Tensegrity Capsule Tower:
A transformable approach to metabolism architecture

Architect/Engineer: kurukowa

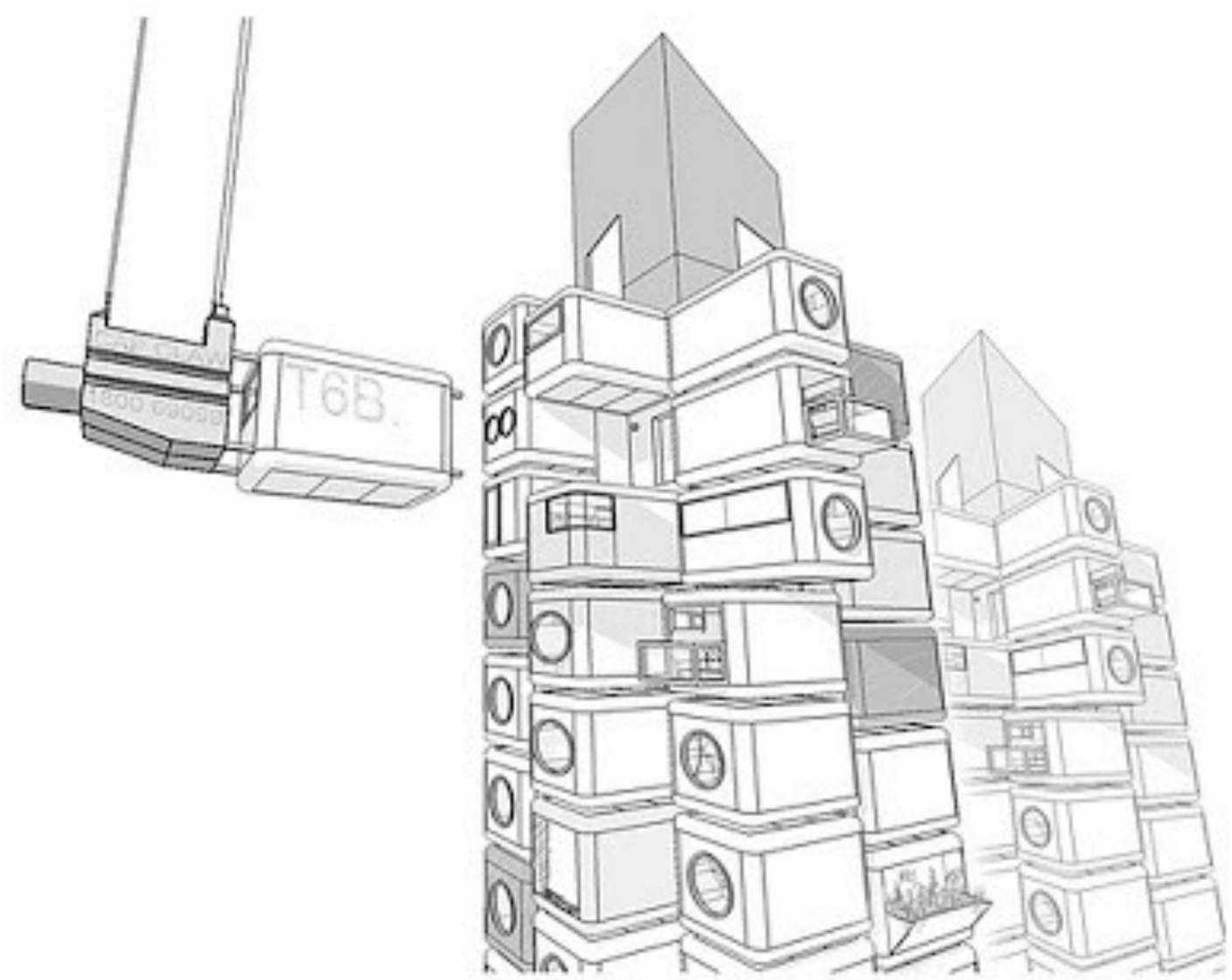
Year:1970 – 1972

Location: Ginza, Tokyo, Japan

Typology : Residential / Apartments

https://arcspace.com/feature/nakagin-capsule-tower/

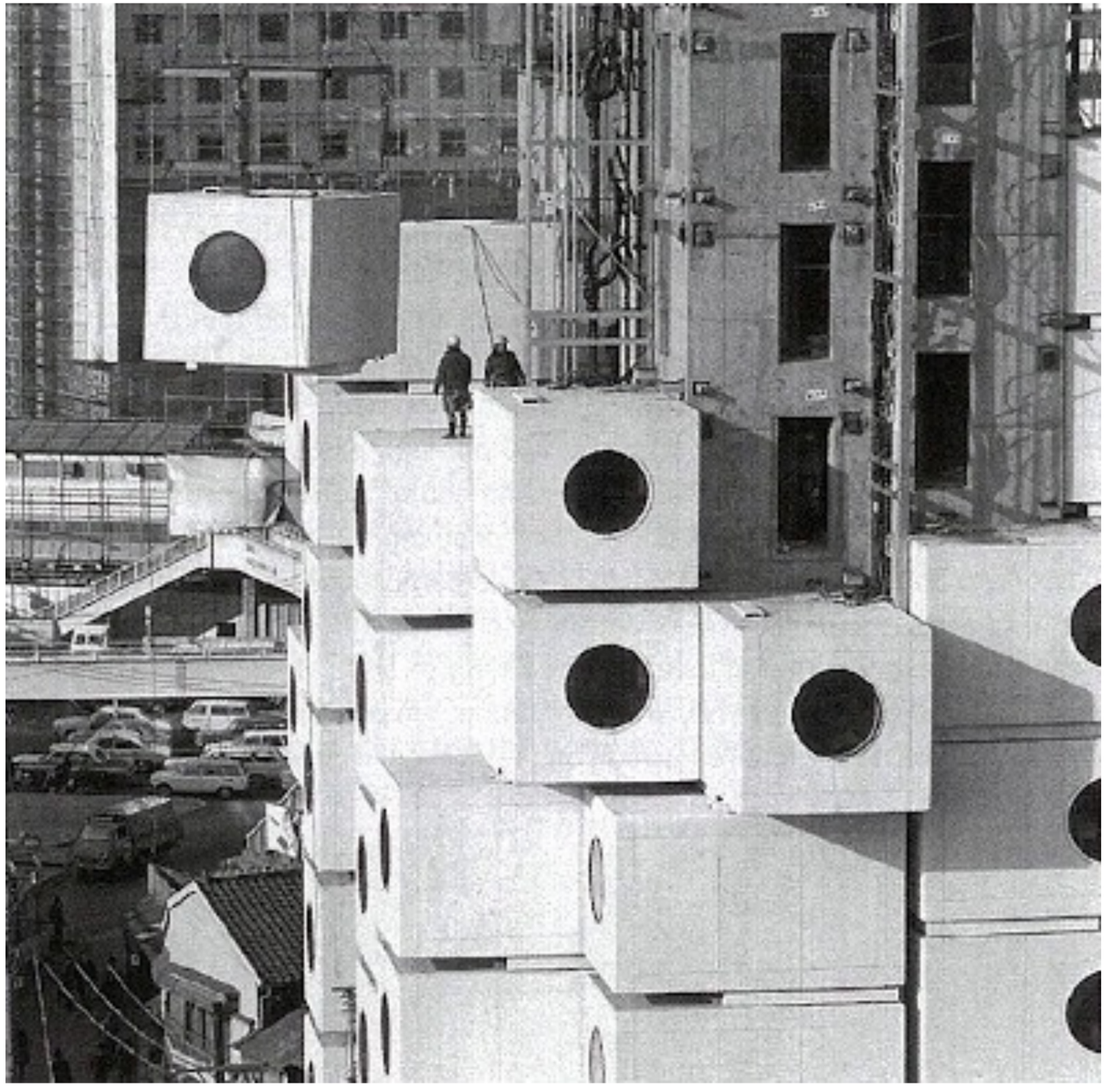
http://archeyes.com/nakagin-capsule-tower-kisho-kurokawa/



Project Description:

- consisted of two towers housing the capsules, that could be growing organically according to future needs, according to Metabolist principles
- The buildings consisted of two components: a mega-structure of reinforced concrete containing the elevators, stairs as well as bridges that interconnect to other buildings, and the capsules, which would anchor the structure in just 4 points for easy replacement every 25 years
- The units were prefabricated and then assembled in situ
- In its 14-story tower 144 units were housed and are arranged randomly to emphasize their assemblable character
- The cabins were designed to accommodate individuals, but could be articulated with each other to accommodate families

http://architecturalmoleskine.blogspot.com/2011/10/kurokawa-nakagin-capsule-tower.html



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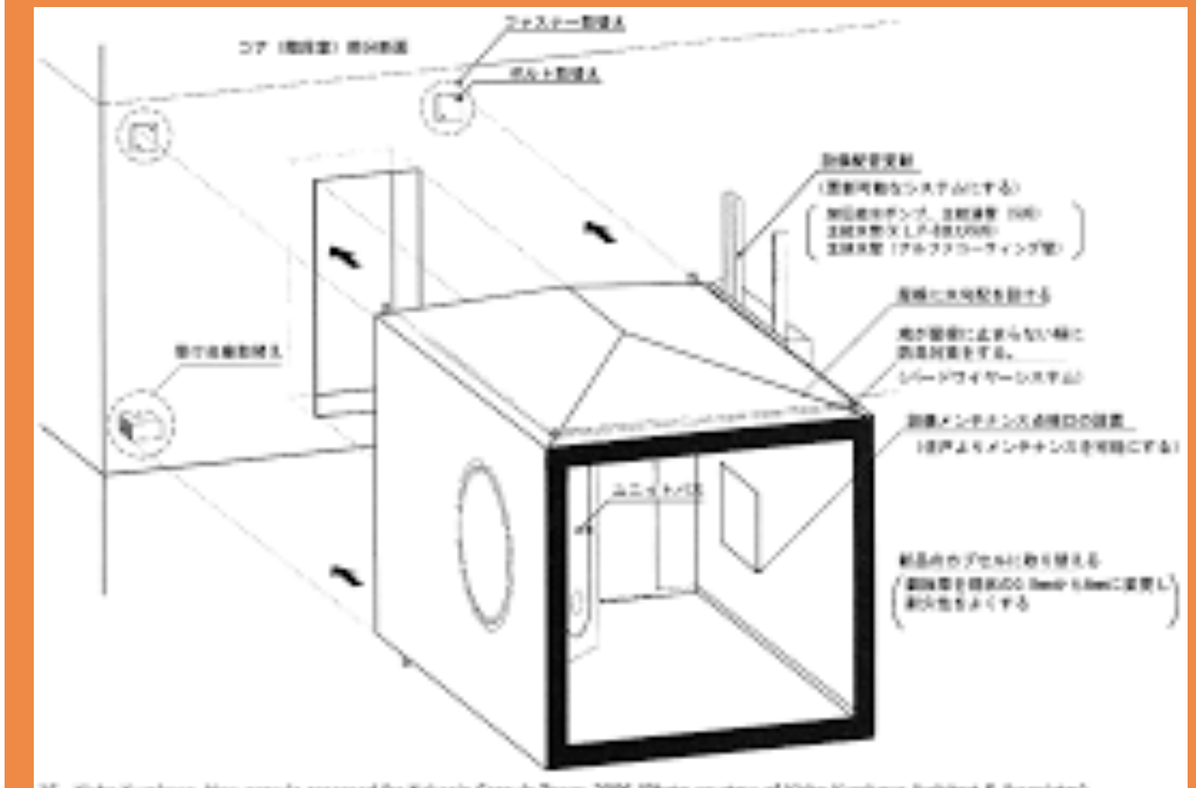
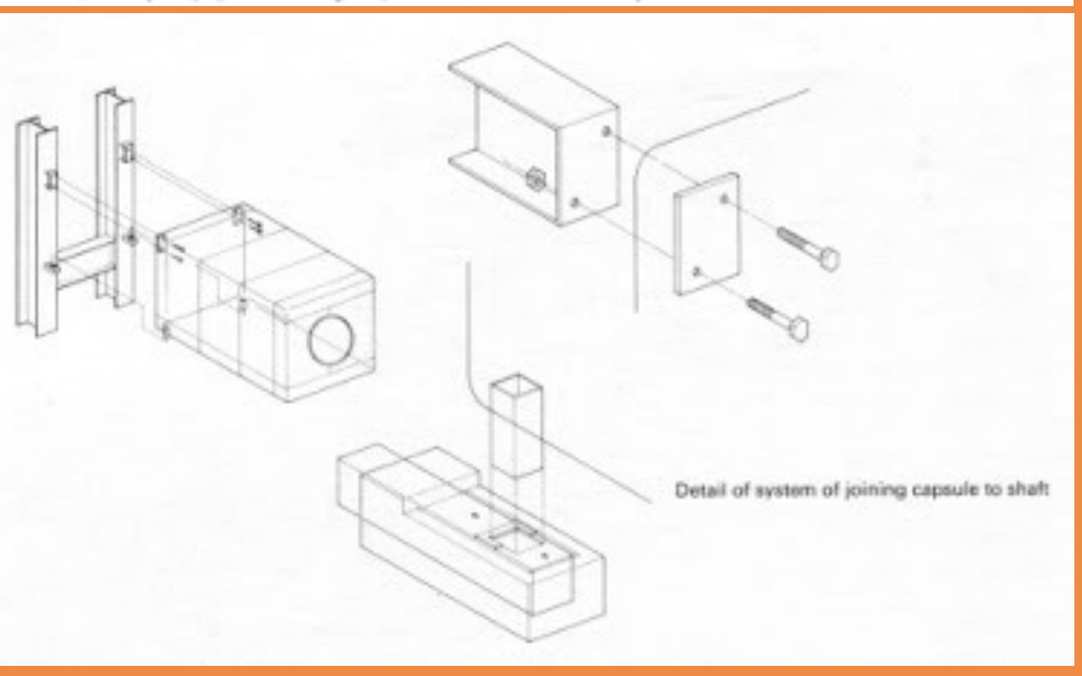
Problem:

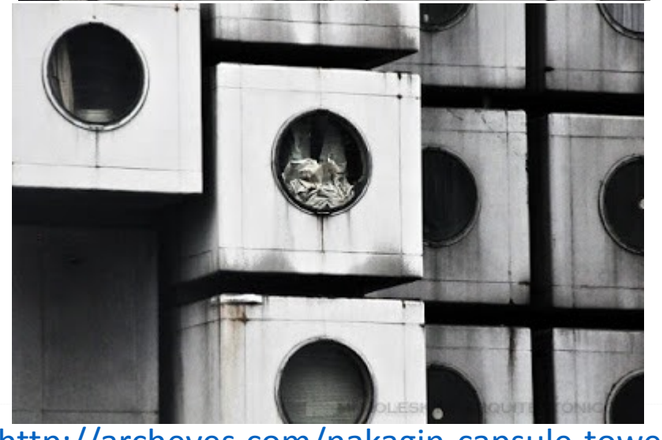
In the past, many creative ideas and approaches to adaptability have been put forward in theory, but in reality, they have not worked like capsule building:

- the building has serious functional disadvantages, such as little flexibility and a huge loss of area in an zone
- these units were intended to be replaced and transported, but they have not been changed in almost 40 years
- future expansion was not considered enough (in real life, the expansion grow of building spaces was not actually managed)
- lack of maintenance and obsolescence of the building have caused many problems
- changes would not be occurred without disruption of adjacent capsules



15. Kisho Kurokawa. New capsule proposed for Nakagin Capsule Tower, 2006 (Photo courtesy of Kisho Kurokawa Architect & Associates).





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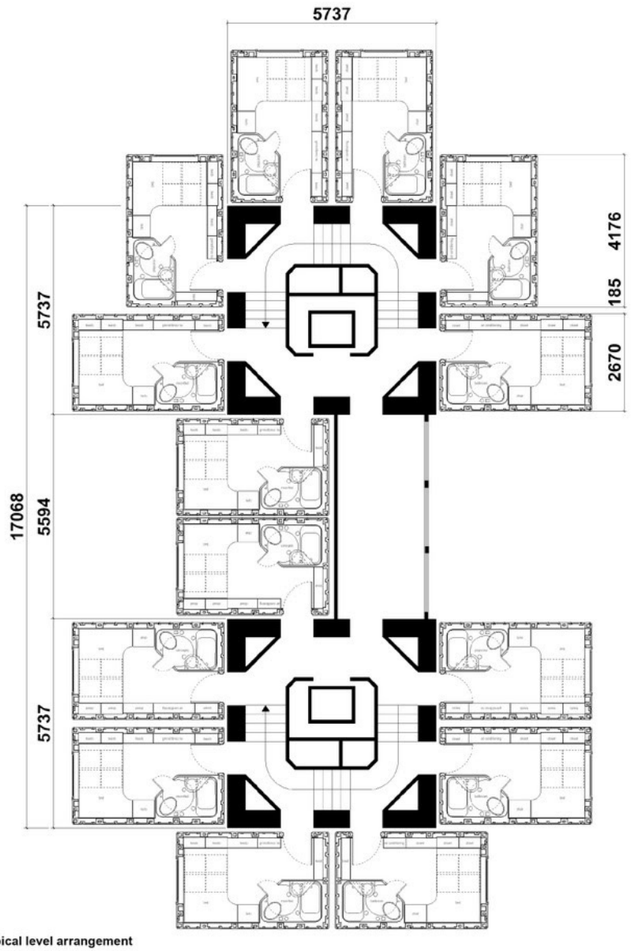
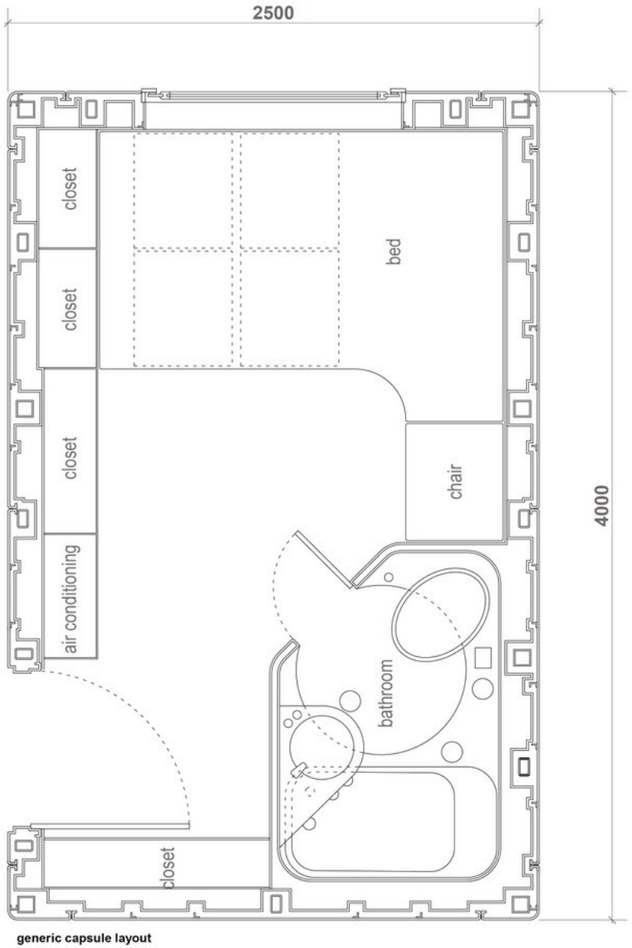
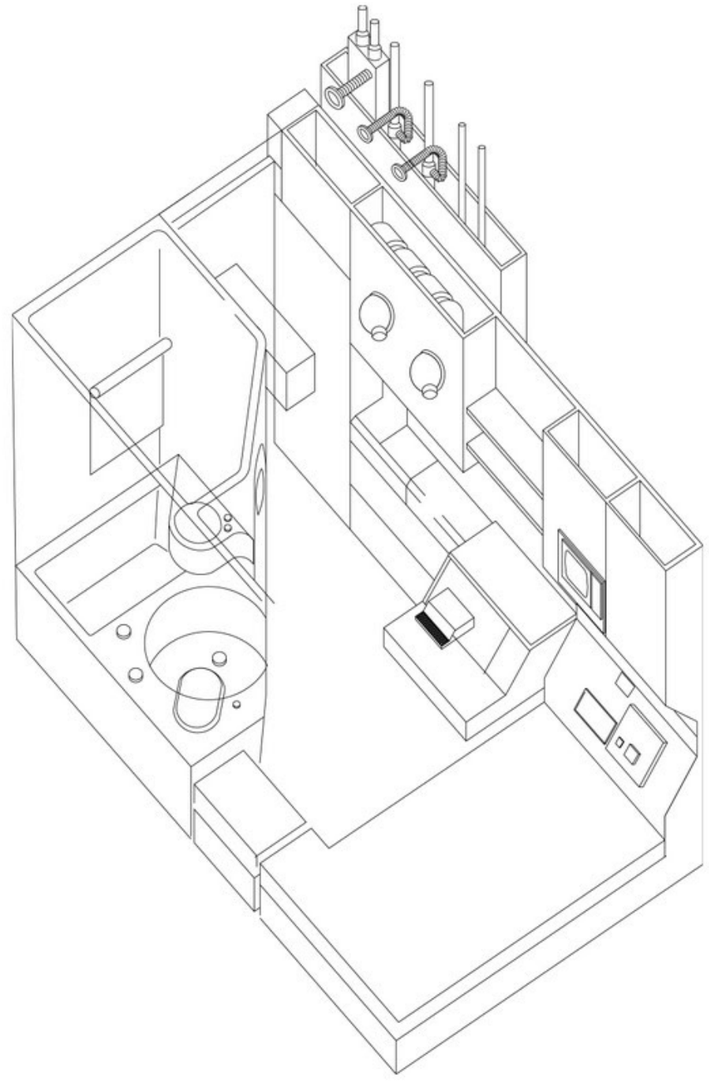
Architectural plans of capsule tower:



typical level arrangement



generic capsule layout



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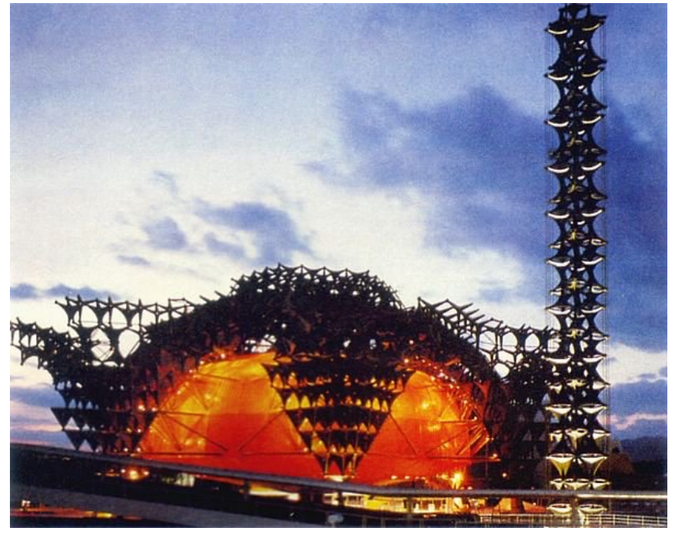
Lessons Learned from precedents:

-Toshiba IHI Pavilion

Lessons Learned: The principles of the Metabolism in the pavilion revolved around ideas of impermanence and change, the movement was intended to have more in common with natural processes due to possibility of having different configurations, The impact of war and natural disasters is shown in resilience of the pavilion, pre-fabricated modules that were designed to be added and replaced as necessary during the expo, Large scale of pavilion which was designed to be a sample of future`s urban deigns



-Osaka Gas Next21

Lessons Learned: Designing the building using "open building" principles, Allowing the spaces to be reconfigured easily to promote a longer life span, The lifestyle, personality and intent of the individual determines the form of the dwelling unit, immediate, Intermittent, Long-term changes of infill systems within a framework of fixed structural supports and modular pieces

Lessons Learned from precedents:

-The BIQ House

Lessons Learned: The principles of the Metabolism in the pavilion revolved around ideas of impermanence and change, the movement was intended to have more in common with natural processes due to possibility of having different configurations, The impact of war and natural disasters is shown in resilience of the pavilion, pre-fabricated modules that were designed to be added and replaced as necessary during the expo, Large scale of pavilion which was designed to be a sample of future`s urban deigns

-Grow home

Lessons Learned: Designing the building using “adaptability" principles, Applying technical strategies in according to flexible principles, Design homes to be built in infill sites as well as new tract developments, Allowing the spaces to be reconfigured easily to promote a longer life span, The lifestyle, personality and intent of the individual determines the form of the dwelling unit

Lessons Learned from precedents:

-Ise Grand Shrine

Lessons Learned: Applying strategies of design for disassemble in a design for impermanence approach, A holistic model of environmentally sustainable construction: using local natural material and local labor in erecting shrines which is a sustainable approach, Shrine construction is compatible with the building layers concepts due to considering the structure as a single separable layer, The term “life cycle” as a recycling hierarchy can be applied in the shrine. construction since extraction, processing, manufacture, assembly, use, demolition, and disposal steps of linear life cycle can be changed in final step because of using natural materials that will return back to nature over time

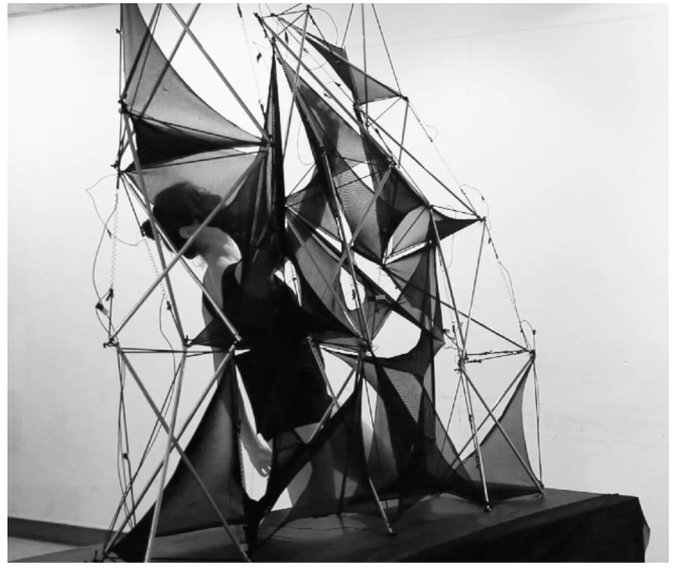
-HygroSkin

Lessons Learned: Biomimetic Principle: Materially-Ingrained Responsiveness (Investigation of biomimetic principles offered by nature that do not require any operational energy input), Scientific Development: Humidity Responsive Wood Composites (Use of strategically structured common material such as wood which can passively respond to environmental stimuli by form changing), Technical Development: Elastically Self-forming and Robotically Fabricated Modular Construction (Applying nature based no-tech approach instead of high-tech mechanical and electronic sensing, actuating and regulating devices)

Lessons Learned from precedents:

-Rolling Bridge

Lessons Learned: Solving crossing of people and boats with the help of strategic design of a pedestrian bridge, Providing dynamic structures by hydraulic technology, Applying small-scale motion in some basic parts of structure in order to make the whole structure move in large-scale



-Alloplastic Architecture

Lessons Learned: The importance of choosing appropriate structure for form transformation (structure), The ability to make the structure adapt to different situations (adaptation), The significance of the control of adaptability and movement of the structure (control), Using structure, adaptation, and control to provide new possibilities for enriching human-environment interactions

Lessons Learned from precedents:

-Nakagin Capsule Tower

Lessons Learned: creating a variety of residential units to accommodate varying households, The family member increase, lifestyle, personality and intent of the individual determines the form of the dwelling unit, Design with the initial concept of adaptability and respond to societal challenges, demographic shifts, and issues of affordability, The aging of the population, The need to build sustainable communities and densify urban environments, Integrating new technologies in an effort to lower cost, Allowing the spaces to be reconfigured easily to promote a longer life span

-Sharifi-ha House

Lessons Learned: 4characteristics of flexible design(Adapt: adapting to seasonal requirements and the functional needs of its residents, Transform: transforming a two-dimensional façade to a three-dimensional one became indispensable, Move: partially moveable structure and foldable handrails, and Interact:interaction through rotation of boxes and applying a BMS system), prefab modular flexibility

Principles of design:

Legend of level of relevance:

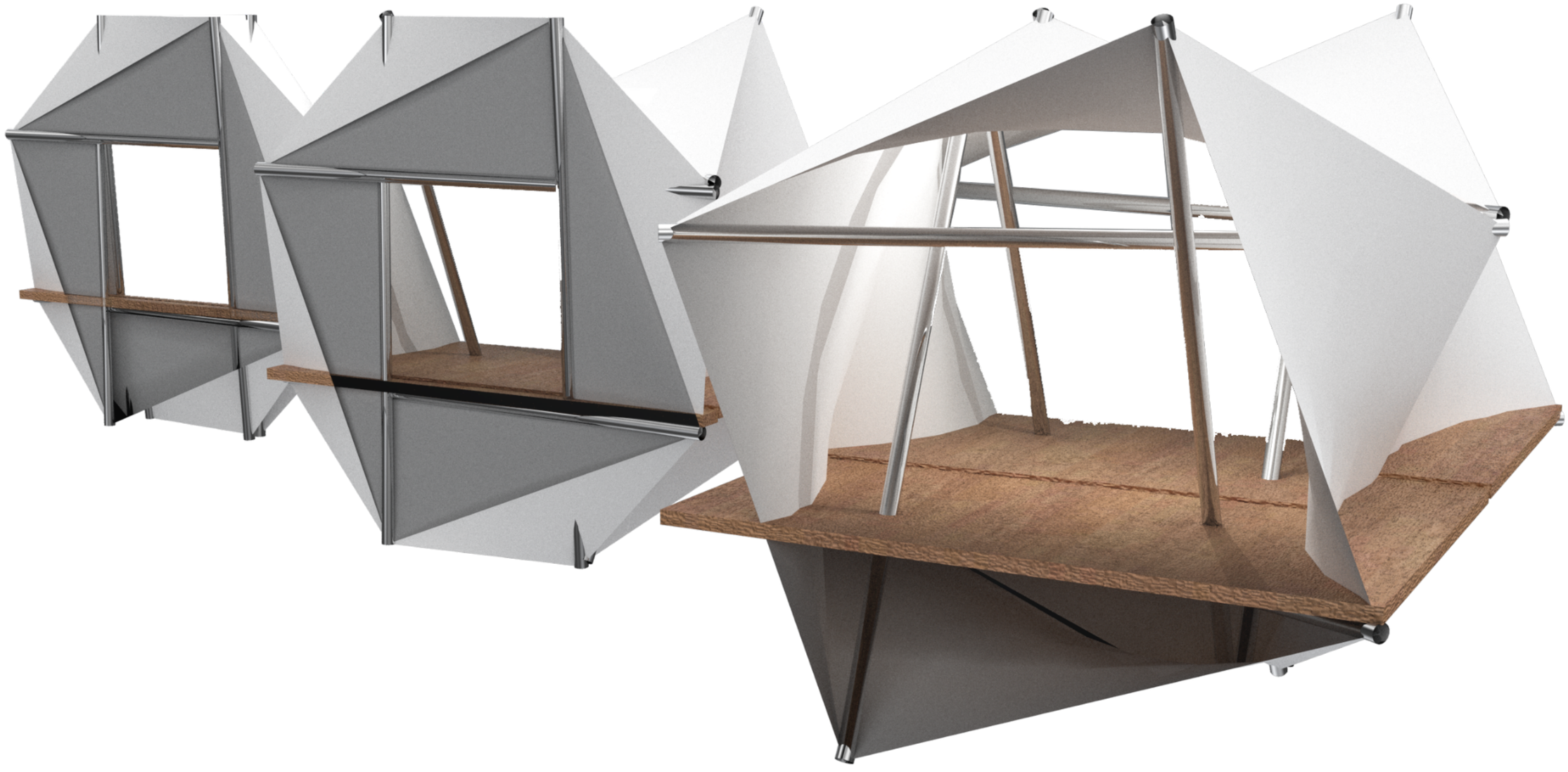
- ● **Highly relevant**
- • **Relevant**
- . **Not normally relevant**

No	Principle	Material recycling	Component remanufacture	Component reuse	Building relocation
1	**Use recycled and recyclable materials**	●	●	.	.
2	**Minimise the number of different types of material**	●	●	.	.
3	**Avoid toxic and hazardous materials**	●	●	.	.
4	**Make inseparable subassemblies from the same material**	●	●	.	.
5	**Avoid secondary finishes to materials**	●	●	.	.
6	**Provide identification of material types**	●	●	.	.
7	**Minimise the number of different types of components**	.	•	●	●
8	**Use mechanical not chemical connections**	.	●	●	●
9	**Use an open building system not a closed one**	.	.	●	•
10	**Use modular design**	.	.	●	•
11	**Design to use common tools and equipment, avoid specialist plant**	.	•	●	●
12	**Separate the structure from the cladding for parallel disassembly**	.	.	●	•
13	**Provide access to all parts and connection points**	•	•	●	●
14	**Make components sized to suit the means of handling**	.	•	●	●

Principles of design:

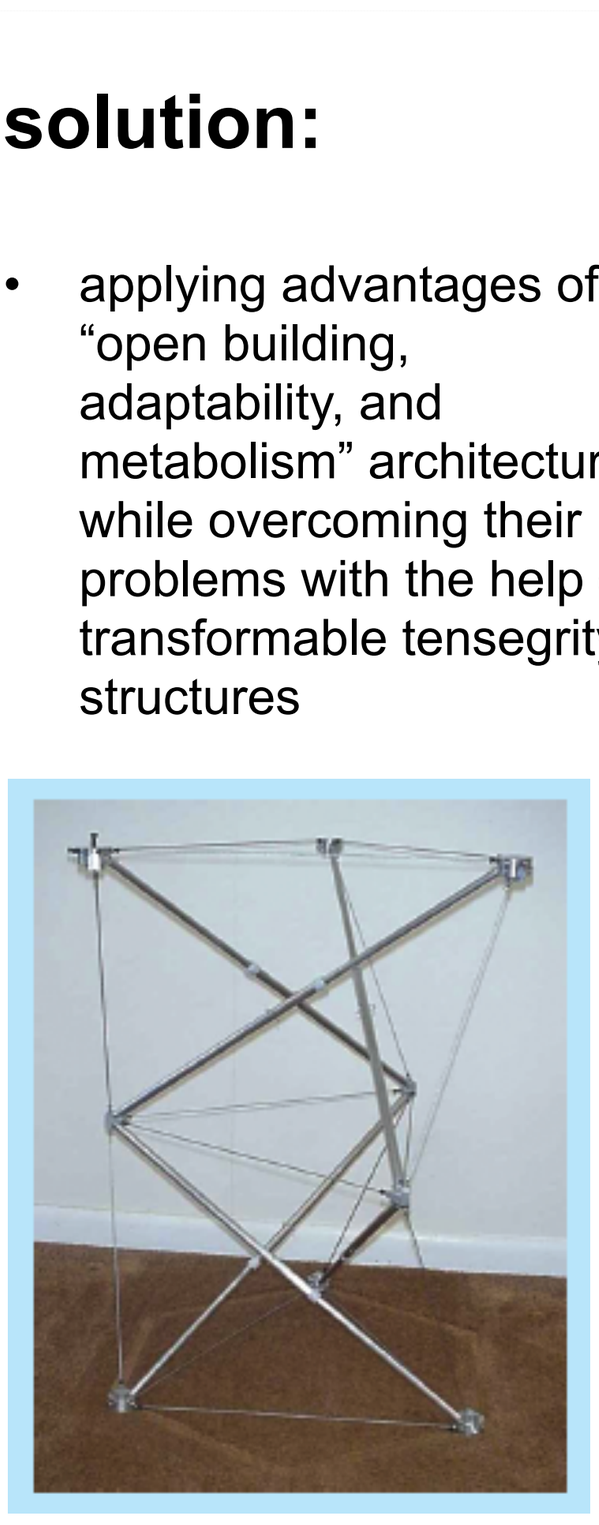
15	Provide a means of handling and locating	.	.	●	●
16	Provide realistic tolerances for assembly and disassembly	.	.	●	●
17	Use a minimum number of connectors	.	●	●	●
18	Use a minimum number of different types of connectors	.	●	●	●
19	Design joints and components to withstand repeated use	.	.	●	●
20	Allow for parallel disassembly	●	●	●	.
21	Provide identification of component type	.	●	●	.
22	Use a standard structural grid for set outs	.	.	.	●
23	Use prefabrication and mass production	.	.	●	●
24	Use lightweight materials and components	●	●	●	●
25	Identify points of disassembly	.	●	●	●
26	Provide spare parts and on site storage for them and parts during disassembly	.	.	.	●
27	Retain all information of the building components and materials	.	.	●	●

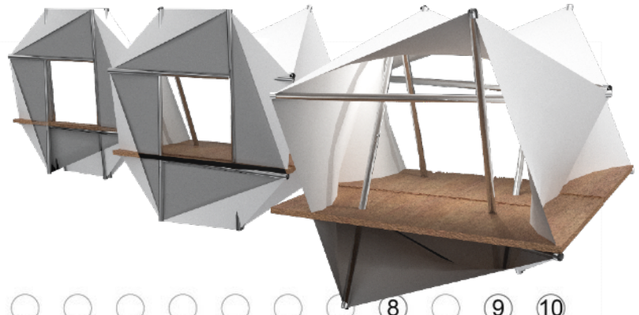
solution:

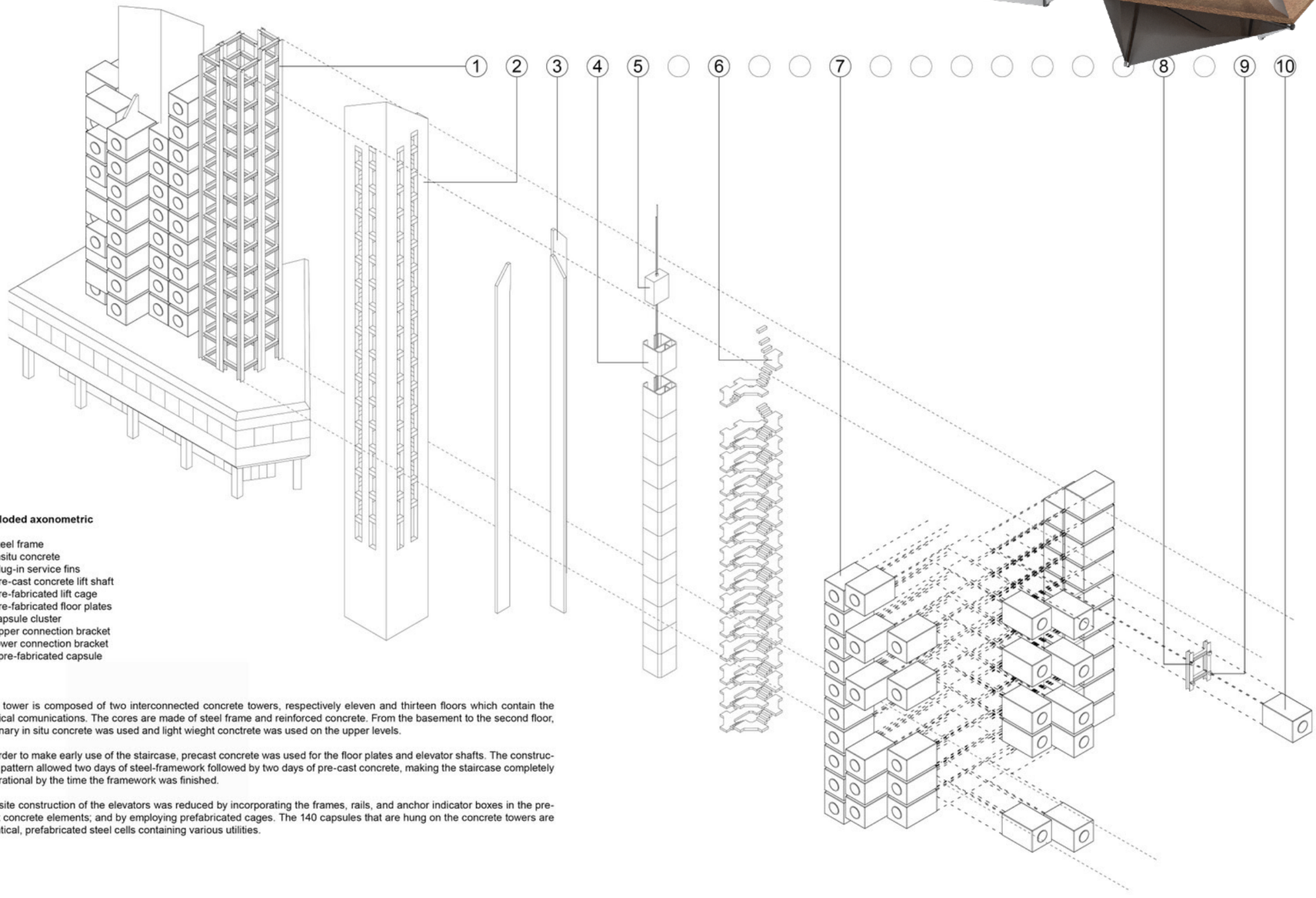


solution:

- applying advantages of “open building, adaptability, and metabolism” architecture while overcoming their problems with the help of transformable tensegrity structures







exploded axonometric

1. steel frame
2. insitu concrete
3. plug-in service fins
4. pre-cast concrete lift shaft
5. pre-fabricated lift cage
6. pre-fabricated floor plates
7. capsule cluster
8. upper connection bracket
9. lower connection bracket
10. pre-fabricated capsule

The tower is composed of two interconnected concrete towers, respectively eleven and thirteen floors which contain the vertical comunications. The cores are made of steel frame and reinforced concrete. From the basement to the second floor, ordinary in situ concrete was used and light wieght conctrete was used on the upper levels.

In order to make early use of the staircase, precast concrete was used for the floor plates and elevator shafts. The construction pattern allowed two days of steel-framework followed by two days of pre-cast concrete, making the staircase completely operational by the time the framework was finished.

On-site construction of the elevators was reduced by incorporating the frames, rails, and anchor indicator boxes in the pre-cast concrete elements; and by employing prefabricated cages. The 140 capsules that are hung on the concrete towers are identical, prefabricated steel cells containing various utilities.

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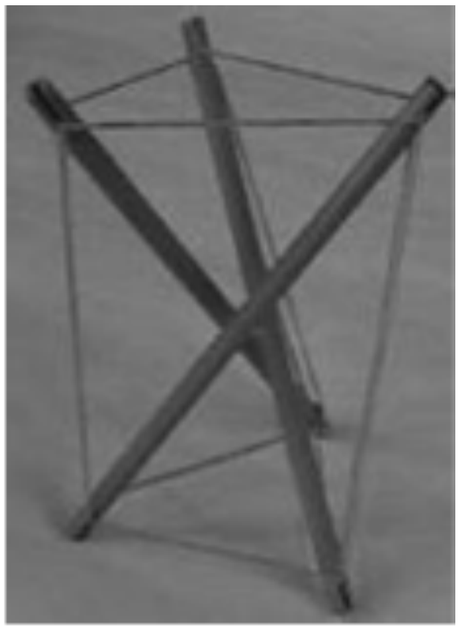
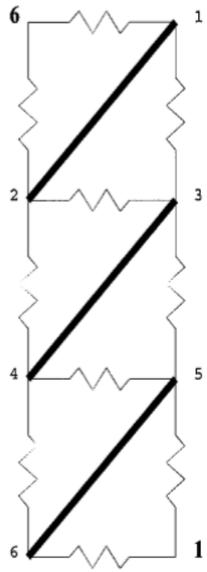
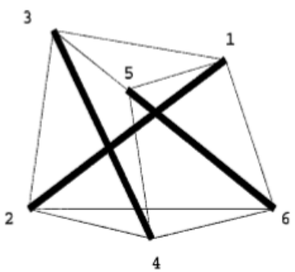
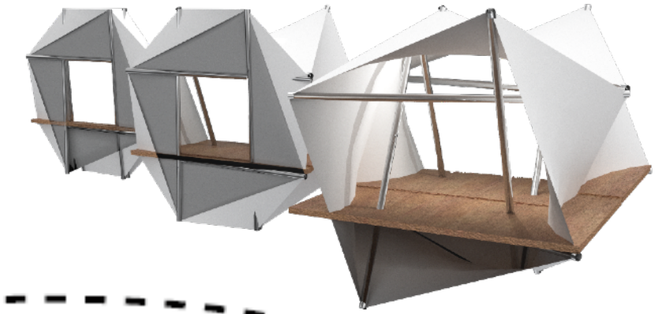
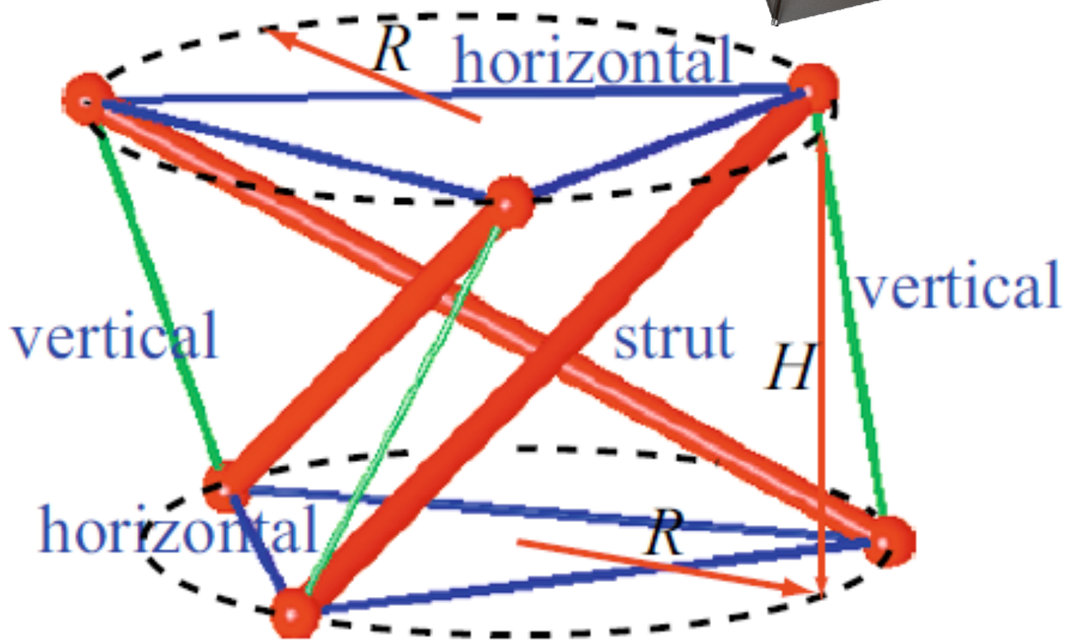
Tensegrity prism:

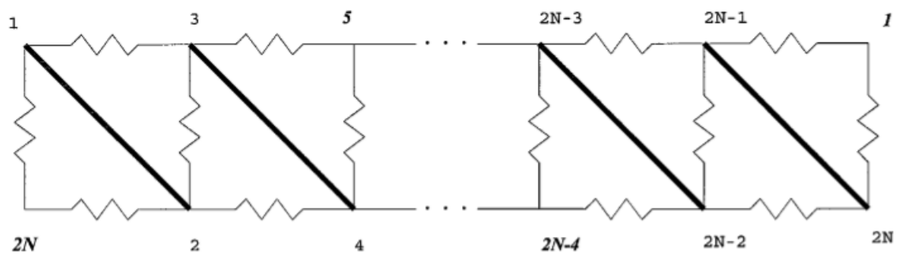




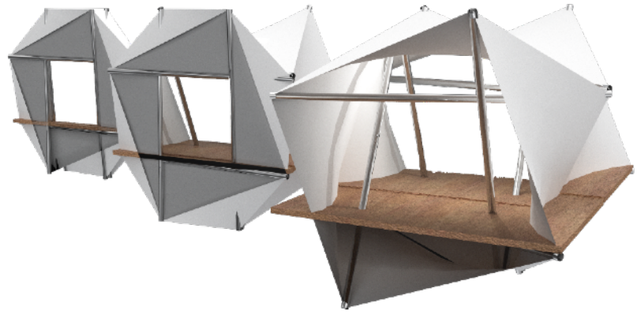


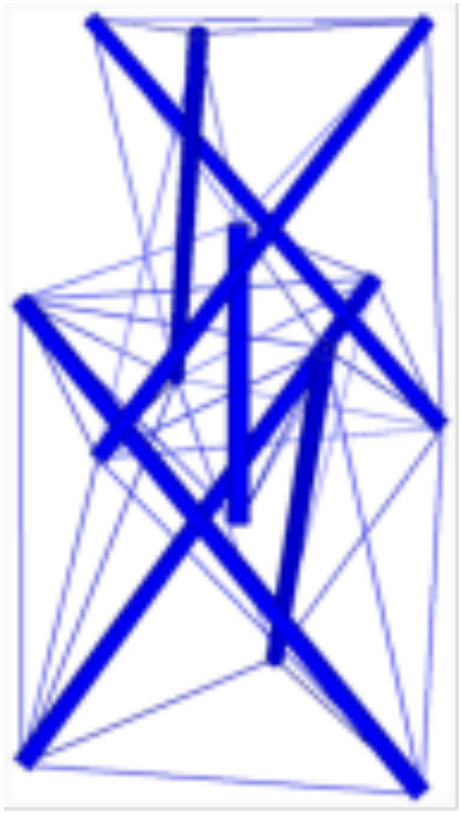


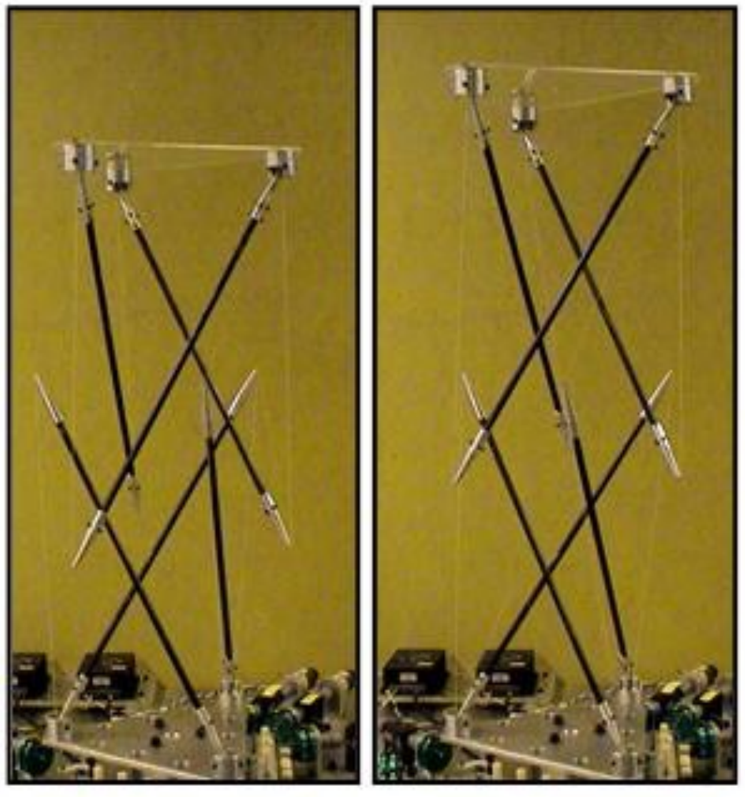


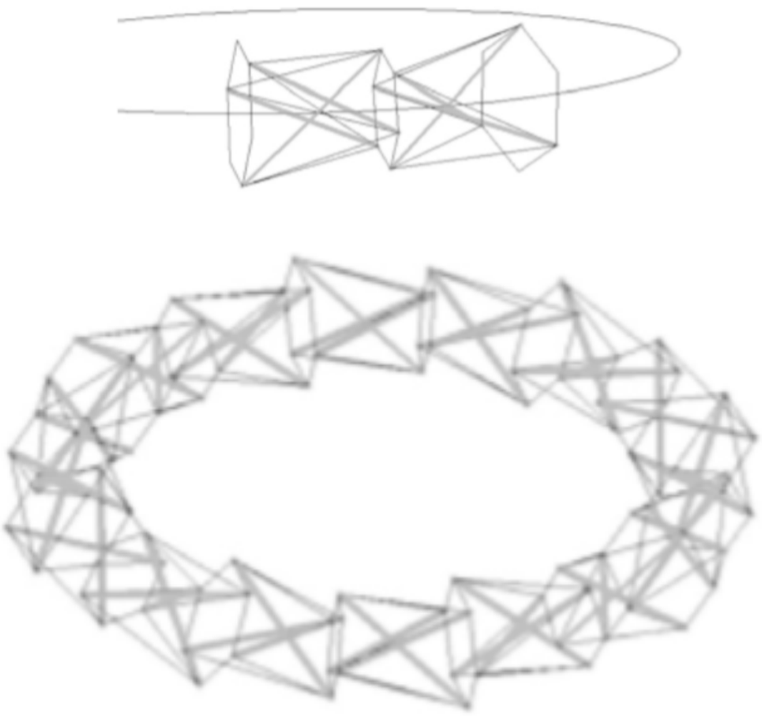


Tensegrity transformable module combination:

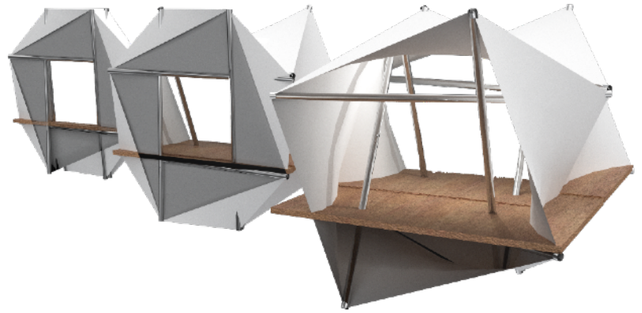


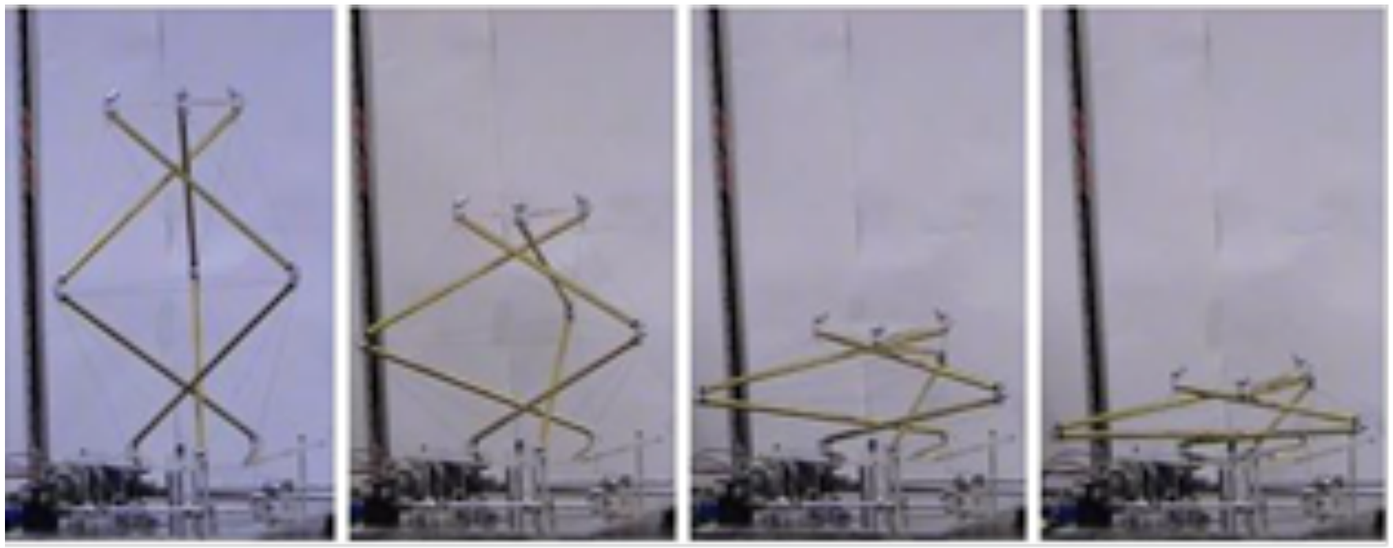


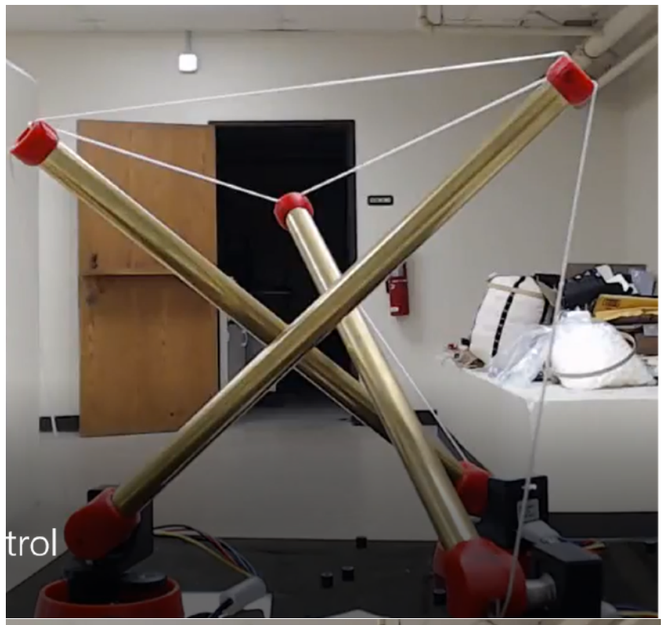


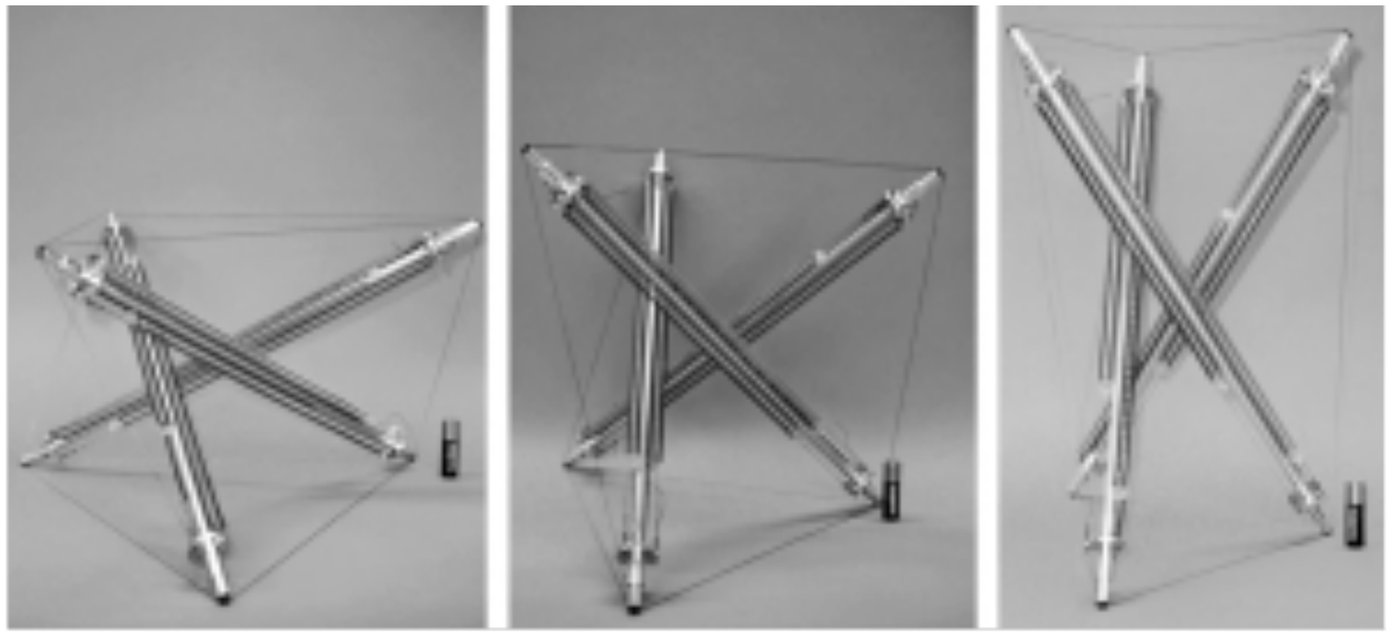


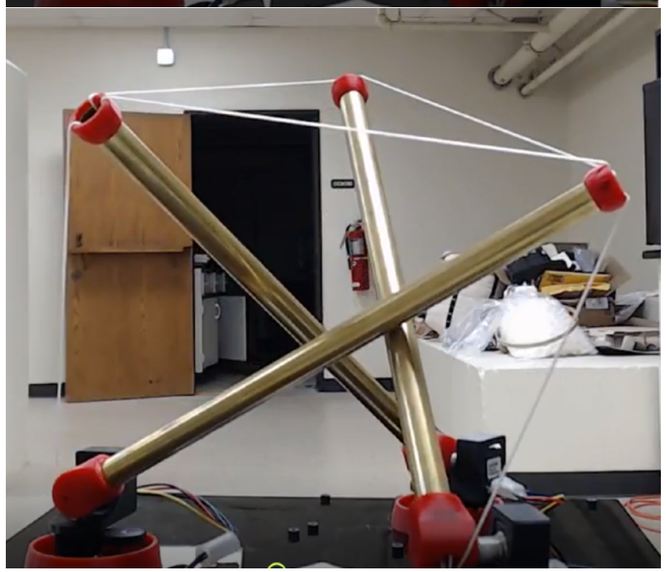
Tensegrity transformable structure:











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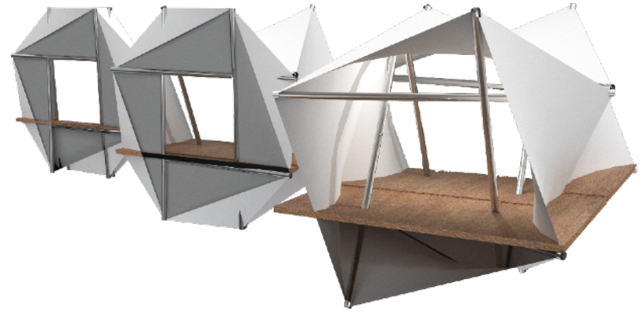
Key Features:

- Apply adaptability and flexibility in design, while providing resilience required of metabolism
- Flexible infill within flexible structural support
- Changeable plan patterns according to different occupants requirements
- Applying expansion changes without adjacent units` limitations (units being sold or rented)
- Changes without making disruptive effects on neighboring modules
- Transform building from one-single-user dwellings to units for families with multiple members
- Low cost change with high impact due to optimized transformability of the structure
- Efficient material consumption of tensegrity structures
- Lightweight structure which is suitable for earthquake prone areas

Parmenidean

Parmenidean/Heraclitean Hybrids



Heraclitean

Gizah Pyramids

Nakagin capsule tower

Rietveld-Schröder House

Tensegrity capsule tower

Archigram's Living City

	Individual Scale	Microsystem Scale (friends, family)	Exosystem Scale (neighborhood, town)	Macrosystem Scale (city, state, region)	Global Scale
Cultural	Personal private values (adaptable open plan requirement)	Family private values (adaptable open plan requirement)	Cultural values of Aging of the population	national knowledge has increased , building more examples of adaptive architecture throughout country	Global values
Social	Personal lifestyle	Demographic shifts& family lifestyle	Social forces of Aging of the population	Urban social lifestyle	Global social lifestyle
Economic	Personal finances	Low cost of changes in for low income families ((no disruption for adjacent entities)	Reducing the complex`s cost of change (no disruption for adjacent neighbors)	Industry requires housing strategy (easy buy and sell)	Global financial market
Environmental	Individual reuse of natural resources	Family reuse of natural resources	Densify neighbor environment& sustainable community	Densify urban environment& natural resources	Global reuse of natural resource
Technical	Individual scale of transformable structures` technological impact	family scale of transformable structures` technological impact	Exosystem scale of transformable structures` technological impact	Macrosystem scale of transformable structures` technological impact	Global scale of transformable structures` technological impact
Aesthetic	Personal delight	Family delight	Neighborhood and surrounding delight	National delight	Global delight

Planning/Design

Metabolism architecture with the approach of transformable structures

Construction

Flexible infill within flexible structure

Immediate Change

Variable open plans and adaptive infill furniture

Intermittent Change

Small-scale transformation of the modules required in intermittent expansion changes (periodically needs of families to large spaces)

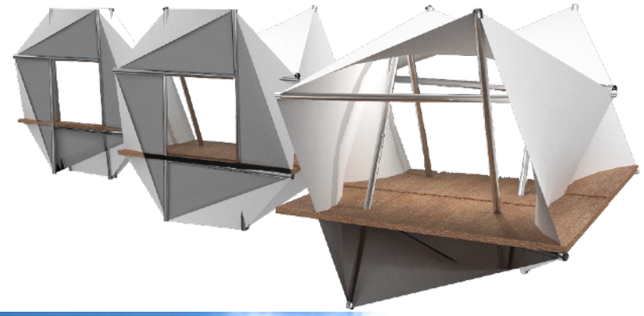
Long-term Change

Large-scale transformation of the modules (adding or decreasing a module to the base module in the case of demographic shifts)

Adaptive Reuse

Design for deconstruction approach can be used in this approach since modules can be transported to another tower in another place

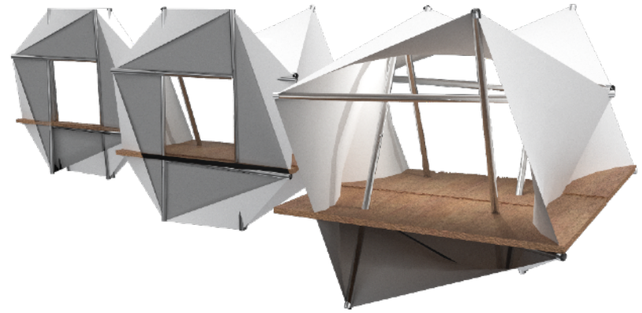
Relevant product Samples:



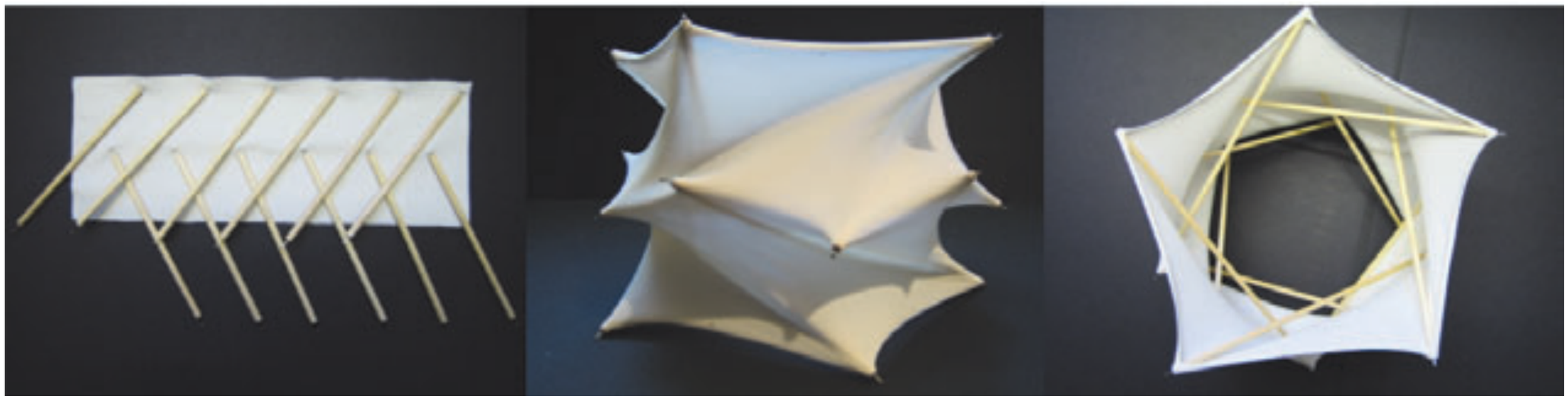
1-tensegrity modules applied in tower

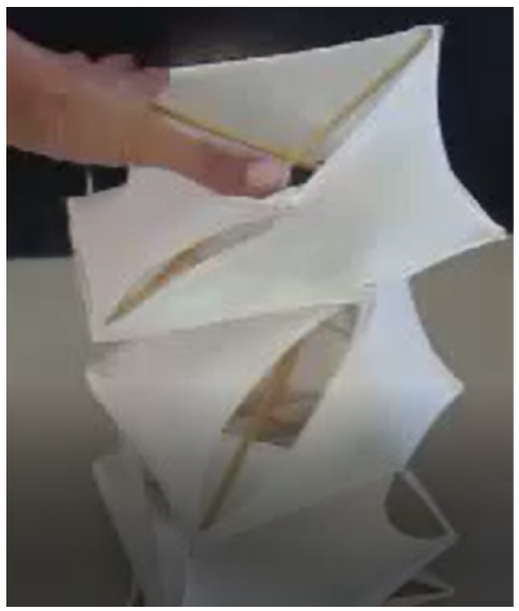
https://hiveminer.com/Tags/museum%2Cneedle

Relevant product Samples:



2-tensile fabric as coverage of tensegrity structure





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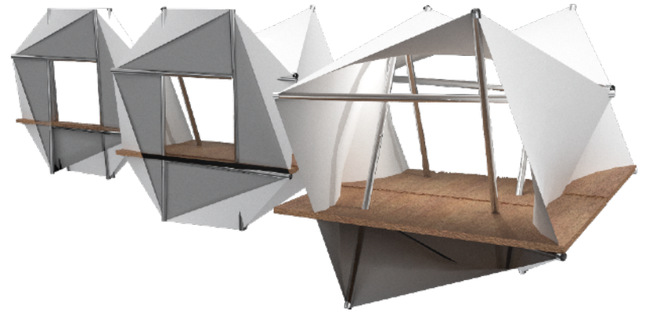
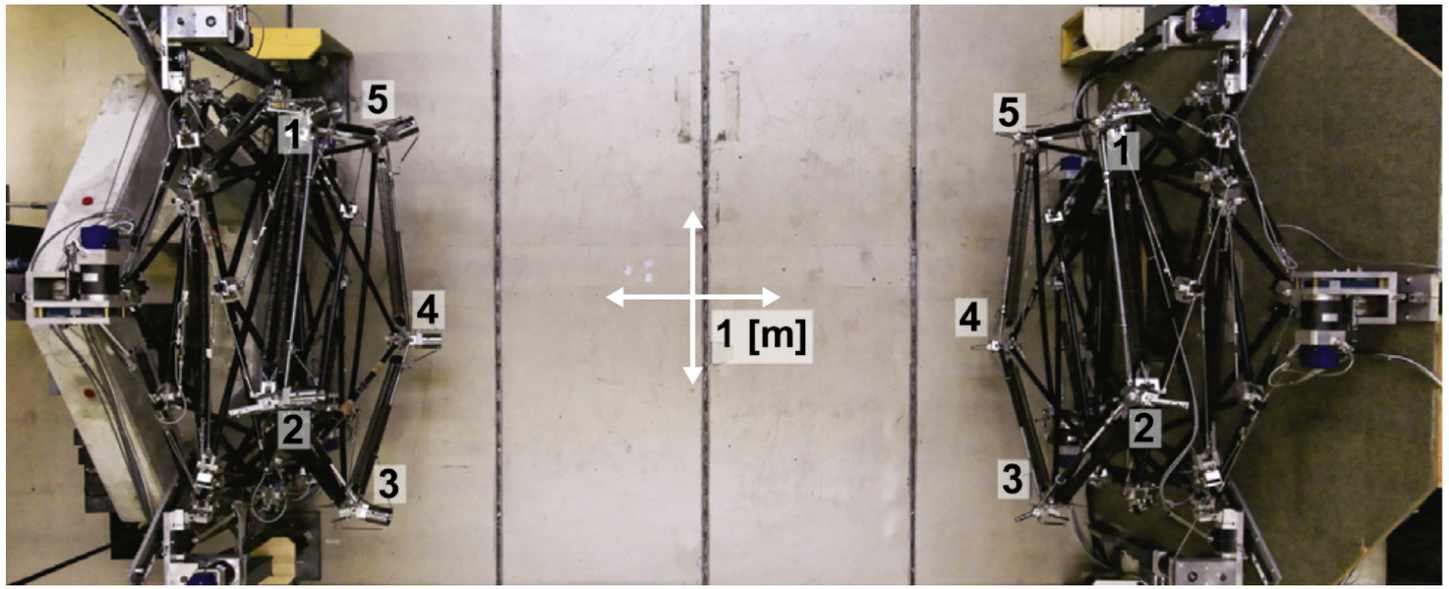
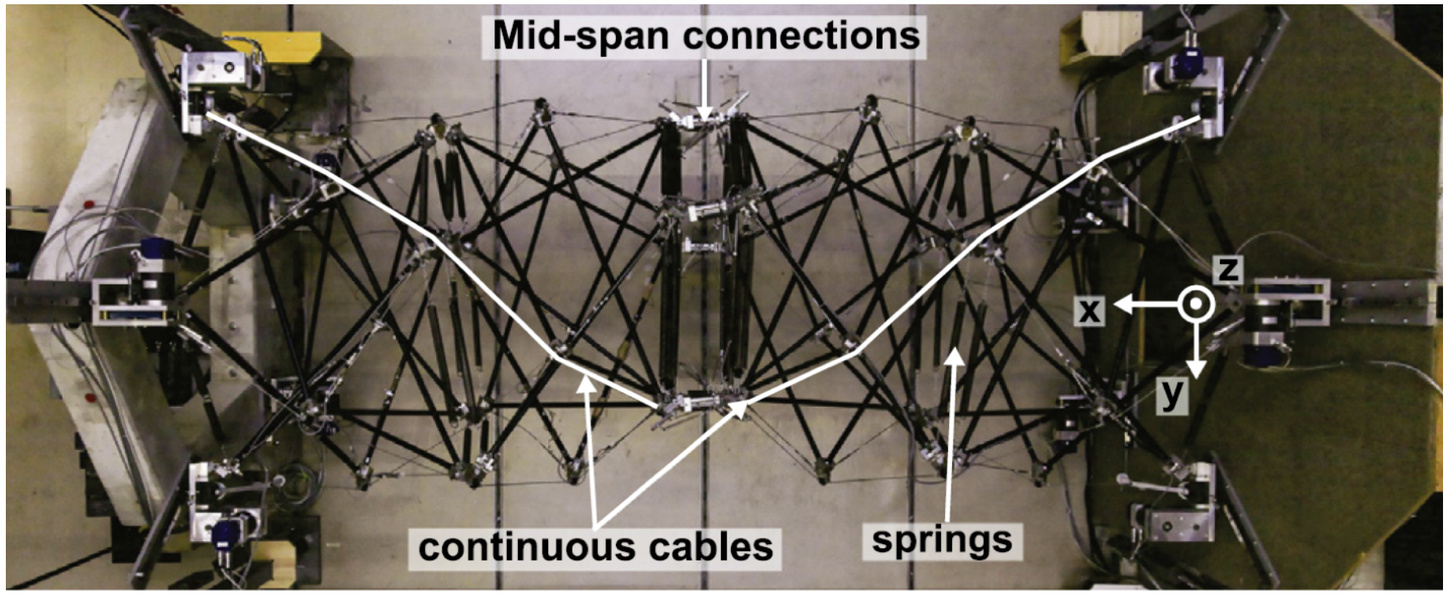


3-cantilevered transformable tensegrity modules



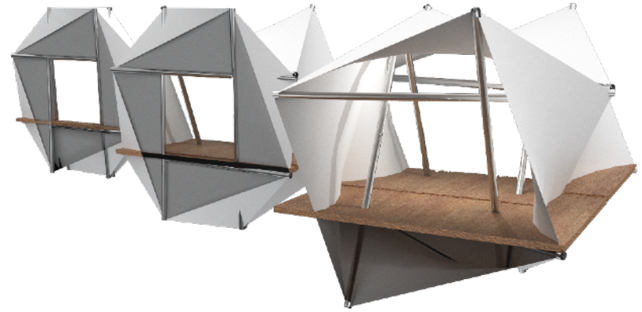


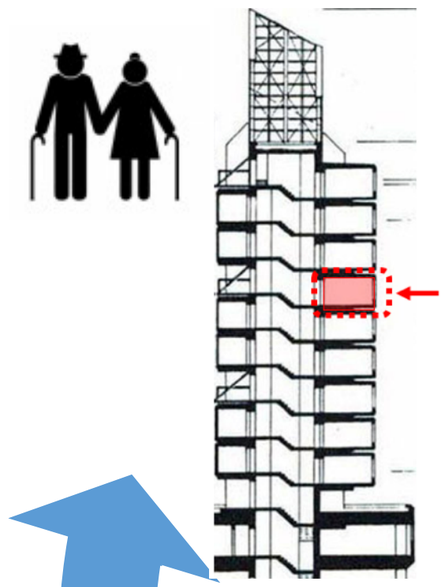
Life Cycle Diagram: (Aging population)

move-in

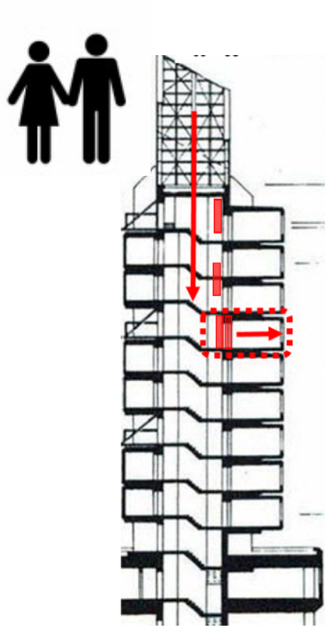
Death/move-out

Life Cycle Diagram: (Aging population)





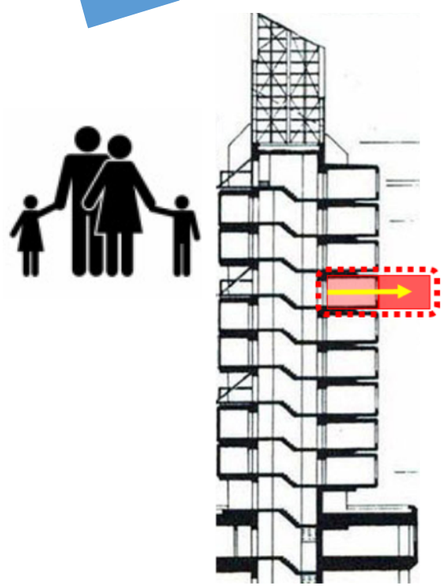
Move-in



Death / Move-out

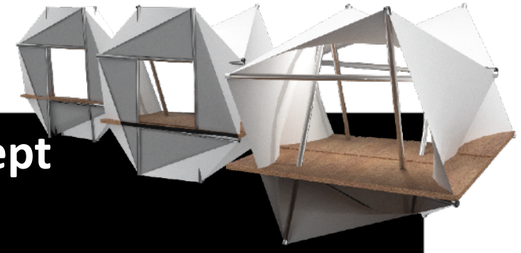
Two member family

Family with children /
immediate need for expansion

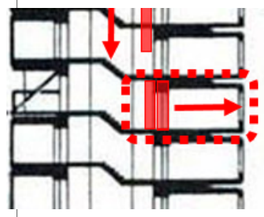
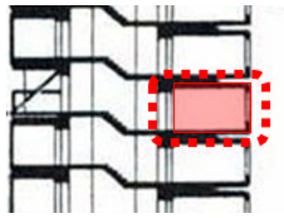
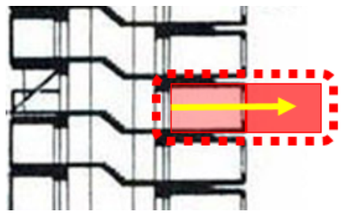
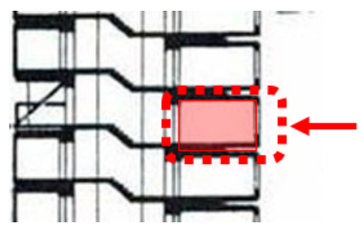
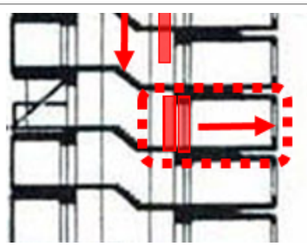


Children's move-out

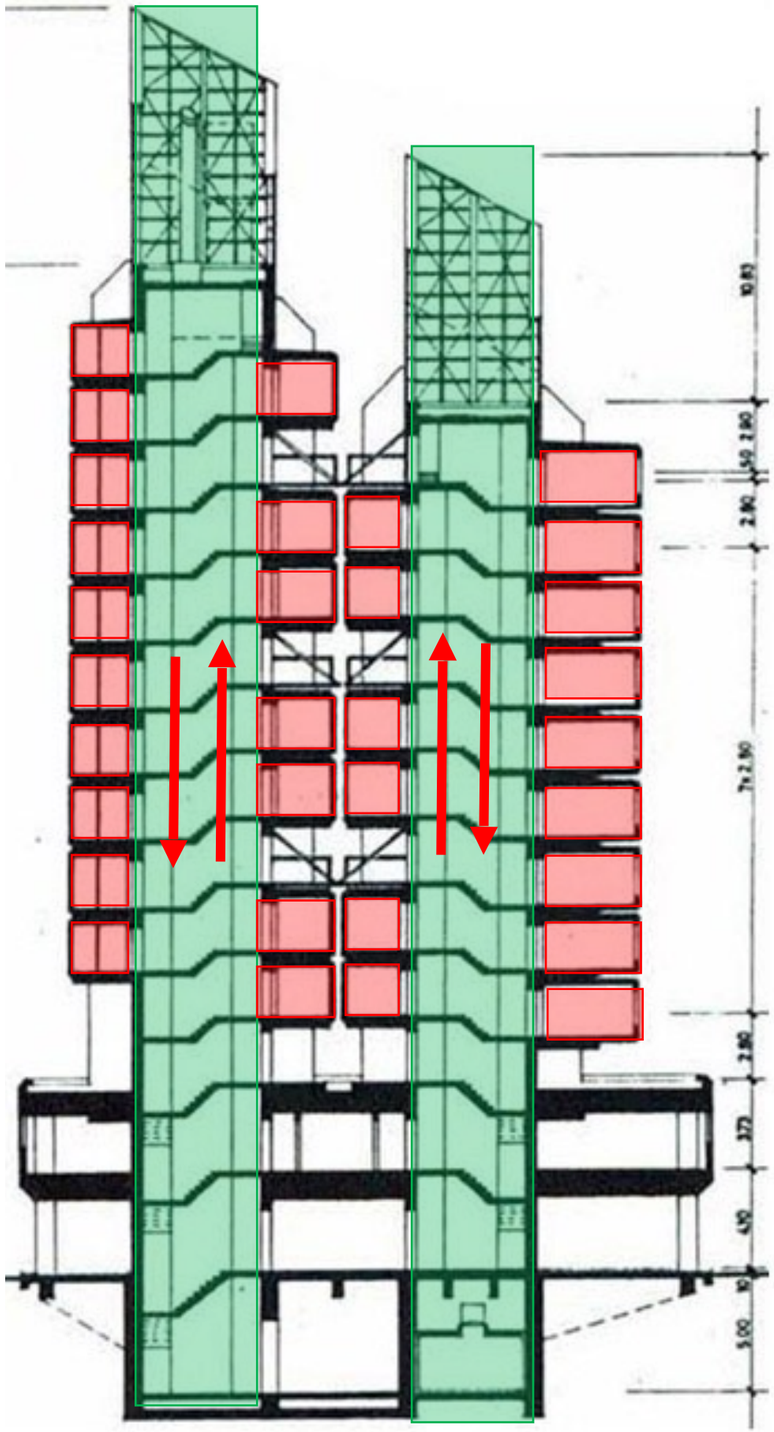
Life cycle Chart: (Aging population)



Life diagram based of aging population as a main force of change

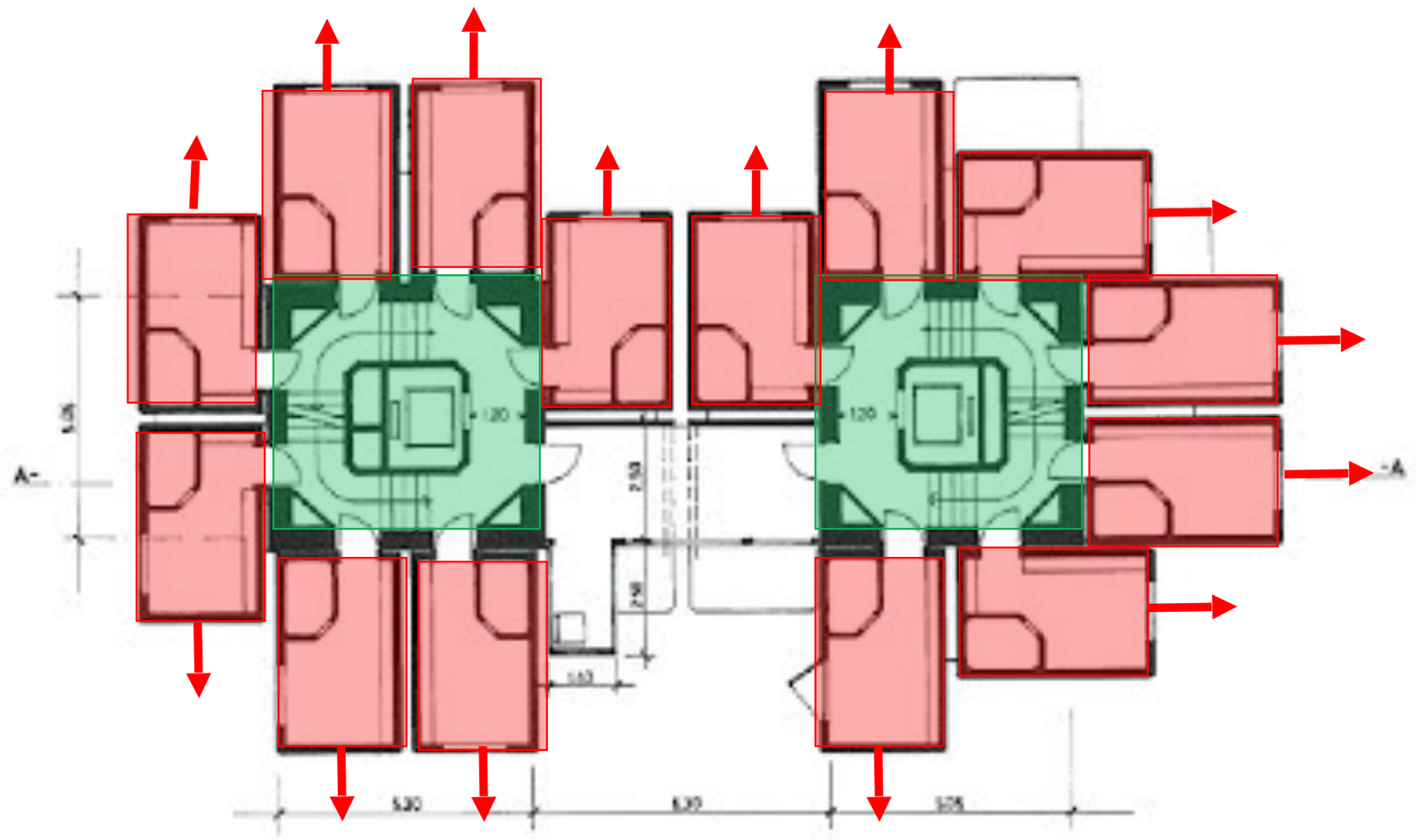
Periods	Title of the periods	Description	Figure	Transforming concept
First period	Move-in	A couple starts a ne life in a new house		
Second period	Two member family	Couple live without having children		
Third period	Family with children / immediate need for expansion	Family expands by adding new members like children/ immediate need for expansion (guest)		
Forth period	Children's move-out	Grown children move out or leave the house		
Fifth period	Death / Move-out	No one lives in the house / family decides to move to a new place		

Functional Diagram: (Portable units)



Central core as a transition path

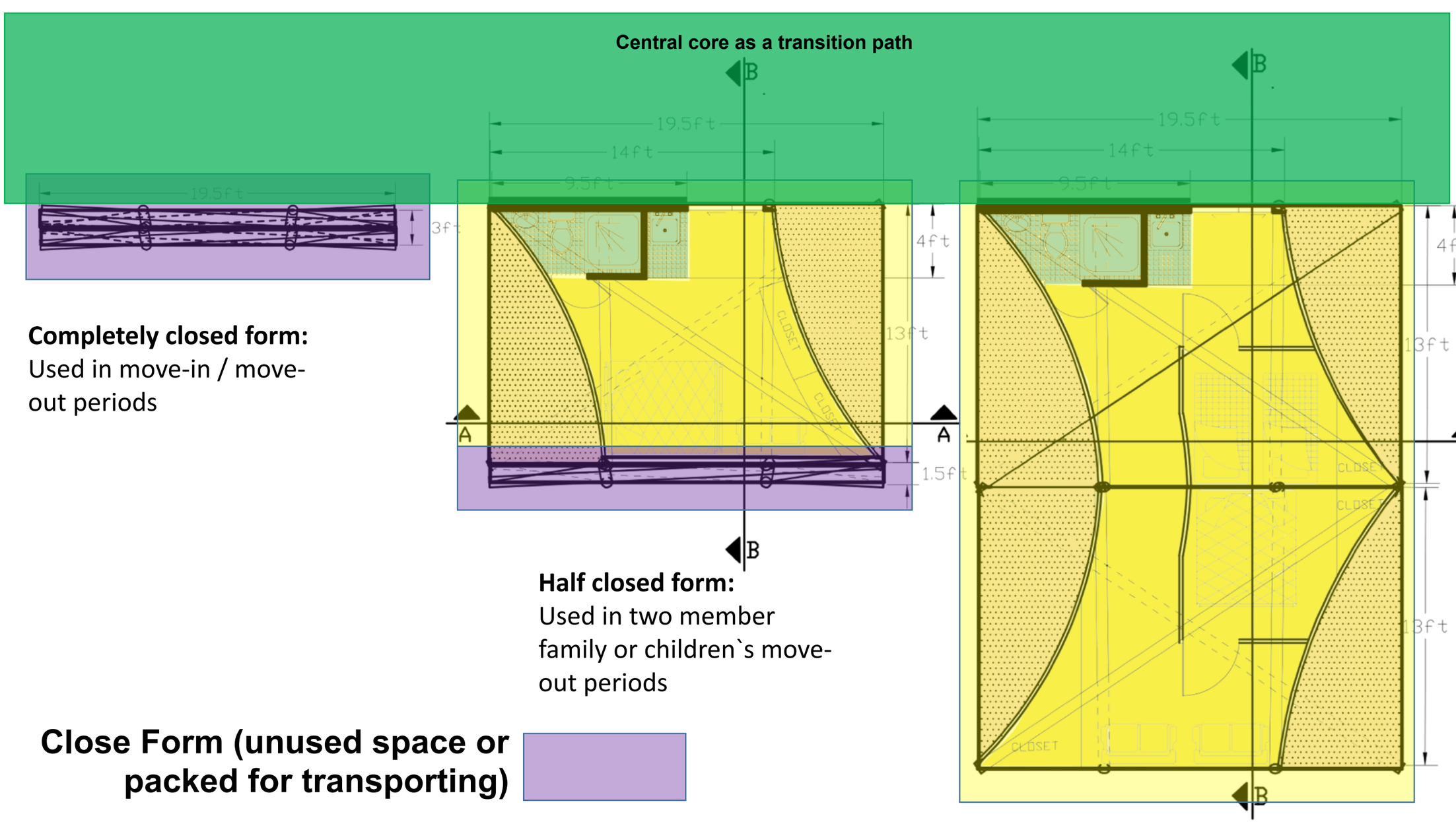
Transformable units

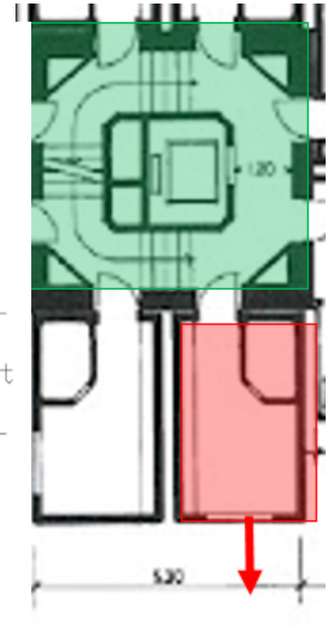


Functional Diagram:
(architectural plan bubble diagram of transformable units)

Central core as a transition path

Transformable units





Completely closed form:
Used in move-in / move-out periods

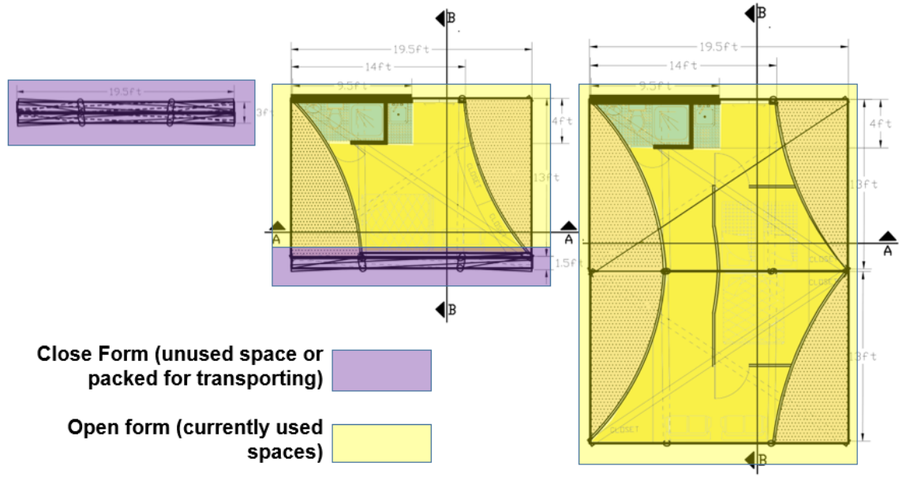
Half closed form:
Used in two member family or children`s move-out periods

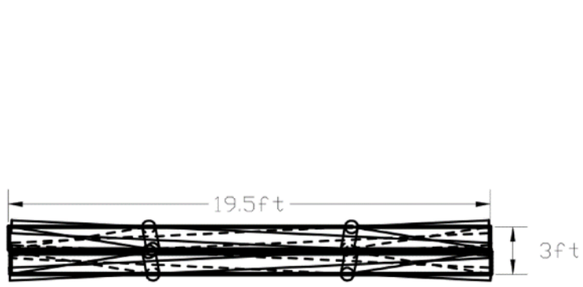
Completely opened form:
Used in family with children period / immediate need for

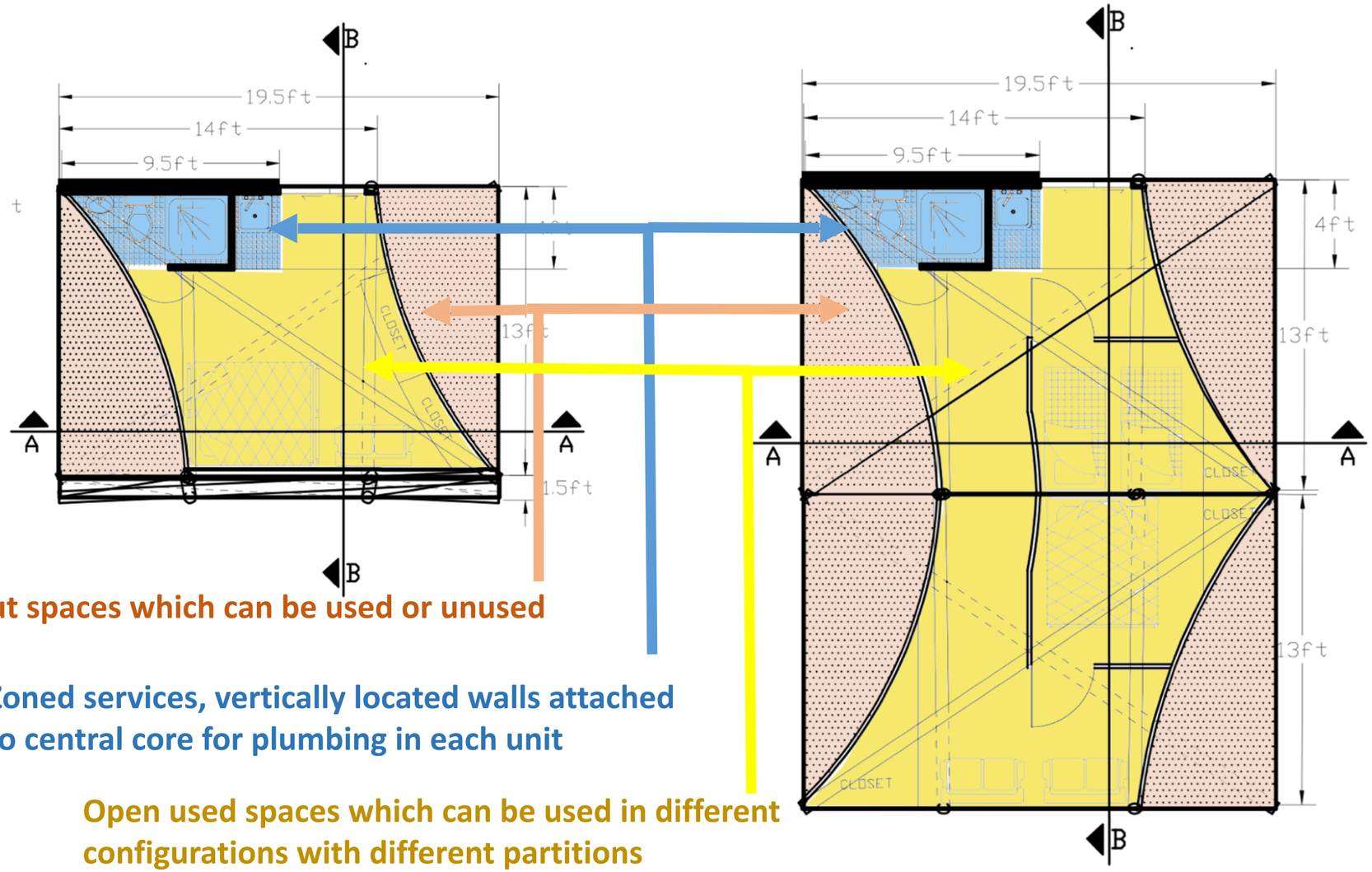
Close Form (unused space or packed for transporting)

Open form (currently used spaces)

Functional Diagram:
(architectural plan diagram of used spaces)







Out spaces which can be used or unused

Zoned services, vertically located walls attached to central core for plumbing in each unit

Open used spaces which can be used in different configurations with different partitions

Necessary social support:
(A manual for maintenance and construction details which makes building sustainable for a long term used)

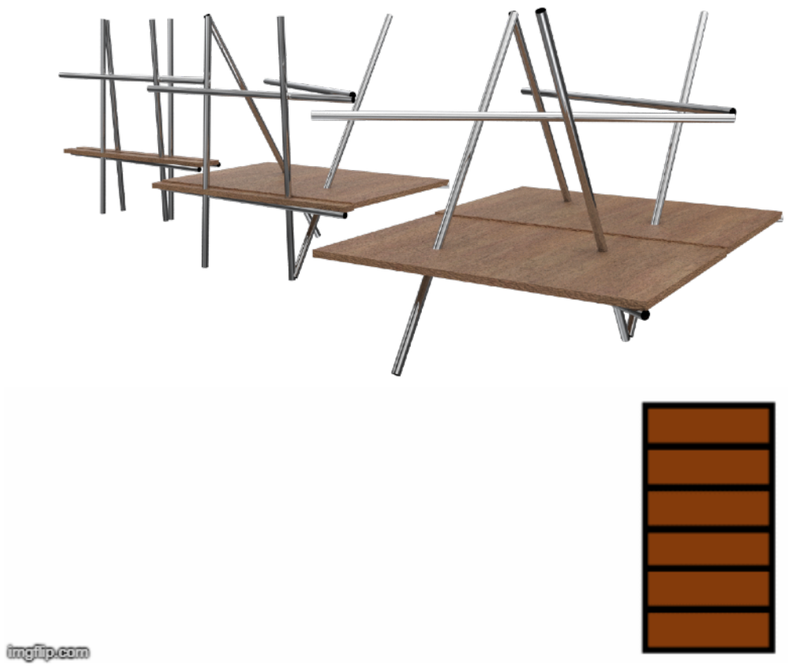
First step: (move-in)
Transferring prefabricated cables, struts, membrane, square-based glass panels and deck to the site.

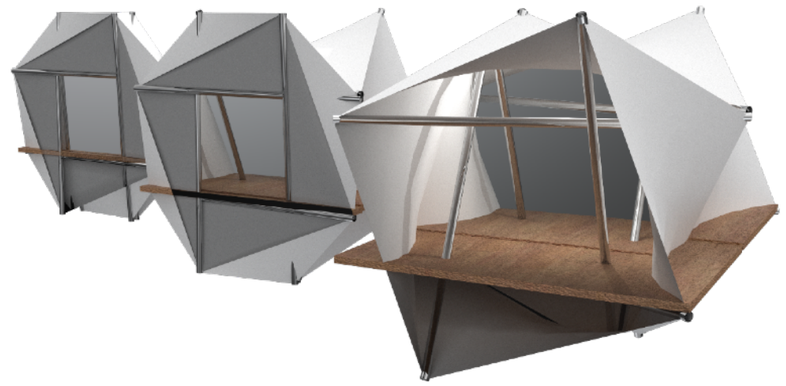
Second step:
Assembling square based glass panels, cables and struts on-site, in order to have a closed tensegrity module. Families who want to expand their members in the future can assemble two modules.

Third step:
Changing the length of struts and diagonal cables, while square-based cables remaining fixed in length. Struts and cables can be changed mechanically, or with the help of sensors and actuators. This will cause transforming the tensegrity module to expand and provide more space.

Fourth step:
Adding a sliding deck as a plate form to provide space to walk on.

Fifth step:
Add membrane as covering of the building. This membrane can be load-bearing or not. If it is made of load-bearing material, it will help cables in tensional load; if not, it will only cover the underneath space.





Necessary social support:
(A manual for maintenance and construction details which makes building sustainable for a long term used)

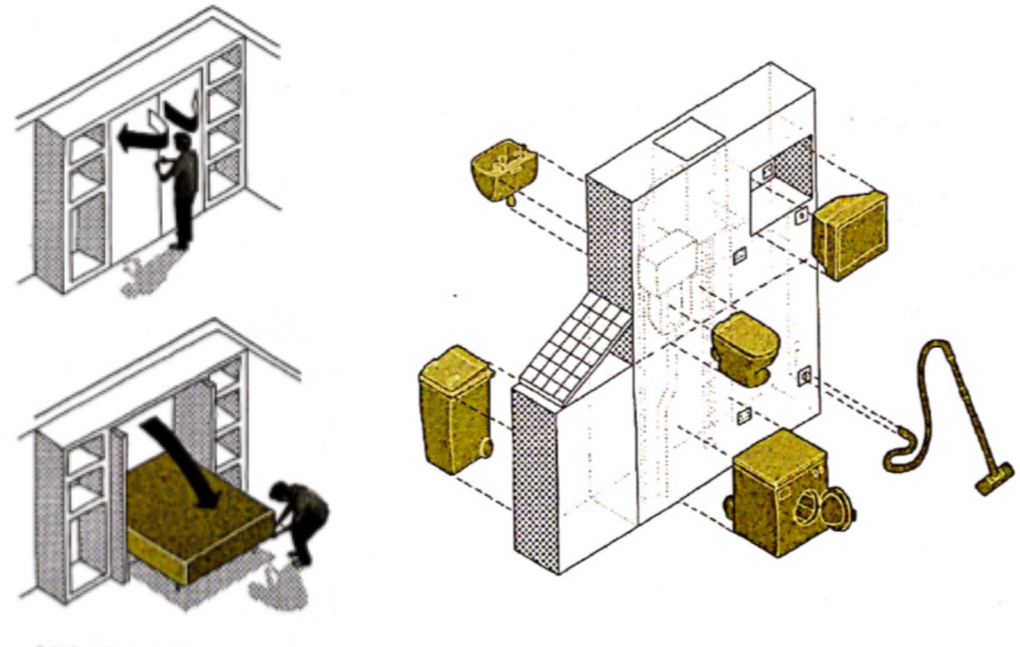
Six steps:
Adding zoned services which is a vertical wall located in each unit and attached to the central core for plumbing. All services needed plumbing are attached to this wall. All capsule towers in each city could store these walls inside the central core for their residents who might move-in in the future.

Seventh step:
Add sliding partitions to divide spaces like bedroom, kitchen, and restrooms.

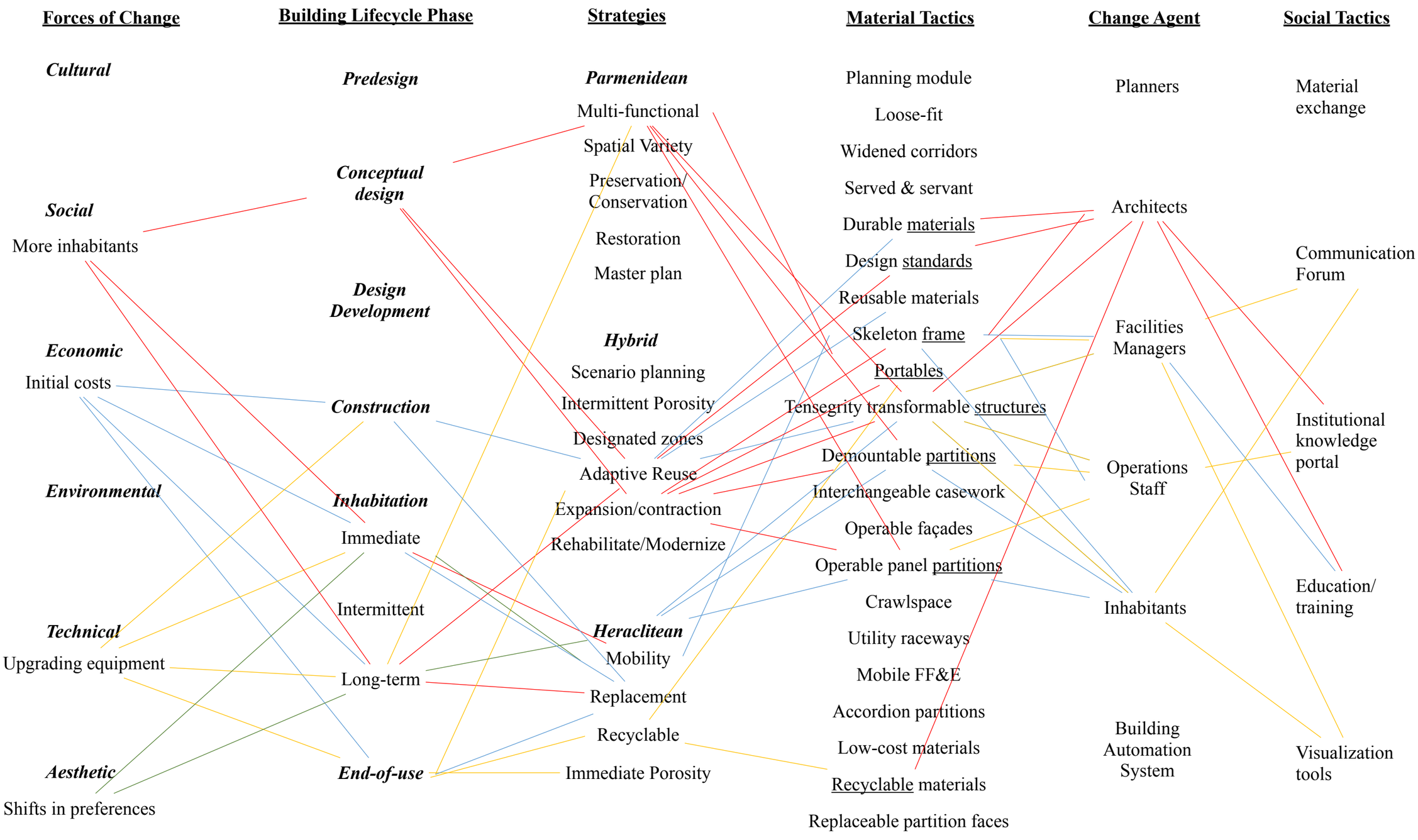
Eighth step:
Add prefabricated furniture like IKEA, or adaptable ones attached to partitions. In this step, all requirements for construction will be finished.

Ninth step: (for maintenance)
During the life cycle of the building, all parts of the building can be replaced with a new one since they are prefabricated. Moreover, the building can be expanded and add another tensegrity module space to the previous one. In this stage, all eight steps should be redone for the new module.

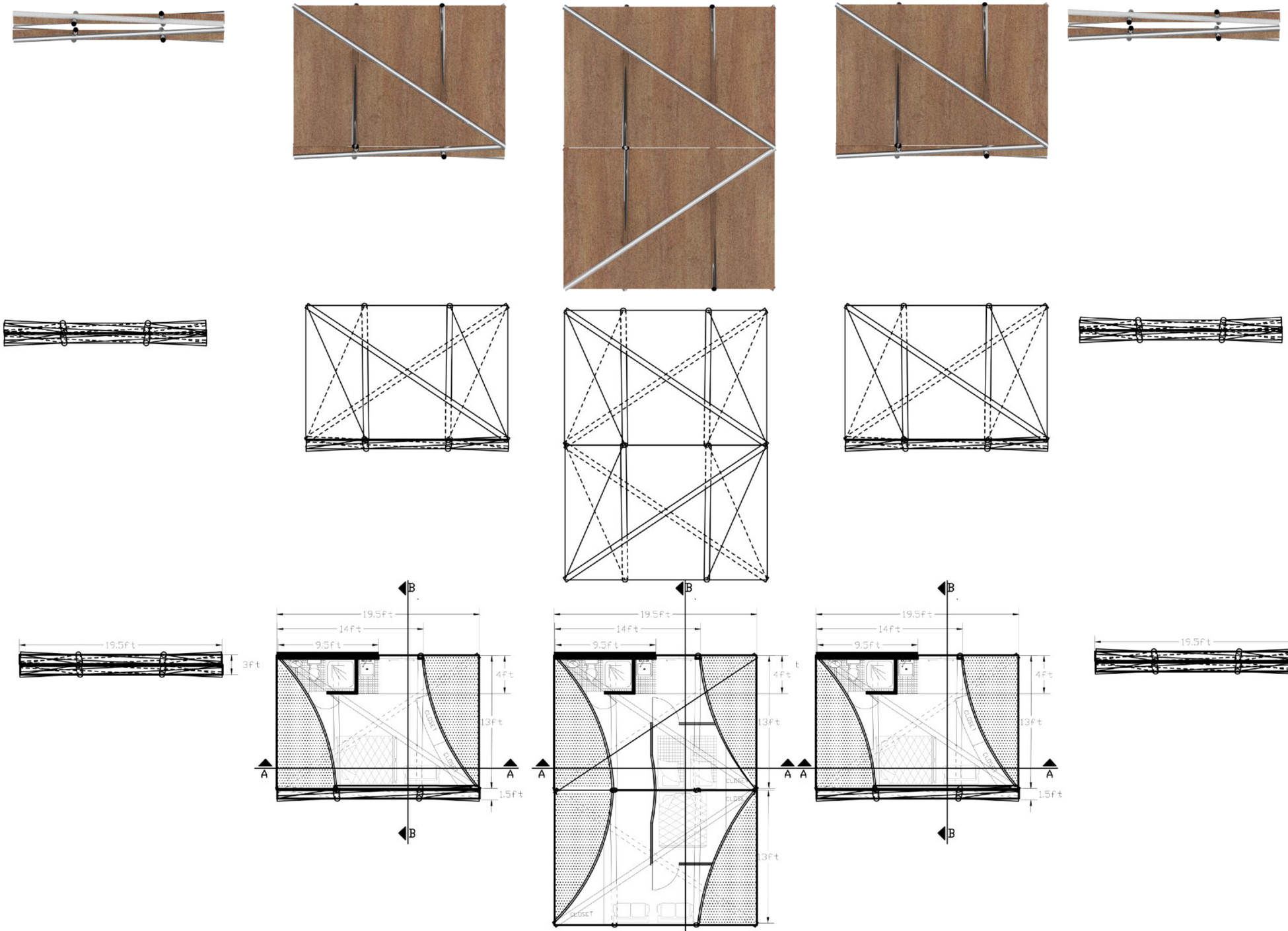
Tenth step: (move-out)
All parts of the building can be separated respectively prefabricated furniture, sliding partitions, zoned service wall, membrane, sliding deck, glass panels, struts, and cables. These parts can be packed and transferred to a new place.

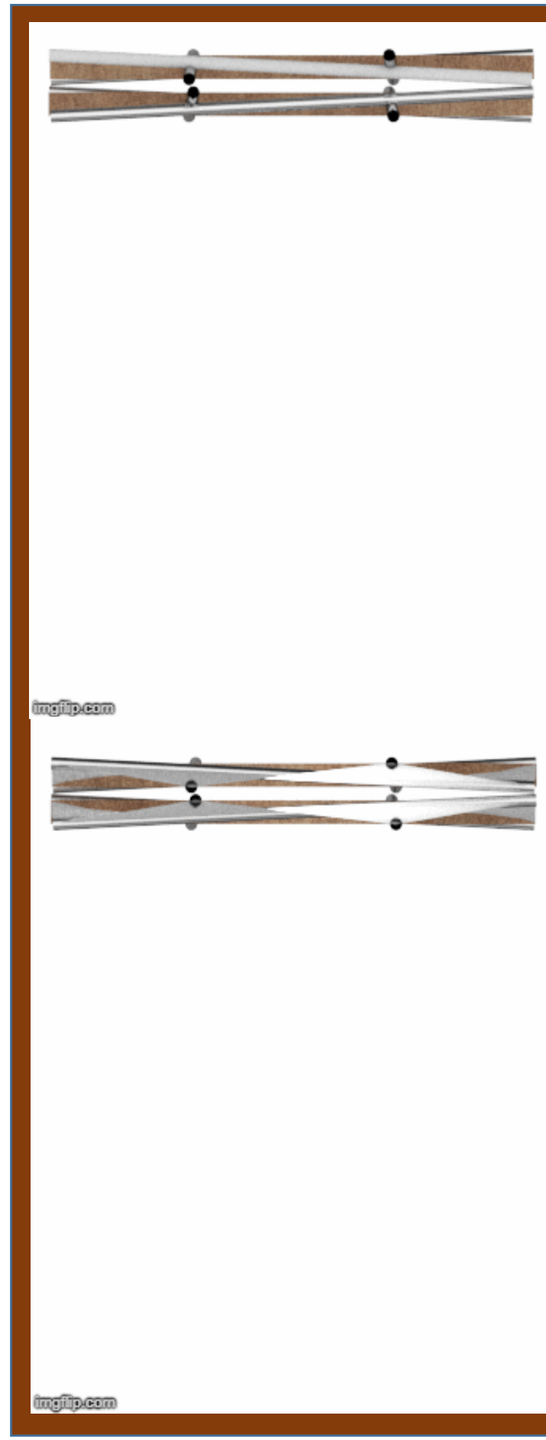


Scenario Development Tool:

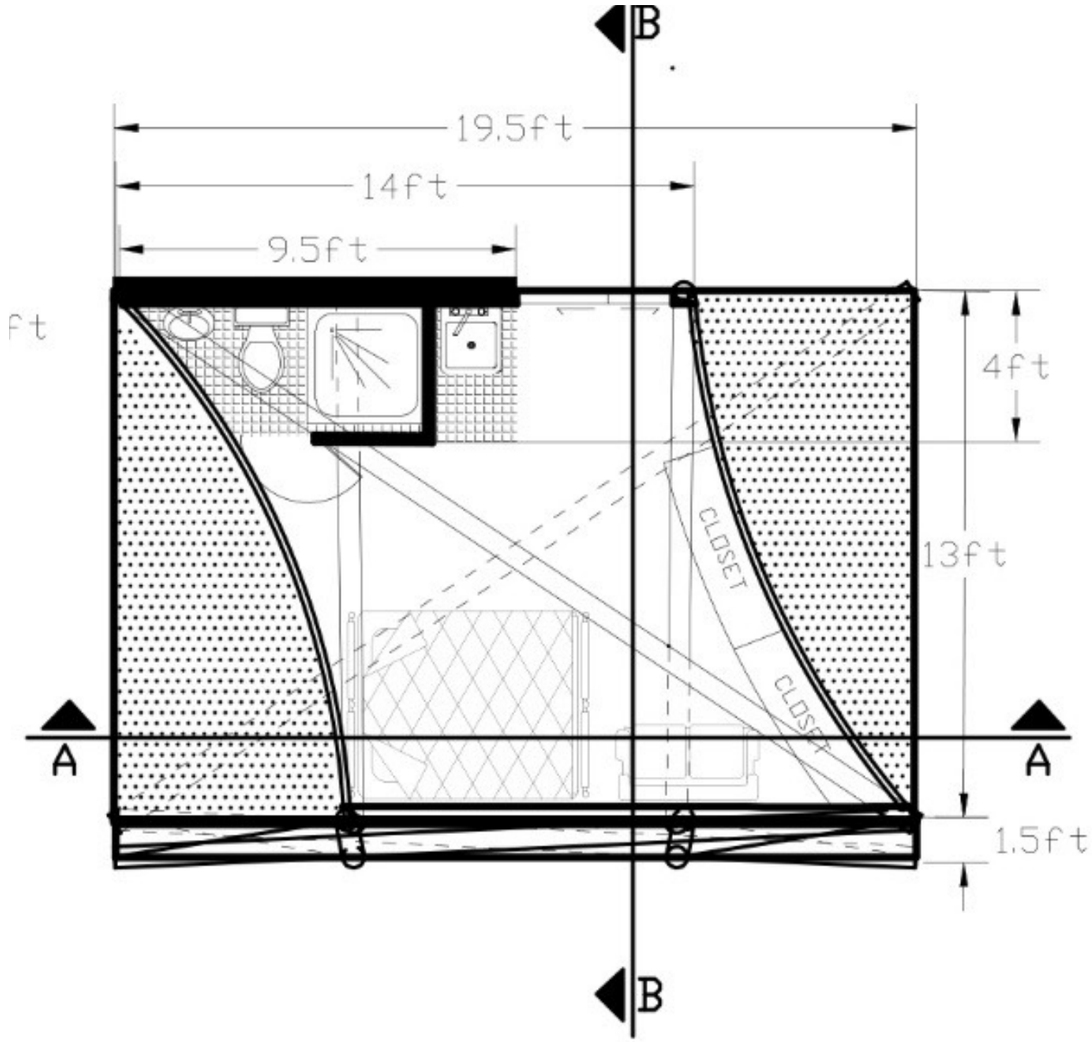


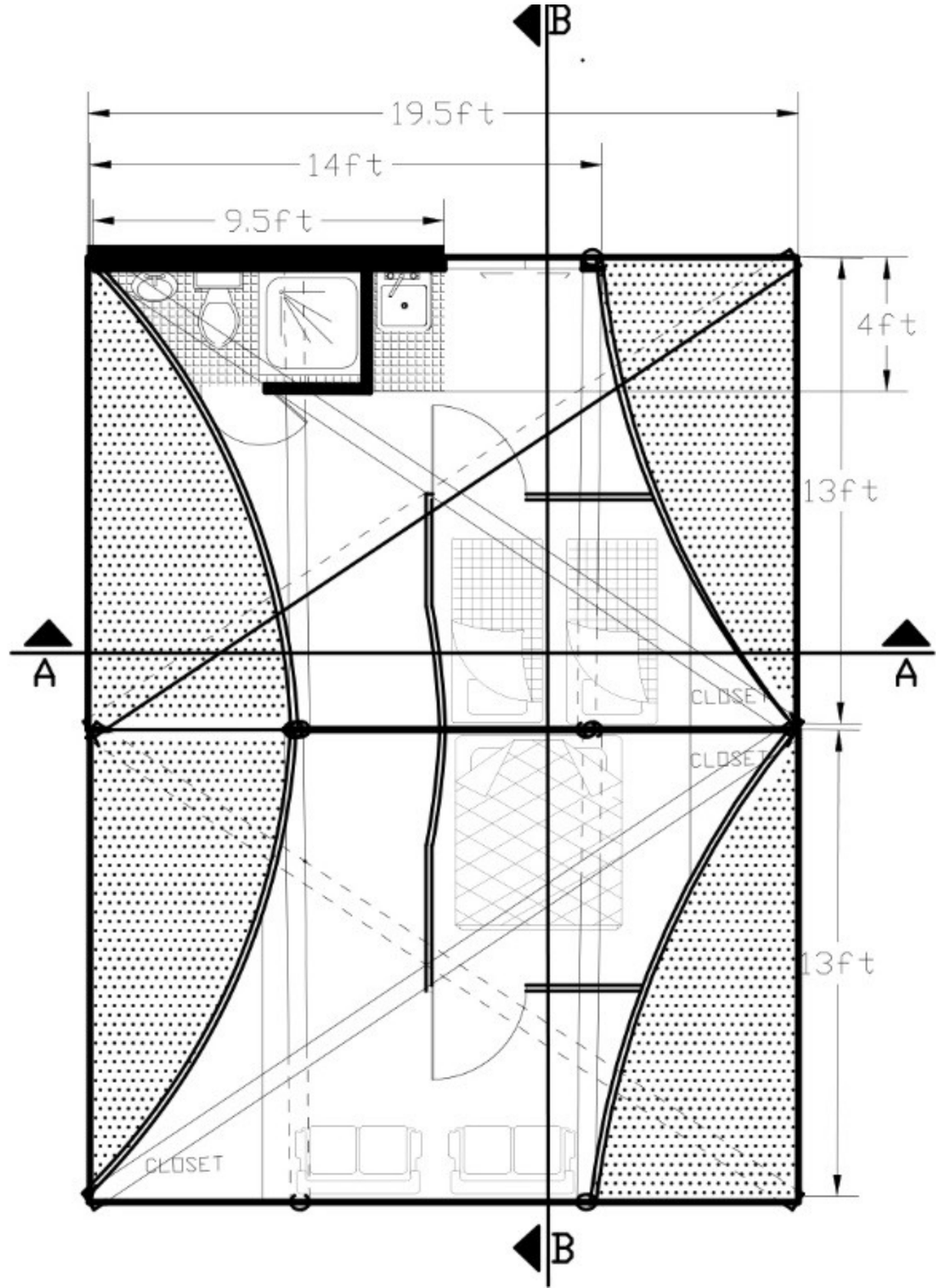
Architectural plans:



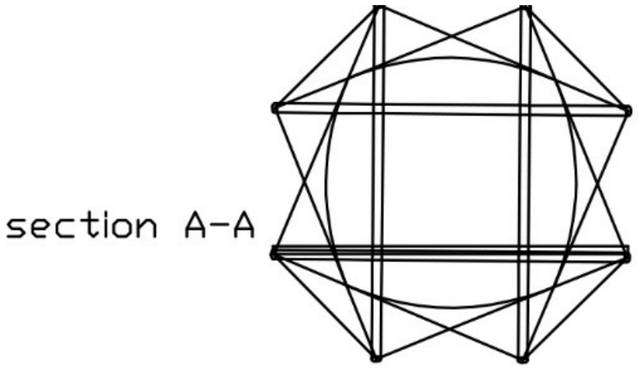


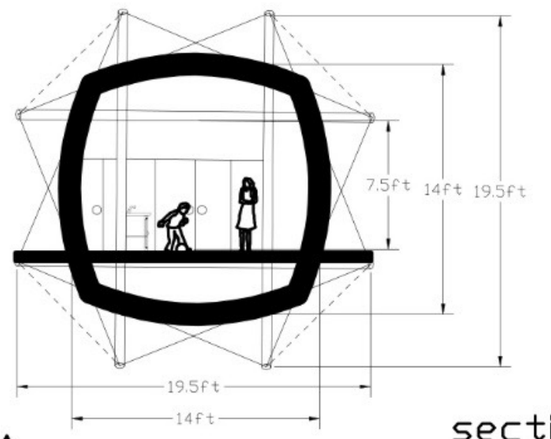
Architectural plans:



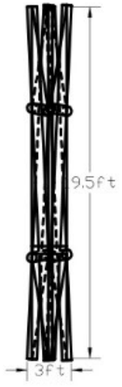


Architectural sections:

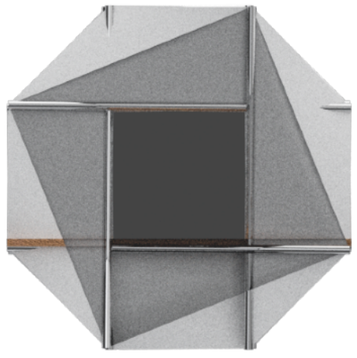


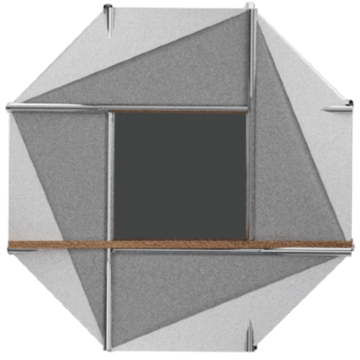


section A-A



section B-B





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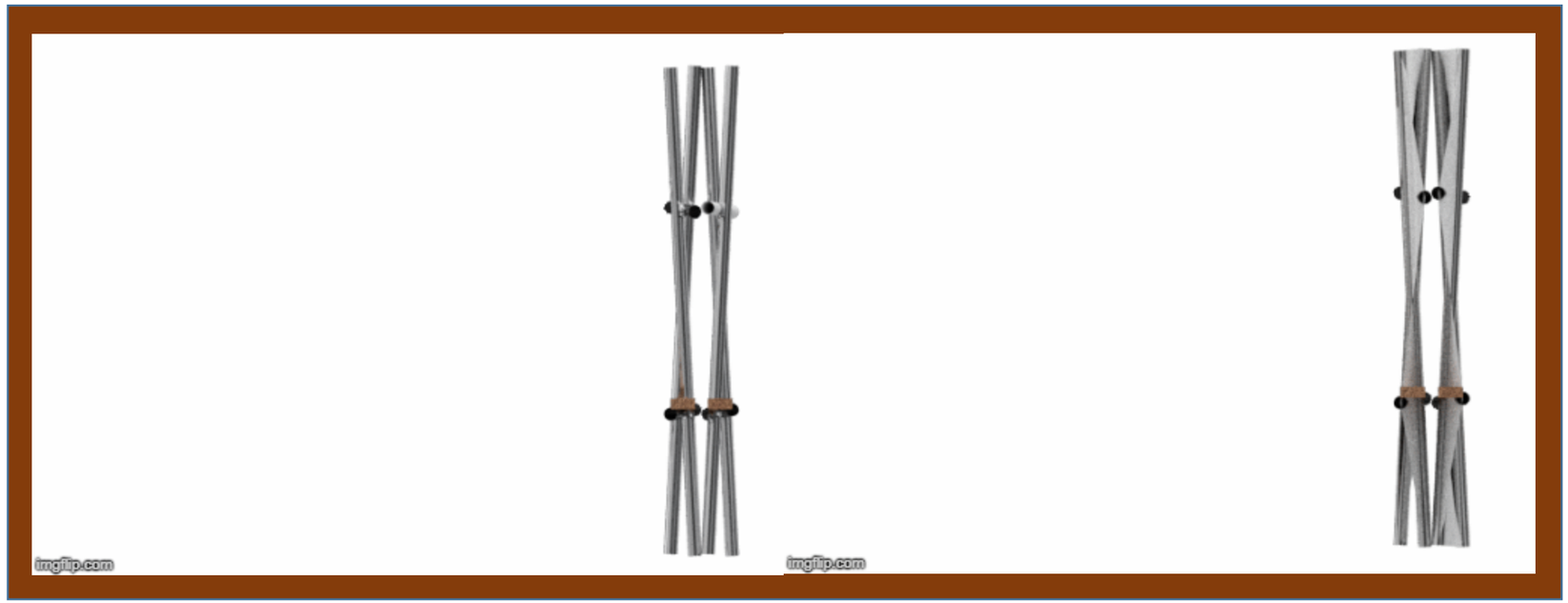

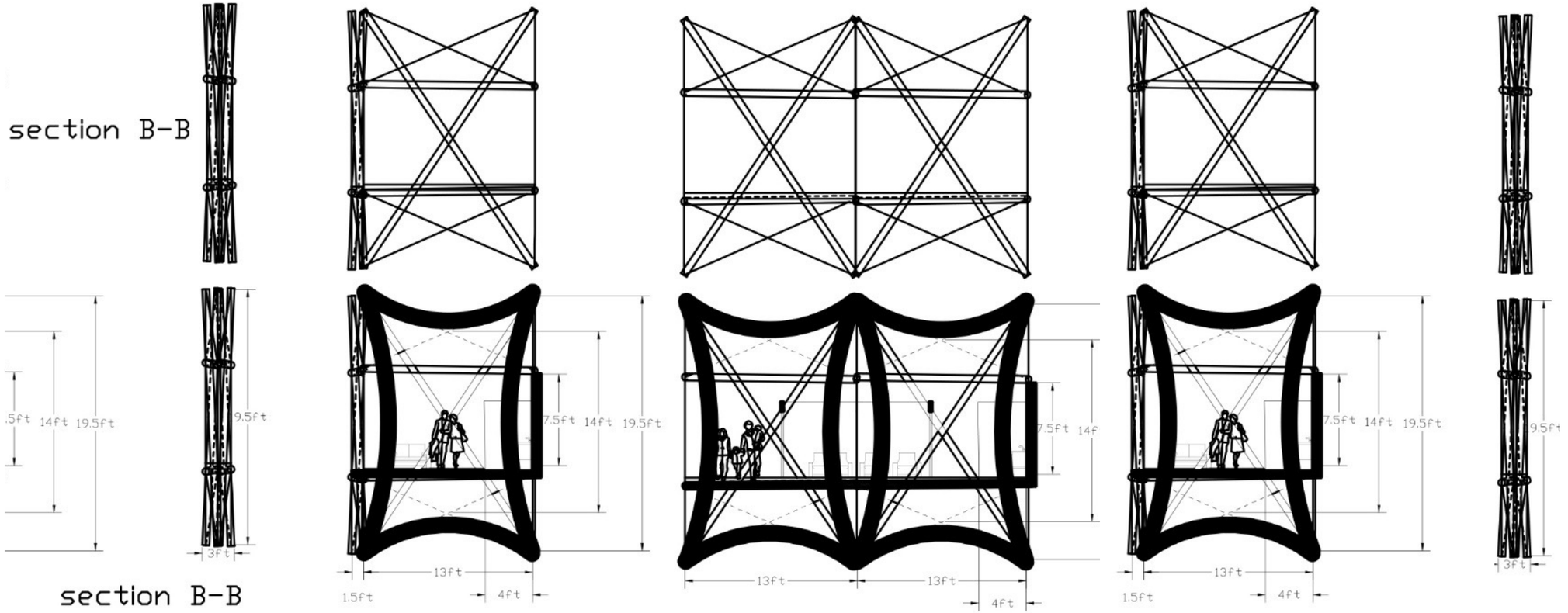

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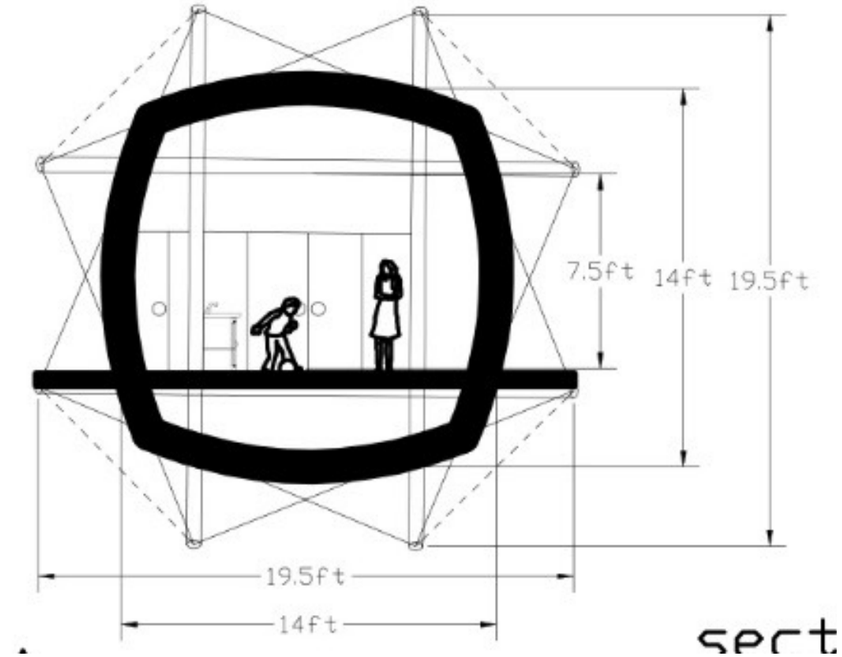
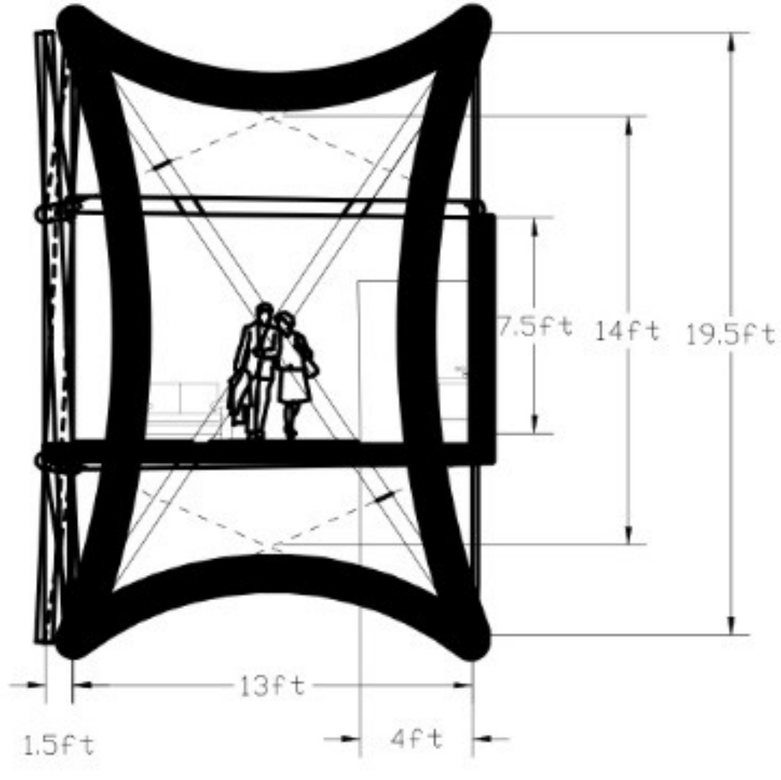
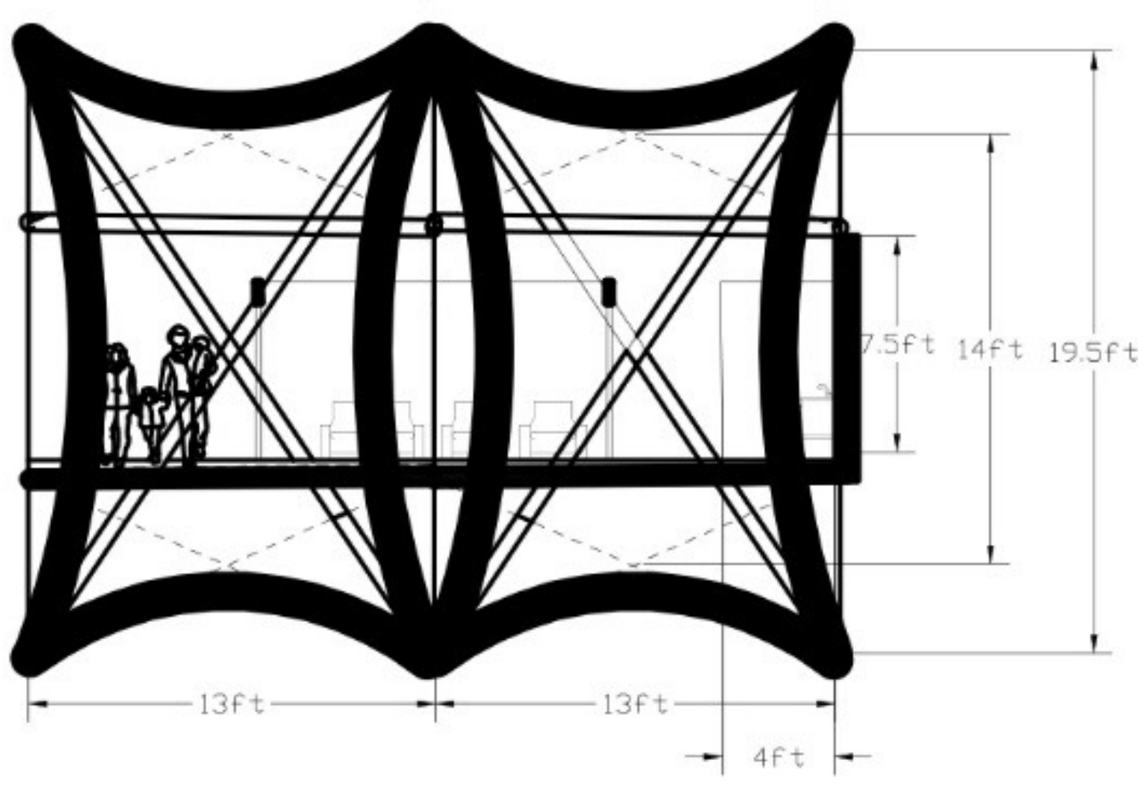
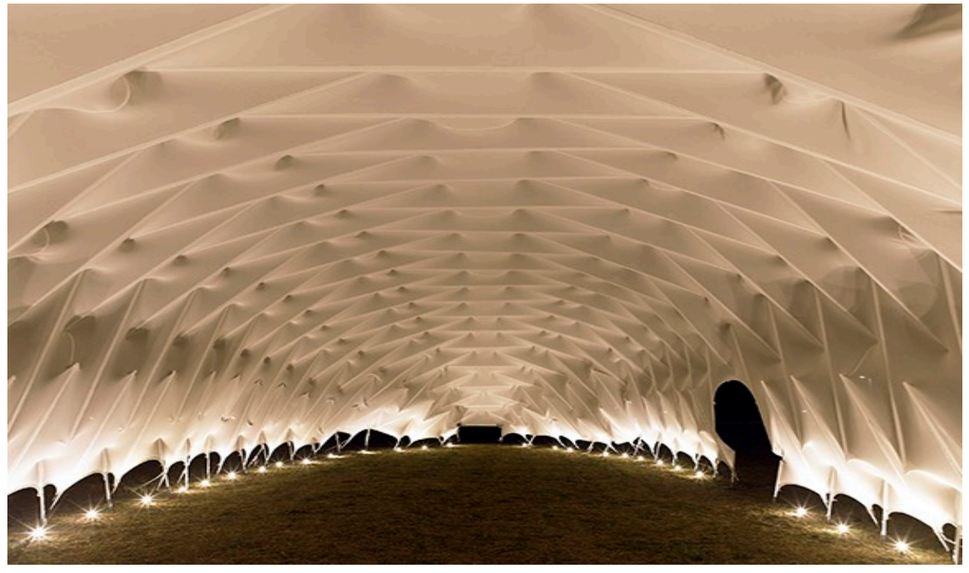






Self-assessment of the solution:



Problems and initial solutions:

Restriction in useable spaces by diagonal structural elements:
In this project, the 4strut module was used since this was an alternative solution for the existing capsule tower, which had box-shaped capsules. However, it is evident that by increasing the number of struts, it is possible to provide more and better architectural spaces. For example, so one of the solutions can be applying a 6strut tensegrity module to decrease the limitation.

Rigid covering:
Tensegrity structures do not provide a sufficient covering by their thin structural members. The cover of these kinds of structures can be adaptable and transformable, as well. The initial solution for the cover problem was applying membranes. However, membranes also need to be maintained yearly, and this causes extra effort.

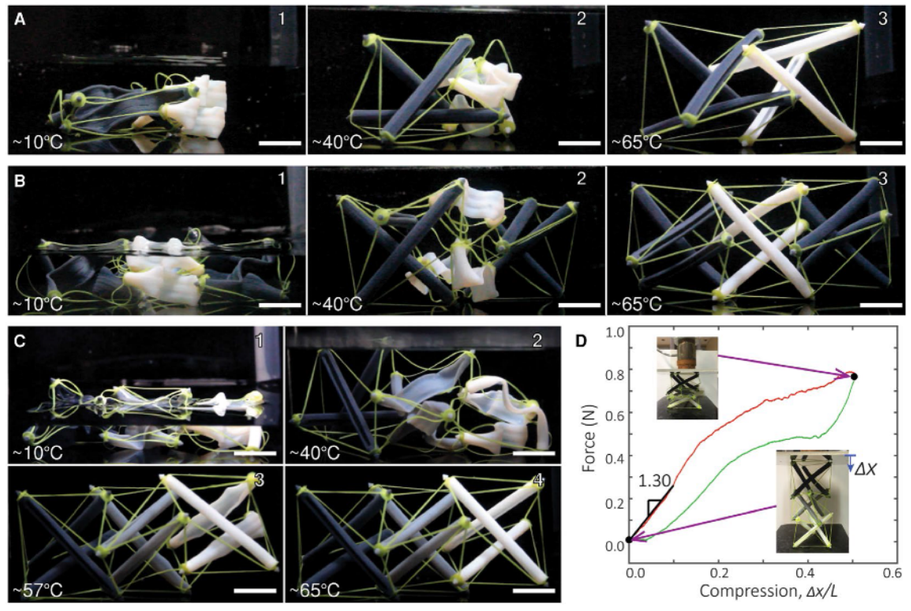
Change the length of structural elements:
In order to achieve the desired shape change of the whole structure, some cables and all struts should change their length. The initial solution for this problem can be mechanical solutions and actuators or sensors, which might cause the extra cost for maintenance of them.

Skilled labor for construction:
Assembling or disassembling of tensegrity structures requires skilled labors. The initial solution for this can be operation staff. However, it needs more residents to be aware of all the details in the construction and maintenance of these structures.

Furniture:
Furniture is the central part of a portable house. Initially adaptable furniture or prefabricated IKEA type furniture is recommended. However, in today's technology, all furniture do not have the adaptability and prefabricated features such as refrigerators, TV, etc., and they should be transferred to the new place in their fixed shape..

Future work:

Problems and future solutions:



Application of shape memory alloys in tensegrities

Restriction in useable spaces by diagonal structural elements:

As mentioned before, one of the solutions can be applying a tensegrity module with more than 4 struts like the 6strut tensegrity module to decrease the architectural space restriction. This requires a capsule tower to be built with a hexagonal pattern in its central core in the future.

Rigid covering:

In the future, we can see the use of rigid materials as the cover of tensegrity structures, which can be adapted as needed. Also, sliding rigid panels and origami patterns can be applied as the cover in the future.

Change the length of structural elements:

Using sensitive smart materials in the structural elements of transformable tensegrity structures can increase the initial cost, but considering the overall life-cycle of the building, it will provide more optimized shape change of the struts or cables.

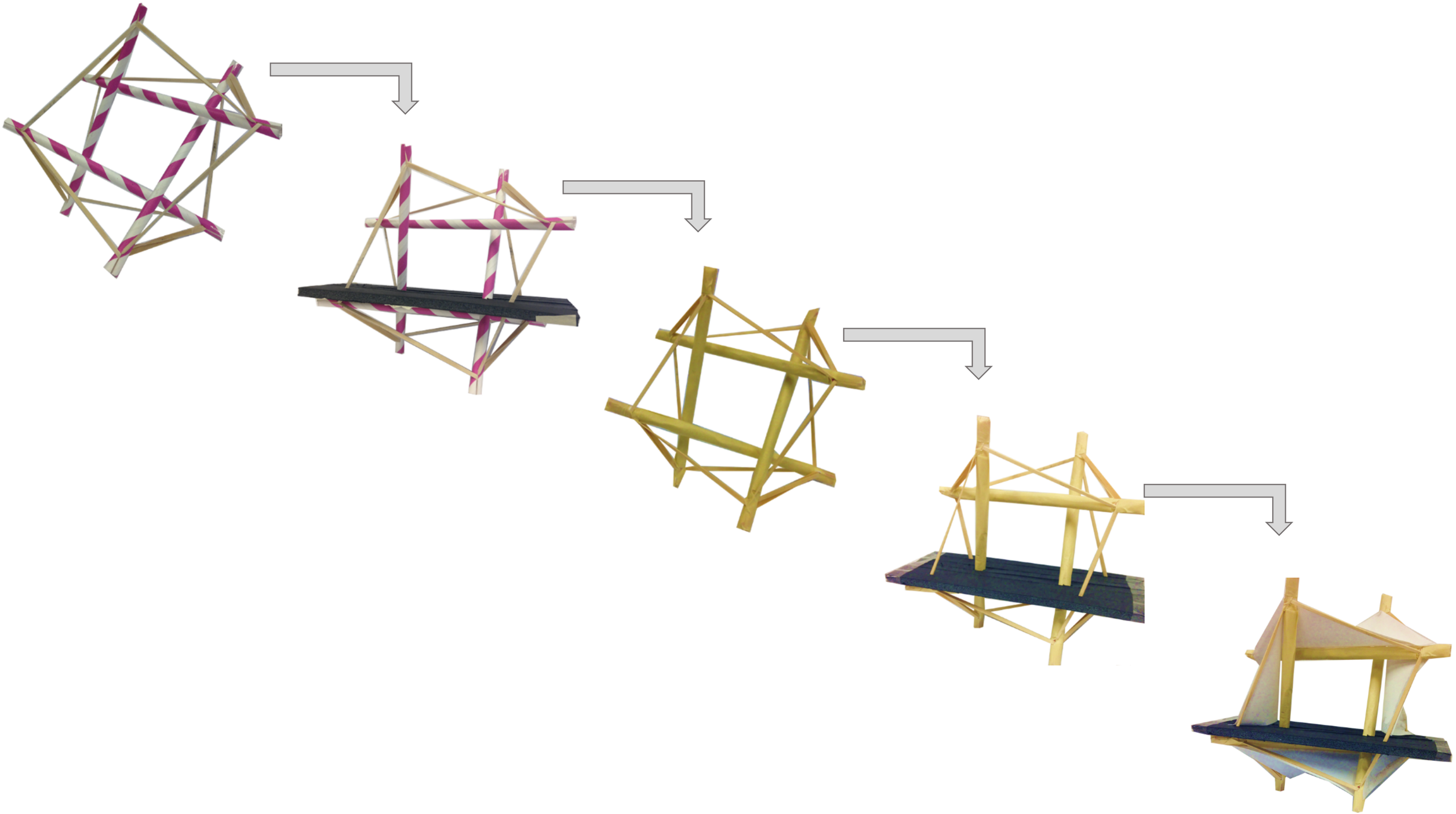
Skilled labor for construction:

In futures, as more people become aware of transformable tensegrity structures, trained residents and facility managers can have the required skill of assembling and disassembling of these structures.

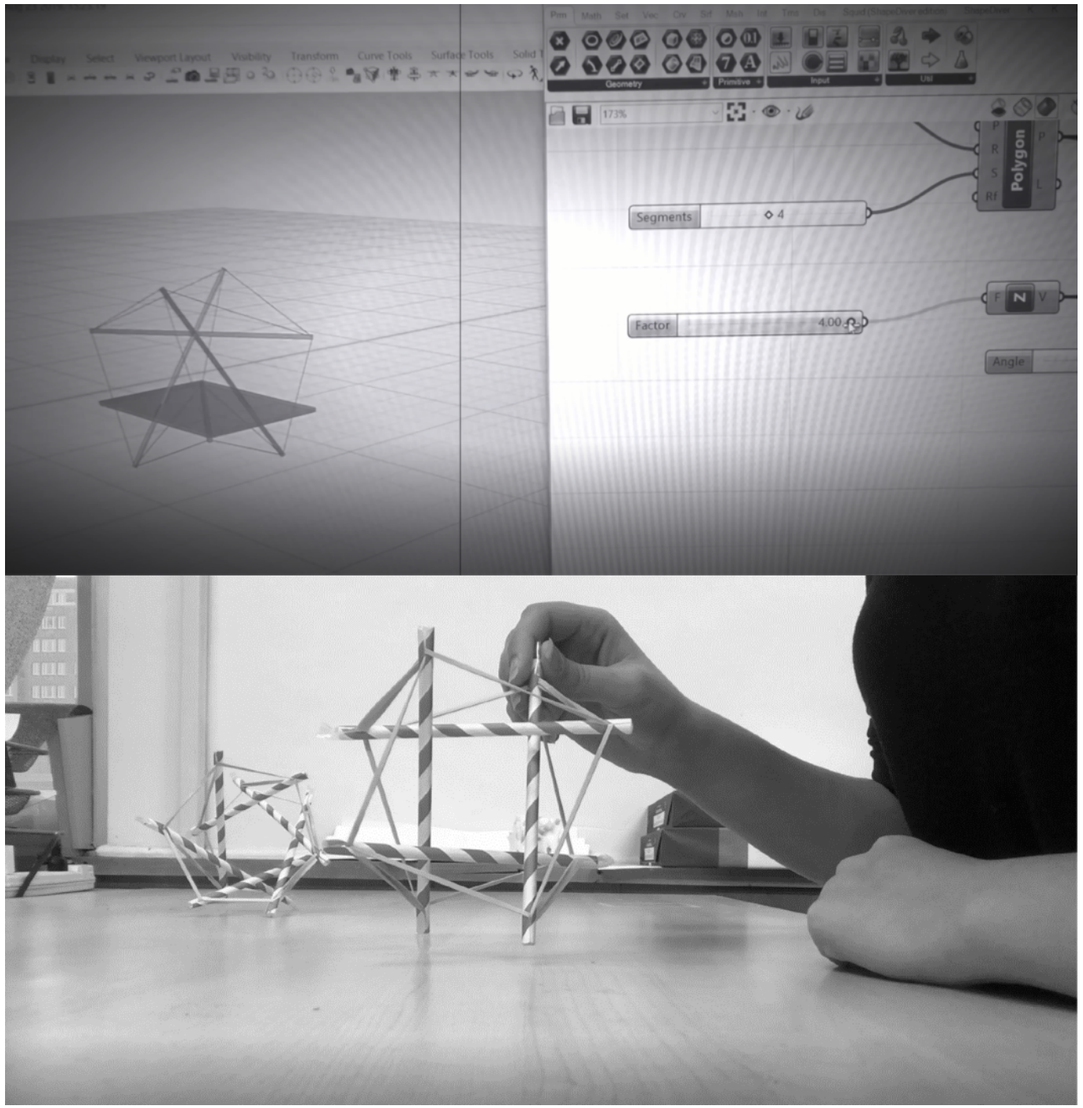
Furniture:

In the future, we might have the technology of more adaptable furniture in which they can change their shape and dimension and be packed into small boxes.

Physical model making process



Play the video clip



Sources:

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