*. San Francisco: Chronicle Books, 2001. P11
6 Mollerup. P17

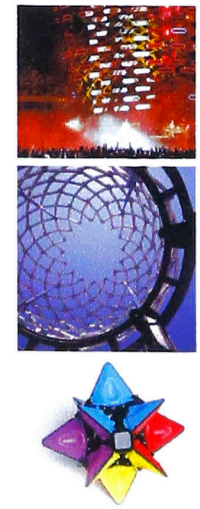
The two primary external pressures which affect architecture and buildings are: environmental conditions and users. A building that can react to the environment can last longer, and a building that can adapt to users' needs, will be used for longer. If a building could adjust to the direction of the sun then it can diminish its amount of sun damage and better maintain its performance. If a building is capable of adjusting its spaces to allow for different programs to occur then it could be reused for more functions and satisfy users' needs for longer. This is an example of how movement can make buildings more functional. In what follows, the benefits of movement in architecture will be explored for both the building and its users.



Examples of Sustainable Strategies
Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P127, 134, 140

Kronenburg explains that "[n]ow, more than at any time in history, an appropriate response to changing external influences is clearly necessary."[7] With a growing concern for issues of global warming and environmental sustainability, there is an increasing importance in the need for sustainable buildings. In response to the sporadic environmental conditions – weather, sunlight, etc., designers are developing and utilizing sustainable strategies. Amongst these large assortments of strategies, a variety of them utilize the possibility of adjustments facilitated by movement.

Chuck Hoberman, an inventor internationally known for his transformable structures[8], explains "[w]e [Hoberman Associates] have developed a whole series of systems for responsive shading and responsive ventilation as new methods for building facades and surfaces. It is inspired because there is an actual need for that now..."[9] Adaptable strategies, created by the incorporation of movement, can make a building more energy-efficient, increase building performance, durability, and longevity. Aside from the sustainable benefits, movement can also allows buildings to



Examples of Hoberman's Transformable Structures
Hoberman Associates: Transformable Design. Hoberman Portfolio. Accessed February 22, 2012. http://www.hoberman.com

7 Robert Kronenberg, "Transportable Environments: Experiment, Research and Design Innovation." In *Transportable Environments 2*, edited by Robert Kronenberg. London: Spon Press, 2003. P52
8 Hoberman Associates – Transformable Design – Team. http://www.hoberman.com/team.html
9 Verena. "Transformable Architecture: Chuck Hoberman." *PingMag*, July 13, 2007, accessed February 10, 2012. http://pingmag.jp/2007/07/13/transformable-architecture/

maintain functionality, and to provide flexibility and space-optimization.

The benefits of movement to users are achieved as a result of the qualities and possibilities of options, change, and customizability. An adaptable building can be manipulated by its users with the aim of fulfilling their needs and desires, and enhancing their personal standards of quality such as raising the amount of indoor lighting, improving indoor air quality, noise levels, enhancing experiences, interest and much more. Dror Benshetrit, a designer who focuses on innovation and transformation, says "the fact that we are transformable beings, we desire different things at different times, both emotionally and physically..."[10] Therefore, the longer a building stays useful to its users, adjusting to satisfy their subjectivity and requirements (assuming a consistent building performance is maintained), the more likely it will continue being used.

Hoberman goes on to explain that "by having the building capable of changing, you also have a new typology of what architecture can be."[11] Rather than traditional buildings that are forced to withstand the environment and users that are forced to conform to the prescribed nature of static buildings, movement in architecture instead introduces a certain level of freedom, allowing the building to change for both users and the environment. By investigating and altering the method of connection between pieces, the way that architecture and buildings are used, experienced, and performs are further enhanced and improved. With this understanding of the potential of movement in architecture arises the question, what are the implications of this towards architectural space?

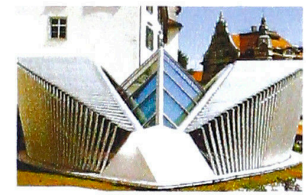
10 Dror Benshetrit. "Interview with Dror Benshetrit." Filmed February 2011 at Design Indaba 2011, 00:18 http://www.designindaba.com/video/dror-benshetrit-di2011
11 Nina Rappaport. "Chuck Hoberman wants buildings to change." *Architectural Record*, Dec 2007. P154

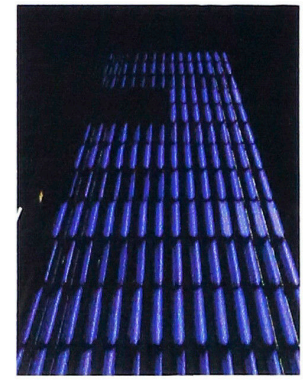
B.2 Movement of Space

B.2.1 Intro

As the principles, incorporation, and benefits of movement have previously been discussed, the next point is to further investigate the relationship that movement can have with space. What can movement do to space? What does dynamic space look like? Let us explore, as Cheng-An Pan and Taysheng Jeng have put it, "the dynamics, flexibility, and adaptability of architectural space."[12]

The different outcomes of incorporating movement, which have previously been mentioned (such as sliding, expanding, folding, etc.) and what they are applied to, can create different possibilities. For example, in an architectural space, programs can be contained in walls that can then move; components, such as stairs, floors and ceilings, can move; there is also the possibility for complete mobile cells to move.[13] A new level of experience is reached when functional building components, such as walls, are capable of moving. Contemporary innovators like Chuck Hoberman and Santiago Calatrava continue to demonstrate the possibilities of dynamics at an architectural scale.[14] Their projects explore this notion of movement and space and will be later presented.





Selectived Work from Calatrava and Hoberman
(top 2) Alexander Tzonis. Santiago Calatrava – The Complete Works, Expanded Edition. New York: Rizzoli International Publications, Inc., 2007.
(bottom 2) Hoberman Associates. Accessed February 21, 2012. http://www.hoberman.com/home.html

12 Cheng-An Pan and Taysheng Jeng. "Exploring Sensing-based Kinetic Design for Responsive Architecture." *CAADRIA 2008* (2008). P286
13 Schumacher, Schaeffer and Vogt. P107
14 Michael Fox, "Kinetic Architectural Systems Design." In *Transportable Environments 2*, edited by Robert Kronenberg. London: Spon Press, 2003. P114

B.2.2 Types

There are different relationships that movement can have with physical space, the quality of space and the perception of space. Kronenburg organized flexible architecture into four characteristics: adaptation, transformation, movability and interaction.[15] Similarly, Michael Fox created four different categories for kinetics in architectural environments: spatial optimization, multifunction design, contextual adaptability, and mobility.[16] Out of the two sets of categorizations, 5 types of relationships were created on how movement can affect space. These relationships are as follows:

movement to 'create space'
'adjust space'
'change space'
'connect space'
'move space'

These influences on space will be examined through existing projects that have utilized movement in an architectural context. There is no defined division between these relationships; some of the examples presented are a combination of different types.

15 Robert Kronenburg. *Flexible: Architecture that Responds to Change*. London: Laurence King Publishings Ltd, 2007. P7
16 Michael Fox and Miles Kemp. *Interactive Architecture*. New York: Princeton Architectural Press, 2009. P31

Create Space

The first relationship that will be explored is based on size adjustment. Space that can close when not in use, diminish in size to become less noticeable and exposed, but that can expand and open up to create useful space. Michael Fox mentions this relationship by saying "objects in the built environment might physically exist only when required and disappear or transform when they are not functionally necessary."[17] Similar to the idea of a child taking a toy out of its box, playing with it, and then when no longer in use, returning it to its box, 'create space' can be a form of space practicality. This idea can be seen in tent trailers/ pop-up campers – a portable and transformable living space. The cover of the trailer can telescope up to become a roof, walls can be attached and beds can be pulled out. This structure expands when necessary and contracts when not. That is the main principle behind this relationship, the transformation of no space into functioning space. In traditional architecture, when a space is no longer in use, it has no option but to remain vacant. This periodically unused emptiness of space questions the buildings usefulness and longevity. Dynamic architecture, architecture that is capable of moving, is a solution to this.

Tent Trailer / Pop-up Camper
Google Images

17 Michael Fox, "Kinetic Architectural Systems Design." In *Transportable Environments 2*, edited by Robert Kronenberg. London: Spon Press, 2003. P116

Muvbox . Resto MUV: The Lobster Box

Sid Lee Architecture. http://www.sidleearchitecture.com/#/project/muvbox

Muvbox® is a concept from Daniel Noiseux, a Montreal restaurant owner/entrepreneur, who was inspired by architect/artist Alan Kalkin's Illy Push Button House. "Muvbox® is a recycled shipping container modified and equipped to your specs to become the ultimate pop up space." [18] The first application of the Muvbox® concept was designed in collaboration with Sid Lee and Aedifica for a Lobster restaurant in the Old Port of Montreal. "Each night the MUVBOX vanishes back into its cube, and redeploys early the next morning at the touch of a button, in less than two minutes!"[19] The intrigue about Muvbox®, compared to the Illy Push Button House, is that it does more than just the one motion of folding open, it expands. Similar to the way that newly purchased parts of Ikea furniture are strategically positioned inside a box to take up the least amount of space, elements in the Muvbox® can be completely moved and compacted inside, minimizing its size when closed. The walls of the shipping container fold down with hydraulics to become the floor, which then has built in chairs that fold up to become the seating area. The roof canopy above the seating rolls out of the container, as well as the counters which slide out from the box to create an enlarged internal preparation area. The box appears as a shipping container when closed, but is possible of unfolding and expanding to create a restaurant, equipped with both a cooking space and an eating space.

Illy Push Button House
http://www.trendhunter.com/slideshow/unique-coffeehouses

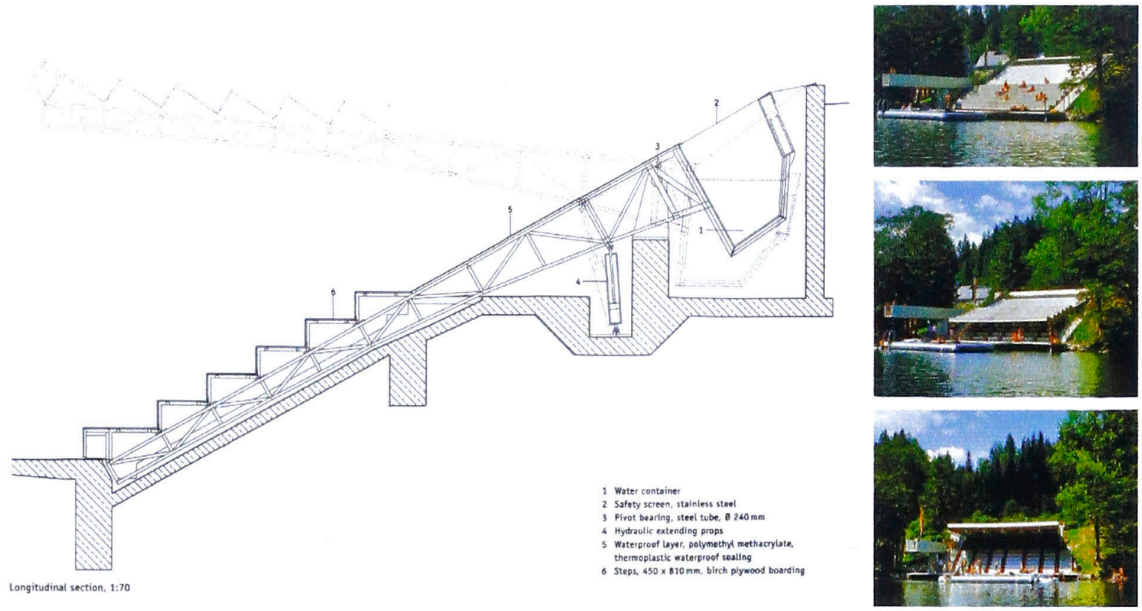
18 MUVBOX: Think Inside the Box. Accessed February 21, 2012. http://www.muvboxconcept.com/en/
19 MUVBOX.

Adjust Space

Adjusting and altering space is possibly the broadest of the relationships, primarily because the main benefit and use for movement is its adjusting capabilities. Compared to static architecture, the benefit of incorporating movement into architectural spaces is the fact that it can react and adjust to users and the environment. Thus, a certain degree of adjustments can be found in all of these relationships. The sunshade in the previous Muvbox® example can be considered an environmental adjustment because if there is no sun or rain the shade does not need to be retracted.

'Adjust space' focuses on the improvement of space, whether it be for functionality, durability or quality. The most common application for this relationship is sustainable strategies. However, an everyday traditional example of an element that uses dynamic connections to adjust to environmental conditions is the window blind. Window blinds are capable of adjusting the amount of light entering a space to help improve the quality of indoor space. The following examples are environmental adjustments with the purpose of improving users comfort, quality of space and protecting them from the elements.

Hans Kupelwieser & Werkraum Wien . Lakeside Stage



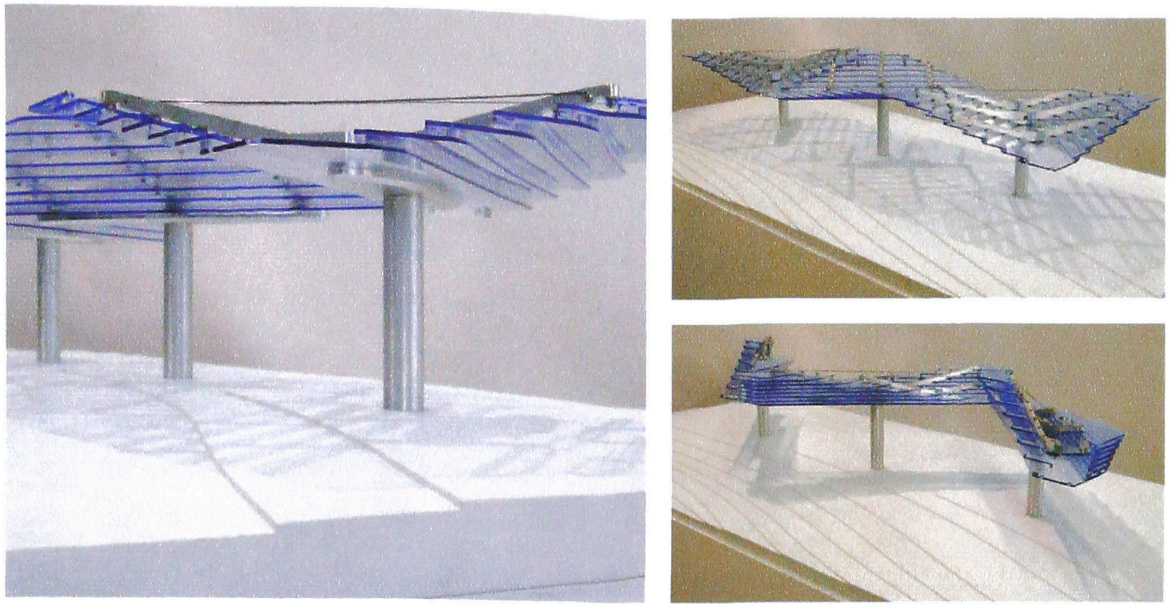
Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P164-5

Artist Hans Kupelweiser worked with the engineering office Werkraum Wien to construct a lakeside stage/seating area in Austria. The open-aired seating area is capable of converting into a covered seating area, protecting its spectators from the elements and acting as an acoustics shell. A water trough is located at the top of the structure above a pivot point. When this trough fills with water (either pumped from the lake or from the rain), the seating rotates from the increased weight of the water and rises to reveal another set of seating concealed below. To lower the seating, a vent is opened in the trough, which drains the water out and back into the lake, returning it to its original position. [20] Because of the strategic placement of the source of movement, the transformation of a floor into a ceiling can take place. This seating structure is capable of responding and improving as a result of the environmental conditions all while maintaining its original function.

A similar application, on a more architectural scale, which can be an adjustment on the quality of space in relations to the weather conditions, can be the adjustable roofs on sports stadiums. This is a form of enhancement and improvement to static architecture.

20 Schumacher, Schaeffer and Vogt. P164

Adaptive Building Initiative . Adaptive Shading Esplanade



Hoberman Associates. Download Portfolio. http://www.hoberman.com/portfolio.php

Hoberman Associates and international engineering consultants Buro Happold have joined forces to create Adaptive Building Initiative (ABI). ABI, as indicated on their website, is "dedicated to designing and delivering a new generation of buildings that optimize their configuration in real time by responding to environmental changes."[21] ABI designed a structural umbrella for an exhibition at the Building Centre Trust in London. The umbrella uses their Strata™ system, which consists of modular units that rotate to create a varying sized shading surface. Even though this example is for a freestanding shading device, this system can be utilized in applications such as skylights or vertical curtain wall shading devices. Depending on the desired amount of lighting, the solar umbrella configures accordingly. Other adaptable benefits of the Strata system, in addition to shading control, are reducing solar glare, and ventilation and airflow control.[22] This capability for a system to respond to the environment can be beneficial in improving space, the quality of space, and even the users' quality of life.

21 Adaptive Building Initiative. Accessed February 21, 2012. http://www.adaptivebuildings.com
22 Adaptive Building Initiative.

Change Space

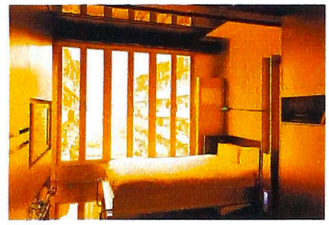
Change space is not so much focused on the adjusting of space but to allow for a whole new function of space, specifically changing the use of a space. The majority of applications for this type of relationship to movement are in the form of multifunctionality. For instance, an object or element that is capable of performing two or more separate functions by moving into certain configurations. Residents with small living spaces tend to gravitate towards utilizing movement to create various living configurations._

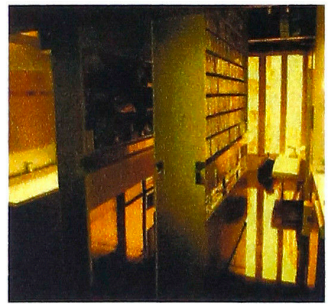
This is an example of how the incorporation of movement can increase the longevity of a building. The usefulness of a space can be insured for longer because of the incorporation of different functions. This concept of multiple functions in a single space increases the efficient utilization of space and decreases its probability of becoming vacant space.

Edge Design Institute Ltd . Domestic Transformer

Gary Chang. My 32m² apartment: A 30-year Transformation. Hong Kong: MCCM Creations, 2008. P122-123 (colours inversed)

Gary Chang, architect and founder of Edge Design Institute Ldt., has been living in the same Hong Kong 32m² apartment his whole life. Over this time several renovations had been made in an attempt to effectively utilize his small space. His latest design is the best example of this relationship of changing space. Chang designed his apartment as one empty room, which is capable of transforming into 24 different spaces. This is possible with the utilization of movement. Programmatic wall systems are placed in tracks on the ceiling and slide to reveal different rooms, as well tables can rotate out, beds can fold down, etc.[23] Rather than having 5 tiny rooms (as the apartment was originally when he was a child), the moving and configuration of these different elements allows for Chang to essentially have 24 different room configurations with a maximum area of 32 m² for each. Because his one 'empty room' is always being used, there is never the possible of uninhabited space and therefore its longevity is prolonged.





Gary Chang. My 32m² apartment: A 30-year Transformation. Hong Kong: MCCM Creations, 2008. P132, 138

Gary Chang explains that "[t]he house transforms and I'm always here, I don't move. The house moves for me."[24] Movement allows Chang to customize his space as per his particular needs. This freedom of manipulation is part of the basis for the proposed architectural project, which also expands beyond the predominance of static architecture. This will be discussed later in more detail.

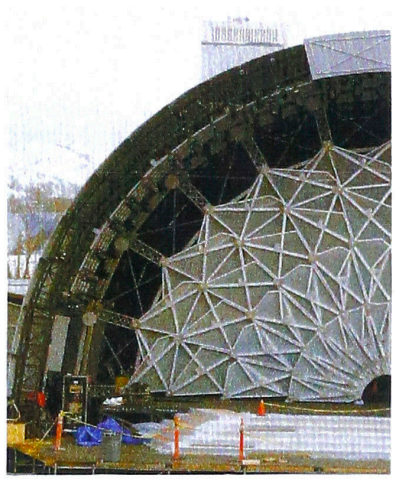
23 Gary Chang. *My 32m² apartment: A 30-year Transformation.* Hong Kong: MCCM Creations, 2008.
24 Planet Green. "World's Greenest Homes: Honk Kong Space Saver." Added January 7, 2010, 04:03. http://planetgreen.discovery.com/videos/worlds-greenest-homes-hong-kong-space-saver.html

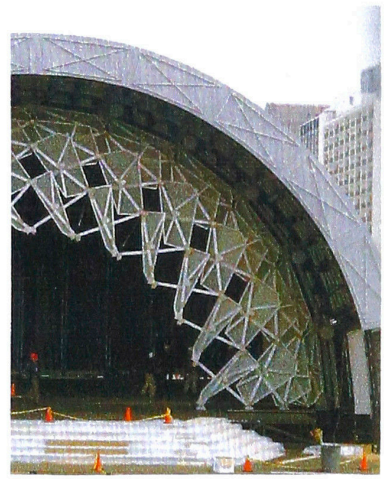
Connect Space

The connecting of space is the conventional application for movement in buildings. This relationship with space is nothing new and should be very familiar. It allows and restricts access to spaces, can link spaces, can open up space, and can change the size of spaces. Doors, windows, fences, and room dividers are existing examples. In the article "Opening the Building Envelope", Michael Lange explains "[t]he functional quality of the opening element has a direct effect on the quality and usability of the space within. In particular the manner in which an element opens, along with its size, can extend or change the ways in which the interior space can be used."[25] In addition to functionally accessing space, the opening of space can also be experiential and performative.

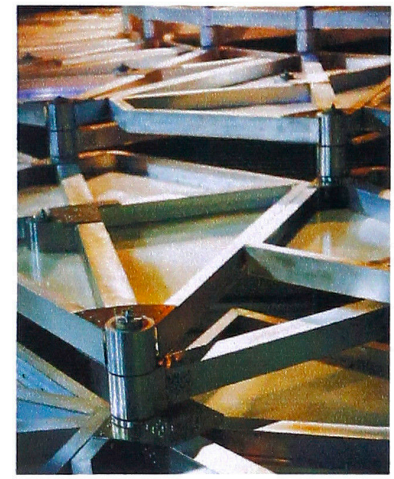
25 Michael Lange. "Opening the Building Envelope," in *Move: Architecture in Motion - Dynamic Components and Elements*, ed. Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, 112-117. Basel: Birkhäuser, 2010. P113

Hoberman Associates . Hoberman Arch





Robert Kronenburg. Flexible: Architecture that Responds to Change. London: Laurence King Publishings Ltd, 2007.P154



Hoberman Associates. Statement of Qualifications. http://www.hoberman.com/about.html

"The Hoberman Arch" as described on their website, "is a transformable curtain that was installed in the front of the stage at Olympic Medals Plaza"[26] for the Salt Lake City 2002 Winter Olympics. The Arch is one of Chuck Hoberman's transformable designs. Its role is that of a stage curtain except the method in which it raises and lowers offers experiential qualities. The curtain is made up of 96 translucent fibre-reinforced panels in 4 different shapes, which are connected together with a bolted connection.[27] Because of the configuration of the connected panels, rotating them opens and closes the curtain in a choreographed movement. This movement creates a magical artistically engineered performance and activates the space so that the viewers can see, hear, and experience both the winning medal ceremonies and the concert performances.

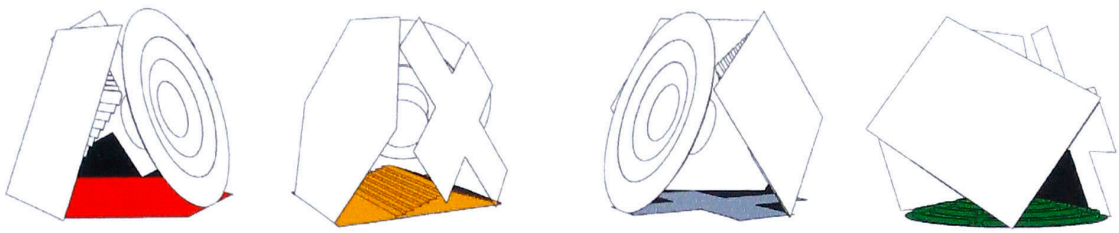
26 Hoberman Associates: Transformable Design: Hoberman Arch. Accessed February 22, 2012. http://www.hoberman.com/portfolio/hobermanarch.php?rev=0&onEnterFrame=%5Btype+Function%5D&myNum=11&category=&projectname=Hoberman+Arch
27 Schumacher, Schaeffer and Vogt. P222-223

Move Space

Even though it had been previously stated that movement, which does not occur at a connection level, would not be discussed however, because it has a substantial impact on space, it must be included and mentioned. The relationship of 'move space' is a form of mobile architecture where the entire space is capable of being relocated. This includes, as Robert Kronenburg has categorized it, "buildings that relocate from place to place in order to fulfill their function better."[28] Rather than presenting examples of mobile architecture, which consists of the same interior space simply relocated (like the tent trailers/ pop-up campers), the examples presented are of projects that utilize the relationship of moving space to create different interior functions or different qualities of space.

28 Kronenburg. *Flexible: Architecture that Responds to Change*. P7

Rem Koolhaas . Prada Transformer



Prada Transformer. http://prada-transformer.com/

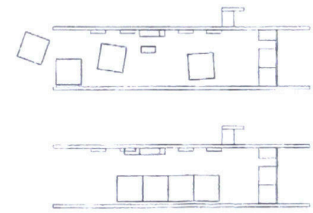
Prada Transformer. http://prada-transformer.com/

The Prada Transformer is a temporary structure in Seoul, South Korea, designed by architect Rem Koolhaas. The concept is to incorporate different disciplines including: art, architecture, fashion and film, into one pavilion. The pavilion is a 4-sided object, with each side having it's own dedicated function. As explained by Koolhaas, "[t]his one [hexagon] is perfect for an exhibition for the Prada fashion, then it is housing that fashion. This is [rectangle] perfect for cinema, so the pavilion rolls and it becomes cinema. This is [circle] perfect for Prada fashion show. This is [cross] perfect for art show."[29] In order to change programs, the whole pavilion gets lifted by cranes, rotated and then placed back down. Walls become floors and floors become walls. Even though it does not occur at a connection level, it is still very interesting how the interior can accommodate and create different spaces and functions. This efficient utilization of interior space is similar to 'change space' in terms of its multifunctionality. This building may not be able to adapt to the individual users' needs like the Gary Chang's Domestic Transformer, but (ignoring the fact that it is a temporary structure) its possibility for different functions increases its longevity of use.

29 Prada Transformer: Video Presentation. Accessed February 22, 2012. http://prada-transformer.com/

Shigeru Ban . Naked House

Shigeru Ban Architects: Naked House. http://www.shigerubanarchitects.com/SBA_WORKS/SBA_HOUSES/SBA_HOUSES_24/SBA_Houses_24.html



Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P110

Shigeru Ban designed a house in Japan, which is both unusual looking and unusually functioning. The client wanted a home that "provides the least privacy so that the family members are not secluded from one another, a house that gives everyone the freedom to have individual activities in a shared atmosphere, in the middle of a unified family."[30] In essence, the home is one large rectangular space with four smaller personal rooms. Each room is placed on wheels and can be moved according to the family's needs. These rooms are capable of rolling around the space, being placed next to each other, at opposite ends, near the light, near the heating and even moved outside onto the terrace.[31] The location of the rooms in relation to each other and in relation to the larger space creates an interesting dynamic relationship with space. This example suggests the possibility of rooms as a form of furniture – furniture being the only adaptable quality and the easiest form of reconfiguring a space in existing buildings. The concept of furniture is currently what ensures the possibility for a buildings reuse.

30 Shigeru Ban Architects: Naked House. Accessed February 22, 2012. http://www.shigerubanarchitects.com/SBA_WORKS/SBA_HOUSES/SBA_HOUSES_24/SBA_Houses_24.html
31 Shigeru Ban Architects.

*

To summarize the relationships of space, each category is slightly varied from one another. As evident in the examples, a given structure may not solely belong to just one type. For example, the Muvbox® restaurant is understandably placed under 'create space' however, when the shipping container is closed, it is capable of 'move space' because it is not permanently fixed. Whichever relationships the examples get categorized as, it is worth noting that it is the utilization of the standard types of movement (rotating, expanding and contracting, etc.) and the basic principles of movement, which are simply arranged in different combinations and methods that makes these different applications possible.

The intent behind these relationships is to strengthen the understanding of the potential and benefits that movement can offer to architecture and space. These examples demonstrate how the incorporation of movement can better utilize, improve, configure, and increase the longevity of space. Their possibility for adaptability, motion, and change makes them transformable structures. This transformability is capable of improving the way that conventional static architecture is used, enjoyed and performed. In comparison to the examples just presented, the current familiar standard for the spaces that are experienced and utilized by most users is that of frozenness. Rather than this idea of adjustable space, users instead are required to themselves adjust their way of life to predefined rigid spaces. This inclusion of the users into dynamic architecture is the next focus of this research.

C . USERS

To paraphrase William Zuke and Roger Clark from their book *Kinetic Architecture*, 'architecture exists for the betterment of man.'[1] Users are the reason for architecture to exist. Buildings are designed and constructed to protect, satisfy and improve the lives of its users. However with that said, the rigidity found in architecture inherently restricts the way that spaces can be used. This form of space impedes the users' experience and limits the users' interactions. The options provided by movement challenges this and suggests new ways in which users can experience and interact with space. As mentioned in 'B.1.3 Reasons for Movement', the benefits of movement from a user's standpoint is to satisfy their subjectivity and to improve the functionality of their spaces.

Michael Fox, in *Interactive Architecture,* speaks about users and space stating, "[a]s an interactive adaptable relationship is established between a user of a space and the space itself, the experience of the space becomes increasingly compelling."[2] A user's perception and experience of space changes with movement. The adjusting of a space sets both the motion of the space and the experience of the space into action. With the creation of different spaces comes the creation of various moments. These moments, whether the result of user's interactions or environmental responses, can trigger different emotional experiences such as wonder and intrigue. These different experiences perceived by users will be further explored.

1 William Zuk and Roger H. Clark. *Kinetic Architecture*. New York: Van Nostrand Reinhold Company, 1970. P157
2 Michael Fox and Miles Kemp. *Interactive Architecture*. New York: Princeton Architectural Press, 2009. P96

C.1 Experience of Movement

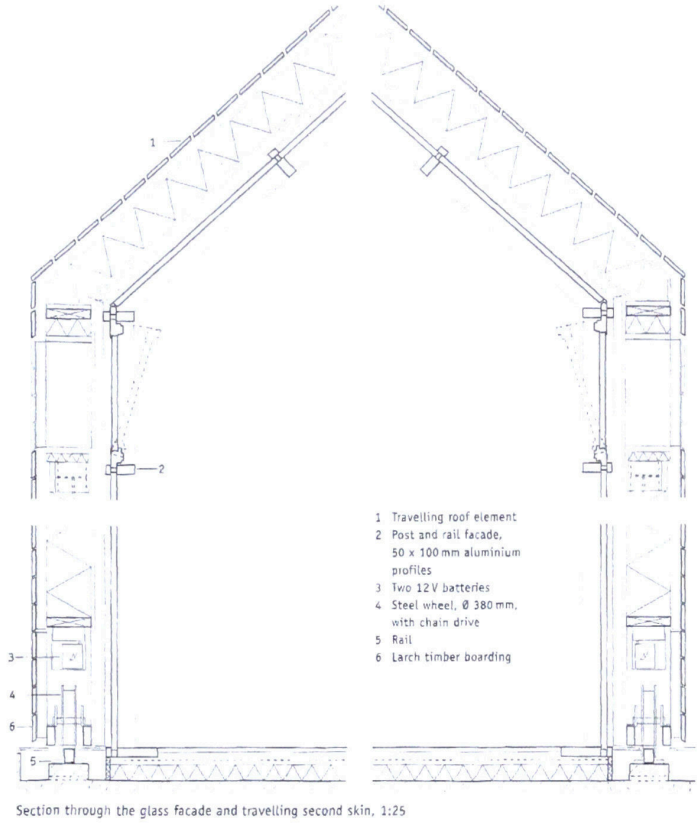
On November 3rd 2011, architect Alex de Rijke gave a presentation entitled "Timber is the New Concrete". He ended the lecture by addressing the idea of the users' experience of architecture. To paraphrase, de Rijke believed that architects were too fascinated with static programmatic experiences and that there was a lack of surprise, fun, imagination and magic in architecture.[3] This comment came after presenting his Sliding House project, which is a house covered by a slideable assemblage in order to encourage many different experiences of space.

Alex de Rijke's Sliding House
Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P199

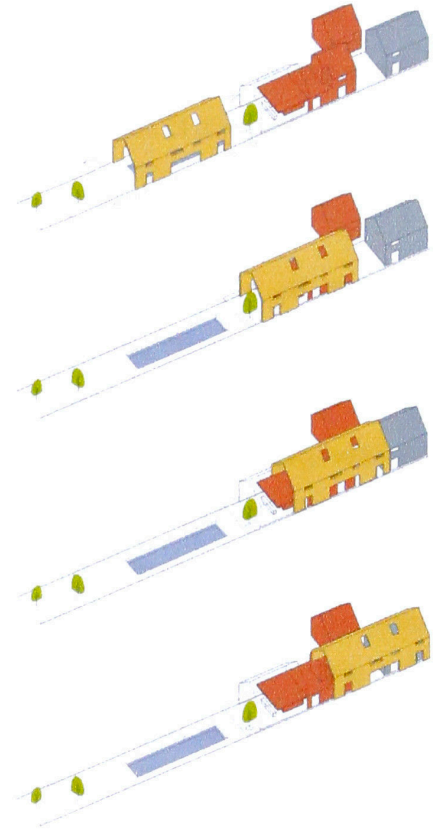
Static buildings create variations on the same experience. Depending on the time of day and the amount of occupants inside the space, the experience changes slightly but for the most part the building appears frozen. This type of experience can be easily represented with a snapshot. In comparison, a space that is capable of moving automatically creates different or additional experiences. Not only does it create an initial and final experience, it also creates a series of experiences along its journey of movement. This journey unfreezes static architecture by creating a performance – a performance that is capable of triggering different emotional responses from its users such as intrigue, stimulating wonder and creativity, as well as suggesting uncertainty, change, anticipation, etc. The responsive quality of a space inherently enhances and creates new experiences. The movement of the Hoberman Arch, presented earlier, was designed specifically to be part of the performance of the stage, whereas other examples presented in the relationships with space, evoke different emotions to users when experiencing the specific performance first hand. Calatrava and Hoberman both utilize and experiment with movement to create experiential spaces and performances. Their work will be further explored, as well as de Rijke's Sliding House.

3 Alex de Rijke, "Timber is the New Concrete." Lecture presented as part of Pit Lecture Series at Carleton University, Azrieli School of Architecture and Urbanism, Ottawa, Canada, November 3rd 2011.

C.1.1 Alex de Rijke



Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P199



de Rijke Marsh Morgan Architects. Sliding House. http://drmm.co.uk/projects/sliding-house

Alex de Rijke's Sliding House, located in Suffolk, England, was designed in the shape of the local farm buildings. The interesting and unusual aspect of the design is the use of a 'sleeve,' which covers the house and is capable of traversing up and down the site. The 'sleeve' can slide to create a combination of outdoor and indoor spaces depending on its position. This movement is possible simply by placing the 'sleeve' on wheels and providing a track for the wheels to slide on. The purpose for this moving element is to "alter the overall building composition and character according to the seasons, weather, or a remote-controlled desire to delight,"[4] as explained on their website. However, beyond its functional roles, the 'sleeve' is very much designed as part of de Rijke's exploration against static programmatic experiences. According to an article written in *The Observer,* this surprising element was a response to a "question posed nearly 30 years ago by Ettore Sottsass Jr: 'Why should homes be static temples?'"[5]

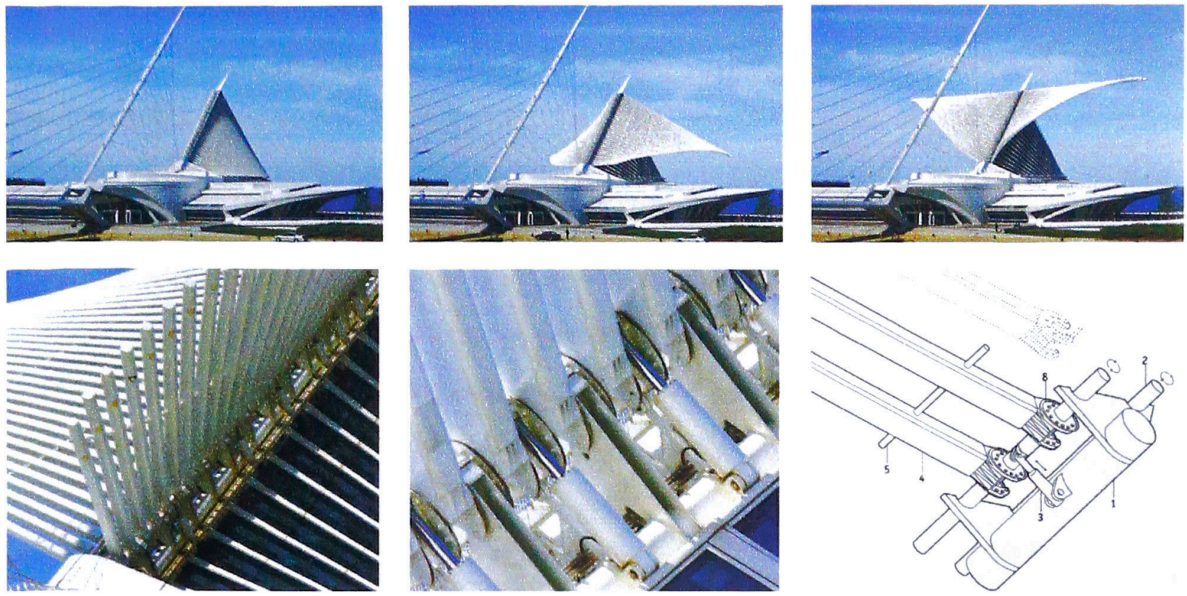
4 drmm: de Rijke Marsh Morgan Architects. Sliding House. Accessed February 27, 2012. http://drmm.co.uk/projects/sliding-house
5 Stephen Bayley. "A roof over your head? So last year..." *The Observer*, February 1st 2009. http://www.guardian.co.uk/artanddesign/2009/feb/01/sliding-house-architecture-drmm

This notion of stasis is continuing to be questioned in this research. The incorporation of movement into homes, as previously mentioned, can enhance its function, performance, experience, and longevity. Movement is the adjustment and improvement of static architecture. This incorporation suggests the redirection of homes away from being static temples. This idea of a static temple will be further challenged in 'D.1 Play'.

The results of these benefits and enhancements due to moving elements can be seen with the Sliding House. Will Jones of De Architects in 2009 commented on the project saying, "This clever combination of efficiency, ingenuity and fun is the essence of Sliding House. It performs well practically and environmentally but, in addition, Sliding House is a joyous building. It excites and enchants with each change in position. What better place to live than a home that alters according to your mood."[6] The Observer stated "...the Sliding House is an extended bravura performance of life-enhancing design possibilities. It is a house for guilt-free enjoyment."[7] With such an experience and improvement resulting from its movement 'sleeve', this house itself answers Sottsass Jr's question. The sliding 'sleeve' successfully demonstrates how movement can create different enjoyable experiences, such as magic and surprise. This home and any building which substantially utilizes movement is, as de Rijke has puts it, "[a] denial of static architecture"[8]

6 drmm.
7 Bayley.
8 drmm.

C.1.2 Santiago Calatrava



Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, Move: Architecture in Motion - Dynamic Components and Elements. Basel: Birkhäuser, 2010. P178-9

The Quadracci Pavilion is an extension to the Milwaukee Art Museum and is one of Santiago Calatrava many projects which, in some form or another, incorporates movement. Aside from the programmatic extension, Calatrava designed a large movable sunscreen named 'brise soleil', with a 217-foot wingspan, on top of the museum's entrance. The wings are made up of different sized steel rods that are attached to a rotating tube, which opens and closes the screen. This adjustment of space dramatically alters the experience, temperature and quality of light in the entrance of the museum. Although the sunscreen was designed for functional purposes, as written in the book, *Terror and Wonder*, "[w]hen the 'brise-soleil' unfolds, it is an event, one that beckons museumgoers outside with their video cameras... This is spectacle and art, a stunning and skillful transformation of heavyweight steel into lightweight kinetic sculpture."[9] As we are led to believe that buildings are not supposed to move, it is quite a sight to see when a building is set into motion. The sheer size and magnitude of this motion, understandably draws a crowd guaranteed to be impressed and amazed. The museum has no doubt increased its popularity and its amount of visitors as a result of this performance, an unexpected benefit of movement. According to the design blog, *Inhabitat*, Calatrava's extension is the new symbol of not only Milwaukee, but of 'change'.[10]

9 Blair Kamin. *Terror and Wonder: Architecture in a Tumultuous Age*, Chicago: The University of Chicago Press, 2010. P134
10 Lori Zimmer. "10 Must-See Design Destinations Around the World," *Inhabitat*, March 15, 2012, http://inhabitat.com/10-must-see-design-destinations/

The main theme in architect, structural engineer and sculptor Santiago Calatrava's work is that of movement. In *Movement, Structure and the Wonder of Santiago Calatrava* read the following, "[t]he forms of his buildings; infrastructure facilities; sculptures; furniture; utensils; drawings – all are related to some aspect of movement."[11] Calatrava is one of the few architects who continues to explore and experiment with movement in architecture and the ways in which movement can shape architecture, allowing his buildings to become transformational and dynamic events. The dynamic nature of movement and its possibility for change inherently creates performances and events. Movement and performance are directly linked together, which causes the incorporation of movement into static buildings to result in new and exciting experiences. Calatrava's 'brise soleil' helps to demonstrate the wondrous experiential qualities created by movement.

Similar to experiencing a magic trick, part of the intrigue and excitement of watching building elements in motion is in questioning how they work. This behavior is derived from our natural instinct of curiousness. Wondering is just one of the many emotions which can be triggered and stimulated by movement in architecture. "The structures that promote this wonder are the structures that invite both learning and creativity."[12] These transformable structures have the power to affect users on a much deeper emotional level than single-snapshot static structures. "Calatrava's structures keep that sense of wonder alive; they open the discerning eye; they are an open invitation to soaring and dream-work."[13]

11 Alexander Tzonis and Liane Lefaivre. *Movement, Structure and the Wonder of Santiago Calatrava*. Basel: Birkhauser, 1995. P12-13
12 Tzonis and Lefaivre. P156
13 Tzonis and Lefaivre. P156

C.1.3 Chuck Hoberman

Original Expanding Sphere . Liberty Science Centre
Hoberman Associates. Download Portfolio. http://www.hoberman.com/portfolio.php

Chuck Hoberman is an expert in designing transformable objects. As much as he utilizes the transformations for their adaptive capabilities of responding to and improving environmental conditions, Hoberman is also fascinated with their experiential qualities. His earlier projects were kinetic sculptures displayed in science museum lobbies. These sculptures expanded and contracted to 4 times its size, up to 18 feet in diameter. The drastic size difference is one of the main reasons for its popularity. Witnessing such a large transformation triggers wonder and curiosity, making its location in science museum understandable. This curiosity excites its viewers, opens up their imagination and invites them to go inside and learn new things. The simple fact is, regardless of its application, the process of transformation has inherent experiential and performative qualities and can delight its users in many different ways.

Hoberman was asked in an article by *PingMag* why his transformations trigger people in an emotional way. His response was "I think there is a psychological association of transformation and life. I guess that everybody picks up that emotional connection: When you see this special behavior [of transformation], you feel it in your body. It may be a physiological connection because you get a sensation, a physical sensation or a mental and perceptual sensation."[14] It can alternatively be mentioned that a big part of

14 Verena. "Transformable Architecture: Chuck Hoberman." *PingMag*, July 13, 2007, accessed February 10, 2012. http://pingmag.jp/2007/07/13/transformable-architecture/

the excitement for transformations is due to unfamiliarity. Even though common every-day items such as umbrellas, balloons, and even air mattresses are capable of transforming, the size and unusual applications which Hoberman designs to transform are what causes such emotional reactions. When familiar objects move in different and unexpected ways, like the example of the Hoberman Arch, it triggers interest, questions its unusualness and intrigues viewers. This originality is part of the reason for individuals' reactions towards transformations. The same can be said for architecture. As mentioned earlier, architecture is understood and accepted as being rigid, so when a floor or wall starts to move, users observe in excitement. Even though dynamic structures already exist, to most individuals, a transforming building is still an unusual sight.

After time, Hoberman noticed that "science museums have a lot of visiting kids, they would look at my spheres opening up and the kids would scream and shout, get very excited."[15] As a result of this enjoyment, Hoberman discovered an uncommon application for his transforming spheres. It became a very popular play toy for kids. Under the toy company 'Hoberman', a variety of other toys were developed such as transformable sports balls, brainteasers, flying disks, etc. All of these toys, in some form or another, transform for the sole purpose of bringing amusement to children. Chuck Hoberman has utilized the experiential and adaptable qualities of movement to make toys for users to manipulate and play with.

Hoberman. Spheres. http://hoberman.com/fold/Sphere/spheres_choice.htm

*

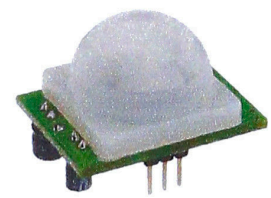
It is quite profound to fully comprehend the effects that altering the method of connection between parts can have in improving architecture. Movement introduces performance into static architecture. Its incorporation can create better and more enjoyable experiences. These experiences are capable of stimulating wonder and curiosity, enhancing delight, and encouraging exploration and play. With the possibility for movement, users can now, because of the adjustability of spaces, form a relationship with and have an effect on space. This encouragement for users to explore their influence on space is the focus of the next section.

15 Verena.

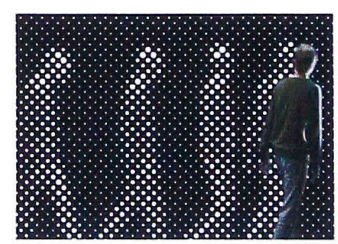
C.2 Interactions with Movement

Given the choices and options available because of movement, this allows buildings and spaces to be adapted for and to its users. The flexible nature of spaces introduces the possibility for users to influence and affect the outcome of architectural space. However, before continuing the discussion about users interacting with movement, it is first necessary to address how movement is activated. The principles and reasons for movement have been previously addressed but at this point it is now important to address the means of controlling change. There are two general ways for movement in space to be initiated which can simply be referred to as *automatic* and *manual activation.*[16]

Automatic activation is responsive technology, which is based on sensors that analyze its surroundings and activates as a response to it. This method is becoming increasing utilized for sustainable strategies as it enables buildings to sense their current environmental conditions and respond to it accordingly (an example of this is Calatarva's 'brise soleil'). This method ensures the performance and durability of a building. In addition to being utilized for environmental conditions, *automatic activation* can also sense users, like the concept of a motion detector. An architectural example of this is an interactive façade installation entitled *Aperture* by Gunnar Green and Frédéric Eyl. The façade senses its nearby users and replicates their silhouette and motion. This type of activation is electronic and intuitive: a user's presence activates the installation but the user cannot directly manipulate the motion and therefore has no direct control over it. This method is more complex whereas *manual activation* is a more basic and simpler means of activation.



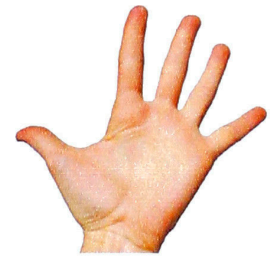
Sensor
Michael Fox and Miles Kemp. Interactive Architecture. New York: Princeton Architectural Press, 2009. P79



Aperture by Gunnar Green and Frederic Eyl
http://www.fredericeyl.de/aperture/index.php?main=2&sub 1

16 Other influences such as the wind can initiate movement, however in terms of movement to improve space, there are two.

Manual activation is based on direct human interaction; users physically changing their environment at their own discretion. This method of activation is the most conventional and familiar. If a user wants to open a door, they turn the handle. If they're cold, they close a window. This method of activation introduces the users to a certain degree of control over the elements present in their surroundings. Depending on the design and capacity for movement or manipulation, the users are capable of directly configuring these elements to adjust and alter their surrounding spaces. This is the concept behind the included project. By incorporating movement, users have the capability to exercise more control and are provided with more opportunities to alter their experience of the surrounding space.



Hand
Google Images

This increased control can alter the relationship that users have with the specific project and architecture in general. As stated in *Move: Architecture in Motion*, "[s]paces change their proportions, their illumination, their sound and their degree of intimacy. The ability to bring about these changes oneself and to experience how the spaces change as a result connects the user directly with the building."[17] This direct link and potential between users and architecture is the reason for a focus on *manual activation*.

Change is inevitable; the environment changes, users' needs change and the uses for buildings change. However, unusually, buildings are designed to resist change. Because of the rigid framework of buildings, users are required to conform to predefined spaces and must instead adjust their way of life accordingly. Movement is the solution to this, offering users more flexibility and freedom. This changes the dynamics of the relationship and the interaction between users and space. The results are buildings that can be customized for each user's particular desires, requirements and functions. This possibility for reconfiguration

17 Michael Schumacher, Oliver Schaeffer and Michael-Marcus Vogt, *Move: Architecture in Motion - Dynamic Components and Elements*. Basel: Birkhäuser, 2010. P102

means not only would users adjust a space when change is needed, but also buildings could be better reused, ensuring a longer duration of usefulness and capacity for adaptability.

This idea of reconfiguration means that users can manipulate the geometry of space for their own betterment and improvement. In addition to the manipulation for functional outcomes, users can also manipulate their space to satisfy their personal preferences and even as a form of exploration. In today's society, it is standard for users to have options and choices. Most everyday items are available with alternatives, from different colours, different sizes, different features, etc. Individuals are accustomed to this lifestyle of personalization and so as architect Gerhard Kalhofer states in his article "Mobile Architecture", "[i]f he [the user] is offered a series of reasonable possibilities, the architecture will be certain to move."[18] The manipulation of movement without specific goals allows users the possibility to configure space solely for the exploration and investigation of new patterns and uses of space. This purpose is a form of play, encouraging its users to develop interesting and unusual situations. The advantages of movement are considerable so if given the possibility, users will not only use it to improve their spaces, satisfy their personal objectives and enhance their quality of life, but they would also use it for customization and amusement.

Car Paint Colour Options
Google Images

This degree of allowed interactions with, and flexibility in architecture, is unusual. Static architecture, as previously mentioned, restricts the incorporation of this movement. However, in manual activation, users are encouraged to manipulate and create their own experiences with space. They are allowed to participate, influence, reconfigure, imagine, and play with spaces because of the possibilities of movement in architecture. This direct manipulation helps the user to understand their personal influence on space and how their direct actions can

18 Gerhard Kalhofer. "Mobile Architecture." In *inDetail: Small Structures: Compact Dwellings, Temporary Structures, Room Modules*, edited by Christian Schittich, Basel: Birkhäuser, 2010. P40

affect their surroundings. This provides users with a new involvement and a deeper connection to architecture, all while challenging the static state of spaces. Movement in space becomes a generator for the exploration and amusement of users. The remaining section will examine play as a means to encourage the exploration of space, but more importantly to expand beyond the predominant static state of architecture.

D . PLAY

As previously suggested, the interaction of movement in spaces can be considered a form of play in architecture. 'Play' in the New Oxford American Dictionary is defined as, "engage in activity for enjoyment and recreation rather than a serious or practical purpose."[1] Anything that is enjoyable and done without a specific purpose can be considered play. Play can be relaxing or it can be stimulating. It can be calming, can encourage dreaming and it can be educational. Play is essential.

Stuart Brown, play researcher and psychiatrist, explains that, "[o]ne of the things about play is it is born by curiosity and exploration."[2] Similar to the activities enjoyed by children, i.e. drawing, building, role-playing... the movement of space can be an activity that encourages the same kind of creativity and imagination. Architect Gerhard Kalhofer gives an example of play in architecture, "Lars Lerup compares architecture with theatres offering props with which users can design their own play. As the users bring individual experience and ideas, they are not 'responding organisms', but active individuals who define the building by approaching it."[3] Because of this relationship that users can have with architecture, they are free to manipulate and explore the possibilities of movement in space. It is from this freedom of exploration that we can start to understand the potential of play in architecture.

The playground is an area designed specifically for play: it is a place that encourages active free play to its users. The equipment and play-structures found in playgrounds are used to encourage this activity of play. There are many variations of playground equipment all offering a different possibility for interaction and use. The reason for mentioning playgrounds is because play-structures are the most ideal solution to address the downfall associated with Ettore Sottsass Jr.'s concept of the 'static temple'. Playgrounds allow unrestrictive and unstructured play. The joy and reward of playing in playgrounds is that its users are allowed to directly utilize the play-structures anyway they please. Users are encouraged to fully interact with the space and the structures for self-exploration, imagination, questioning and learning. This is contrary to the notion of static architecture, which has been questioned throughout this research. An example of a static structure is an office cubicle as it

1 New Oxford American Dictionary, 3rd edition. Oxford University Press, Inc. 2010
2 Stuart Brown, "Stuart Brown says play is more than fun" Filmed May 2008 at Serious Play the 2008 Art Centre Design Conference, TED video, 26:38, Posted March 2009. http://www.ted.com/talks/stuart_brown_says_play_is_more_than_fun_it_s_vital.html. 07:40
3 Gerhard Kalhofer. "Mobile Architecture." In *inDetail: Small Structures: Compact Dwellings, Temporary Structures, Room Modules*, edited by Christian Schittich, Basel: Birkhäuser, 2010. P40

confines users to work in a restrained space with little possibility for customization and personalization except for limited personal items such as pictures or souvenirs. Users should have the ability to interact and influence their space, and static architecture needs to fully consider and incorporate the benefits of dynamic connections. The included project incorporates the ideas set forth for the design of new playground structures, which are capable of moving and being manipulated by its users to explore, experiment and learn about adjustable spaces. However, before presenting the proposed play-structures, let us take a moment to further examine the benefits and potential of play-structures.

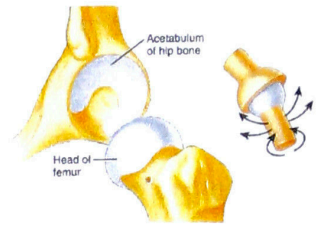
D.1 Learning by Playing

The term 'users' have been used to describe the broad array of people who can utilize and benefit from movement in architecture. In terms of play-structures, the users can still be such broad array however, the individuals who will primarily be using the play-structures and will benefit the most from them, are children. The development of a child is done through playing; playing with their toes and fingers, with the noises they can make with their mouths, with toys, with other children and at playgrounds. All of these different tools contribute to the imagination, exploration, thinking and development of a child's basic skills and understanding of their bodies and of their environment.

Playgrounds are spaces designed specifically for children to play. It is explained in *Play and Child Development,* that the benefits of playgrounds are extensive. "[P]laygrounds enhance motor development, and promote motor skills, manipulative skills, and social skills."[4] As part of a child's perceptual-motor development, they start to understand the relationship between movement and the environment. This includes body and spatial awareness. "Body awareness means the child's developing capacity to understand body parts, what the body parts can do, and how to make the body efficient. Spatial awareness refers to knowledge of how much space the body occupies and how to use the body in space."[5] The proposed play-structures, which allows its users to directly manipulate and move parts of the structure to affect and change its shape, further questions, develops, and enhances a user's body and spatial understanding. The possibility to personally bring about change in a dynamic environment through play-structures is a new way to challenge 'how to use the body

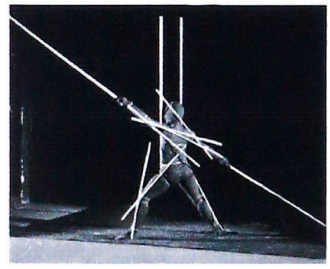
4 Joe Frost, Sue Wortham and Stuart Reifel, *Play and Child Development: Fourth Edition*. New Jersey: Pearson Education, Inc, 2012. P291
5 Frost, Wortham and Reifel, P132-133

in space'. The proposed play-structures incorporate movement, as consistently mentioned in this thesis, at the joint between two parts. Witnessing these moving parts resembles, suggests, and can compliment to a more thorough understanding of the connections and joints in one's own body. The connections in the structures are similar to the connections in a human body. This reinforces a child's already developing embodied knowledge and body awareness.



The joint in the hipbone is similar to the joint in the proposed play-structures
Gerard Tortora and Bryan Derrickson. Principles of Anatomy and Physiology: Eleventh Edition. New Jersey: John Wiley & Sons, Inc. 2006. P270

German painter, sculptor, designer, choreographer and teacher at the Bauhaus, Oskar Schlemmer, created a performance in the 1920's, which also challenged and explored this idea of body and spatial awareness. The piece was entitled 'Pole Dance/Slat Dance'. Rather than focusing on the joints between elements, like the proposed play-structures do, Schlemmer instead focused on the elements themselves. The dance consisted of one dancer with 12 long rods attached to each primary body part; legs, thighs, hands, biceps, torso and head. When the dancer moved, the poles accentuated the movement of his body and created an unusual and interesting perspective on its influence with space. The long rods were used "to outline the geometrical division of the space occupied by the dancer"[6]. This dance utilized a different approach to also challenge the understanding of how a body can occupy space.



scene from Oskar Schlemmer's Pole Dance/ Slat Dance
Emory University English Department. 'The Expressionists." Accessed May 8, 2012. http://www.english.emory.edu/DRAMA/ ExpressionImage.html

Another outcome of playing, in addition to improving a child's motor development, is to stimulate different experiences. Scott Eberle, a historian of play and vice president for interpretation at the Strong National Museum of Play in Rochester, New York, believes that most people experience six steps of emotions as they play: anticipation, surprise, pleasure, understanding, strength, and poise.[7] These emotions are triggers as part of the play process and are not specific to playgrounds However, as mentioned in 'C.1 Experience with Movement',

6 Emory University English Department. 'The Expressionists." Accessed May 8, 2012. http://www.english.emory.edu/DRAMA/ExpressionImage.html
7 Stuart Brown and Christopher Vaughan. *Play: How It Shapes the Brain, Opens the Imagination, and Invigorates the Soul*. New York: Avery, 2009. P18-19

the experience of a moving structure, in this case, the proposed play-structures, further strengthens these emotions. Especially "'surpise': the unexpected, a discovery, a new sensation or idea, or shifting perspective. 'pleasure': a good feeling, like the pleasure we feel at the unexpected twist in the punch line of a good joke. And 'understanding': the acquisition of new knowledge, a synthesizing of distinct and separate concepts, an incorporation of ideas that were previously foreign."[8] The unfamiliarity and unusualness of a structure that is capable of changing enhances and strengthens these 3 experiences the most. The delightful and potential qualities of the structures will become more evidence once the project is described in more detail.

The proposed play-structures allow individuals to change their surroundings. During a period of development and understand of their surroundings, this potential can have significant influences on children. Understanding from a young age that they are capable of altering space, can change the way they view the world. This creates individuals who are more used to and familiar with adaptability. In *Toys and Playthings* it was said "[c]hildren of the future need not be so very different from the child we look for today. They will have to be flexible, adventurous, quickly aware, capable of adjusting to change; for the one thing we can be sure of in an advanced technological society is that changes will happen at an ever-increased rate, whatever they may be"[9]. A child that learns and understands the possibility of adaptable space can be better prepared to encounter the constantly changing world. But for now let us finally learn about the specifics of the proposed playground structures.

8 Brown and Vaughan. P18-19
9 John and Elizabeth Newson. *Toys and Playthings: in development and remediation*. London: George Allen & Unwin Ltd., 1979. P20

D.2 Movement at Play

The following project is a series of dynamic, freestanding playground structures. The structures are designed to move and encourage its users to play by manipulation and reconfiguration. Each play-structure incorporates movement differently and is interacted in different ways. All the structures in some form or another are meant to simulate space so that users can better explore and understand their influence on space. The direct interaction and manipulation of the structures can delight its users, stimulate their curiosity and question their understanding of movement.

These assemblages are designed as additions to existing catalogues of playground equipment. They provide interesting and innovative dynamic alternatives compared to the more traditional mix of swings and seesaws. In addition to playgrounds contributing to the development of motor skills, promoting physical exercise, and improving communication/social skills, the proposed play-structures also introduce mental stimulation, delight, wonder, educational qualities, as well as the body and spatial awareness previously mentioned, to both new and existing playgrounds.

*

The intentions behind the design:

The play-structures were designed with simplicity in mind. The structures consist of simple pipes, which have been dynamically connected together. These dynamic connections are what create the experience and magic of the structures. Rather than designing more complicated structures, which may provide a more amusing experience, it may also hide its connections making it harder to understand how it works. The simplicity of the structures is further meant to increase the level of intrigue and curiosity perceived by its users.

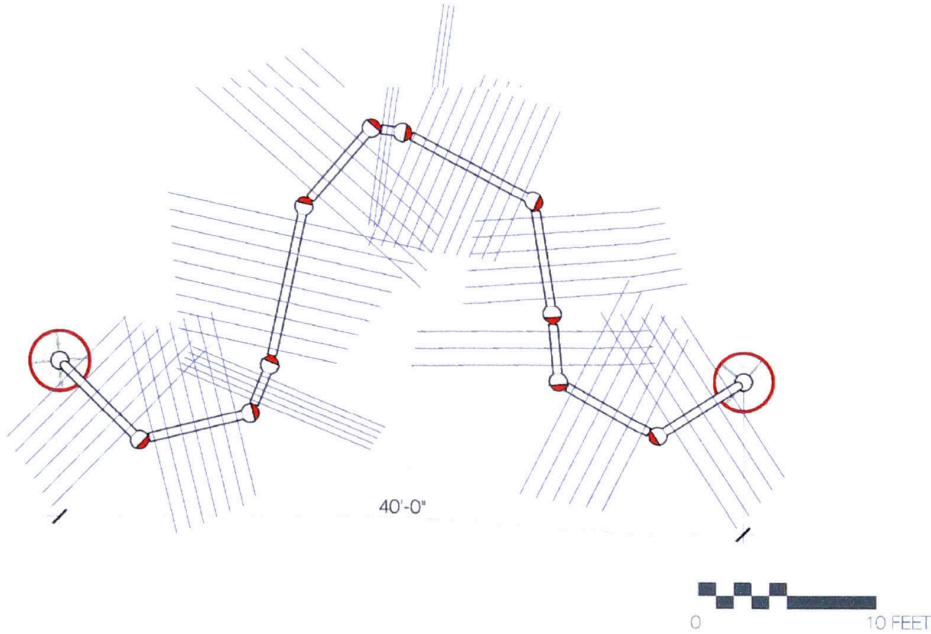
Each play-structure requires a user in order for the movement to become activated. The users direct manipulation, in addition to the method and location in which the parts are connected, creates the movement of the structure. Depending on the number of users manipulating the structure, the perceived space becomes more dynamic and unexpected.

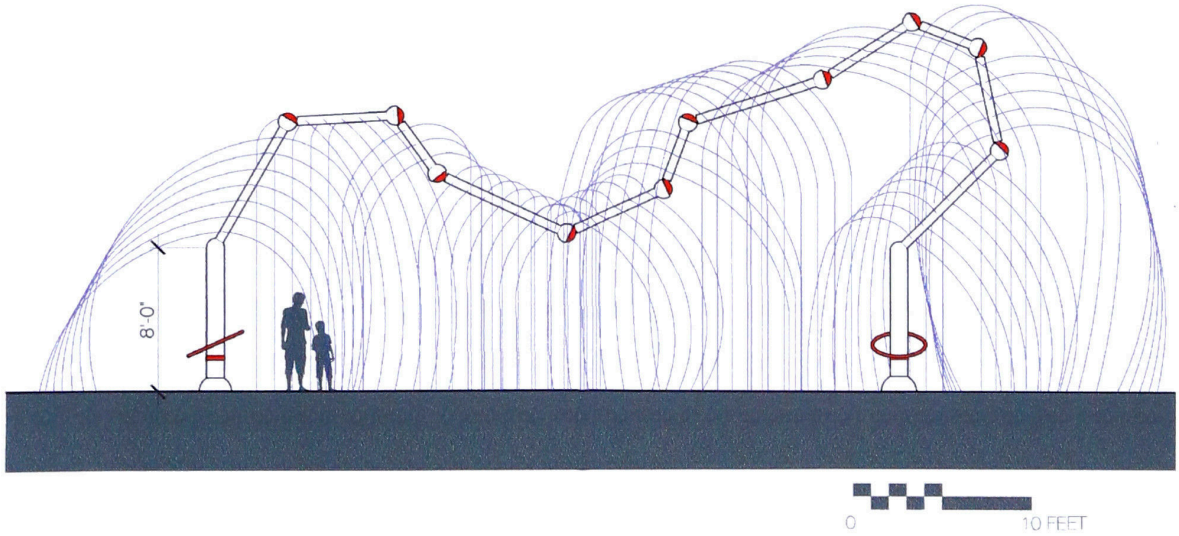
Bold colours are used in the play-structures as a means to emphasize and accentuate movement. The amount of colour seen, as well as the change in shade of colour, is the result of the movement in its connections.

The primary joint used for these play-structures is the ball-and-socket joint. This is "a joint in which a ball moves within a socket so as to allow rotary motion."[10] This type of joint offers 3 degrees of freedom in rotation making it the main reason for its utilization. The proposed connections are meant to be part of the conceptual nature of the proposal, therefore the accuracy of the connection cannot be fully ensured. Different variables such as the strain on the connection, the weight of the structure, the strength to weight ratio, etc. has not been considered. These allowances, along with others, needed to be taken in order to better focus on the conceptual idea for the play-structures. If this proposal were to become realized, specialists outside of the architectural profession, such as mechanical engineers, playground manufacturers, and child development specialists, would need to become involved, along with years of prototyping to insure proper functionality, safety, durability and longevity of the structures.

10 Merriam-Webster Online – Dictionary and Thesaurus. http://www.merriam-webster.com/dictionary/ball+and+socket?show=0&t=1331428708

D.2.1 Aqua Snake

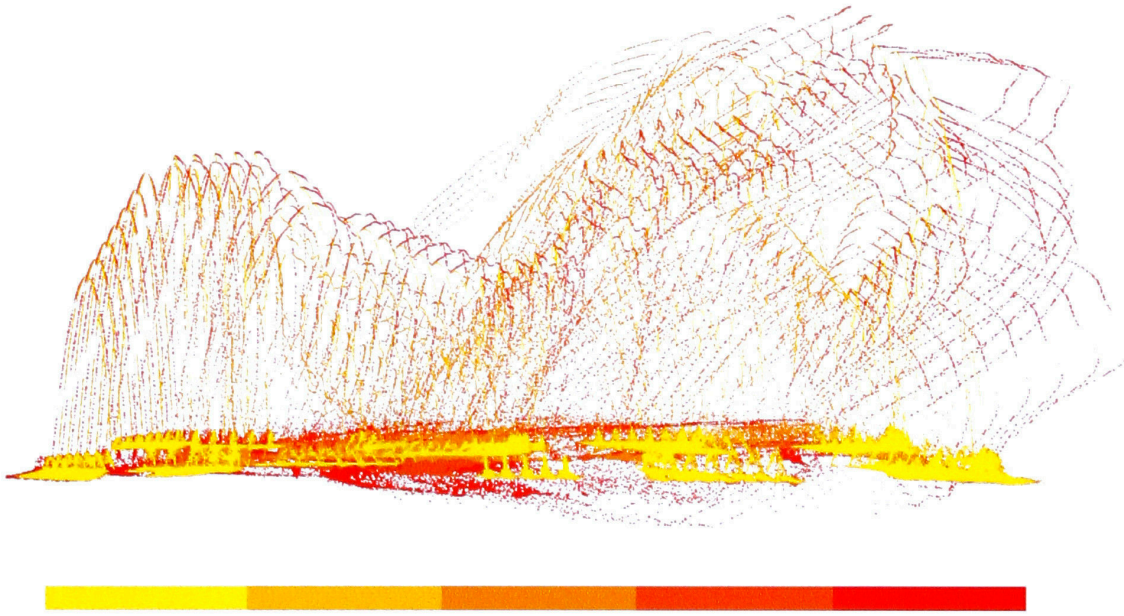

40'-0"
0
10 FEET


8'-0"
0
10 FEET

'Aqua Snake' is a type of interactive aquatic play-structure which can be used indoors or outdoors and in both an aquatic play pad or water playground scenario.[11] The play-structure consists of 2 supporting posts with 11 arms linking in between. Each arm has a series of holes on two of its sides, which sprays out water. These arms are connected together with ball-and-socket joints so that when the posts rotate, the arms are capable of moving in all sorts of directions creating unique spaces of water as a result.

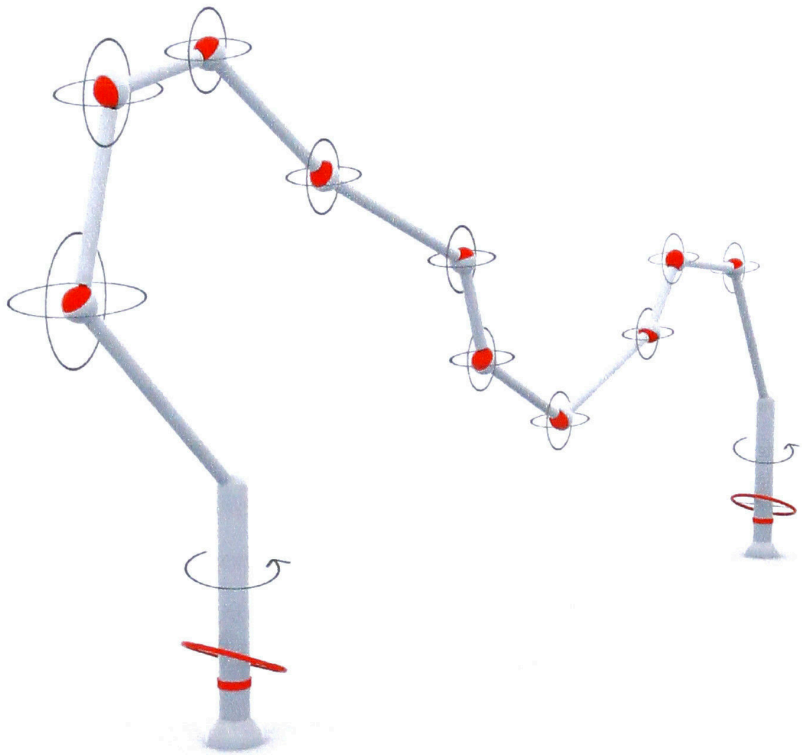
Kids and parents alike are capable of directly manipulating the spaces that are created by water. Without any manipulation the water space stays constant, but the moment the handle on one of the posts starts to rotate, the structure is set into motion. Depending on if both posts are rotating, in which direction, and at what speed, the arms will continue to change to create excitingly unlimited spaces. This play-structure is designed for multiple users.

11 The difference between these two scenarios is that a water playground allow for standing water, meaning it is essentially a shallow pool, where as play pad cannot hold water.



water spaces through time

'Aqua Snake' empowers its users to be in control of what happens. It encourages manipulation and demonstrates how spaces can be affected as a result. Whether rotating the posts or running in between the water spaces, the dynamic qualities of this play-structure insures that its users will stay engaged for hours of water fun. In addition to getting wet, the users will learn, explore, and be truly entertained.

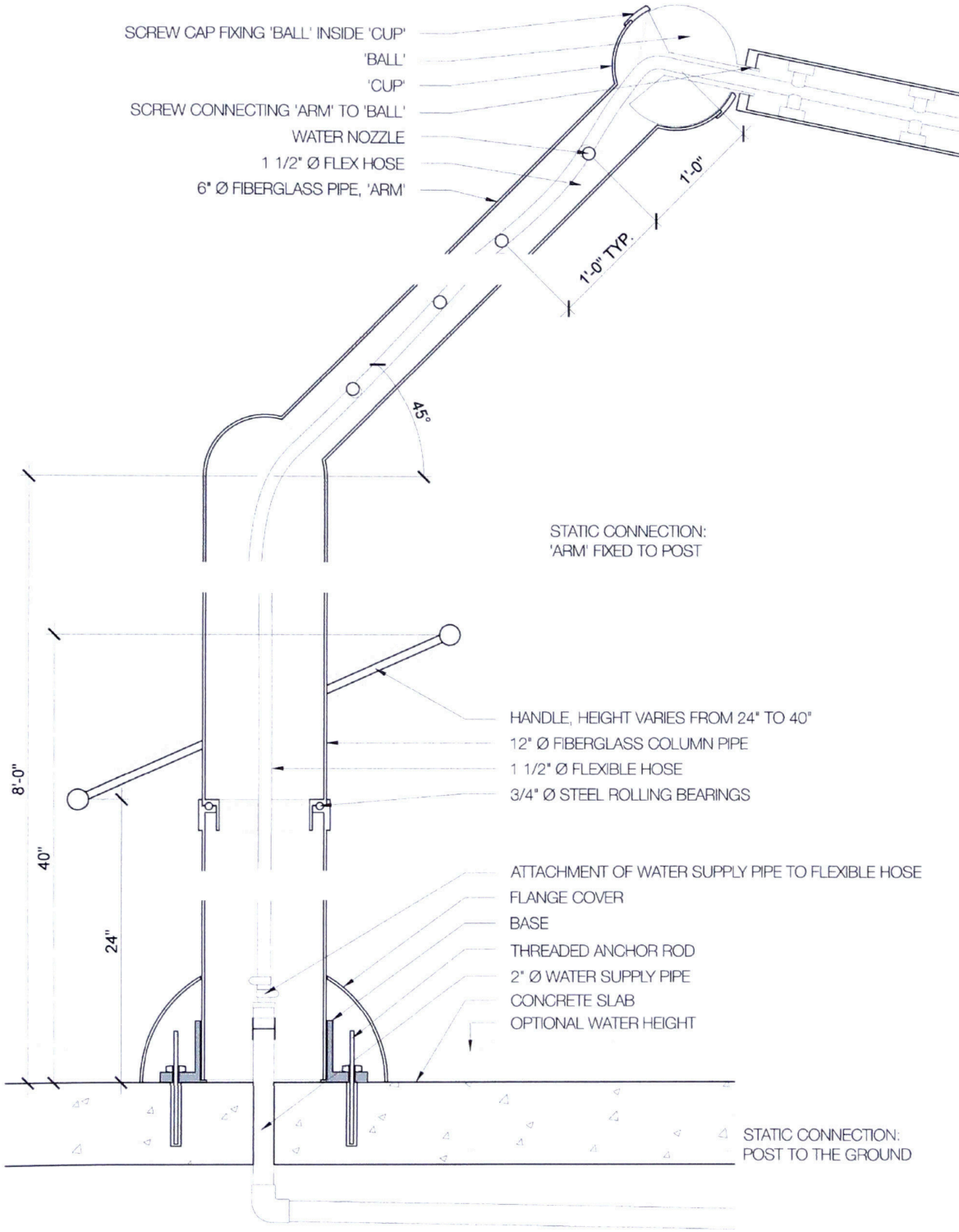


The handles are capable of rotating the upper portion of the post 360 degrees. The first arms on each ends of the posts are fixed at a 60° and 45° angles. This restriction constrains the remaining arms from lowering and coming into contact with its users. It also forces the first arm to rotate with its designated post, causing the remaining arms to react and adjust accordingly. This adjustment is what alters the spaces created by the water, the water pressure, and the effects of gravity.

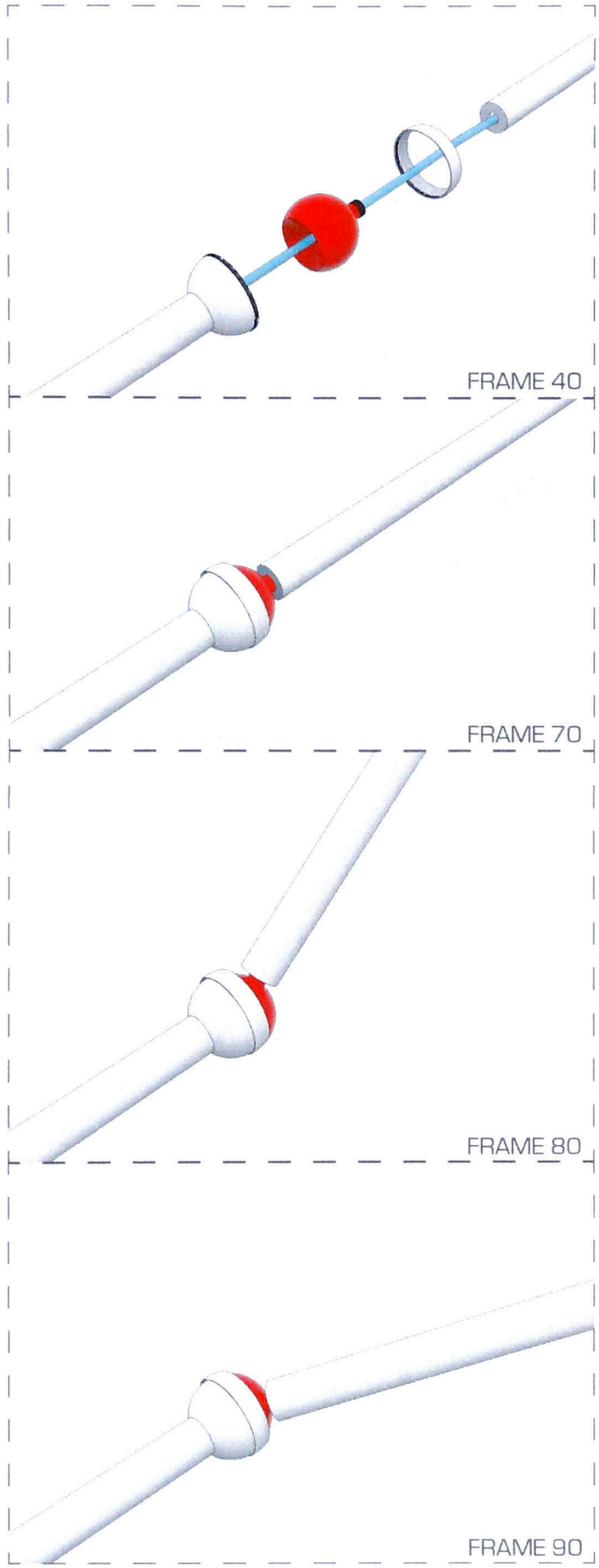
The ball in the ball-and-socket joints that connect the arms, are intentionally a separate colour from the arms and posts. This colour is meant to distinguish and emphasize the type, amount, and location of the movement created by the rotating arms. The two handles are the same colour as the 'balls' to better link the users motion to the structure's movement.

The simplicity of the structure emphasizes the important and power associated with the method of connection. The joint is what connects the arms, it is where the movement is incorporated and it is what creates the experience. 'Aqua Snake' has three significant types of joints, the main ball-and-socket joint, the joint that allows the posts to rotate, and the static joint that connects the posts to the ground.

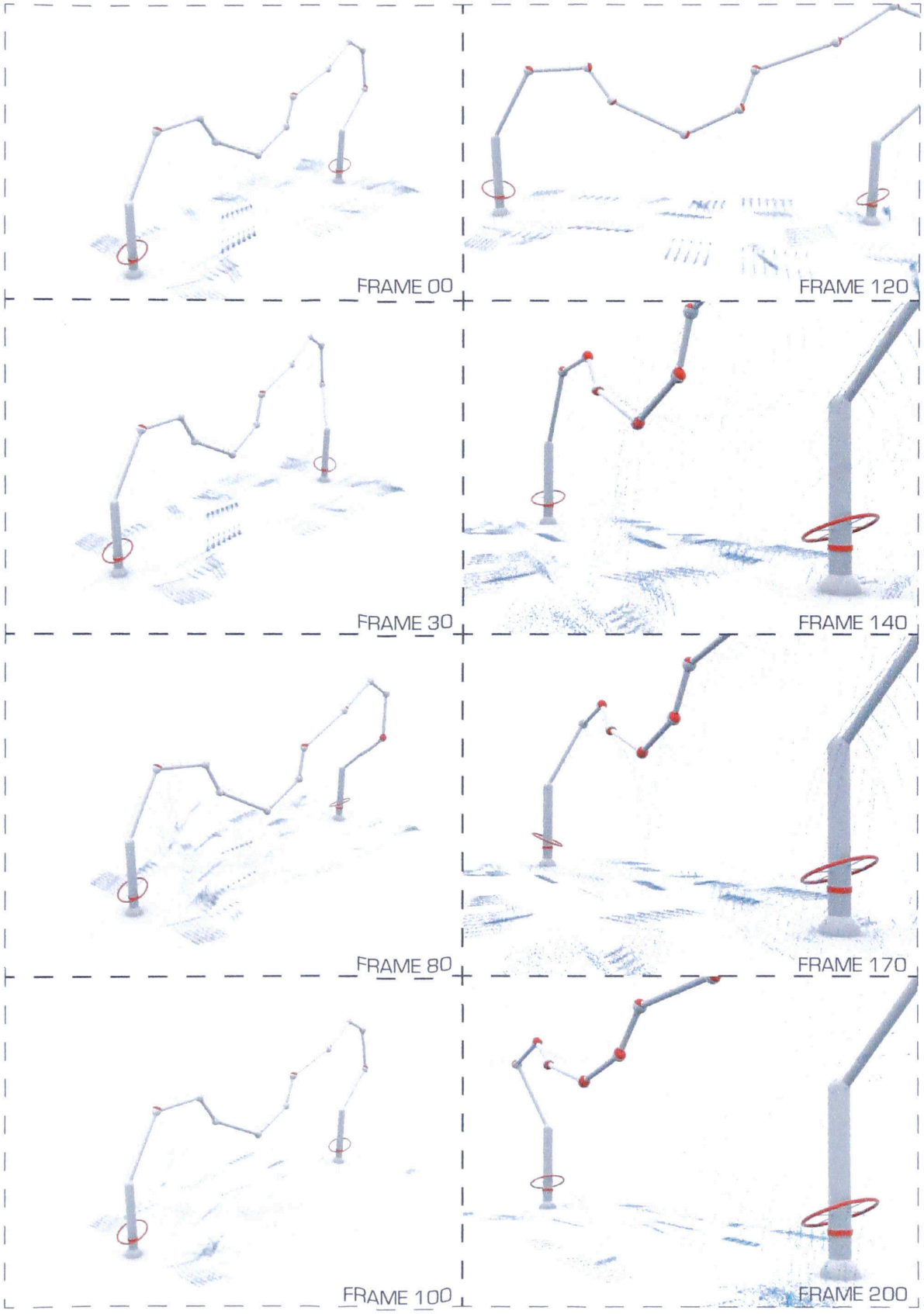
A water supply pipe is installed prior to pouring the concrete slab. A flexible hose is rigidly attached to the supply pipe and travels throughout the posts and arms, supplying the structure with water. The posts are attached to a base that is directly bolted to the slab. The base is then covered to protect the attachments and to give a cleaner appearance. The size, shape and finish of the posts make it difficult for users to climb. At 2'-0" from the slab, a special connection with built in ball bearings attaches the top section of the post to the lower, allowing for it to rotate. The height of the handle varies slightly to accommodate for the different users' heights and is directly attached to the top section. The posts and arms are made of a lightweight but very strong fiberglass. The first arm is rigidly attached to the post. Located at the end of the first arm is a 'socket' and at the beginning of the second arm is a 'ball' with a hole through it. The hole allows for the flexible water supply pipe to pass through and the 'ball' sits in the 'socket' where it is secured with a screw cap. The remaining arms are attached in a similar fashion.

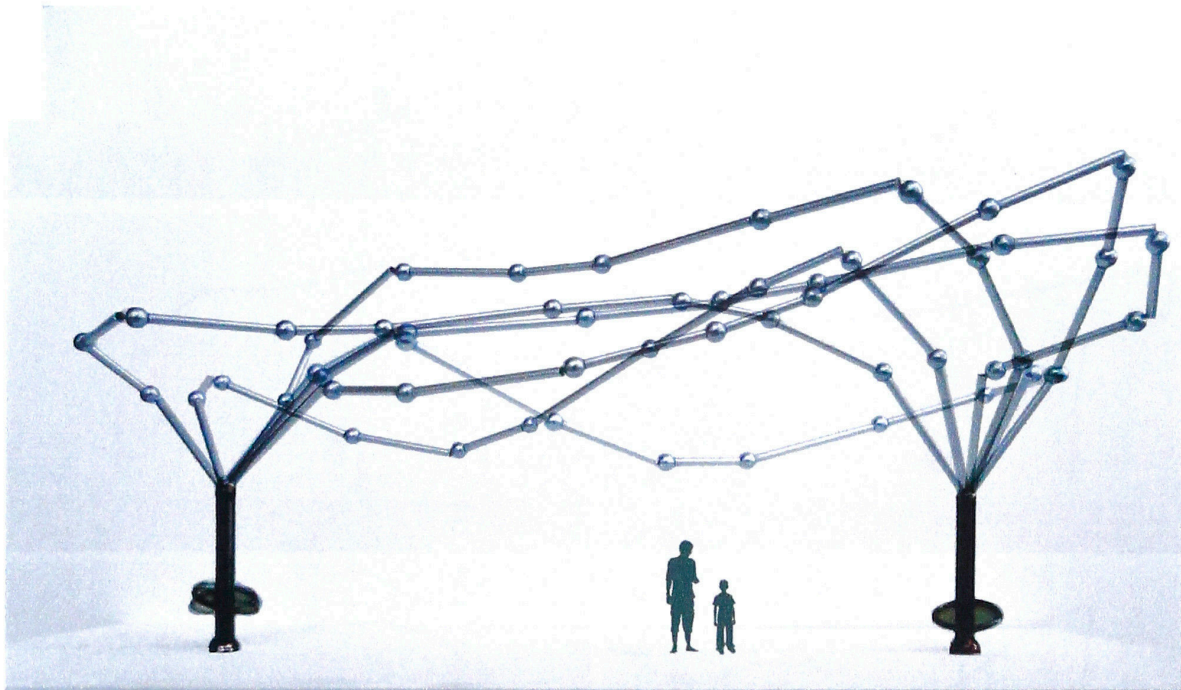

SCREW CAP FIXING 'BALL' INSIDE 'CUP'
'BALL'
'CUP'
SCREW CONNECTING 'ARM' TO 'BALL'
WATER NOZZLE
1 1/2" Ø FLEX HOSE
6" Ø FIBERGLASS PIPE, 'ARM'
1'-0"
1'-0" TYP.
45°
STATIC CONNECTION:
'ARM' FIXED TO POST
8'-0"
40"
24"
HANDLE, HEIGHT VARIES FROM 24" TO 40"
12" Ø FIBERGLASS COLUMN PIPE
1 1/2" Ø FLEXIBLE HOSE
3/4" Ø STEEL ROLLING BEARINGS
ATTACHMENT OF WATER SUPPLY PIPE TO FLEXIBLE HOSE
FLANGE COVER
BASE
THREADED ANCHOR ROD
2" Ø WATER SUPPLY PIPE
CONCRETE SLAB
OPTIONAL WATER HEIGHT
STATIC CONNECTION:
POST TO THE GROUND

SNAPSHOTS FROM VIDEO EXPLAINING TYPICAL JOINT



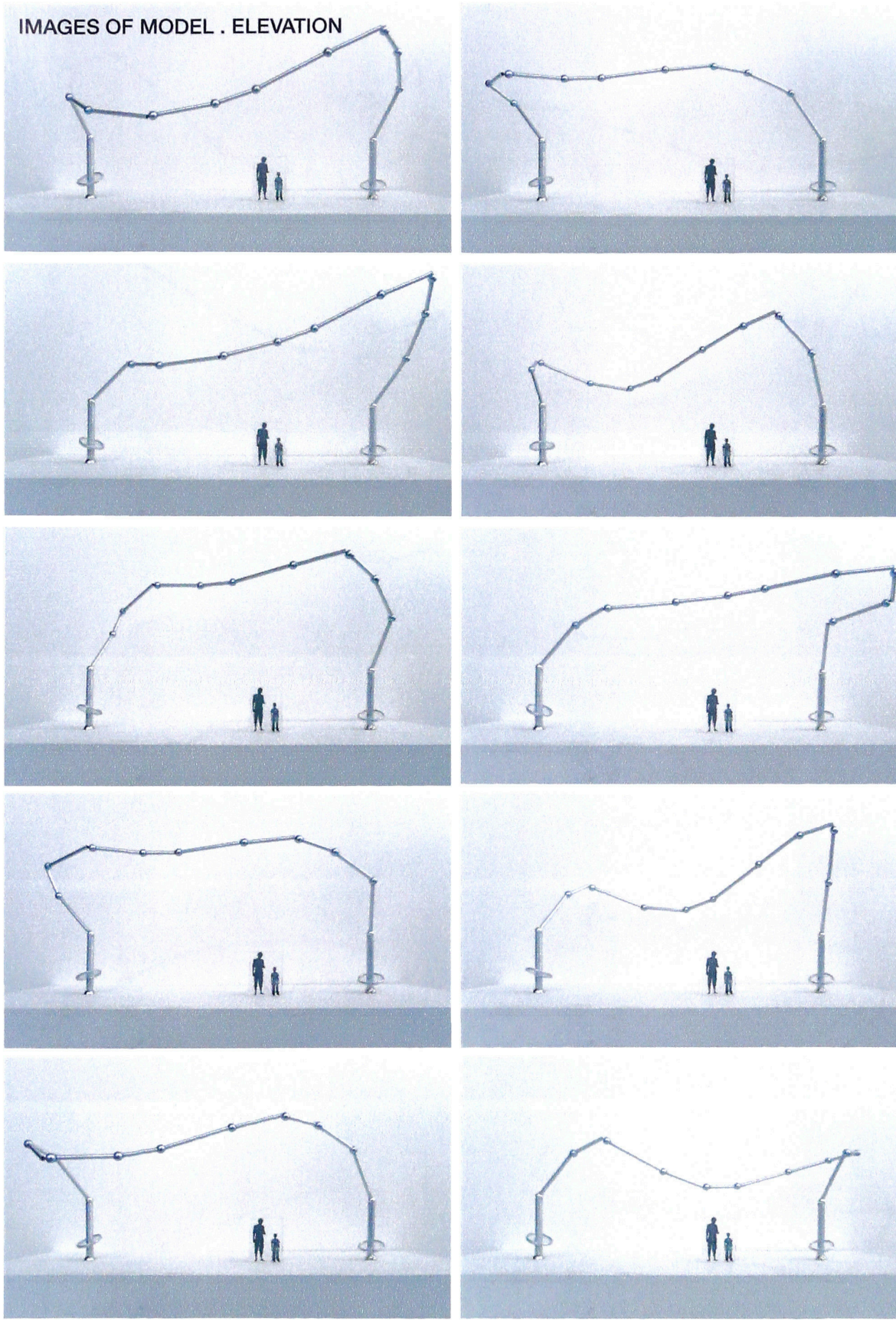
SNAPSHOTS FROM VIDEO



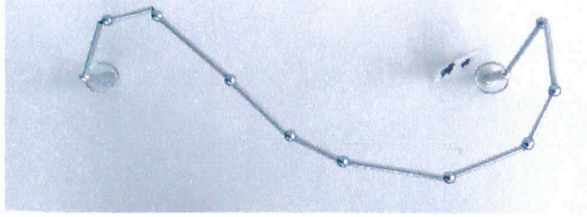
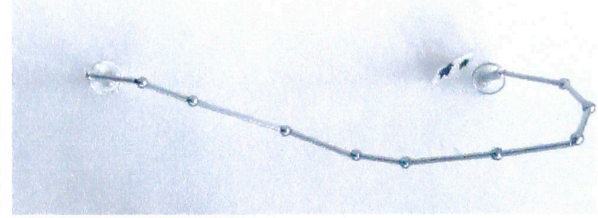
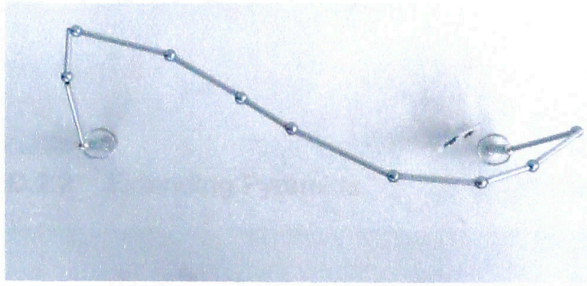
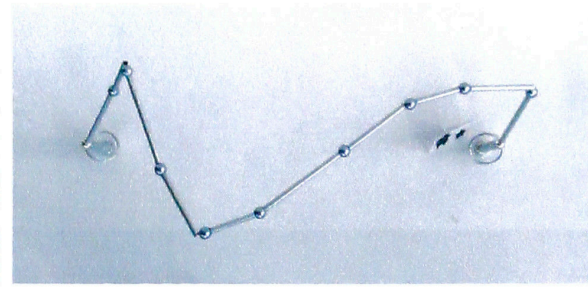
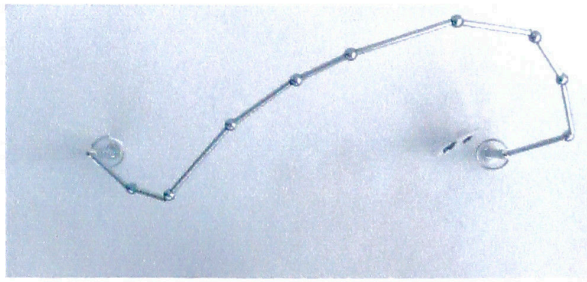
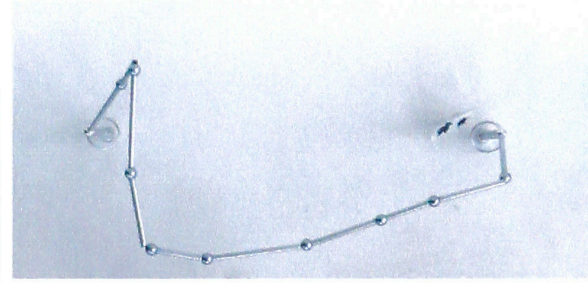
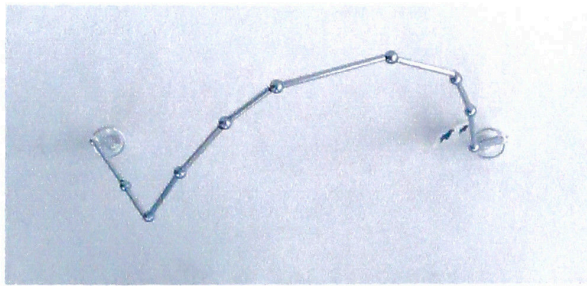
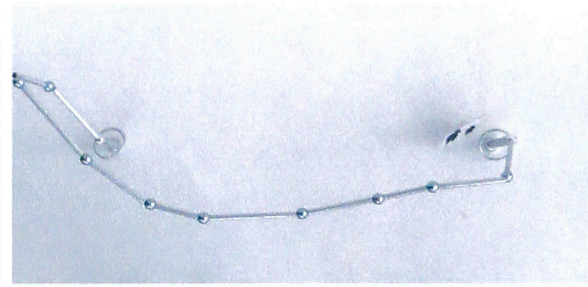
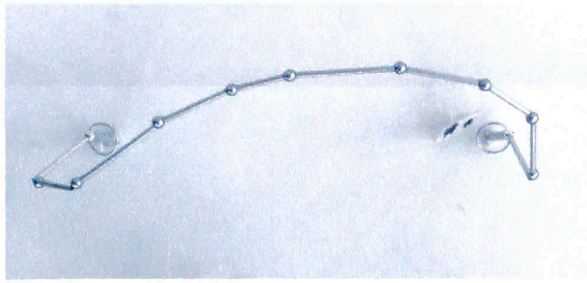
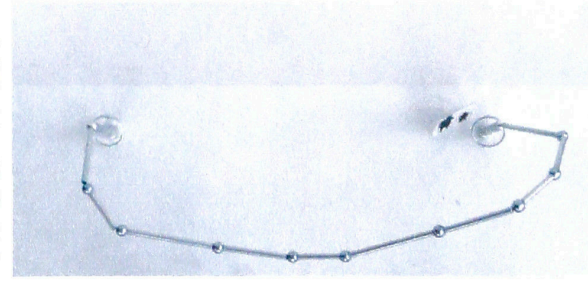
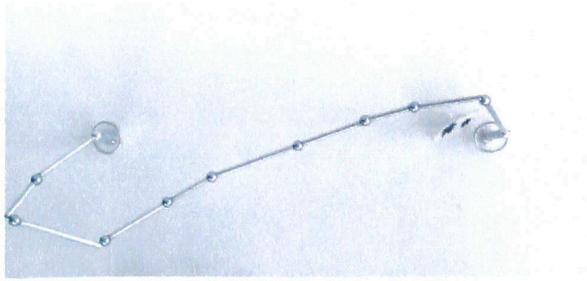
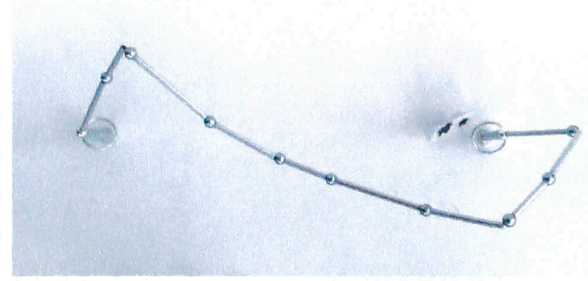


COMPILATION OF IMAGES OF THE MODEL

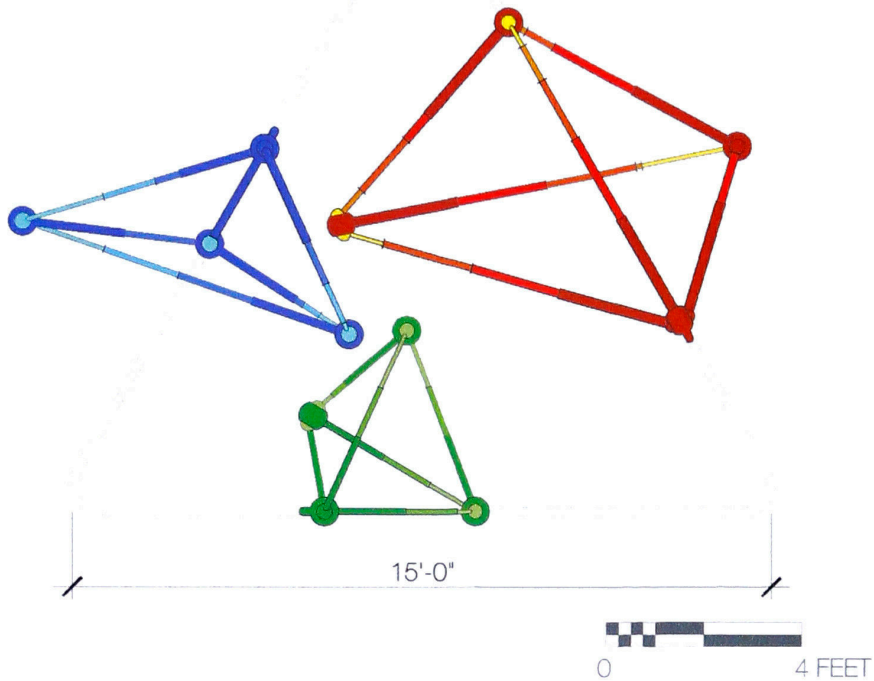
IMAGES OF MODEL . ELEVATION

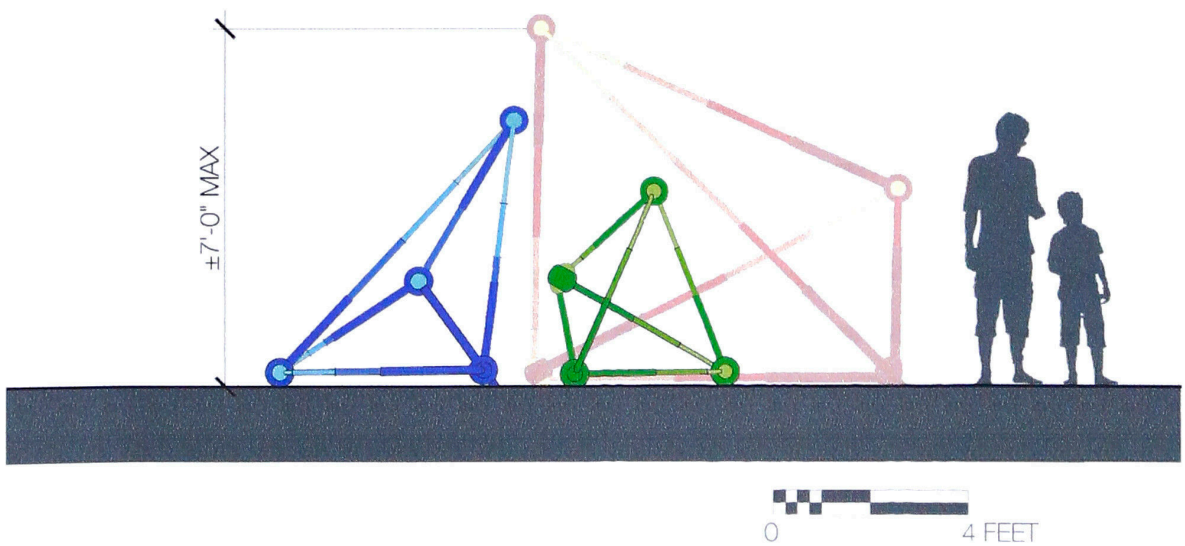


IMAGES OF MODEL . PLAN

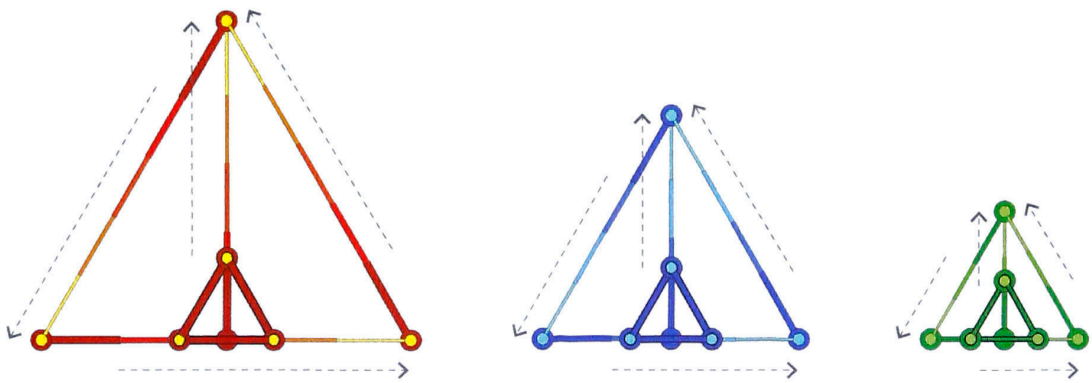













D.2.2 Extending Pyramids


15'-0"
0
4 FEET


±7'-0" MAX
0
4 FEET

'Extending Pyramids' is a transformable play-structure, which is similar to a life sized play toy. Users are encouraged to manipulate, mold, and configure three pyramids to significantly change their size, shape, and space. Each pyramid is made up of 6 extendable arms. These arms can double, triple, and quadruple in size depending on the pyramid. The pyramids are attached to the ground at one of its corners to allow the complete structure to rotate onto its side. They are placed in tracks in the ground so, in addition to individually transforming their shape, the spaces between the pyramids also transform. In situations where a specific age appropriate play area is required or where space is limited, there is the option of incorporating only one of the pyramids. 'Extending Pyramids' embraces the users playful curiosity and promotes imaginative play through the transforming of spaces.



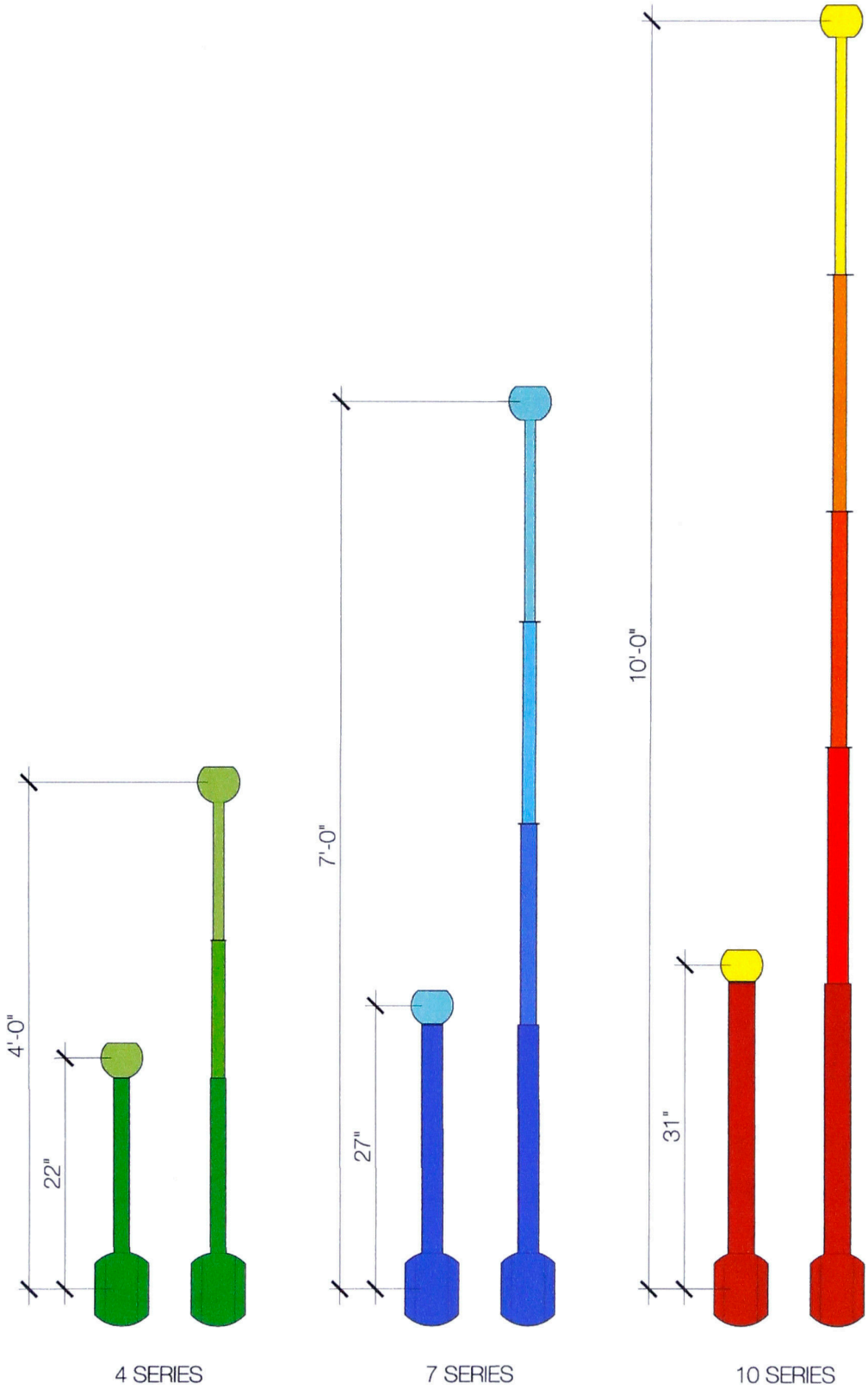
Simply put, users slide arms in and out, enlarging and shrinking the shape and size of the pyramids. Users are encouraged to experiment in changing the spaces around, of and within the pyramids. This play-structure offers a relaxing alternative, based on exploration, and creative and imaginative stimulation compared to other existing high-energy physically based (running, sliding, climbing...) structures. 'Extending Pyramids' is both a collaborative and individual play-structure.

Each of its six arms is telescoping so when they are all attached together it creates a size-adjusting object. The arms are connected together through individual ball-and-socket joints to allow for their independent extension regardless of the length of its 2 neighbouring arms. This allows for the possibility to create more distortedly shaped pyramids. By attaching the pyramids to the ground via a 'ball' in a track, this allows each pyramid the capability to rotate and translate. 'Extending Pyramids' introduces users to the possibility of altering and configuring their own spaces.

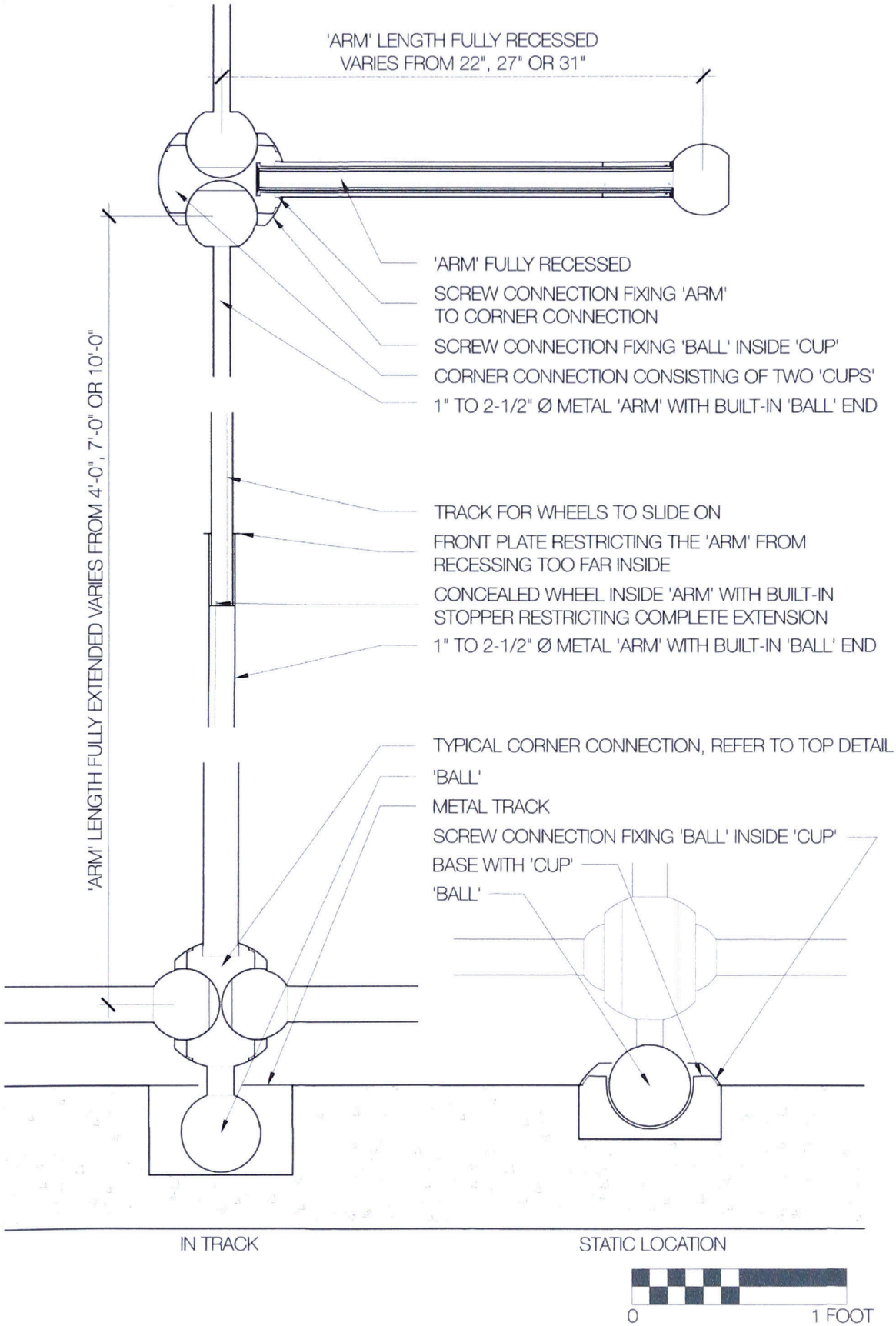
Colour plays an exciting role in this play-structure. Each extendable section of an arm is of a different hue. When the sections are fully recessed, the pyramid appears to be one colour but when the sections start to extend, a brighter shade appears. This intensified colour makes the transformable nature of the pyramids more obvious and striking from a distance. It also enhances the user's delight and wonder when the pyramids are in motion.

'Extending Pyramids' has three significant types of joints: the typical corner connection, the extendable sections within the arms, and the connection of the pyramid to the ground. These joints are vital to the movement, manipulation, and transformability of the play-structure.

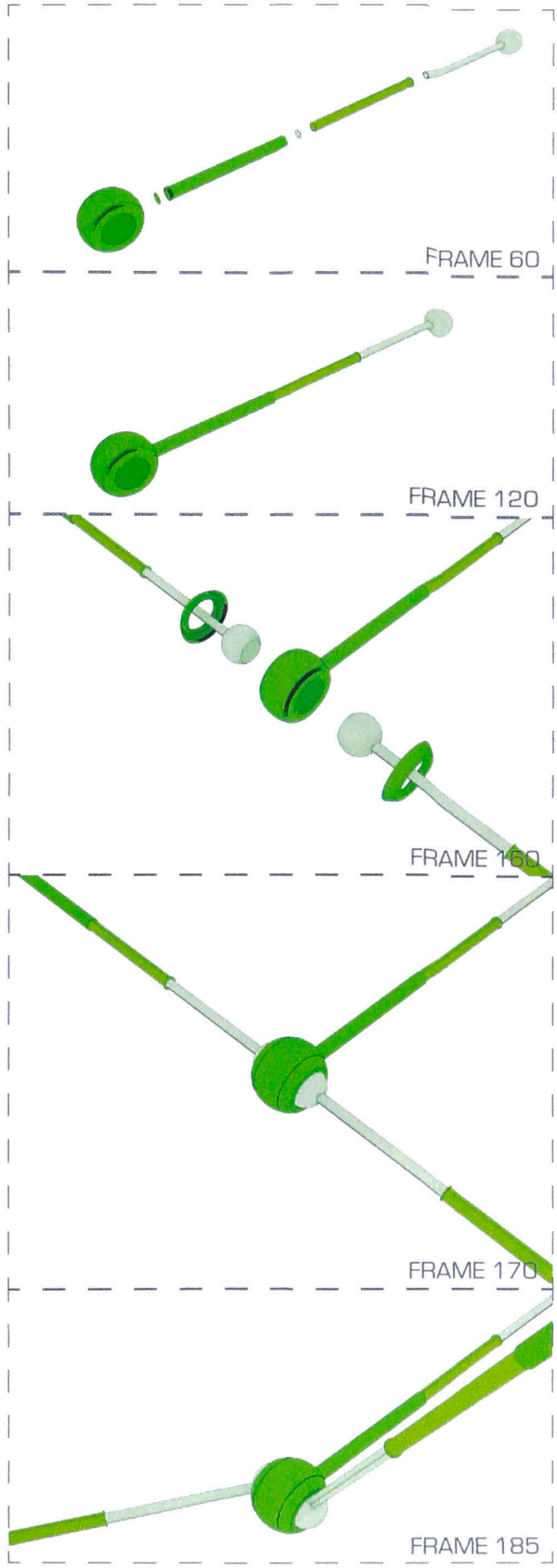
A typical corner connection consists of 2 ball-and-socket connectors and a screw connection. Located on either end of an arm is a threaded pipe and a 'ball'. The 'ball' end is placed inside the 'socket' of the corner connection and a screw connection fixes the ball in place. The threaded pipe on the opposite end is screwed directly into the corner connection. Each of the other 3 corner connections are done similarly with the exception of one. The connection of the pyramid to the ground is slightly different for it has an additional built-in 'ball'. This 'ball' fixes the pyramid to the ground. If more than one pyramid is utilized then a track is placed in the concrete slab. This track accepts the 'ball', allowing the pyramid to freely move along the track. If only one pyramid is utilized then the 'ball' sits inside a 'socket' located on a fixed base connection. A screw connection fixes the ball inside the socket so that it cannot fall out. Each arm contains 3, 4, or 5 separate sections. Concealed wheels are incorporated inside each section to create the extending motion. Built-in stoppers are included inside the arm to restrict the wheels from extending the sections too far out. A front plate located at the end of each of the sections restricts the sections from receding too far inside the arm.

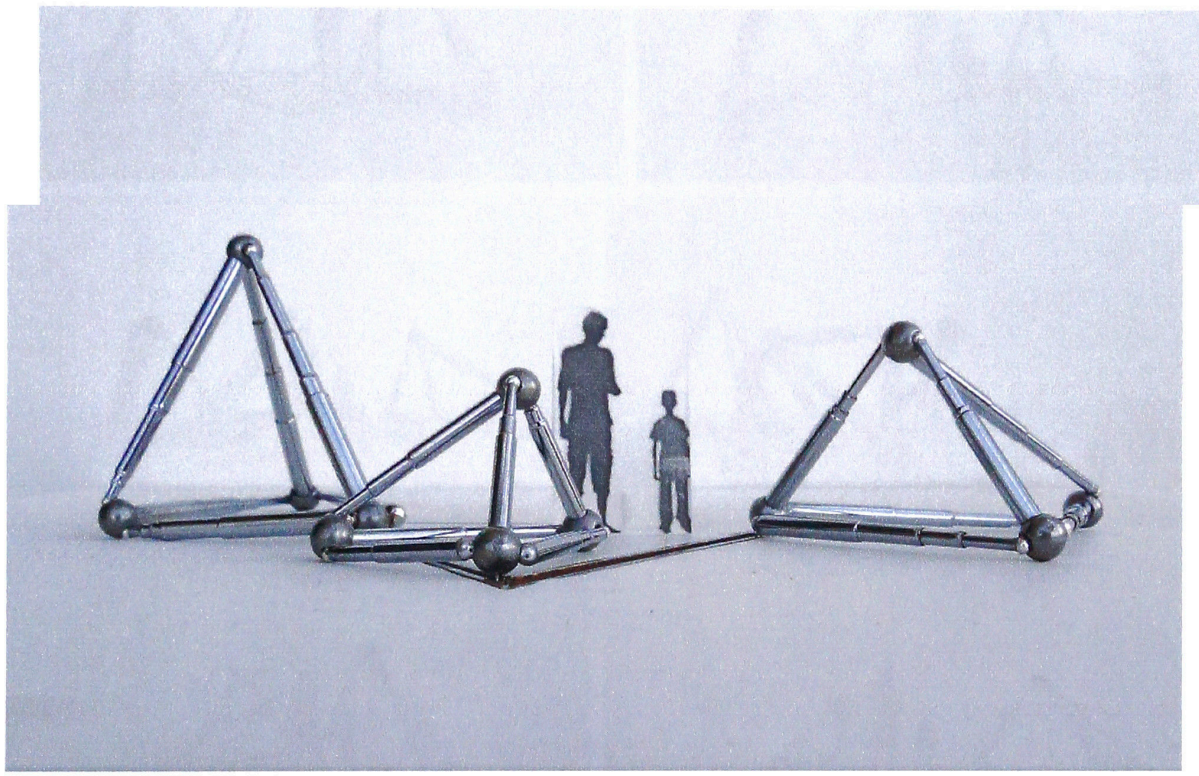


The pyramids are available in 3 sizes: 4 foot, 7 foot and 10 foot.

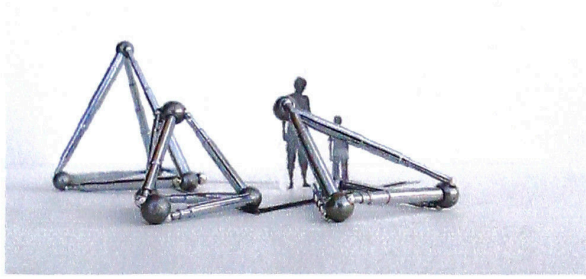
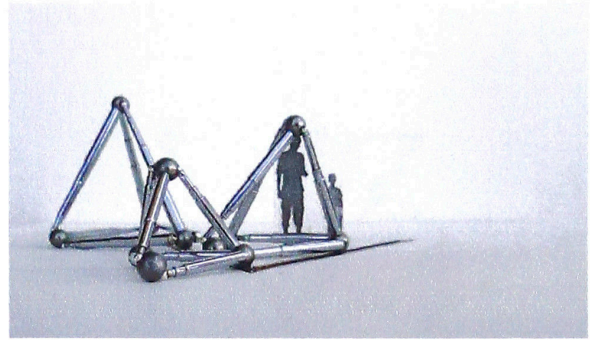
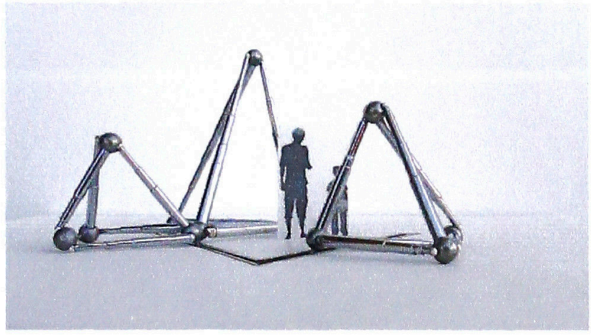
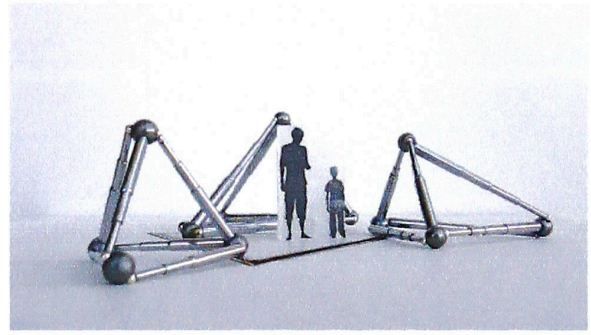
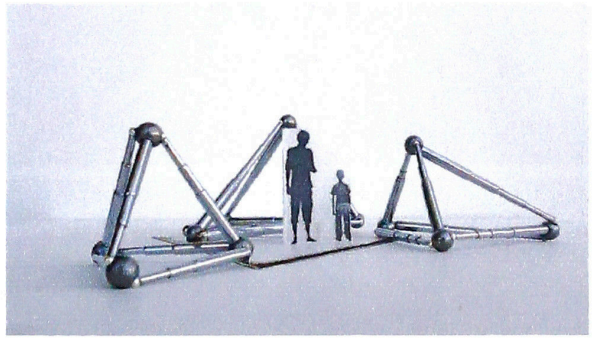
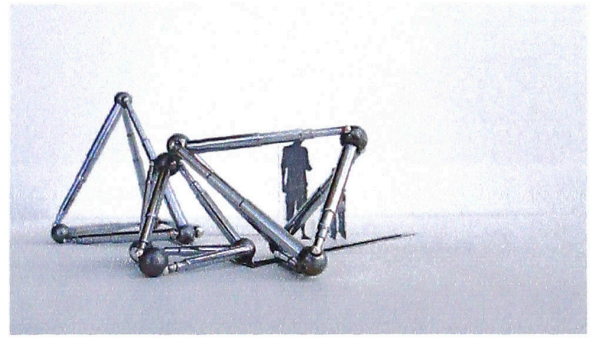
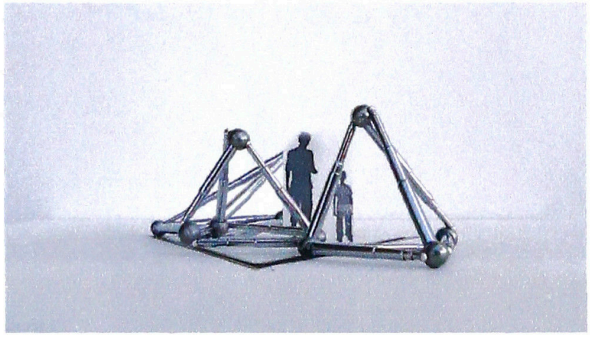
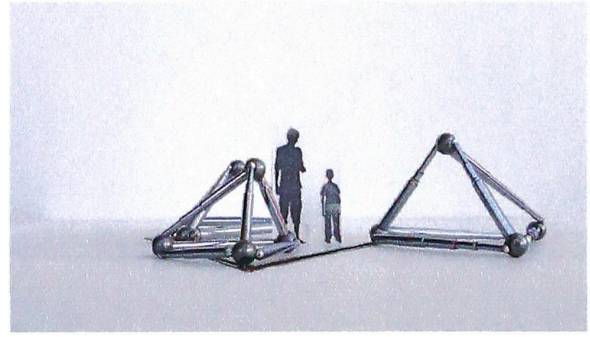
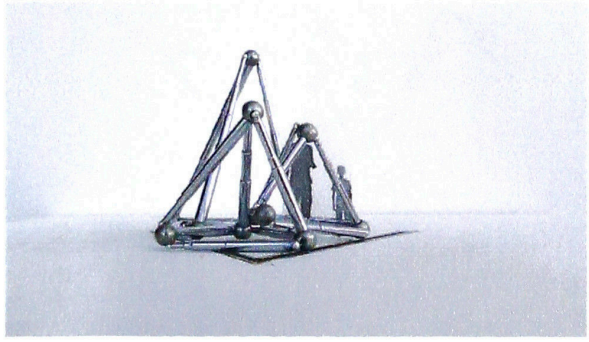
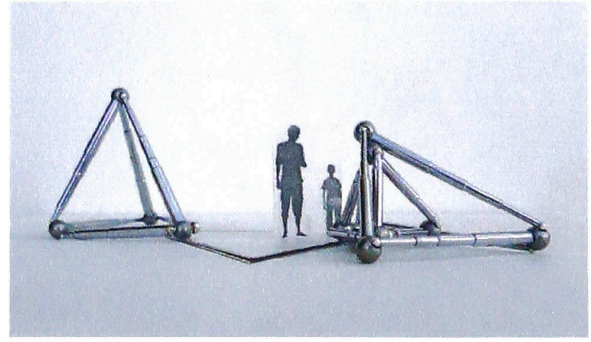

'ARM' LENGTH FULLY RECESSED
VARIES FROM 22", 27" OR 31"
'ARM' FULLY RECESSED
SCREW CONNECTION FIXING 'ARM'
TO CORNER CONNECTION
SCREW CONNECTION FIXING 'BALL' INSIDE 'CUP'
CORNER CONNECTION CONSISTING OF TWO 'CUPS'
1" TO 2-1/2" Ø METAL 'ARM' WITH BUILT-IN 'BALL' END
'ARM' LENGTH FULLY EXTENDED VARIES FROM 4'-0", 7'-0" OR 10'-0"
TRACK FOR WHEELS TO SLIDE ON
FRONT PLATE RESTRICTING THE 'ARM' FROM
RECESSING TOO FAR INSIDE
CONCEALED WHEEL INSIDE 'ARM' WITH BUILT-IN
STOPPER RESTRICTING COMPLETE EXTENSION
1" TO 2-1/2" Ø METAL 'ARM' WITH BUILT-IN 'BALL' END
TYPICAL CORNER CONNECTION, REFER TO TOP DETAIL
'BALL'
METAL TRACK
SCREW CONNECTION FIXING 'BALL' INSIDE 'CUP'
BASE WITH 'CUP'
'BALL'
IN TRACK
STATIC LOCATION
0
1 FOOT

SNAPSHOTS FROM VIDEO EXPLAINING TYPICAL JOINT

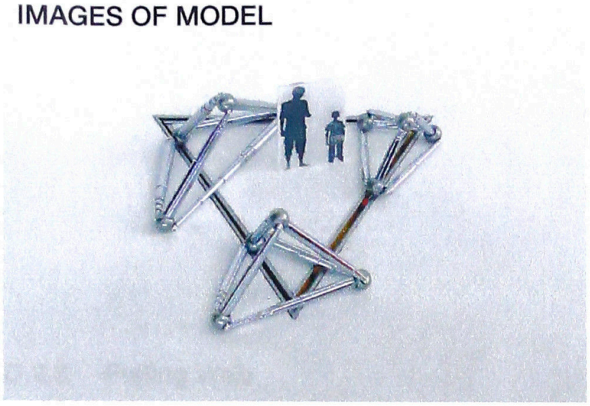


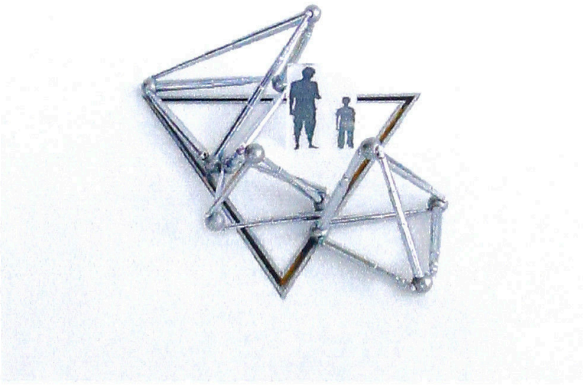


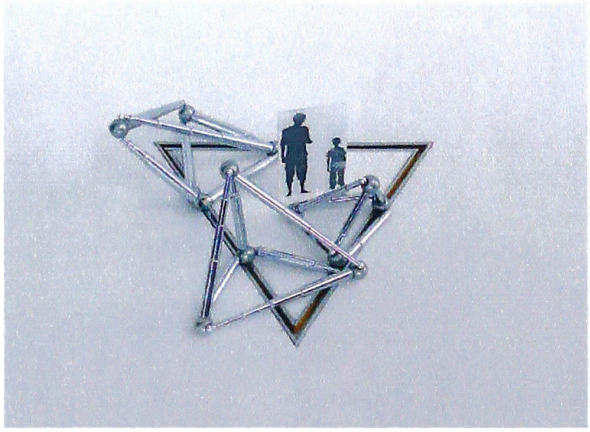
IMAGES OF MODEL

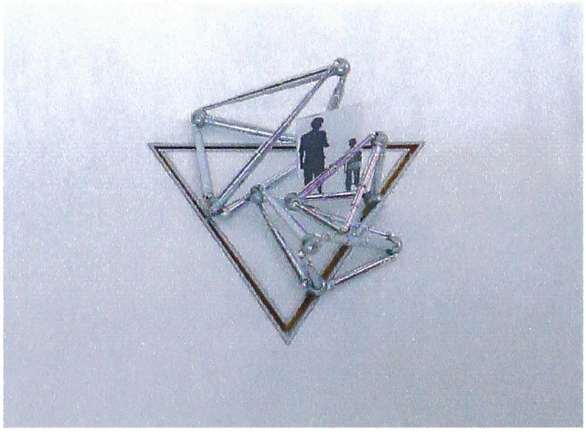











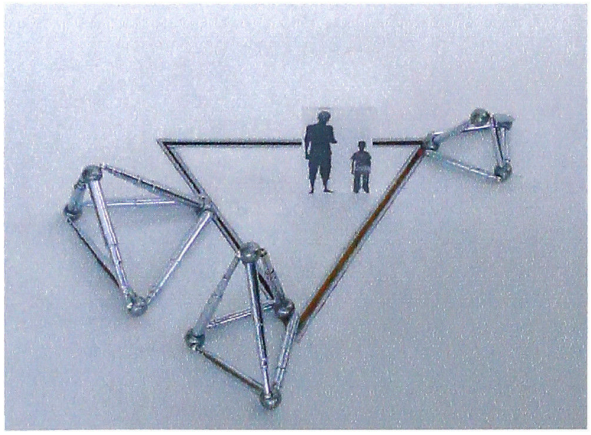
IMAGES OF MODEL

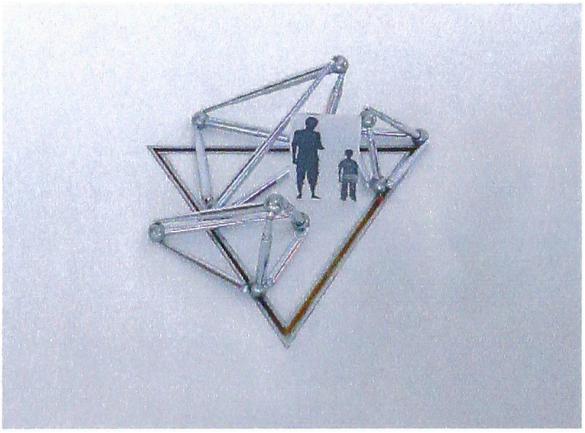


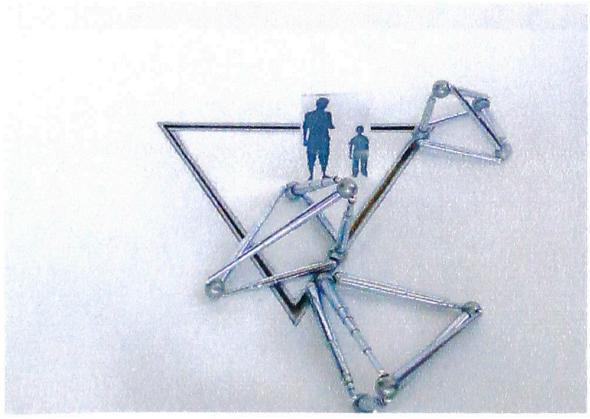


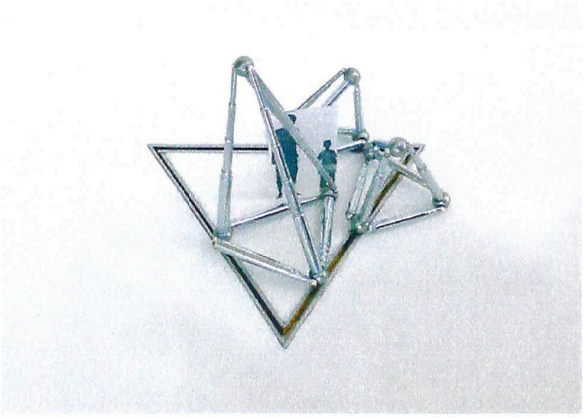




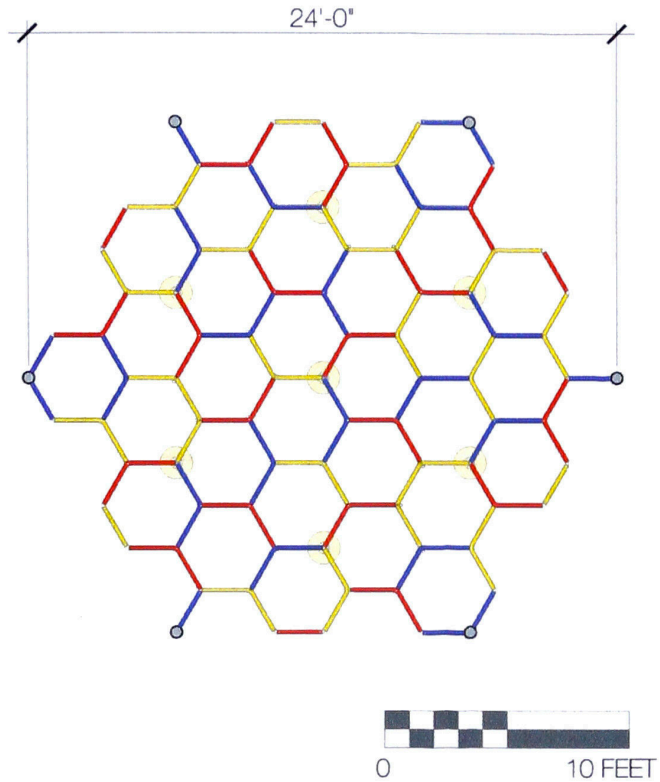


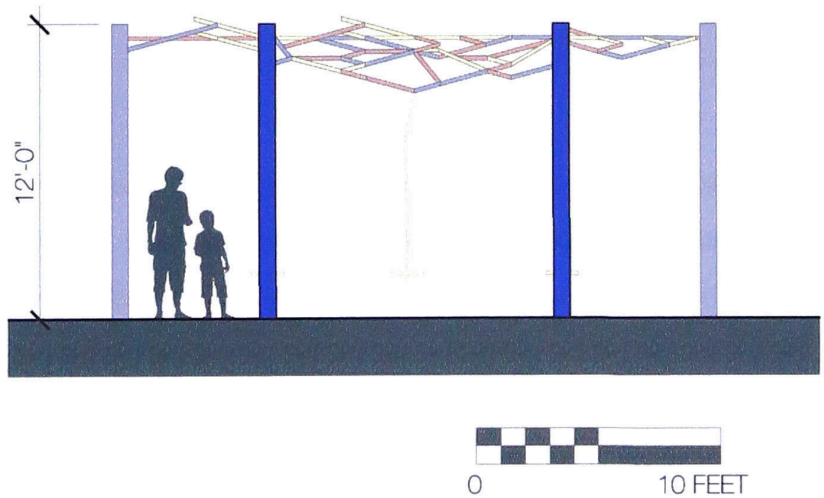




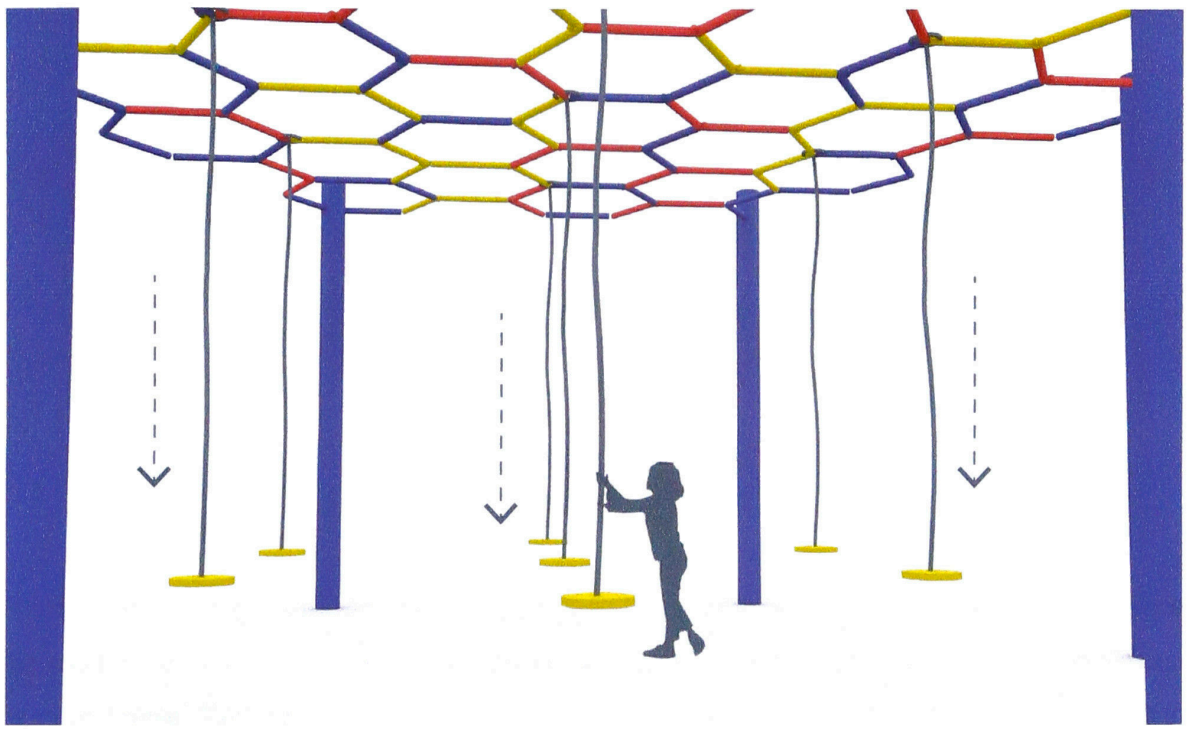


D.2.3 Pulling Web

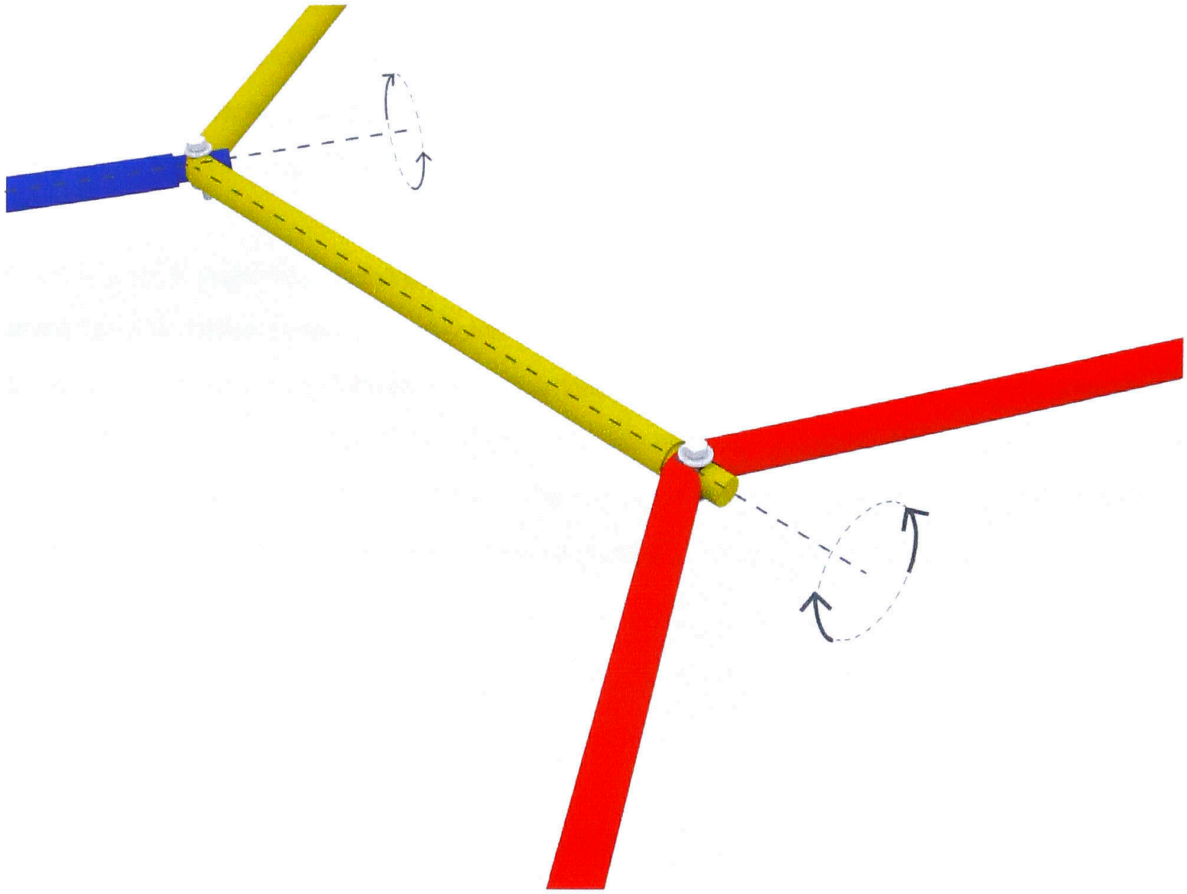

24'-0"
0
10 FEET


12'-0"
0
10 FEET

'Pulling Web' is an overhead surface that welcomes manipulation. A hexagon pattern of pipes and joints make up a web like structure. The arrangement of the pipes is done in such a way so that when a user pulls on the web it activates the surface and moves it in unexpected ways. The web morphs depending on the location, direction, strength, and number of the users. In addition to the web being pulled towards the user, the remaining sections of the surface are designed to react and move accordingly and interestingly. When multiple users are pulling on the structure, its shape and outcome become more interesting and unpredictable.



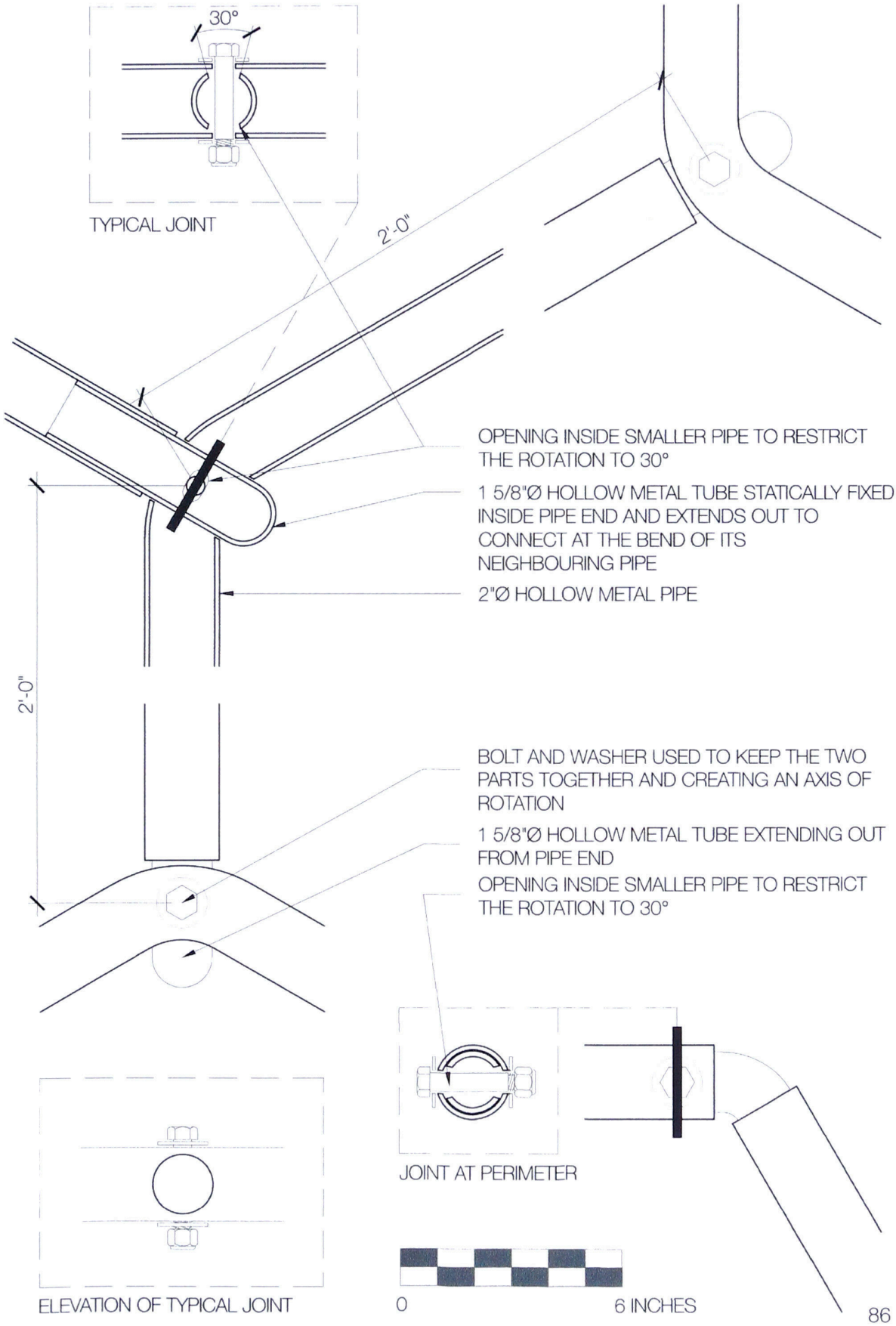
A cord is attached to the web in specifically placed locations. This cord is what allows the users to manipulate the structure. They can pull, sit, or swing on the rope while witnessing and becoming intrigued at how their actions have moved the surface and how the surface was able to transform. When more than one cord is being pulled, understanding the structure becomes harder. The structure appears to be more random and the shape of the web appears to be more sporadic. The excitement and intrigue about 'Pulling Web' is seeing the affects that the users directly had over a surface. This creates a stronger link between the users and their space.



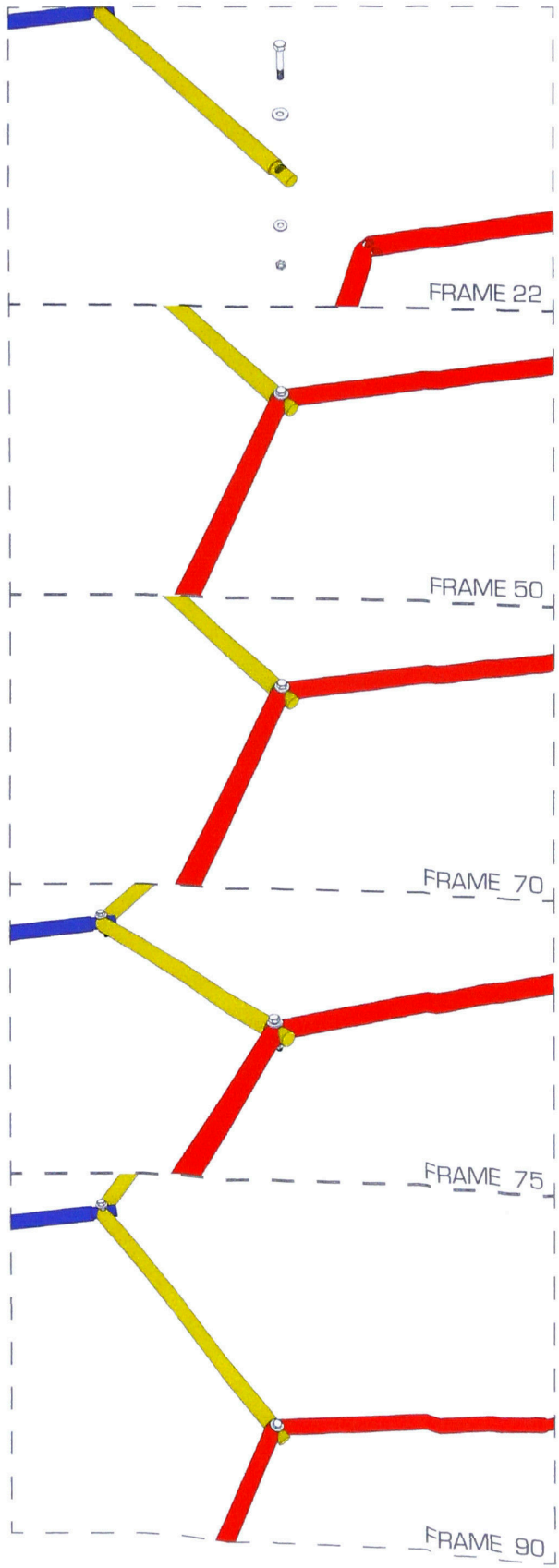
There is only one type of movement in this structure: the rotation of pipes. The power and experience behind this structure is through the configuration and pattern of these pipes and where the movement is incorporated. Each pipe is bent to form 2 angles of a hexagon. Each end of the pipe is connected to the middle (where the bend occurs) of another pipe. This pattern and repetition continues throughout the structure. The only exception to this method is where the cord is attached to the web and along the perimeter of the web. The standard motion of the pipes is constrained to allow only 30 degrees of rotation. The reason for this restriction is to insure that the web cannot obstruct the users. Another reason is so that when the user pulls the cord, the reaction is not a quick jerk from one of the pipes but a slower motion from several pipes. When one area gets pulled it starts a chain of events as more and more arms start to adjust accordingly to deal with the applied force.

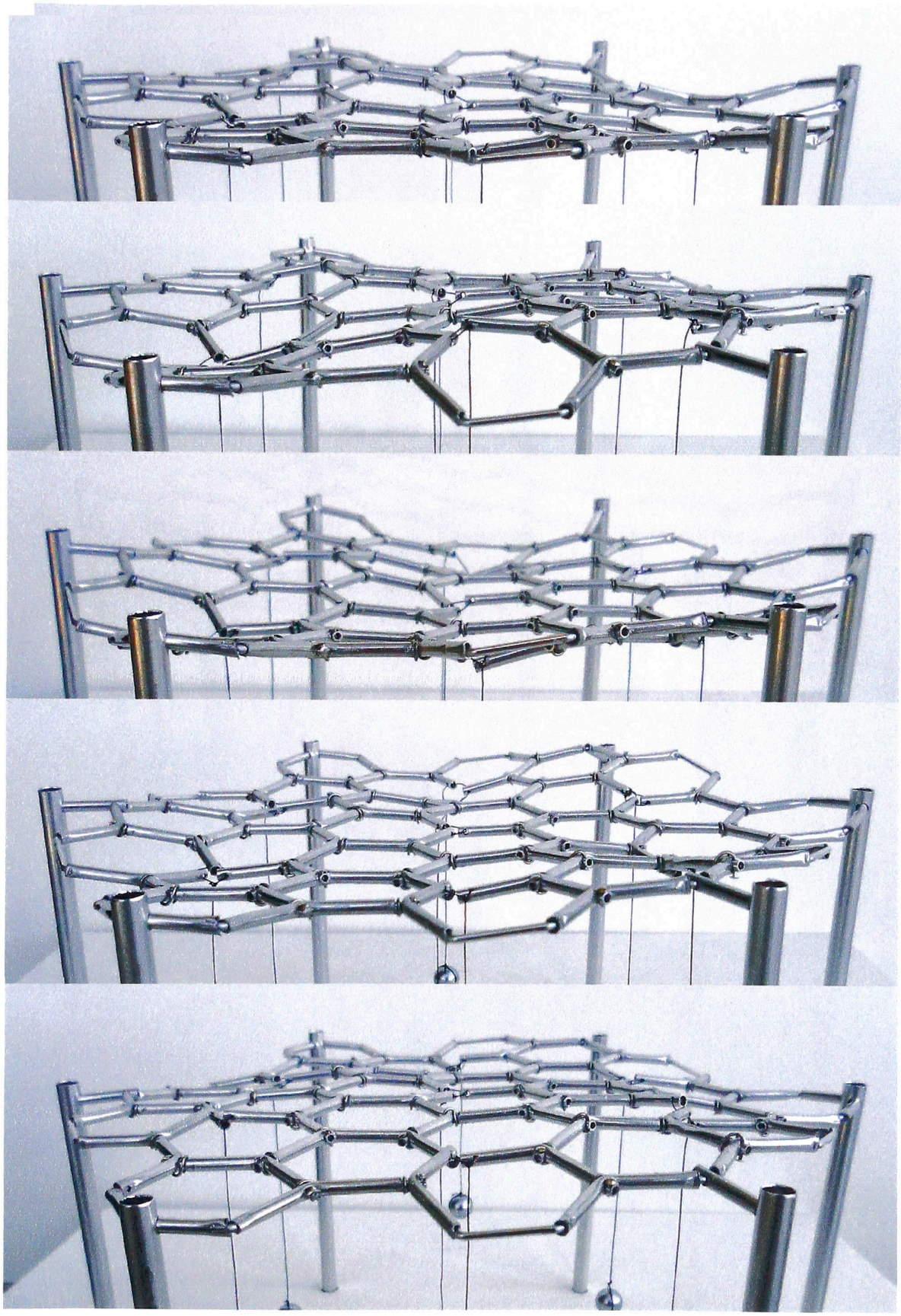
'Pulling Web' utilizes colour as an aid in understanding how the action occurs. Even though most of the pipes are typical, colour is used to help explain the pattern. Each pipe is given one of three colours. The specific colour of the pipe is not important but what is important is that no pipe of the same colour is attached to each other. By looking up at the structure, the configuration of the pipes becomes clearer and helps in understanding the fashion at which the pipes move.

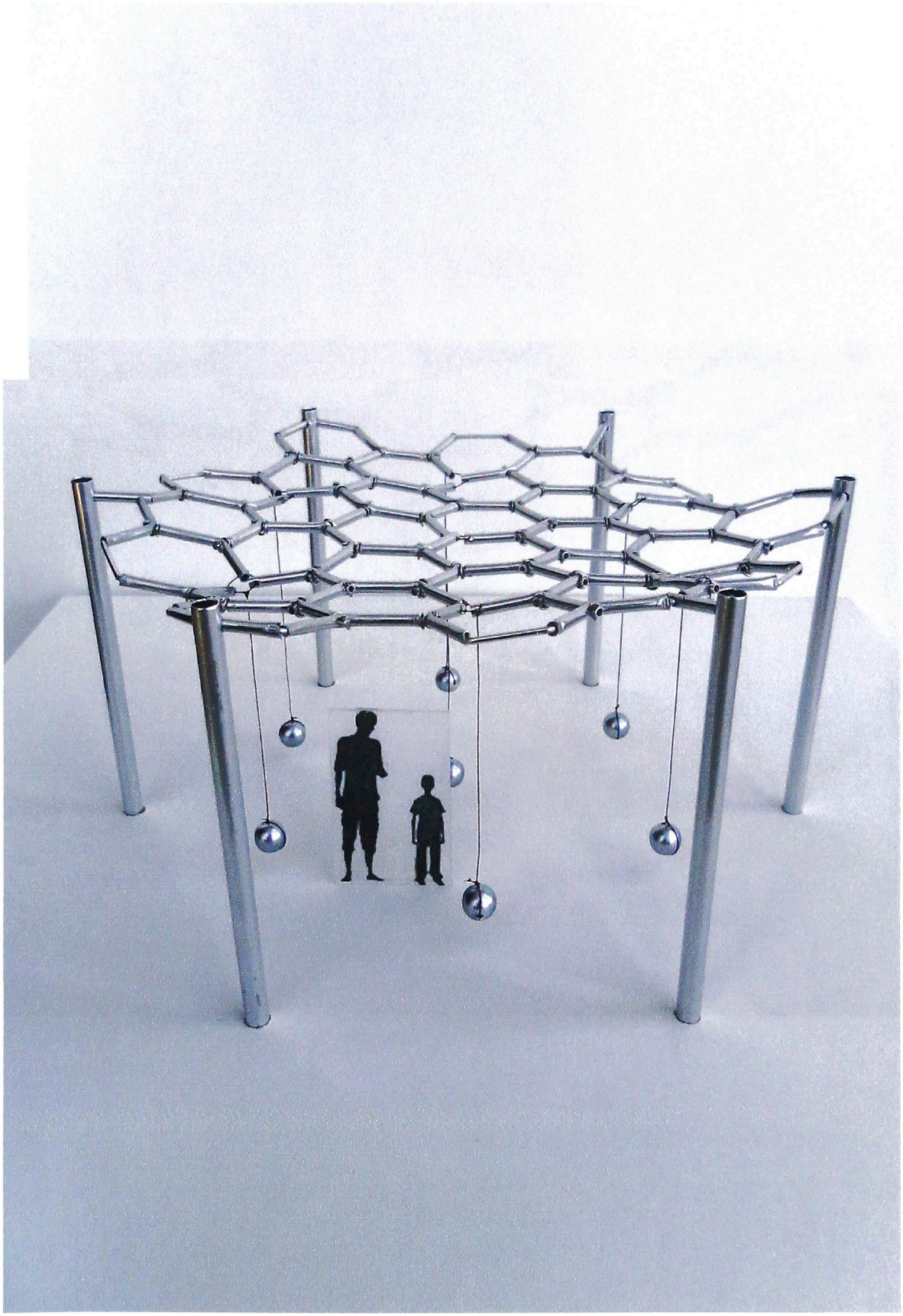
'Pulling Web' is suspended in the air by six posts, which are statically fixed to the ground. The web is made up of 60 hollow pipes, all connected in a similar fashion. There is a smaller tube sticking out of the ends of each pipe. This tube slides into the hole in the middle of the bent pipe. A bolt connects the two pipes together. The hole in the smaller pipe, which accepts the bolt, is designed slightly bigger to allow the bolt and the larger pipe to rotate. The size of the hole also limits its rotation. In this manner, the bolt becomes the axis at which the pipes can rotate.

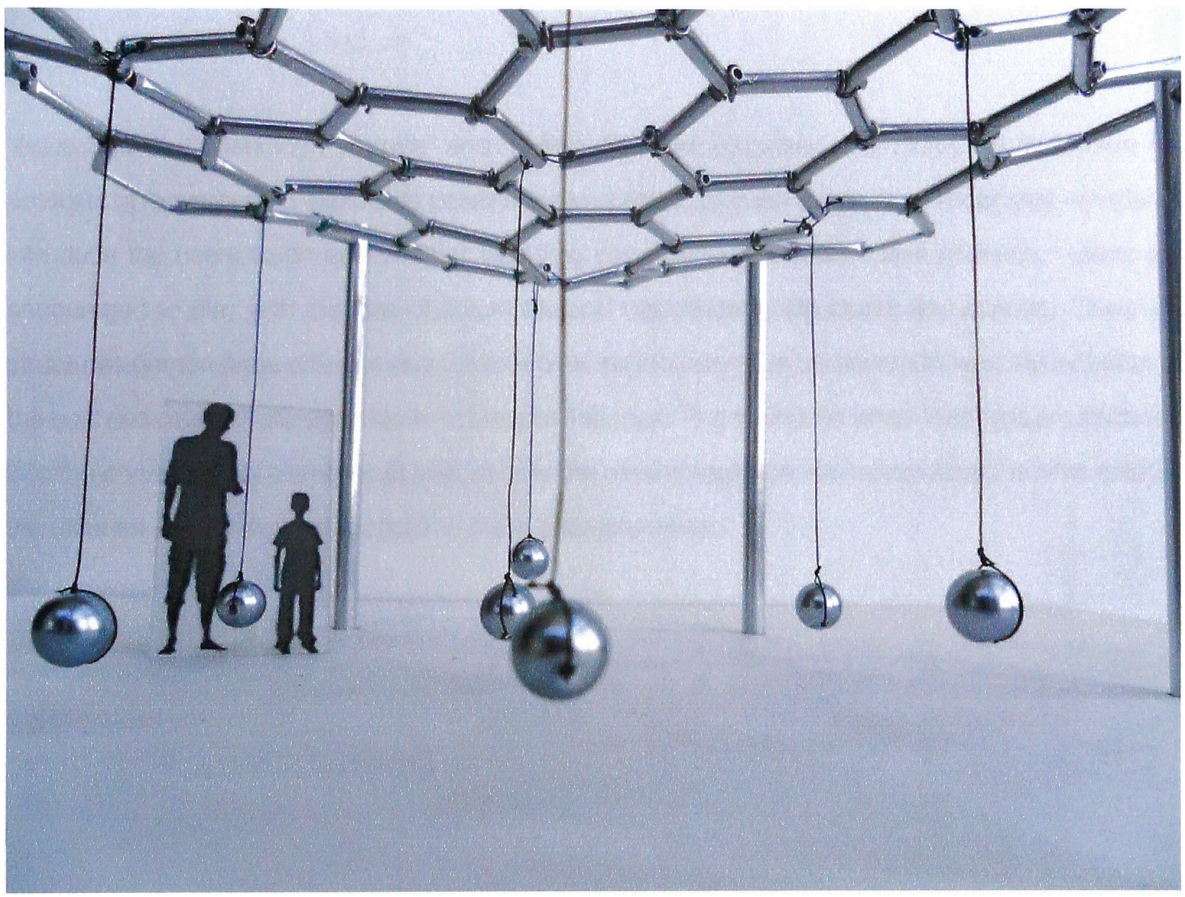

30°
TYPICAL JOINT
2'-0"
OPENING INSIDE SMALLER PIPE TO RESTRICT THE ROTATION TO 30°
1 5/8"Ø HOLLOW METAL TUBE STATICALLY FIXED INSIDE PIPE END AND EXTENDS OUT TO CONNECT AT THE BEND OF ITS NEIGHBOURING PIPE
2"Ø HOLLOW METAL PIPE
2'-0"
BOLT AND WASHER USED TO KEEP THE TWO PARTS TOGETHER AND CREATING AN AXIS OF ROTATION
1 5/8"Ø HOLLOW METAL TUBE EXTENDING OUT FROM PIPE END
OPENING INSIDE SMALLER PIPE TO RESTRICT THE ROTATION TO 30°
JOINT AT PERIMETER
ELEVATION OF TYPICAL JOINT
0
6 INCHES

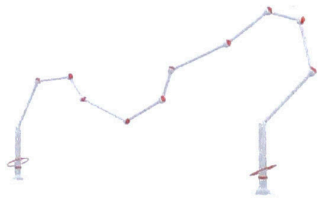
SNAPSHOTS FROM VIDEO EXPLAINING TYPICAL JOINT

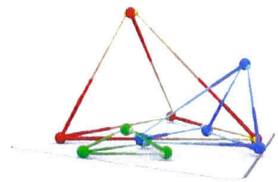












*

'Aqua Snake', 'Extending Pyramids' and 'Pulling Web' are proposed play-structures that utilize the potential of movement to explore its possibilities in contrast to static structures. These play-structures introduce the users to an environment that they can directly manipulate and influence. Users are encouraged to play with the idea of adjustable and customizable structures and spaces. The play-structures demonstrate different examples of how the incorporation of movement and the inclusion of the user can create these dynamic structures and spaces. The method in which motion is incorporated into the connecting of elements as well as how the assemblages can be manipulated, is what creates the different possibilities and options in these play-structures.

CONCLUSION

Change is happening all the time, all around us. In order to cope, people constantly have to adapt themselves. Buildings have been designed to resist change but if architecture exists for the betterment of man, then buildings must continue to satisfy their changing needs and therefore should themselves be adaptable to change. Buildings also need to be able to adjust to the pressures of the environment because if it is capable of changing for these two significant factors then its performance, functionality, and longevity can be increased. The incorporation of movement into architecture means that change can be understood, appreciated and encouraged. A building that can accommodate change can enhance and improve architecture.

The objectives from both the research and the project can be divided into 3 areas.

• Emphasis on the importance of the building joint for architecture and for movement.

The connection between building elements is what creates the functional aspects of architecture and is the location at which movement is incorporated. The connection defines how elements function, how they create space and how they endure over time. This understanding of joints, as well as the principles, methods, and examples of incorporating movement, can greatly contribute to different possibilities, options and spaces in architecture.

• Understanding how movement can be beneficial.

A building that can respond to its users can satisfy their needs and subjectivity, stay functional, and therefore can be used for longer. A building that can adjust to the environment can be more energy-efficient, perform better, be more durable, and as well, can last longer. Movement can enhance and improve the way that architecture and buildings are used, experienced, and performs.

• Introduce users to the potential of dynamic architecture.

This potential was explored through the project where the users are themselves in their own developmental stages. Users learn through self directed, manipulated and reconfigurable spaces. They can understand this enhanced relationship with architecture and its possibilities to change. They are thus exposed to possible ways of molding and customizing elements in their environment for functional purposes, for improvements, and for personalization. These users will then be free to experience, interact, learn and play with the possibilities of adjustable space.

Further Research and Potential Applications

The research of such a broad topic means that there will always be different avenues and opportunities for further investigation. In keeping with the concept behind the play-structures, which is the familiarity with movement, it's possibilities, how it allows users direct manipulation of their surroundings, and how it expands beyond the predominance of static architecture. Further explorations can be through the incorporation of movement having a more significant role in the everyday lives of users. Offering customization, personalization and improvements to the everyday build world. As illustrated in recent and increasing publications, like Robert Kronenburg's Fl*exible: Architecture that Responds to Change and* Michael Fox and Miles Kemp's *Interactive Architecture*, users are given more opportunities to influence and adjust their existing environments so that they can become more familiar with, more appreciative, accepting and potentially, overtime, more dependent on adaptable environments. This means the further exploring of how moving architecture can be incorporated into homes, workplaces, places of recreation, etc. If people understand and experience firsthand how these new types of environments can be valuable to them, then it may one day be part of the full spectrum of architecture. Included in this potential application would be the need for extensive investigation into the performance of the building joint. Specialists will be needed, in addition to years of research and prototyping to investigate how change would realistically be able to occur and be designed to last.

With that said, there are various other concepts which can be extracted from this research. If one decides to focus specifically on the benefits of multi-functionality rather than the user's direct manipulating of a space, then a potential application can be a space that can grow and shrink to whatever size is needed by its users, similarly for example, to an accordion stretching open. This allows for the accommodation of a wide variety of sized programs and functions. Another direction and potential application that can be taken is for an entire exterior wall or components which make up a wall, to rotate to follow the path of the sun, similarly to the way a flower bends towards the sun, in order to maximize its amount of natural lighting. A malleable surface, curtain walls system, even temporary and mobile architecture are potential applications that are currently being developed and share similarities to this thesis.

A focus specifically on dynamic connections can lead to its own array of possibilities. Through a repeated moving joint one can create a transformable surfaces or skins. The exploration of a universal dynamic joint similar to, for example Konrad Wachsmann's 'universal partition wall system', can allow movement in various configurations through the efficiency of one joint. A large repertoire of standardized hardware can be created to move entire building elements. In all cases and examples, the final hope for this thesis is to inspire and stimulate the imagination of different possibilities and opportunities for movement in architecture.

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