: FOLD
>FLY
>INFLATE

LIGHT STRUCTURES
DIGITAL FABRICATION

Ignacio Borrego (ed.)
Collaborative Design Laboratory

TU BERLIN
Universitätsverlag der TU Berlin

CoLab Berlin VOL 05
The scientific series *CoLab Berlin* is edited by: Prof. Dr. Ignacio Borrego

TU Berlin | Collaborative Design Laboratory
FG Architekturdarstellung und Gestaltung

Universitätsverlag der TU Berlin

The scientific series “CoLab Berlin” is edited by Prof. Dr. Ignacio Borrego.

Light Structures and Digital Fabrication
TU-Berlin in collaboration with ETSAE Cartagena and Feng Chia Taichung.

Advisory Board and Authors:
Prof. Dr. Ignacio Borrego | Dr. Pedro García Martínez | Dr. Martino Peña Fernández-Serrano | Antonio Cerezuela Motos | Carlos Chacón López | Gaizka Altuna Charterina | Benjamin Albrecht

Layout:
Dr. Pedro García Martínez | Michael Klingner | Catalina García Jiménez | Álvaro Sánchez Garda | Juan Antonio Abril Ortega

Photo Documentation:
Dr. Pedro García Martínez | Catalina García Jiménez | Àlvaro Sánchez Garda | Juan Antonio Abril Ortega | CoLab Berlin

Selected Students *Flying Structures*:
Ilaria Abdelmessih | Tareq Almuhammad | Wasita Amatyakul | Pablo de Britto | Eduardo Brizio | Nicolas Colman | Daniel Dieren | Jacqueline Ekteshafi | Milyausha Garaeva | Guilherme Gaspar | Alexander Grams | James Heusser-Kowoll | Jennifer Jiang | Noa Karmi | Michael Kierrcz | Lukas Kleiter | Julie Laconte | Tan Phong Nguyen | Naz Özkan | Chloe Ozoux | Mathilde Pagneux | Jakob Passernig | Esraa Refaat | Aria Rodomonti | Clara Salaun | Katia Schmit | Julian Seyda | Zeki Smajli | Abigail Sobel | Radoslaw Stanko | Nicolas Diaz Tamayo | Paula Vargas Torres | Masayoshi Waku | Leonard Zweck

Selected Students *Fold Fly Inflate*
趙宇涵 Zhao I 賴柏廷 Lai I 李默菲 Lee I Jakob Passernig I Catalina García Jiménez
廖譔堯 Liao I 陳伊婷 Chen I 賴尉齊 Lai I Esraa Refaat I Aria Rodomonti
蔡旻家 Tsay | 楊允澤 Yang I 劉兆旻 Liu I Krishna N. Patel I Nicolas Colman
蕭仲筠 Hsiao I 李奇 Lee I 蕭仲筠 Cheng I Luis Álvarez Ayuso

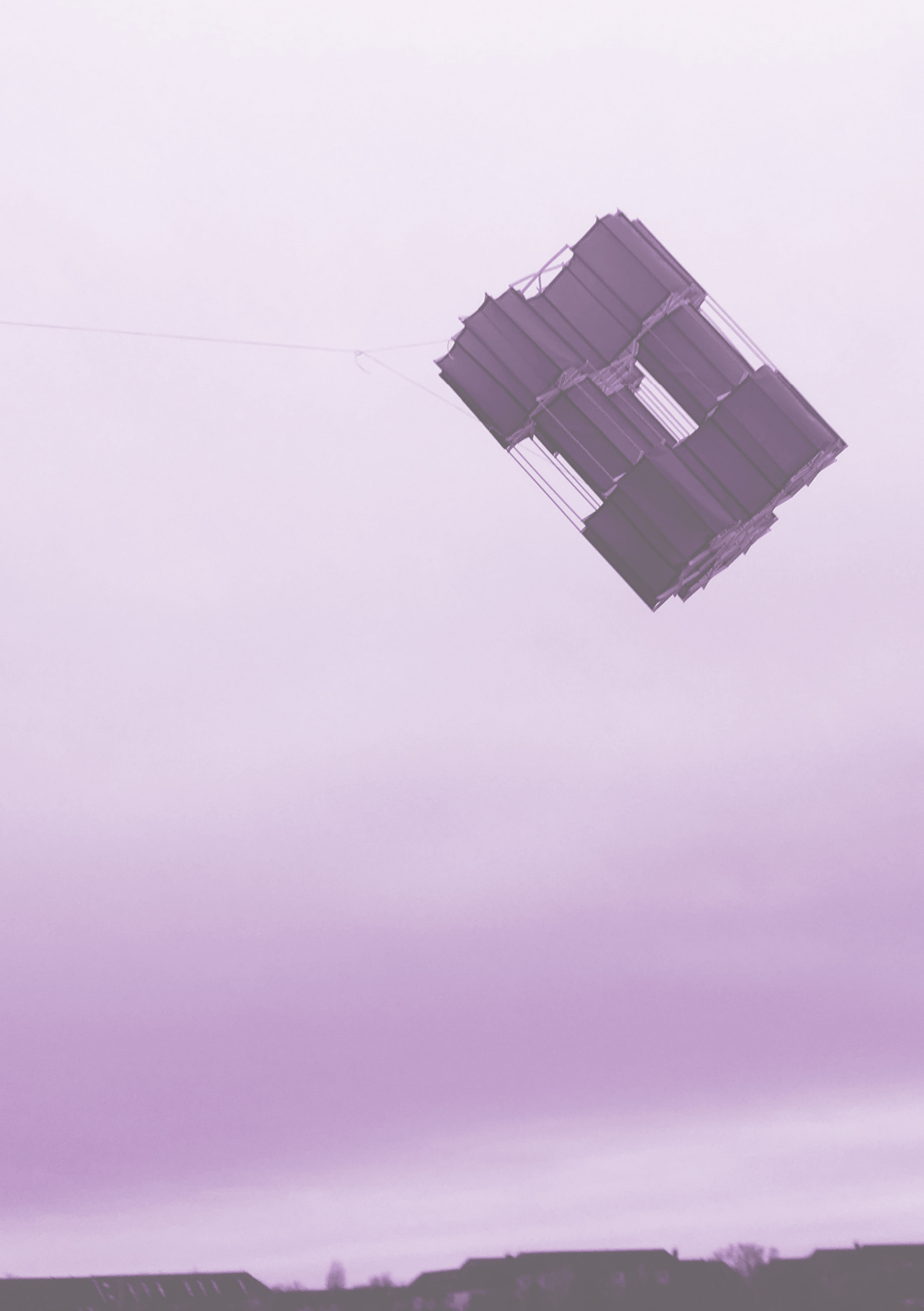
: FOLD >FLY >INFLATE

LIGHT STRUCTURES AND DIGITAL FABRICATION

CoLab Berlin VOL 05

Edited by Ignacio Borrego

// CONTENT



CoLab is a Collaborative Design Laboratory at TU Berlin. Its goal is to investigate those transfers which shall exist between design strategies and new design processes employed in contemporary industry, to apply to the design practice and architectural representation, employing a collaboration model based on collective work.

CoLab Berlin is part of a wider network which includes also a team in Madrid, where it emerged in 2009. CoLab Berlin is located in the department of Architectural Representation and Design at the *Technische Universität Berlin* (TU Berlin).

I am again very pleased to present and to include in our CoLab publication collection the new research results of the academic modules “Digital Fabrication & Flying Structures” and “Digital Fabrication & Deployable, Flying and Inflatable Structures”, that have taken place in our Institute for Architecture at the *Technische Universität Berlin* (TU Berlin) in Winter Semester of 2018–2019.

In this occasion the internationalization has been expanded as we have collaborated with teaching staff and students from three universities from Europe and Asia. The “Architecture representation and Design Department” of the TU Berlin (CoLab) has received visiting lecturers from the following Institutions: Pedro García Martínez, Martino Peña Fernández Serrano and Antonio Cerezuela from the Architecture and Building Technology Department of the University of Cartagena (Spain); Carlos Chacón from the Feng Chia University School of Architecture in Taichung (Taiwan); and Gaizka Altuna from the Polytechnic University of Madrid (Spain). Their invaluable support and initiative made the experience possible. From our department, Benjamin Albrecht has been involved as teaching staff, and has coordinated the module “Digital Fabrication & Flying Structures”, inheriting his experience from previous Summer Schools by the AA in Hawaii.

I would like to make explicit once more the great repercussion of this docent interchange, that enriches not only the students, but also the docent teams. The transfer of knowledge includes content and teaching methodologies. In my opinion very important aspects of contemporary teaching methodology were tested from design to construction, through a collaborative process, and the practical use of new fabrication technologies.

The proposed tasks have been developed internally in TU Berlin by Master level students during one semester (October 2018–January 2019) in the case of the Flying Structures.

The Deployable, Flying and Inflatable Structures where developed during 5 days in March 2019 during the international Workshop with the collaboration of the above mentioned four universities.

I am also very happy to confirm the continuity of this row of experiences to bridge these universities in Cartagena and Berlin, with new connections to Taichung and Madrid.

Prof. Dr. Ignacio Borrego

Light Structures and Digital Fabrication

Dr. Ignacio Borrego	*Professor/ TU Berlin.*
Dr. Pedro García Martínez	*Guest Teacher/ UPCT.*
Carlos Chacón Pérez	*Guest Professor/ Feng Chia.*
Benjamin Albrecht	*Research staff/ TU Berlin.*
Dr. Martino Peña Fernández	*Guest Teacher/ UPCT.*
Gaizka Altuna Charterina	*Research staff/ TU Berlin.*
Antonio Cerezula Motos	*Guest Teacher/ UPCT.*

Lightness. Form is Cheaper than Matter

Prof. Dr. Ignacio Borrego

Technische Universität Berlin

In the year 2040, the world's population will have doubled and the pressure on the environment will be unsustainable if deeply lying changes in our way of life and systems of production are not brought about. The limitation of available resources and the economic and climatic costs of energy inevitably lead to light constructions as a necessary means of curtailing consumption.

In an academic environment, research on light structures and digital fabrication allows us to bring students closer to contemporary problems and at the same time to the issues that will be imminently part of our profession. Beyond the concrete developed prototypes that are not necessarily linked to current architectural practice directly, this experience aims to reflect on new procedures and technologies that will guide our activity with increasing intensity.

From the standpoint of materials, in addition to being mindful of their full life cycle, we can also optimize their use in order to limit waste. To do so, by manipulating their geometry, their functions may be increased with a minimum amount of matter. Big objects may become smaller and therefore transportable. Its mobility allows them to extend their lifespan and its reuse capacity. The assembly of their parts allows them to be repaired, to be recombined, and to be transformed. Heavy materials may become light materials.

By chance, German physicist Frank Mirtsch discovered an unexpected reaction to a cylindrical steel sheet during an experiment in his laboratory. If a steel cylinder with thin walls is subjected to external pressure and is contained inside with rigid rings, the surface sags when the point of instability is surpassed and small square vaults spontaneously appear and confer enhanced resistance to the surface. During the research, hexagonal deformation patterns also appeared as a function of the exterior and the contours. Hexagonal structures were finally chosen because they offered a greater structural isotropy than the rectangular structures.

The lightening of construction materials is not limited to merely their folds, but other mechanisms have been developed such as extrusion, injection and hybridations allowing the mechanical qualities to be maintained while bringing about

substantial weight loss. Cellular polymers, metals extruded into honeycombs, metal foams, and composites are different models of materials whose resistance is enhanced by optimizing their form.
3D printing techniques allow us to shape each piece to optimize structural performance. Searching for maximum strength, maximum rigidity, maximum durability, maximum stability, maximum fatigue capacity, maximum versatility of use and maximum number of applications, a single minimum parameter must be considered, which determines the optimization: the minimum amount of material. The minimum use of material directly implies an optimization in manufacturing times, execution costs, and minimum weight. This leads us to maximum lightness, which can be achieved both by the reduction of the printed volume, and by the location of areas that can be lightened internally. The volume of 3D-printed material, which in our investigation has always been polylactic acid (PLA), can be densely produced with 100% of the compact volume, or by means of cellular structures in strategically lightened areas depending on your mechanical solicitation. This lightening can be done automatically using a catalogue of 3D-print patterns, or it can be designed specifically for each area. This would imply a deeper design assignment, but a greater efficiency of the piece.
The manufacturing process involves an additional variable to that of the properties of the materials and the appropriate form to the entrusted function. The process introduces the need to be fast and cheap. Digital manufacturing offers the possibility of making different pieces in a given envisaged format and overcoming traditional standardisation constraints. The modern movement put forward an isomorphism in design that has reached our days as an intellectual determining factor technically overcome. Yet it can barely be overlooked in professional practice due to the lack of development and implantation of digital manufacturing processes. However, until new design processes based on versions and variations are determined, the incipient proliferation of digital manufacturing machines requires generalising a new rulebook.

However, there are other restrictive conditions related to digital manufacturing: on the one hand, cutting and 3D printing time, and on the other hand the maximum manufacturing dimensions, limited by the dimensions of the cutting maximal area or the maximal 3D-printing volume. Both final requirements and the limitations of manufacturing size must be considered during the design of any piece. In the conventional construction industry there is a relationship, generally direct, between the size of the elements at a construction site (from small bricks to complete elements of facades executed off-site and transported), and the socioeconomic development of a construction sector. The limitations of the dimensions of the prefabricated elements are linked to technological development, and especially with transportation from the factory to the construction site. However, digital manufacturing is still limited today due to the production dimensions of the machines. There are large scale digital manufacturing experiments on-site, but the efficiency and quality of their results are still far from the market.

The challenge of the prototypes with which we have developed at TU Berlin has been to specialize the manufacturing processes, to concentrate the geometric complexity in the 3D-printed pieces, but at the same time to make them as small as possible to speed up the production. The combination of these geometrically sophisticated pieces with standardized simple elements has allowed the process to be optimized.

Lightness is not exclusive to the new digital manufacturing processes. The pull that the Earth exerts on any matter is a determining factor in construction. The history of construction has been characterised by the quest for new mechanical solutions for structural problems to the extent that technological progress has largely been responsible for the evolution of construction. Whether it be the aspiration to float or to fly, or to achieve the most heterodoxical lightness enunciated by Greg Lynn, all are mechanisms to evade one of the most merciless conditioning factors. Yet at times, these innovations unleash new configurations that redefine what is contemporary.

Throughout history, techniques have afforded new possibilities that have lightened structures' material content and even led to the segregation of bearing and wrapping elements.
The massiveness of architecture where the bearing material and wrapping material could be mistaken for each other was to give way to their disassociation when skeletons were developed. On this subject, Le Ricolais was to affirm that: "if one thinks in terms of what is empty, instead of working with solid elements, the truth appears...the art of the structure consists of how and where to place the holes".
Lightness is currently imposed as a need given the limited resources available, particularly due to the fact that energy has become more expensive. The concept of performance per energy unit has emerged, entailing optimising production in industry, infrastructure and building.
Differentiation between the bearing and wrapping material opens new horizons for representing space. Boundaries are blurred and permeability can be controlled. It would seem that man was thus able to replicate the foreboding examples of this disassociation found in nature through all sorts of bone configurations. But the answer to this question, far from being a settled debate, remains uncharted territory. We can hardly think that technique and emotion can walk separately. They are part of the same organism, as the Strandbeesten of Theo Jansen already did, wandering along the vast Dutch beaches.

From the Mechanism to the Structure
and from the Structure to the Mechanism:
Exploring the Variables of Two-Layer Deployable Structures

Dr. Pedro García Martínez

Escuela Técnica Superior de Arquitectura y Edificación

Universidad Politécnica de Cartagena

In 1961, Emilio Pérez Piñero, when he was still a student in ETSAM (Madrid), won an international competition that would change his life. This contest required participants to design a itinerant theater, and it was part of a major event: The UIA Congress that took place in London that year. Since then, this Spanish architect, based in Calasparra (a small town in Región de Murcia), was considered a pioneer in the design and construction of deployable structures worldwide. Piñero patented some of his inventions not only in Spain, but also in the US.[1] During his career, he interacted with such important characters as Fuller, Félix Candela and Dalí.[2]

Later, the Spanish architect Félix Escrig, together with his coworkers Juan Pérez Valcárcel and José Sánchez Sánchez, teachers and researchers in Universidad de Sevilla (Sevilla University), developed inventions and patents of deployable structures.[3] In fact, in Spain, Félix Escrig is considered a successor to Piñero's work.

The American designer, Charles Hoberman, in his first patents, refers to those of both Spanish architects.[4] In them, he took as a starting point the structures patented by Piñero and Escrig, and developed new deployable modules. They were thought specially to obtain structures with shapes close to that of the sphere. Hoberman improved the previous solutions and thought about how to apply this knowledge not only to buildings but also to smaller objects. In fact, his toy sphere became world famous.[5] Meanwhile, another Spanish architect insisted on the idea of producing a building that can be packed, transported,

---

[1] Pérez-Piñero, E.: *Estructura Reticular Estérea Plegable*. Ministerio de Industria y Energía. Registro de la Propiedad Intelectual. Spain, 1961.
Pérez-Piñero, E.: *Three Dimensional Reticular Structure*. United States Patent Ofice. U.S., 1965.

[2] García Martínez, P.: „Lessons from a future past: Hoberman and new parameters for deployable structures". In: :*Fold. >Refold. Deployable Narratives and Digital Fabrication.* Berlin: CoLabCollaborative Design Laboratory, 2019. p. 14–22.

[3] Escrig Pallarés, F.: *Sistema modular para la construcción de estructuras espaciales desplegables de barras.* Ministerio de Industria y Energía. Registro de la Propiedad Intelectual. Spain, 1984.
Sánchez Sánchez, J. Escrig Pallarés, F. Ponce Ortiz de Insagurbe, M.: *Poliedros desplegables de estructura tubular y cerramiento textil*. Oficina Española de Patentes y Marcas. Spain, 2015.

[4] Hoberman C.: *Reversibly Expandable Doubly-curved Truss Structure*. United States Patent Ofice. Patent n.: 4943700, U.S., 1990.

[5] https://www.hoberman.com/portfolio/hoberman-sphere-toy/

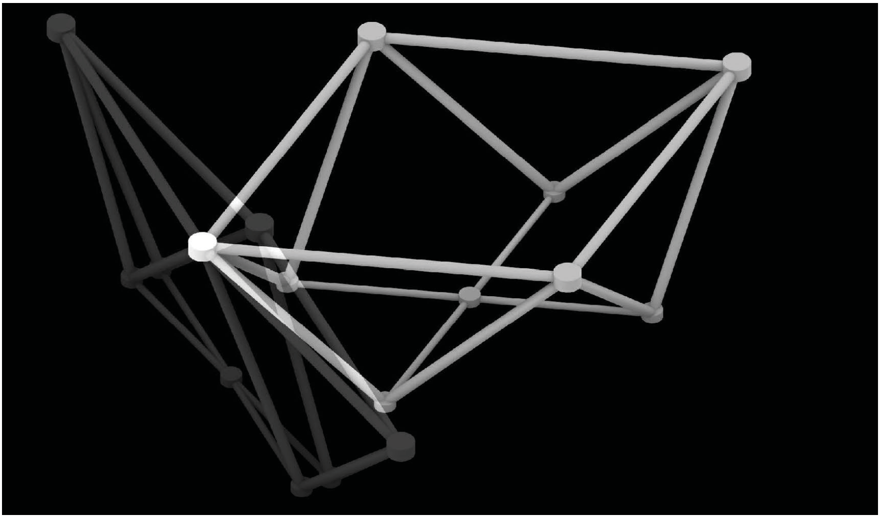


Fig. 1: Isometric view of a basic module of Juan Carlos Gómez de Cózar´s deployable structure system. Source: Pedro García Martínez

and reassembled in any place. His name is Juan Carlos Gómez de Cózar and nowadays he is also a teacher and researcher working for Universidad de Sevilla. In 1997, Cozar registerd the patent of a deployable system. Maybe, this invention is not as well known as those related before, but it has interesting features. His patent is named *Sistema para la construcción de estructuras estéreas de dos capas desplegables, formadas por mallas de rombos y aspas, multianguladas (System for the construction of space frame structures with two deployable layers, formed by rhombuses and scissor smeshes, multiangulated)*, and was finally conceded in Spain, in 2001.[6]
The previous systems were conceived as a set compound by rods arranged to generate a geometrical mesh that works as a mechanism, and therefore, it can

[6] Gómez de Cózar, J. C.: *Sistema para la construcción de estructuras estéreas de dos capas desplegables, formadas por mallas de rombos y aspas, multianguladas.* Oficina Española de Patentes y Marcas. Patente 2152787. Spain, 2001.

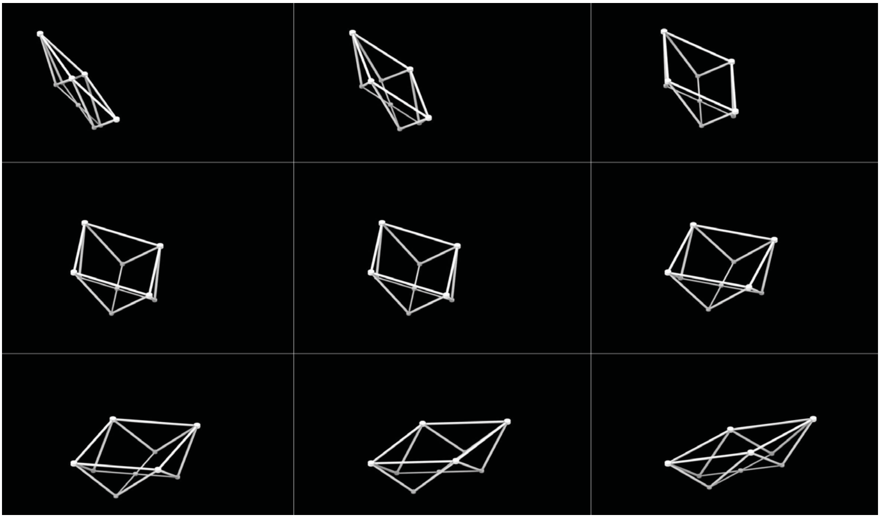


Fig. 2: Isometric view of a basic module of Juan Carlos Gómez de Cózar´s deployable structure system, at different times of the folding and unfolding process. Source: Pedro García Martínez

be folded and unfolded. In consequence a great number of bars need to be added, once the structure is deployed, to set this mechanism as a stable structure. However, Gómez de Cózar‘s approach starts from considering that the structure can eventually become a mechanism. This allows the whole set to fold or change shape, to facilitate its rapid assembly, while maintaining greater rigidity.
Gómez de Cózar gets this extra-rigidity in his structures by adding triangulated elements to the system. In consequence, these elements are not foldable, even if the whole assembly is partially collapsible. The fact of arranging these elements, forces to decide the height of the structure beforehand. It is, therefore, a two-layer system, whose base module is rhomboidal at the top and is completed with a scissor at the bottom. Scissors are also used to attach a module to

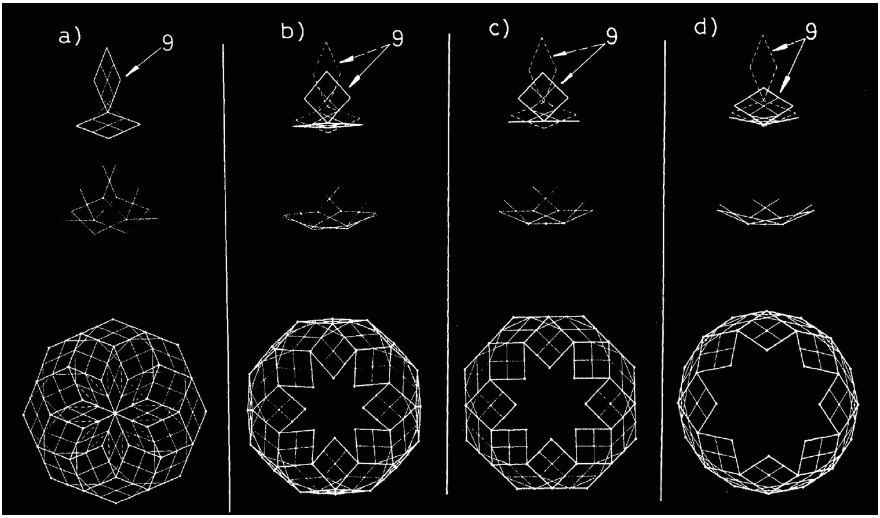


Fig. 3: Gómez de Cózar, J.C.: Sistema para la construcción de estructuras estéreas de dos capas desplegables, formadas por mallas de rombos y aspas, multianguladas. Oficina Española de Patentes y Marcas. Patente 2152787. Spain, 2001, p.12

its adjacent ones, as we will see below. In fact, in general terms we can say that these modules have as their starting point the geometry of the rhombus. A rod is placed on each side of the rhombus. These rods are joined together by their ends, two by two, by means of joints, which allow the rotation of the rods in the plane of the rhombus. Besides, each of these rods is actually the base of a triangle that extends in a plane perpendicular to the one containing the rhombus, thus generating the aforementioned triangulations. In each triangle, the vertex opposite the bar that forms the rhombus is connected to the rest by means of the aforementioned scissors, with a hinge at each end. Each of the rods of these scissors has the same length as the sides of the rhombus, in the case described.

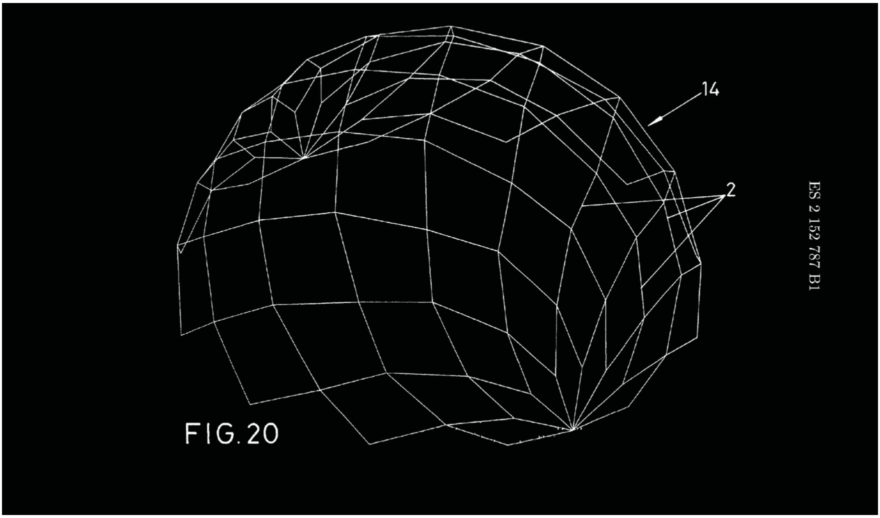


Fig. 4: Gómez de Cózar, J.C.: Sistema para la construcción de estructuras estéreas de dos capas desplegables, formadas por mallas de rombos y aspas, multianguladas. Oficina Española de Patentes y Marcas. Patente 2152787. Spain, 2001, p. 20.

The whole structure is obtained by putting several of these modules together. With the premises described so far, the result is a flat structure of constant height. In fact, if the length of the rods that form the scissors of each module is the same as the length of the rods located on the sides of the rhombus, a straight module is obtained and consequently a flat structure as described above. But if the rods that make up the scissors are shorter than those located on the perimeter of the rhombus, the triangulated elements cease to be in planes perpendicular to the one contained in the rhombus. In this case, pyramid modules are generated. These modules give rise to structures that make up a vaulted surface, and even a hemispherical dome as Gómez de Cózar himself shows in

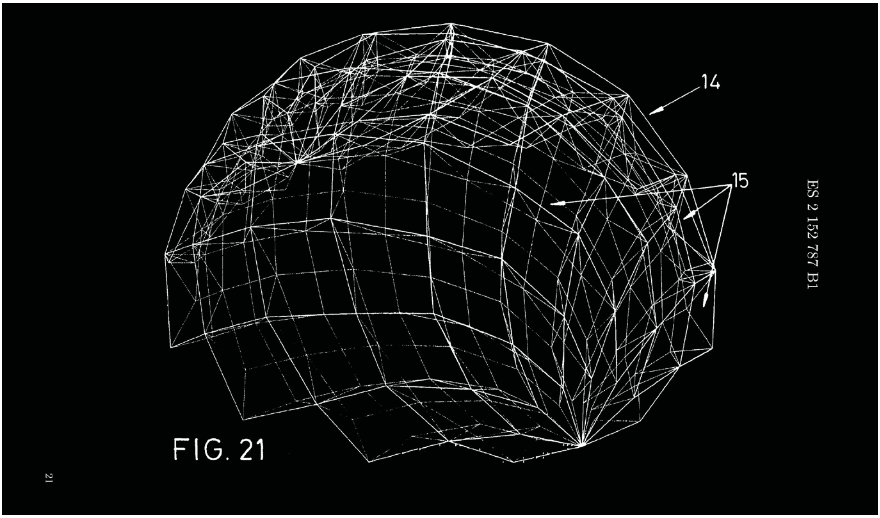


Fig. 5: Gómez de Cózar, J.C.: Sistema para la construcción de estructuras estéreas de dos capas desplegables, formadas por mallas de rombos y aspas, multianguladas. Oficina Española de Patentes y Marcas. Patente 2152787. Spain, 2001, p. 21.

his drawings. For all this, and in any case, when working with this type of structures, it is necessary to take into account that as it contains a rigid part, and given the configuration of the rhombus module, the relationship between folded volume and unfolded volume is greater than what occurs in those of Piñero and Escrig. Gómez de Cózar's structures fold in one of its two main directions, increasing, on the contrary, the length in the other direction. On the other hand, the knots of these structures are simple when the shape taken by the set is flat. However, when such a structure is designed to adapt to curved surfaces, the knots must vary their geometry. Consequently, the nodes cease to be flat and their geometry has to be modified to accept bars contained in two or more

different planes. In the case of Piñero and Escrig's structures, when they were arranged to adapt to curved geometries, the knot was not altered, it was still composed of simple joints that could be manufactured previously, repetitively. The position of the knots along the rods was the variable that allowed the whole structure to adopt a curved or domed shape. In this case, the same does not happen and the knots must be manufactured specifically for it.
Despite this, there are interesting questions in the invention of Cózar that is important to highlight. In the first place, it must be taken into account, as has already been said, that assemblies endowed with greater rigidity can be achieved by having fixed triangulations oriented according to the structure's edge. At the same time, the fact of being able to modify the length of the rods that constitute the scissors independently gives these structures the possibility of adopting various geometric shapes when they are deployed. In addition, it should be borne in mind that it is possible to modify not only the length of the rods that constitute the blades that join the vertices of the same module, but also those that connect a module with its adjacent. This new variable allows to display an interesting range of possibilities that broadens the range of geometries that can be modeled with these structures and, consequently, the panoply of their applications. Cózar is aware of this and in his patent records it. It includes a series of illustrations that reflect various positions of a structure used to form a roof that performs as a diaphragm, in its folding process.
In his drawings, Gómez de Cózar already hints at the possibility of attaching textile elements to his structures applied to the construction of roofs. At the same time as in his texts he specifies that, since his invention relates a two-layer structure. One of these layers, the outermost, allows incorporating elements that act as a roof, while the one located inside can support elements that act as a ceiling. All this provides with a more efficient thermal behavior.

In any case, and given the recent character of the invention of Cózar, it is possible to observe that this solution is likely to explore configurations with various geometries. As well as the incorporation of different forms and materials to the elements that stand at the height of the structure to multiply its possible applications.

Bibliography

Escrig Pallarés, F.: *Sistema modular para la construcción de estructuras espaciales desplegables de barras. Ministerio de Industria y Energía*. Registro de la Propiedad Intelectual. Spain, 1984.

García Martínez, P.: „Lessons from a future past: Hoberman and new parameters for deployable structures". In: :*Fold. >Refold. Deployable Narratives and Digital Fabrication*. Berlin: CoLabCollaborative Design Laboratory (2019), p. 14–22.

Gómez de Cózar, J. C.: *Sistema para la construcción de estructuras estéreas de dos capas desplegables, formadas por mallas de rombos y aspas, multianguladas*. Oficina Española de Patentes y Marcas. Patente 2152787. Spain, 2001.

Hoberman C.: *Reversibly Expandable Doubly-curved Truss Structure*. United States Patent Ofice. Patent n.: 4943700, U.S., 1990.

Pérez-Piñero, E.: *Estructura Reticular Estérea Plegable*. Ministerio de Industria y Energía. Registro de la Propiedad Intelectual. Spain, 1961.

Pérez-Piñero, E.: *Three Dimensional Reticular Structure.* United States Patent Ofice. U.S., 1965.

Sánchez Sánchez, J. Escrig Pallarés, F. Ponce Ortiz de Insagurbe, M.: *Poliedros desplegables de estructura tubular y cerramiento textil.* Oficina Española de Patentes y Marcas. Spain, 2015.

Quantic Urbanism

Prof. Carlos Chacón Pérez

Feng Chia University

It´s been already 15 years since Rem Koolhaas predicted the failure of urbanism in his text "what ever happened to urbanism?".[1] Still today, most of our cities have been planned through a procedure that has proved to be outdated and unable to respond to the citizen´s needs.
If we agree with Thomas Kuhn´s idea that science evolves specially through small fast revolutionary discoveries, called changes of paradigm, often related to technological developments, and therefore, those are able to provide, through the appearance of new tools, small revolutions.[2] These new approaches create a leap forward on their scientific field. If we believed that the theory and practice of architecture and urbanism, evolved with the welcoming of binary computers, we can speculate that the urbanism of the 21st century is going to be quantic.
The end of the 20th century, since the arrival of personal computers to architecture offices during the 80´s, progressed leaning on a binary determinism growth. The system of ceros and ones, bits of information, transistors and logic gates, composed since then arrangements through its combinations, turning into more and more complexities based always on multiple certainties. These certainties have become nowadays, intensive operations processed in parallel to computing power, allowing us currently to explore through parametric design instant live consequences to requested operations.
However, although this faster computing enables multiple linked decision making, even rizomatic procedures[3], there is not a physical consequence on the city urban space, as built architecture is not able to respond to flexible programmatic instructions dragged by its constructive rigidness. As a result, the complex reasoning backing up parametric design procedures stays frozen and unable to react to any external contextual factor in real urban experiments. What we are facing here is a deep dichotomy between the theoretical process of design and it physical application, that is blocking the development of a real time adaptive urban design.
With a complete loss of faith in our ability as architects and urbanist to provide new concepts, the 21st century citizenship has turned their gaze into the world

---

[1] Koolhaas, Rem. What ever happened to urbanism? From S,M,L,XL, OMA, (with Bruce Mau), The Monicelli Press, New York, 1995. p. 959–971.

[2] Kuhn, Thomas. The Structure of Scientific Revolutions. University of Chicago Press. Chicago, 1996.

[3] Deleuze Gilles. Rizoma. Editorial Pre-Textos. Madrid, 1977.

of computer engineering searching for new answers. Our society and politicians believe now that the apparently never-ending development of hardware and software, might result into tools and strategies based on the concept of smart cities, able to open new gateways to react to urban problems. However, in fact, we believe that leaving behind the 20th century rationalism approach to plunge into a hyper-rationalism based on computing sensors and devices might not be enough to propose an alternative to current planning, and may only become a disguise made of atractive gadgets unable to provide real time changes. Deceived by the market and pushed by capital and cosumism oriented premises, we are led to believe smart cities will modify our concept about collective living. Nevertheless we believe soon, we will realize we just dived into a new dead end, as behind a fancy technological curtain, the background is still the same reactionary rationalism run during the 20th century, and cities, composed by increasing millions of individual circumstances, are actually a collective unforeseeable chaos that requires a more agile and open reaction system.

Andrea Branzi in "Ten Humble recommendations for a New Athens Charter" in 2014, was already mentioning how "weak models" of urbanization and architecture, should substitute the "Machine for living" models, what he calls with the catchy formula of "high Tech Favelas".[4]

Under this premises, boundaries and perimeters, labeled as functions and programs, should be substituted by categories and conditions. Its content shall be able to fit multiple reversible events, which are in fact the background of a society where we consider individual situations as able to conform a compound of unstable facts and ready to react to its own mutation, more than as a perfect set of articulated pieces waiting for an input. This brand new strategy is what we will call here "Quantic urbanism".

Quantum mechanics have set into motion from the theoretical field into the pragmatic one through the upcoming release of quantum computers.[5] They are a breakthrough that is addressed to deeply change soon some of the things we assume as usual, a new "scientific revolution" and a alternative understanding

---

[4] Branzi Andrea. diez modestas sugerencias para una nueva Carta de Atenas. Providencia, Santiago, Chile. ARQ ediciones, 2015.

[5] Bernhardt, Chris. Quantum Computing for Everyone. Chicago, MIT Press, 2019.

of how information can be processed. Qubits are the base of quantum computing, we discovered two of their main properties have the potential to change the way we design.
The first property that caught our attention is SUPERPOSITION. Superposition is the property of QUBITS to stay on hold, not polarized into ceros and ones, but being both and none of them until requested. It becomes a new understanding about how to identify a particle into a system considered as open to request. The QUBIT is then a superposition of probabilities still to be defined according to the spinning of their magnetic field, which only collapses into an answer, a stable state, when it is requested to do it. It remains un-programmed, uncategorized, until it needs to reply to an input. The fact that they are not qualified allows them to store more possibilities than our regular computers.
The second property we consider a game changer is ENTAGLEMENT. Through entanglement, QBITS create a close connection that makes each other react to a change according to the other particles behavior instantaneously. No matter how far they are from each other, they become interdependent. This means that the measurement of one particle gives you automatically the measurement of the whole set of QUBITS, accelerating the process of reaction that they are able to provide to a request.
We consider SUPERPOSITION (unprogrammed architecture) and ENTAGLEMENT (interdependent systems), gateway concepts to a new urban design understanding, and we believe its physical translation from theory to action, can rely on the capacity to transform themselves that deployable and inflatable architecture can perform as active assets for the future city.
Deployable and inflatable architectures are not new, they have been researched and developed during the 60´s and 70´s trying to discover its possibilities and strengths, but something has made them unsuccessful, they didn´t adjust to a perfect machinery concept of a city, not even to the diagrammatic theories developed at the end of the 20th century.

If we believe the city needs to be resilient, and its multiplicity, resistance to disaster and adaptability encouraged, Quantic Urbanism can be applied through the development of this interdependent objects, with high capacity for transformation. These architecture devices will be based on weak footprints in case to be underused or unwanted and a blurry identity able to cope with a hybrid society.
Their capability of SUPERPOSITION relies on its lack of clear definition, or in its potential to change, precisely the opposite of the complex labelling that characterized diagrammatic planning. Our strategical application of these objects as a system, will grant their capacity for ENTAGLEMENT, as only on coordinated inter-related functioning can urbanism respond to a society that has proven to be too complex to be predicted. Only through a change of paradigm will urbanism be able to be useful to society again, and only through instability management, will architecture be able to cope with th hybrid multiplicity that is contained within megalopolis.

Flying Structures

Benjamin Albrecht

Architekturdarstellung und Gestaltung

Technische Universität Berlin

On a sunny autumn day, I rush westward across a large empty field. The sun is still low and the wind is blowing in my face heavily. In my right hand I hold a cup of coffee, the hot liquid spilling out onto my hand; wedged under my left arm is a stack of papers I try to keep from flying away; around my shoulders hangs a camera, and in my left hand I clutch the handle of a large unwieldy bag. I walk briskly and despite the cold wind I get uncomfortably hot. The field seems to be never-ending.

On the horizon to my right I see a small figure approaching in the distance, carrying something large. Between us are wide strips of concrete and completely flat grasslands. The view is much broader than what I'm used to in the city. It's a completely different landscape and understanding distances is next to impossible. The other person appears to be still in the same spot, however it seems that we have the same destination, somewhere on the other side of the field. I am trying to identify the object the person is holding. It appears to be very difficult to keep it from flying away... I see more and more people approaching, all with their own large awkwardly shaped objects.

Finally after a good twenty-minute hike we all arrive at the same point, a small concrete block on the side of a wide runway. We are at Tempelhof airfield in Berlin, a large former airport that shut down in the early 2000s and is now used as a sort of public park, although not much conversion has taken place. It is still just an airfield, but one occasionally full of people using it for whatever they cannot do between the perimeter blocks of their city. We are here to use it for its original purpose: flying. In the late 19th century this was a site for early attempts by a few reckless inventors who wanted to get as much air as possible between their feet and the ground.

Our mission is similarly adventurous, but not quite as dangerous. We have all gathered here for the kick-off to our Flying Structures workshop with the architecture students of the *Technische Universität Berlin* (TU Berlin). Many have come in order to participate in the class. Each one had spent the mornings navigating their bulky and wind sensitive flying objects, first through the rush-hour of the city (some on public transport, others on bike, or by foot etc.), and then across the airfield to this meeting point. They would get more and more familiar with this process as the season got colder, the semester continued and objects developed. They grew in size and became increasingly intricate and sophisticated in their designs. We had many sessions going back and forth between developing, testing, redesigning and testing again. The goal of the class was to create the biggest object possible that would maximize being airborne – and all of that using no fossil fuels, only pure wind energy and our design skills. We used digital fabrication, tested all sorts of fabrics, and explored different construction processes and materials. The students came up with unconventional methods, misusing the machines and inventing new manufacturing techniques such as laser-cutting sails from mylar and ripstop fabrics and bending wood and aluminum into tensegrity structures. We visited other pilots such as the group Aerocene at the studio of Thomas Sarraceno, who creates black balloons that inflate with sunlight and stay afloat for a very long time – an impressive technique but not quite the result we were looking for on our mission. So we dedicated our workshop to the investigation of architecturally constructed flying machines, using our skills as spatial practitioners, engineers and artists to imagine alternative modes of flying. Gliding between its leisurely vocation and its scientific relevance, we immersed ourselves into this legacy designing the world's oldest form of aircraft: the kite.

Ranging from abstract sculptures to flying photographic devices, the design, construction and flying techniques of our machines were at the core of our studies and our explorations into the unique environment of the Tempelhof Airfield in Berlin. As a starting point to the class we investigated the manifold history of kite through design, fabrication, geometry and utility. From its earliest use as a measurement tool for the city, the two-thousand-year history of the kite is deeply rooted in architectural and urban investigations. In addition to the flying machine, the term "kite" also refers to the geometric condition of a quadrilateral. The symmetry produced by the equal lengths of the adjacent sides is a primary trait of the topological kite and is what allows the surface, in its most simple form, to fly. Today the design of the kite is as much a spatial exercise as a planar one, with most kites designed for utility or exploration being comprised of a collection of repetitive geometries organized in balance with one another. Partially to accommodate structure (strength/weight) and partially to increase lift, the modern derivation of the kite remains remarkably similar, in purpose and possibility, to the first kites built over 2,000 years ago.

Essential for its operation, the anchoring of a kite provides a firm, uniquely tangible connection between the site, the operator and the designer. Stemming from the kite's significant urban past and often overlooked modern scientific relevance, this seminar explored the architectural possibilities and future of what is the world's oldest form of aircraft. Design, construction and flying techniques were the basis for this design seminar. During and after the construction, ancient surveying techniques as well as contemporary digital tools were used to explore the unique site of Tempelhof Airfield, engaging in the history of aviation at the location of the former “Luftbrücke” to Berlin.

Together with the talented students of the class we gained new analog and digital fabrication skills tied to structures subject to real world forces, that function and operate (as opposed to model building and structural/operational speculation). Parametric design tools were taught and utilized in the development of the kite systems and geometries. Thanks to the curiosity of the students, their savviness in adopting new digital fabrication, digital design, site observations and exploration skills we were able to develop impressive structures – some of which really took off. One group was able to create a series of tensegrity structures, in which none of the beams touched one another and were only held together under high tension. The biggest challenge here was the actual assembly strategy, for which the students had developed an intricate scaffolding structure that would hold all the pieces in place while they were brought under tension in a surgical operation. In the end the students had a set of modular components they could combine into a gigantic bird-like flying structure.

Another group set the challenge for themselves to use the geometry with the worst surface-to-volume-ratio for flying: a perfect sphere. Their idea was to create a fantastic flying sculpture that would surprise all viewers with its light behavior when flying despite its seemingly heavy morphology. Many studies had been done on how to divide the sphere into a set of tetrahedral-shaped wings while still maintaining a solid appearance. Thanks to continuously optimizing the design and weight of all the 3D-printed connection elements, tensions rods and ropes, the end result was an impressive flying sphere. Other groups created a large color wheel that also followed the tensegrity strategy and invented sophisticated cutting patterns for the fabrics by hacking digital manufacturing techniques of the laser-cutter. While others learned from the tedious trips from the workshop to the testing grounds at the airfield and focused on the portability of their flying structure. They developed a foldable prototype made of delicate 3D-printed x-wings with thin components and membranes. Throughout the process, we gained new knowledge with each prototype, and in the end the results were adventurous, refreshing, often surprising, sometimes frustrating, beautiful, and most importantly, inspirational.

Thank you very much to all the participating students, the teaching assistants, the whole Co-Lab team and Prof. Dr. Ignacio Borrego for trusting me and giving me the opportunity to run this experiment with such talented people.

From Graham Bell´s Kite to the Foldable Flying Artefact

Dr. Martino Peña Fernández

Escuela Técnica Superior de Arquitectura y Edificación

Universidad Politécnica de Cartagena

“The structural grid as a concept could be found in the first models made by Graham Bell in 1907: a prefabricated net of bars organized in pyramidal or tetrahedral prisms is stable due to its geometry , [. . .] and any load systems is able to be balance when there are no bending moments and the loads are applied on the knots”.[1]
Lawrence Hargrave designed the well-known cellular Box-kite. Around the last years of the XIX century he was working with cellular kites with different geometries, most of them rectangular ones. Usually the Hargrave kite consists of two rectangular cells separated from each other and connected together by a light framework. The lifting power of the kite was given by rectangular planes which were in the cell and they were made of light fabrics as silk. As we know the weight increases as the cube of the dimensions, while the surfaces increase only as the square of the dimensions. In this way, when the lifting surface is added, at the same time much more ballast has the kite, shrinking its ability to fly. In the other hand “the rectangular cells are structurally and easily collapsed or distorted, giving rise to the necessity for internal bracing. This bracing adds to the dead loads and (owing to the shape of the cell) is necessarily so disposed as to increase the resistance of the wind”.[2]
In his patent from 1904, known as “Aerial Vehicle”, Graham Bell developed a kite system improving the above mentioned from Hargrave. Instead of using rectangular cells, Bell had introduced a triangular one. This fact has several advantages. Foremost among them, the triangular shape is stable and needs no bracing, which do not increase the weight of the artifact. In his own words: “I have found, however, that advantageous results may be obtained by utilizing the triangular cell as a unit or element and building up structures of large size by combining a number of this units or elements. Triangular cells are specially adapted for combinations into a compound structure in which the aeroplane-surfaces do not interfere with each other. Where the edges of two or three of the elements coincide, a single bar or stick will suffice, thus dispensing with the weight of one or two bars or sticks”.[3] In Fig 1 a sketch of this first patent is shown, where

[1] Ramón Araujo: “Construir en acero: forma y estructura en el espacio continuo”: Tectónica 9 acero, p. 12. Madrid: ATC Ediciones, 1995.

[2] Graham Bell: Aerial Vehicle. United States Patent n.: 757.012, April 12, 1904. p. 1.

[3] Ídem

two hexagonal cells are bounding together with metal rods. The cells are divided into triangular units at the same time, some of them are covered with fabrics in order to gain wind resistance and lifting capacity. Although his work with the name “Tetrahedral Principle in kite structure” was first published as a paper in 1903, it is in 1907 when appeared his patent “Connection device for the frames

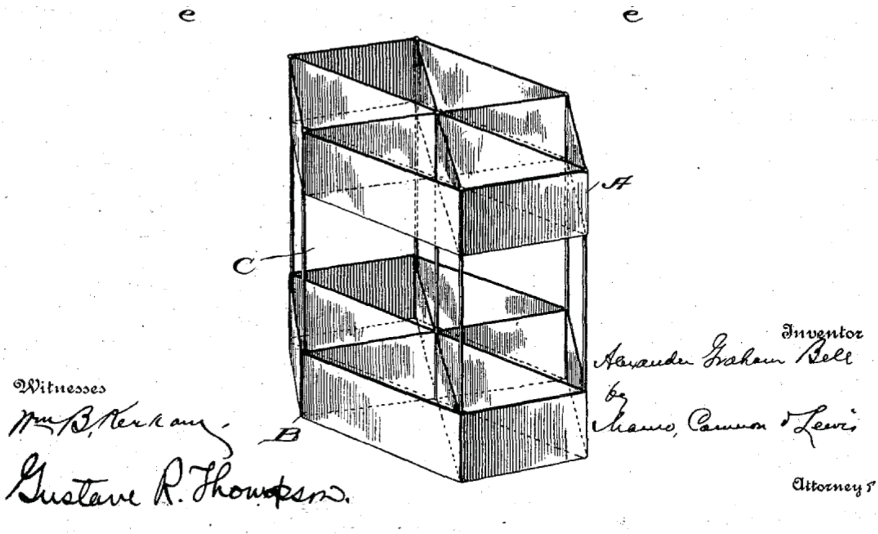


Fig. 1: Hexagonal cells in Aerial vehicle. Graham Bell. Patent USA 757.012. 1904.

of aerial vehicles and other structures” where the tetrahedral kite was defined. Gram Bell was aware of the importance of the tetrahedron and its properties. Having four triangular faces, it was stable and not only in surface but in volume too. As he said; “the adoption of triangular construction in every direction (longitudinally as well as transversally) and the clear realization of the fundamental importance of the skeleton of the tetrahedron, specially the regular tetrahedron, as an element of the structure or framework of a kite or flying-machine”.[4] The tetrahedron has four triangular faces and only six edges. It is showing more lifting surface within an optimal framework formed by six rods and “it is not simply braced in two directions in space like triangle, but in three directions like

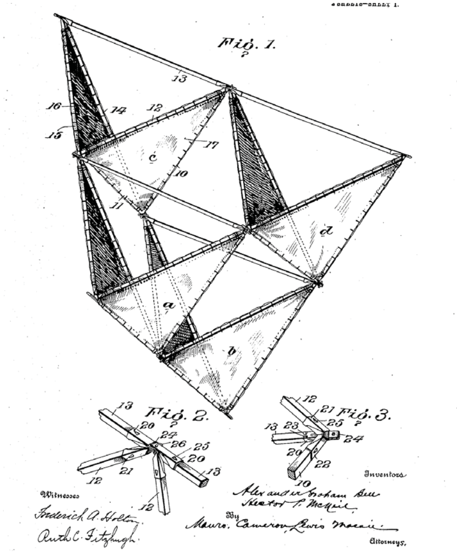


Fig. 2: Tetrahedral Kite. Graham Bell. Patent USA 856.838. 1907.

a solid. If I may coin a word, it possesses `three dimensional´ strength; not `two dimensional´ strength like a triangle, or `one dimensional´ strength like a rod. It is the skeleton of a solid, not of a surface or a line”[5] and increasing in this way the number of faces or triangles which were able to cover with fabric to gain resistance to the wind.

[4] Graham Bell: “The tetrahedral Principle in Kite Structure”. National Geographic Magazine. Washington D.C., 1903.

[5] Ídem

Graham Bell had in mind the aim of developing a kite large enough to carry a man. That why he developed structures of increasing size but having always an optimal density, knowing the problem of the weight mentioned above. The tetrahedral units were manufactured in his workshop and carry on to the site where they were assembled together, and the triangles were covered with canvas.

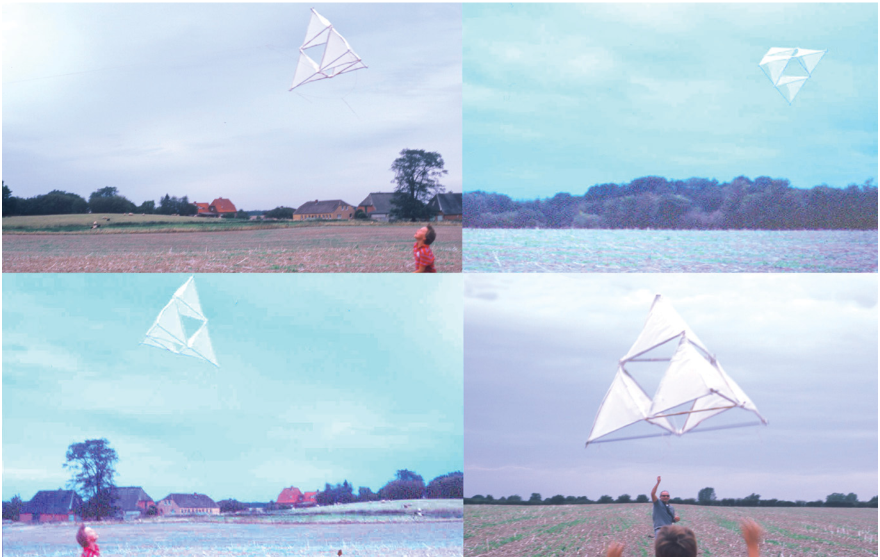


Fig. 3: Tetrahedral Kite. Scale Model. Martino Peña.

"This system was used to provide a temporary shelter wherever needed on Bell´s state-sometimes housing his sheep during the heavy winter".[6]
In the patent from 1907 with the title "Connection device for the frames of aerial vehicles and other structures" Graham Bell introduce the tetrahedral kite, but the joints were the issue which was actually protected. In the drawings bello-

[6] Bill Busfield. "Alexander Graham Bell". Architectural Design 8, p. 377. London, 1970.

wing to the specification of the patent a Tetrahedral kite can be seen. It is made up of four tetrahedral units which conform, at the same time, a bigger tetrahedron. In this way adding more units the kite could grow as the cube of the dimensions, but increasing less ballast, because the cells are sharing the edges when increasing the units. Furthermore, the planes covered with fabric increases at the time not only in two dimensions but in three. The four similar winged tetrahedral cells have the same two faces covered in order to gain resistance to

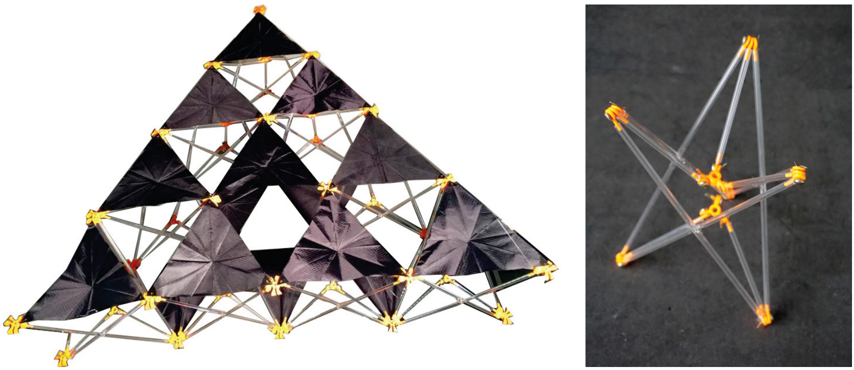


Fig. 4: Deployable Kite. Fold/Fly/Inflate. TU Berlin. 2019

the wing. As shown in the drawing mentioned above two of the triangles formed by bars are covered with a suitable material and constitute what is known as a “winged element”, or “winged tetrahedral cell”.
But as said before the aim of the patent was to protect the connection between bars, that is to say, the joints. It is very common that patents protect this part of the artifact. In this case, it makes more sense due to the lightness that the kite should have. The connection device is made from a blank of suitable sheet metal. The three arms of the blank are bent to attach the three bars needed to achieve the shape of a tetrahedron and having always 60 degrees between

them. For a better understanding, in the claims of the patent it can be read; “The combination with the meeting ends of a plurality of bars and strips at one corner of a polyhedral frame or element, of a connection device made of a single piece of sheet metal and having a plurality of arms or branches one for securing the end of each bar, and a lug adapted to be juxtaposed to a similar lug at a corner of another frame to join said frames corner to corner”.[7]

Graham Bell was aware of the importance of the improvement made by the invention. The frame could be used for kites or other structures as he said. It has the advantages to grow adding its tetrahedral units but not increasing the weight as Bell has shown. The 4-cell kite weight four times more as the cell and has four times as much wing surface. Furthermore the 64 cells kite has sixty-four times as much weight, but the same proportion for the wing surface. The ratio of weight to surface is the same for the larger kites as for the smaller. In big structures the weight could be such a problem too, lightness has to be sought. The research from Bell became a structural one, which was with the time recognized. Some of the realization in the xx Century known as Megastructures has an original beginning in the cellular system developed from Gram Bell:

“Bell continued to develop his structural idea and in 1907 built a tower, 80 feet high from ordinary 1/2” iron pipe with iron connectors, to demonstrate its application to a familiar engineering problem. It was in fact the final workout on this aspect of Bell´s work, pointing a direction for others to follow”[8] In the workshop Fold/Fly /Inflate the Students, who have taken part of, had to develop an artifact having two of the above-mentioned actions or properties. A group have decided to enhance the Bell´s kite by introducing the foldability. They have achieved this feature improving the connections, as Bell did in the second patent from 1907. In this case the joints were designed with CAD software and manufactured with the 3D printer during the workshop and have allowed the kite to fold and unfold. Due to the lightness of the material used (polymers), the weight added to the system was not very important according to the theories made by Bell: “This form seemed to give maximum strength with the minimum of material”.[9]

---

[7] Graham Bell: Connection device for the frames of aerial vehicles and other structures. United States Patent n.: 856.838, June 11, 1907. p. 2.

[8] Bill Busfield. “Alexander Graham Bell”. Architectural Design 8, p. 377. London, 1970.

[9] Ídem

Rapid Prototyping Tools as a Means to Transfer the Creative By-Product[1] of Educational Environments to Society

Gaizka Altuna Charterina

Architekturdarstellung und Gestaltung

Technische Universität Berlin

[1] "A by-product or byproduct is a secondary product derived from a production process, manufacturing process or chemical reaction; it is not the primary product or service being produced." By-product. (n.d.). In Wikipedia. Retrieved January 5, 2020, from https://en.wikipedia.org/wiki/By-product

1. Rapid prototyping as a link between classrooms and society

The main objective of an educational environment (regardless of the level of their teaching) should be to train students. However, during the learning process of disciplines such as architecture, there is a wide creative production. Although this is a byproduct of a learning process, it can be of great value. Sometimes, such creative production transcends society through different formulas such as exhibitions, cooperation agreements, publications ... etc. But normally it does not leave the classrooms and when it does the communication channel is unidirectional.

This fact is aggravated because architecture is normally studied through representations of reality (plans, drawings and models), which, although they have a great intellectual interest, usually are not directly useful to ordinary citizens. However, this relationship with society could change by working through prototypes. A prototype is, according to the UXL Encyclopedia of Science "an initial model of an object built to test a design". That is, a prototype can be tested and used. However, the prototype, traditionally, requires for its construction a greater amount of resources, time, tools and expertise, both to be manufactured by students and to be reproduced by citizens. The representation using plans and drawings instead is cheap and easily reproducible for dissemination.

However, the democratization of rapid prototyping tools has opened up new possibilities. The fact that any citizen has access to digital manufacturing machines, not only enables students to work more easily and at a lower cost through prototypes, but also allows any citizen to reproduce these prototypes, test them and modify them.

This text defends the use of rapid prototyping as a link that can bring to society the creative byproduct of learning processes that occur in educational environments. But first it is necessary to know some facts from the contemporary context to understand why this is defended.

2. Current context

2.1. Democratization of digital manufacturing tools

The technology on which contemporary digital manufacturing tools are based is not new. Already in the 40s and 50s of the last century the first CNC[2] tools appeared. Until the beginning of the 21st century, only large companies and laboratories had access to this type of technology. However, from the first decade of this century, due to various phenomena such as the appearance of the Fab Labs (Gershenfeld, 2012) and the expiration of the patent of 3D FDM[3] printers, digital manufacturing tools for rapid prototyping are increasingly accessible.
Nowadays, any university has rapid prototyping tools and they are becoming more frequent in training centers of other lower levels. In the same way, any citizen can have access to this kind of tools on Fab Labs, Makerspaces or manufacturing services on demand. It is a technology accessible practically for everybody.
Rapid prototyping machines allow objects to be manufactured without the expertise and know-how that manual manufacturing requires. On the other hand, as the instructions and files necessary for the machine to manufacture the objects are digital, it is possible to receive and send them through the Internet. This allows for the easy reproducibility and modifiability of designs anywhere in the world.

2.2. An increasingly participant and dilettante society

We live in an increasingly dilettante and participant society. From the 40s of the last century, university studies were gradually becoming more accessible. As a consequence, the current middle class is over-formed and the boundaries between consumers and producers or professionals and amateurs are increasingly blurred (Howe, 2008). Already at the beginning of the 80s of the last century

[2] CNC Computer Numerical Control

[3] Fused Deposition Modeling

Alvin Toffler coined the word Prosumer to define the user who participates in the production of the products he/she consumes (Toffler, 1980). In 2004, in a study entitled “The Pro-Am Revolution: How enthusiasts are changing our economy and society” (Leadbeater & Miller, 2004) Leadbeater and Miller coined the term Pro-Am or amateur professional. Pro-Am is an individual who performs an activity with professional standards in his spare time. In this text Leadbeater and Miller present a demographic study conducted through surveys in which they conclude that 58% of the population of the United Kingdom performs some leisure activity that can be framed within the definition of Pro-Am. That means that there is a great mass of trained, active people, willing to use their skills and with the ambition to participate in the productive processes.

2.3. The democratization of the media and the connection of niches of interest

Chris Anderson wrote for the first time about “The Long Tail” in an article published in Wired magazine on October 10, 2004[4] (Anderson, 2004, 2007). The long tail is explained through a hyperbolic graph.
The horizontal axis of the graph shows the products ordered by popularity. On the vertical axis, however, the popularity of the products is expressed. The result is a hyperbolic curve. In this hyperbolic curve Anderson differentiates two parts which he calls “head” and “the long tail”.
The long tail chart tells us that there are a few products that are highly demanded while the vast majority are niche products that do not have much demand. However, “the long tail” can also be applied to ideas and knowledge.
According to Anderson, thanks to the democratization of the internet, “the long tail” has become thicker since it has connected the niches with all those who were interested in them.

[4] Nowadays the original article can be consulted in the following link: https://www.wired.com/2004/10/tail/

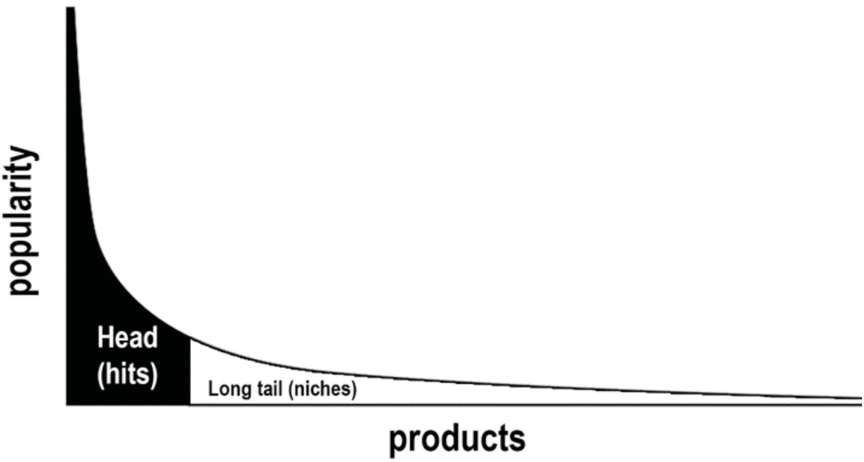


Fig. 1: Illustration of Chris Anderson's "Long Tail" theory

3. The open repository. A format for the transfer of knowledge through digital prototypes

As shown, the current context has the necessary ingredients to transfer knowledge from classrooms to society. There are manufacturing technologies that allow real and functional objects to be reproduced without the need of practically no expert knowledge, both in classrooms and at the disposal of citizens. There is a sector of society increasingly dilettante and participatory, wanting to be part of the production processes. And finally, we have some means of communication that allow us to share, send and access information of all kinds, and that connect small and isolated niches of knowledge with those who may be interested in them. However, it is necessary to specify the format and means through which said transfer actually takes place. Open repositories have been widely popularized in the last decade as a means of sharing creative developments of all kinds, such as GitHub, possibly the most popular repository dedicated to programming. There are also repositories dedicated to prototypes aimed at amateur users. Possibly the most relevant of its kind are Thingiverse[5] and Instructables[6].

In these repositories is possible to share the necessary instructions and files so that any other user can replicate them. In addition to replicating, another user can make use of a shared prototype to modify it and develop a new creation, which can be shared again. Meanwhile, any user can comment and evaluate the prototypes. This way, iteration after iteration, interaction after interaction, a collective knowledge is built. The production of this open collective knowledge obviously favors citizens. But what is the benefit that students acquire in these processes?

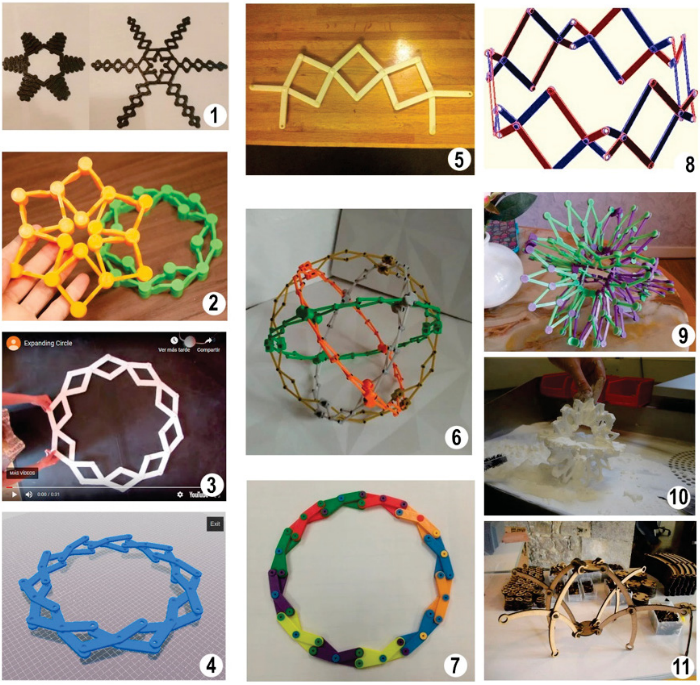
4. Teaching advantages of an open learning process

Sharing through open and public repositories the prototypes derivate from the creative production as a result of learning processes can bring numerous benefits not only to society. Massive collaboration generates a series of unconventional situations in the traditional teaching models from which students and their learning processes can benefit.

Face the reality outside the classroom. The world outside the classroom is a much more complex and demanding reality. In the classroom, students face reviews from teachers and in some cases from their classmates. The eyes that review their work in the classroom are few, however, in a repository they are exposed to the eyes of hundreds of users of which dozens can replicate their prototypes. As Linus Torvalds said “Given enough eyeballs, all bugs are shallow.” This implies a greater demand of rigor in the student‘s work. However, this is a great source of feedback, which gives the student a large number of inputs from different points of view.

[5] https://www.thingiverse.com/

[6] https://www.instructables.com/



Variations of Hoberman Sphere shared on Thingivers. In this selection it is possible to appreciate how the rapid prototyping machines are allowing citizens propose and build variations of the same idea participating in a not regulated open innovation processes. The byproduct of the teaching processes in which the rapid prototyping tools had been used could highly contribute to those forums.
1. Hobermann snowflake (from 15 cm to 25 cm) by Donotseemyself[I]. 2. Print in Place Expanding Circular Linkage by plusalphaDesigns[II]. 3. Hoberman Sphere - „Expanding Circle“ by Matt[III]. 4. Hoberman Circle Segments by NateTG[IV]. 5. Hoberman 1/4 circle by WoodmanXI[V]. 6. Hoberman sphere (Cuboctahedron) by SiberK[VI]. 7. Make Sense of the Hoberman Sphere / Circle, Linkage by lgbu.[VII]. 8. Hoberman Sphere by videan42[VIII]. 9. Hoberman Sphere by adibadro[IX]. 10. Hoberman Sphere by GavinMayDesign[X]. 11. Hoberman Sphere by FablabGrenoble[XI] (Sources P.55)

Learn to discern the relevant reviews. The massive internet can provide the student with a large number of opinions, which is positive. However, not all the opinions have the same relevance and many of them can even be counterproductive. Learning to discern in the massive feedback the relevant opinions and irrelevant ones is a basic skill in contemporary reality. The classroom, thanks to the teacher's support, is a great environment to start building that critical skill.
The relevance of the instructions. In the most widespread model of architecture teaching, the final document of the creative production is a representation of a design. However, if we intend to share a prototype it is necessary to focus attention on the production of instructions, on how to manufacture. It is more important to know how it is built than to know what it will look like.
Communication at different levels of expertise. The crowd is diverse, so it is often necessary to transmit the information by communicating it at different levels. For this reason, it is important to be conscious of the different levels of complexity in the design that you want to share and know how to identify and transmit them.

5. Conclusions

Today there are perfect ingredients so that the creative byproduct resulting from learning processes in the educative environments can transcend society by working through rapid prototyping tools. There is a common technology accessible to all (students and citizens), an active and trained global population and the media to connect stakeholders with niches of interest.
However, it is necessary to work on certain aspects, such as, for example, specific licenses for content produced in an educational environment, to protect both the intellectual property of students and students themselves. Licenses such as Creative Commons[7], Free Art License[8] or WTFPL[9] are used by the authors to regulate the use of content they have published. Although there are generic licenses that could be used in educational settings, there are relevant agents in

[7] https://creativecommons.org/

[8] https://artlibre.org/licence/lal/en/

[9] http://www.wtfpl.net/

those processes (such as teachers or the educational center appear) that the standard licenses do not include.
In any case, although there is still a lot of work to be done for its normalization, there is no doubt that rapid prototyping techniques have the potential to establish new links between the educational environments and society.

Bibliography

Anderson, C. The long tail. WIRED Magazine, 2004.

Anderson, C. The long tail: How endless choice is creating unlimited demand. Random House, 2007.

Gershenfeld, N. How to make almost anything: The digital fabrication revolution. Foreign Aff., 91, 43. 2012.

Howe, J. Crowdsourcing: How the power of the crowd is driving the future of business. Random House, 2008.

Leadbeater, C., & Miller, P. The Pro-Am revolution: How enthusiasts are changing our society and economy. Demos, 2004.

Raymond, E. The cathedral and the bazaar. Knowledge, Technology & Policy, 12(3), 23–49. 1999.

Toffler, A. The third wave (Vol. 484). Bantam books New York, 1980.

[I] https://www.thingiverse.com/thing:2763237. Licensed as Creative Commons Attribution 4.0 International (CC BY 4.0), https://creativecommons.org/licenses/by/4.0/

[II] https://www.thingiverse.com/thing:4112141. Licensed as Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) , https://creativecommons.org/licenses/by-nc-sa/4.0/

[III] https://www.thingiverse.com/thing:19739. Licensed as Creative Commons Attribution 4.0 International (CC BY 4.0), https://creativecommons.org/licenses/by/4.0/

[IV] https://www.thingiverse.com/thing:19773. Licensed as Creative Commons Attribution 4.0 International (CC BY 4.0), https://creativecommons.org/licenses/by/4.0/

[V] https://www.thingiverse.com/thing:278261. Licensed as Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0), https://creativecommons.org/licenses/by-nc/4.0/

[VI] https://www.thingiverse.com/thing:2456551. Licensed as Creative Commons Attribution 4.0 International (CC BY 4.0), https://creativecommons.org/licenses/by/4.0/

[VII] https://www.thingiverse.com/thing:3364912. Licensed as Creative Commons Attribution 4.0 International (CC BY 4.0), https://creativecommons.org/licenses/by/4.0/

[VIII] https://www.thingiverse.com/thing:11146. Licensed as Creative Commons Attribution 4.0 International (CC BY 4.0), https://creativecommons.org/licenses/by/4.0/

[IX] https://www.thingiverse.com/thing:408688. Licensed as Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0), https://creativecommons.org/licenses/by-nc/4.0/

[X] https://www.thingiverse.com/thing:79493. Licensed as Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0), https://creativecommons.org/licenses/by-nc-nd/4.0/

[XI] https://www.thingiverse.com/thing:64379. Licensed as Creative Commons Attribution-ShareAlike 3.0 Unported (CC BY-SA 3.0), https://creativecommons.org/licenses/by-sa/3.0/

A Stroll through the Sky - Flying Architecture

Antonio Cerezuela Motos

Escuela Técnica Superior de Arquitectura y Edificación

Universidad Politécnica de Cartagena

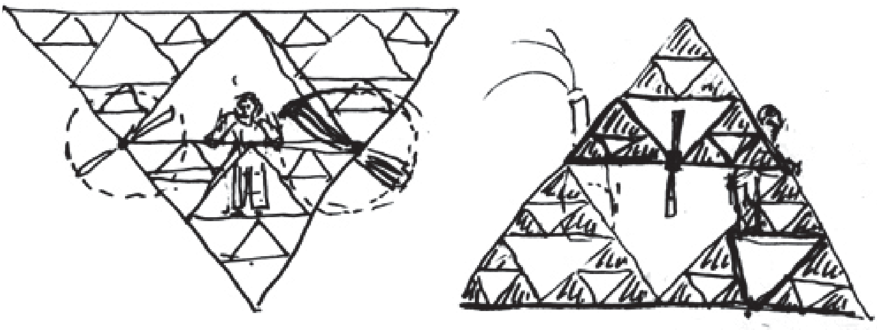


Fig. 1: Graham Bell´s Drawings

A dream at aerial locomotion age

The end of the 19th century is the period in which, thanks to technical advances, man set out to fly. At that time, mechanical science turned the 19th century into the age of locomotion, as shown their most important inventions like locomotives, bicycles, airships, automobiles or planes. At such times, another way in the aerial locomotion arise from this generation of inventors obsessed with locomotion, such as Graham Bell and Lawrence Hargrave and their flying machines. These inventors were reaching the goal that a man might cross along to the sky with a mobile machine. Similarly, as man cross the landscape on a bicycle or a steamship cross a river. It was time of dreaming of a man might cross slow relaxed the sky, as if were a stroll through the sky.
Harvage was the precursor, but Bell was the most experimental and creative. At such time, the point of view moved near to architecture approaches. Bell reminds us of utopian who imagine new possibilities behind the limits. It realized

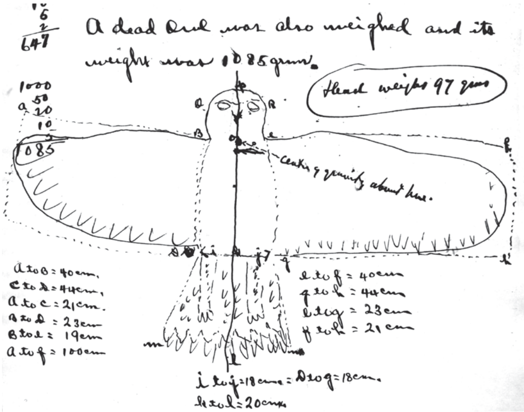


Fig. 2: Graham Bell´s Drawings

prototypes of geometrical beauty, with structural principles and a capacity for abstraction. It supposed other was that Leonardo da Vinci and his Uomo volante. In 1906 Augustus Goss (4) wrote an article about Bell “It is now about seven years since Professor Bell became so thoroughly a believer in the possibility of making a successful flying machine that he abandoned all other enterprises and devoted himself exclusively to efforts in that direction”. As long as the belief in the utopia and in the technology exist, Bell‘s scientific explorations and architecture were sharing a common view. On the one hand, Bell lives in the age of the mechanical paradigm, which founded Newton´s science and Decartes´s Enlightenment two hundred year before, and the nineteenth century it probably reached the highest significant, so that the world was filled with mechanisms and artefacts by inventors. Moreover, it seemed that the engineering dominates the culture of this time, which included the overflowing idealism of the mathematics and mechanics. Thus Bell´s flying machines represented in a sense this faith in science for flying.

On the other hand, from our time, we appreciate nearly and present validity this technological dream, as if it had contemporaries features. Thereby the recorded images of the several attempts of Bell and Hargrave‘s flying machines show the excitement of the possibility to live something extraordinary. It reminds us the experiences related to installations and happenings of the seventies, while collectives and artist (Archigram, Haus Rucker Co, Joseph Beuys, ...) are creating a large number of activities regarding technological dreams. In this way nowadays artists, such as Tomás Saraceno, have been exploring their curiosity for the sky with the Solar Bell, based on Graham Bell´s kites.
The belief in science is something that have continued in architecture at the beginnings of the modern movement. Rayner Bahnam, in the book´s introduction of the book Theory and Design of the First Machine Age (1983) said: „We may be older and wiser today, but we are still children of that turbulent generation“, referring to the generation in the early 20th century.

Flying machine

Graham Bell aims to use the principles of kites to build a flying-machine. He was fascinated by the lightness with which heavier bodies than air could be held stably in the air while maintaining balance with the wind pressures. But an important aspect was the Bell´s admiration of the Hargraver´s work, particularly about the well kwon Hargraver Box Kite. In opinion of Bell “This represents, in my opinion, the high-water mark of progress in the nineteenth century“, and it involved the starting point for his own research.
Graham Bell was enthusiastic about the cellular construction of Hargave, the well-known Hargrave box kite, created with the principles of the thetahedron. The air suspension of the tetrahedron was based on the increase of surface area in contact with the wind with respect to the own weight. The bigger this ratio was, the easier it was to fly. In addition, Bell studied their strength, lightness and steady as the main parameters.

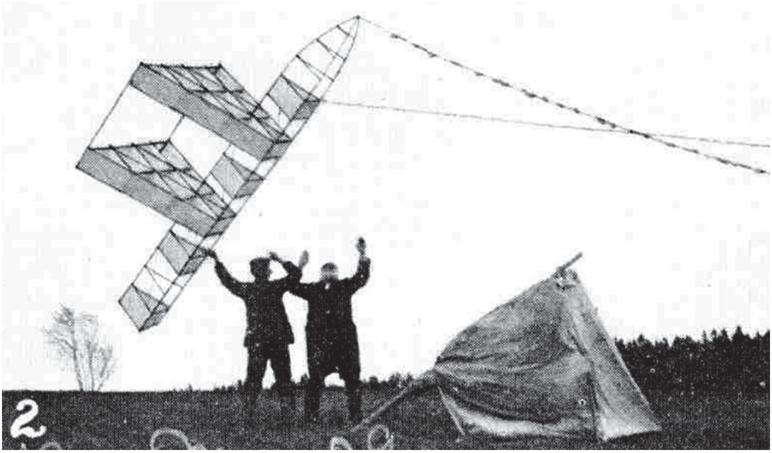


Fig. 3: Graham Bell´s Kites

In this way, a large number of prototypes emerged that were systematically analyzed by their reactions and aptitude for flying. Bell defined his objectives as follows: „First, by rendering the kite heavier, so that the ratio of weight to surface is increased; and, secondly, by increasing the head resistance of the kite" (3). As a result of his research, Bell replaced the Hargrave boxes with triangular cells that maintained the weight/surface area ratio, but with less weight by reducing bars in the cell.

Space architecture

For many years the possibilities of thetahedron to build frameworks for flying was researched by Bell. As result he obtained more than twenty prototypes in different shape and scale, which he pretended to sail on the sky. All of this work were published by Aerial Experiment bulletins. These Kites adopted geometrical forms from a triangular cell, thus they seemed like prism and pyramid, which were called Gygnet. Most of the kites were formed with a long element as basis boy, and others perpendicular elements as wings. This machines looked like a plane including a ship, because it seemed that he wanted to transform theses

Fig. 4: Graham Bell´s Kites

well known locomotion shape in cellular structures, so that they could fly only with pressure breeze. According to Bell´s drawings the goal behind the experiments with big kites were to introduce a human inside in order to can sail the

flying machine. The aim to increase the dimensions of the kites was to enable a possible inhabitant inside. Thus it would achieve with the increase of surface for staying in the air, but it ended up with an increase of weight at the same time, which it blocked the possibility to fly. In spite of that Bell always has been working under the same dream for many years. At the time August Goss (4) said: “It is his fondest wish that he may live long enough to solve for mankind the problem which he believes to be just within his grasp”, in other words, in a sense his own personal task was to unravel the secrets of nature.
However, few years ago Wright brothers had inverted the plane, but in spite of this Bell was reaching the way how to float a man in the air, but nevertheless he achieved a large number of floating architectural objects in the air like space aircraft. Today everybody has watched in many science fiction films a wide range of space aircraft which you can compare to Bell´s artefacts. All of them didn´t need to consider the breeze because of zero gravity.
There is one of Bell´s flying machine that best represents all of above mentioned aspects in Bell´s work, and it is the ring kite. The ring kite was the only one that was not designed to look like a plane. Indeed, in most of flying machine can distinguish a main long body and several wings, weather like a plane or like a bird, but not the ring kite. Why did Graham Bell a ring kite? Nobody knows a bird like a ring. That kite is the best example to appreciate the experimental and abstract work of Bell. It reminds the spaceship of the film 2001; A Space Odyssey (1968) of Stanley Kubrick.
According to the conclusion in Graham Bell´s report in 1908 (2), the ring kite “rose very steadily and gracefully into the air”, however these horizontal aeroplanes can “at unexpected moments to slide off to one side and come down edgeways to the ground”. It seems to be really an alternative to the form family based on the plane. Unlike others prototype this path were not working by Bell.

Conclusion

As has been shown, not only Graham Bell´s work represents a technical significant step forward in framework design, but it also set out an experimental and an empirical methodology relevant, especially for educational purposes today. Above all Graham Bell´s experiments fascinate as installation into the landscape in open air, with whose experience could happen something or not. It seems clearly its value such as references for architectonical structures or spaceship is still current. But, we ought not to forget that Alexander Graham Bell was a man of science and also he represented the thought of his age, the aerial locomotion, nevertheless his perspective was unlike any other, Bell spent a lot of year all efforts in these experiments because of his strong belief was that man could scientific fly similar to a bird, so it may male him really a pioneer.

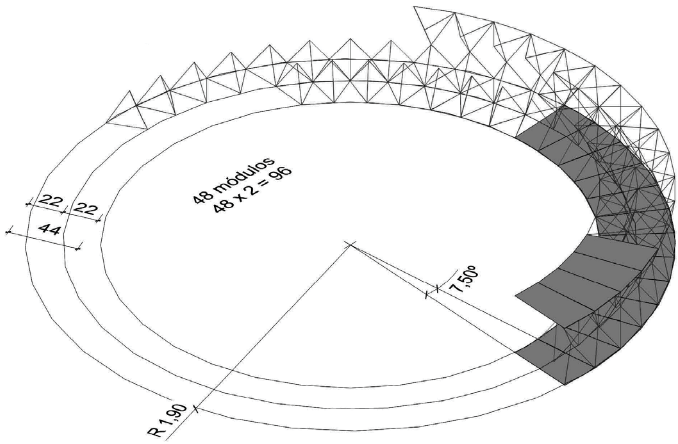


Fig. 5: Graham Bell´s Kites (Drawing by A. Cerezuela)

Bibliography

Fig. 1: BELL, Alexander Graham. Drawings by Alexander Graham Bell?, from September 1901 to. from September 1901 to, 1901. https://www.loc.gov/item/magbell.20500103/

Fig. 2: BELL, Alexander Graham, Aerial Experiment Bulletins. 1908. https://hdl.loc.gov/loc.mss/magbell.14100101

Fig. 3: BELL, Alexander Graham. The Tetrahedral Principle in Kite Structure. 1903. https://www.loc.gov/item/magbell.37700202/

Fig. 4: GOSS, Augustus. Alexander Graham Bell and His New Flying Machine. 1906. https://www.loc.gov/item/magbell.21700307/

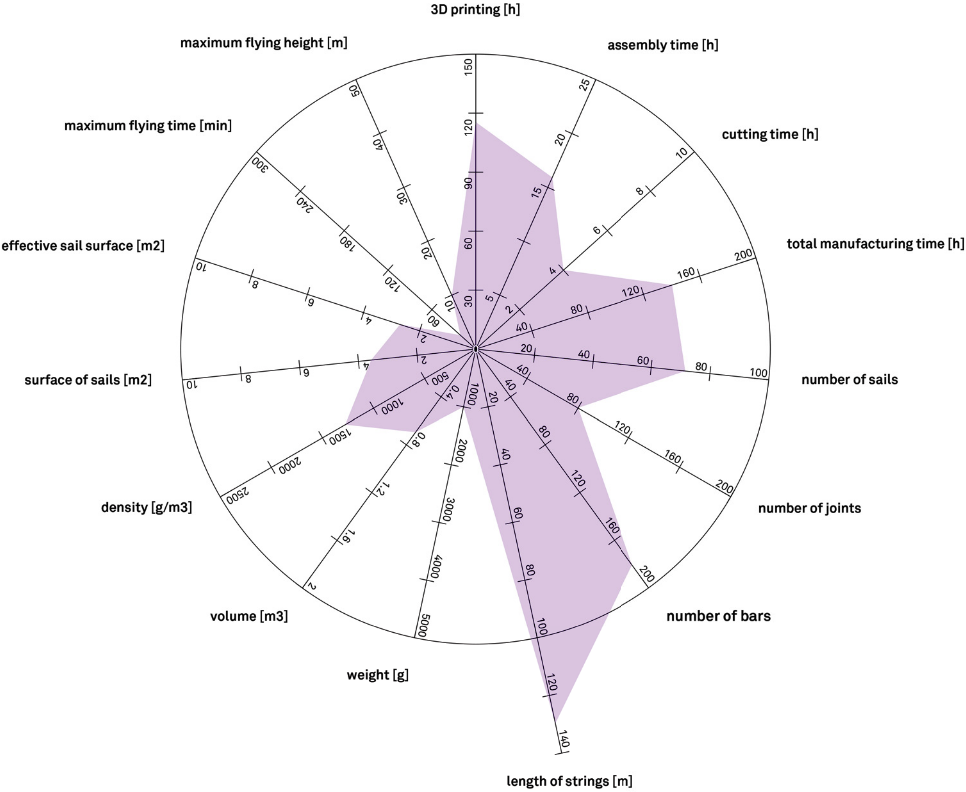
>> FLYING STRUCTURES

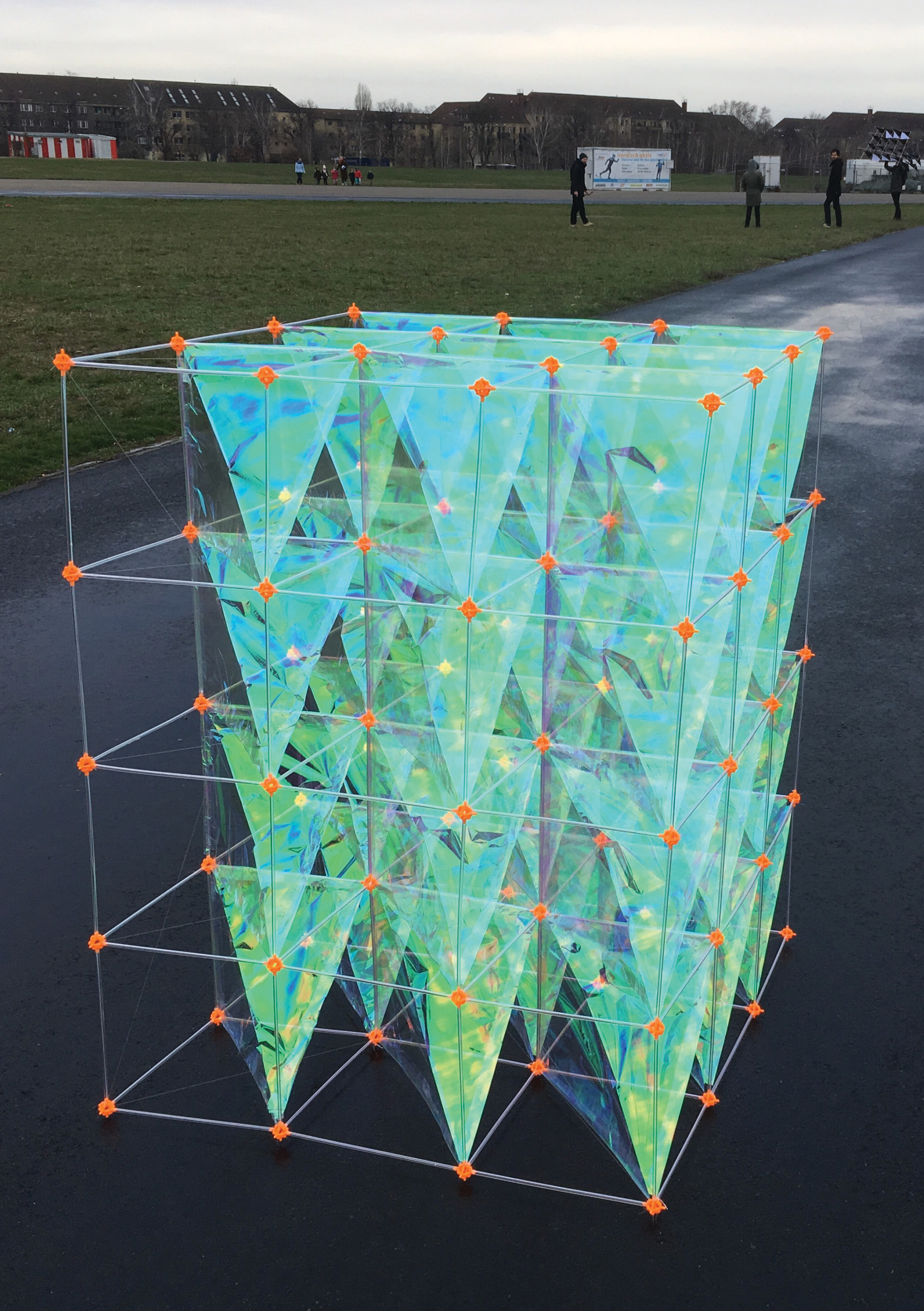
TU Berlin | FG CoLab

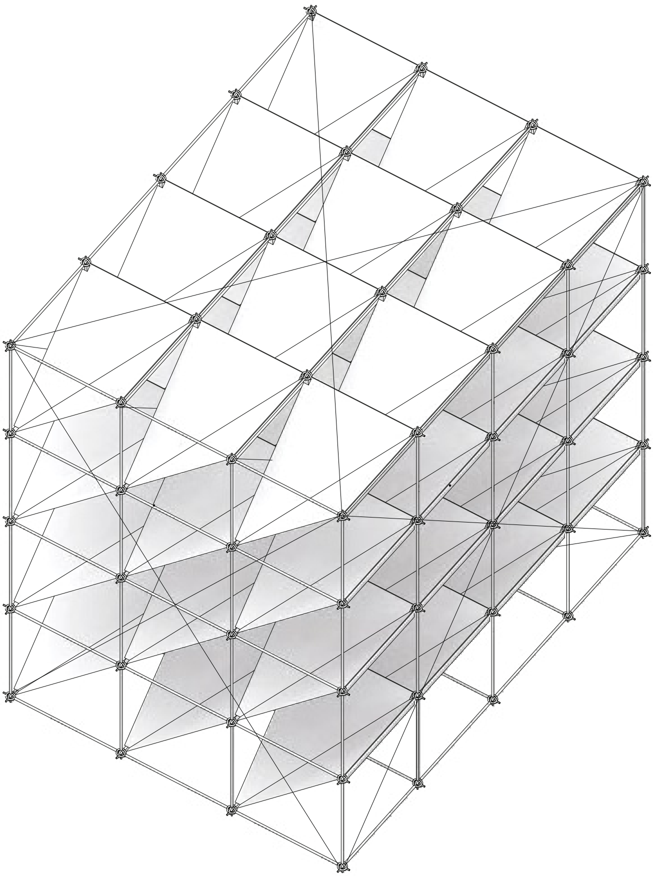
> BOX KITE

: Milyausha Garaeva
: Wasita Amatyakul
: James Heusser-Kowoll
: Masayoshi Waku

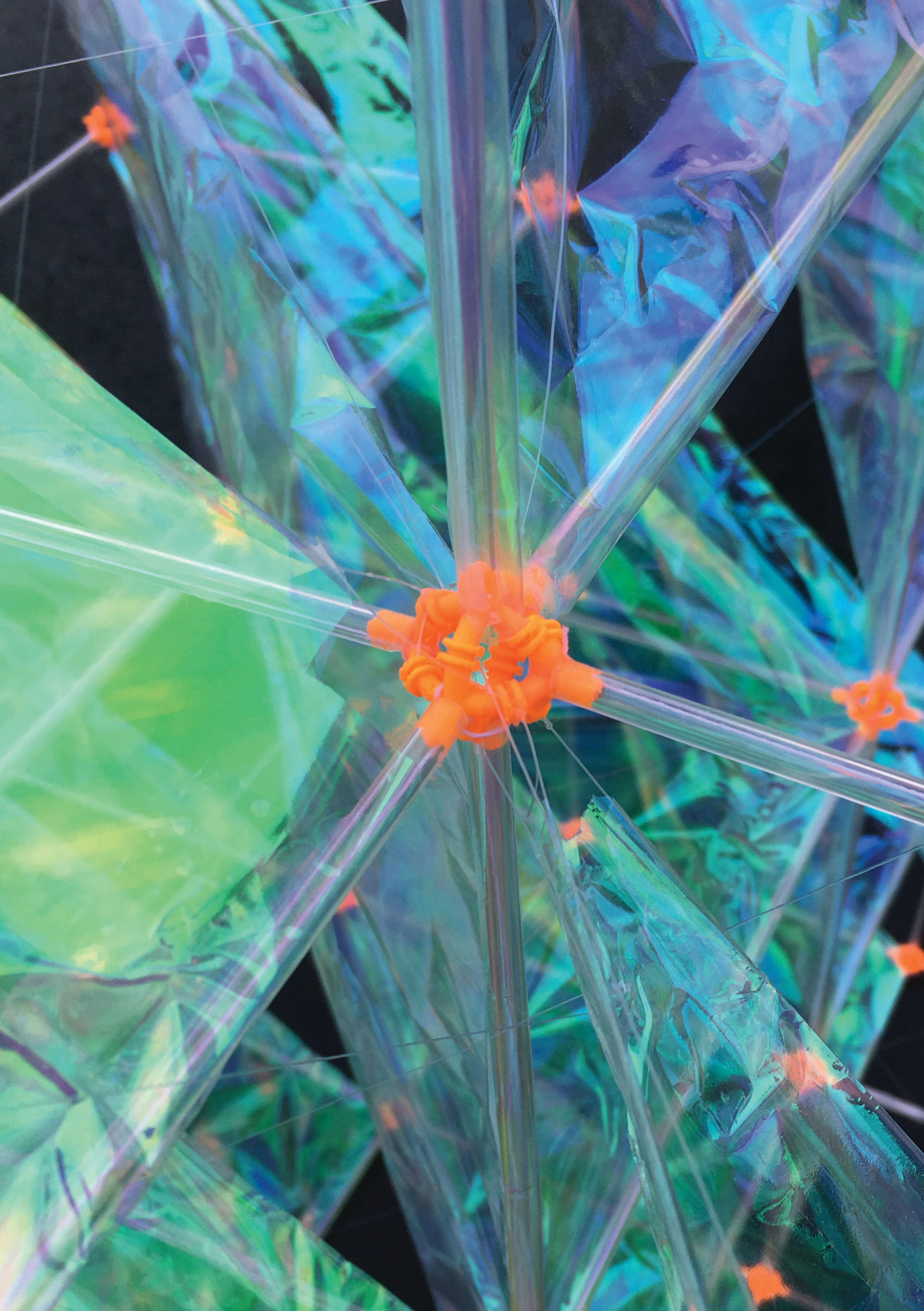
/ PROPERTY CHART

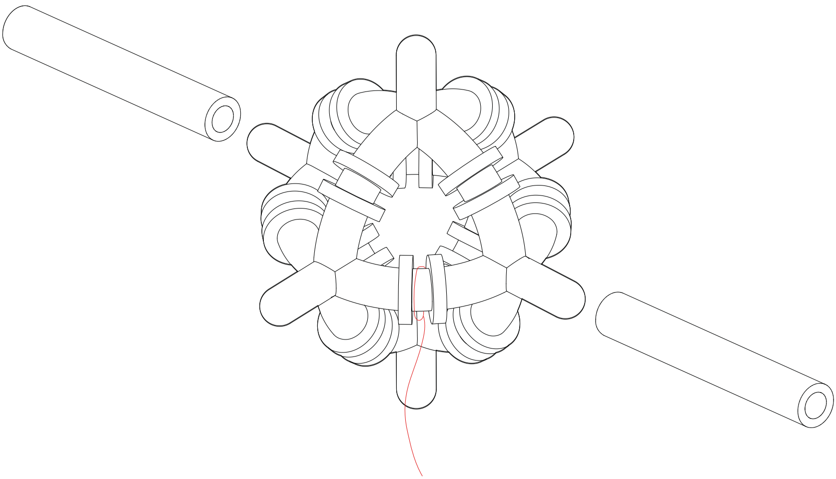


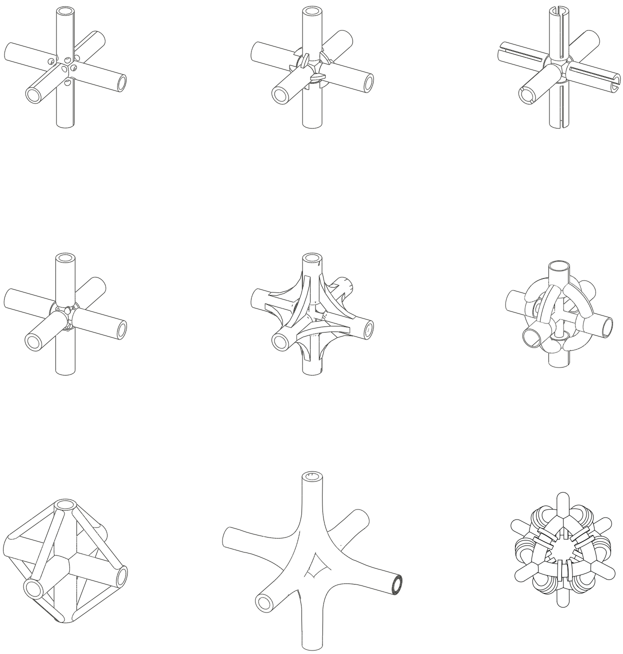

nordisch aktiv

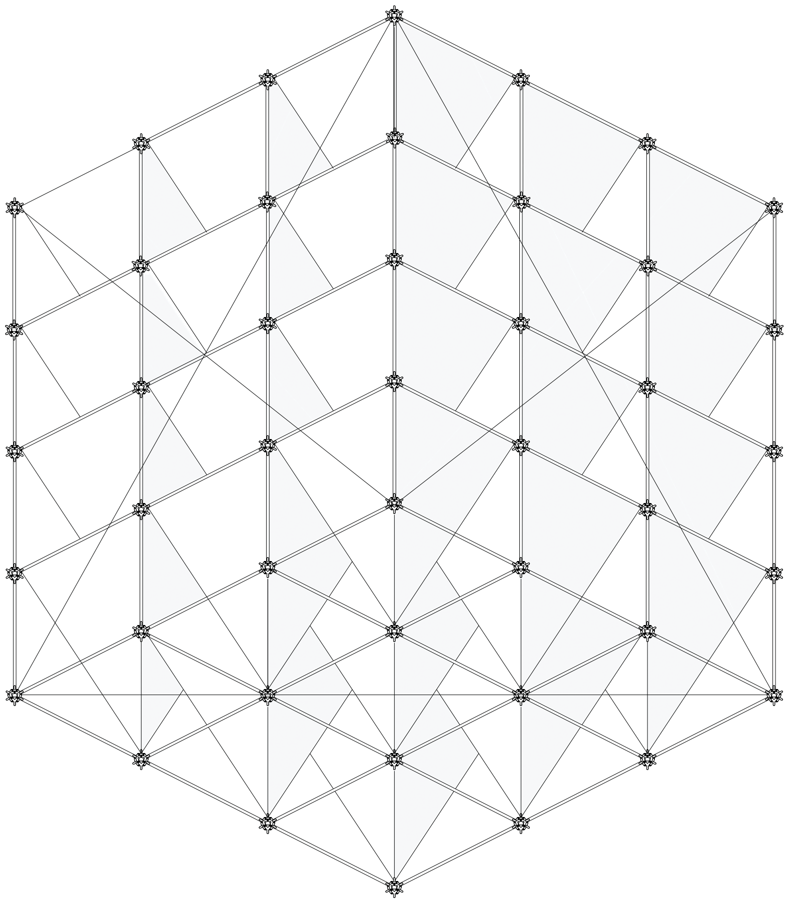


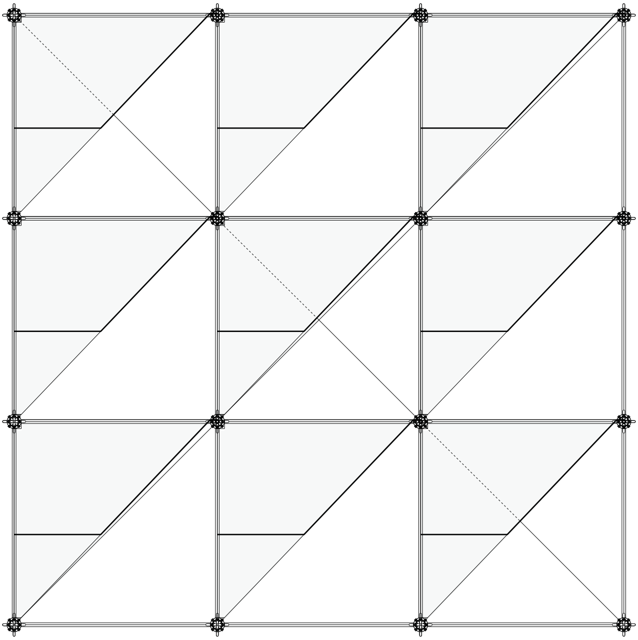
0
100
250
500 mm.

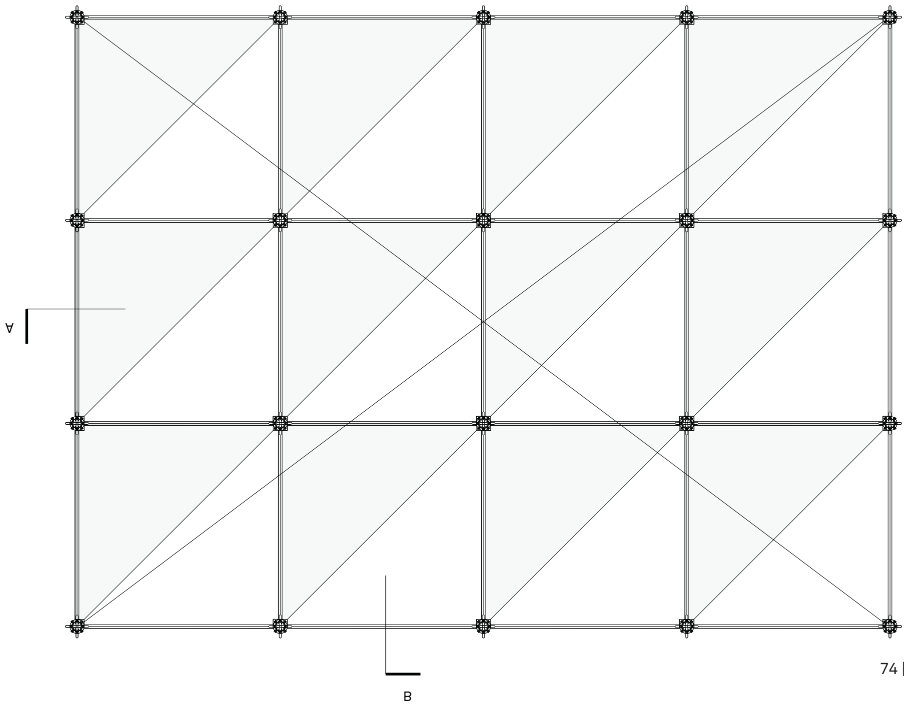


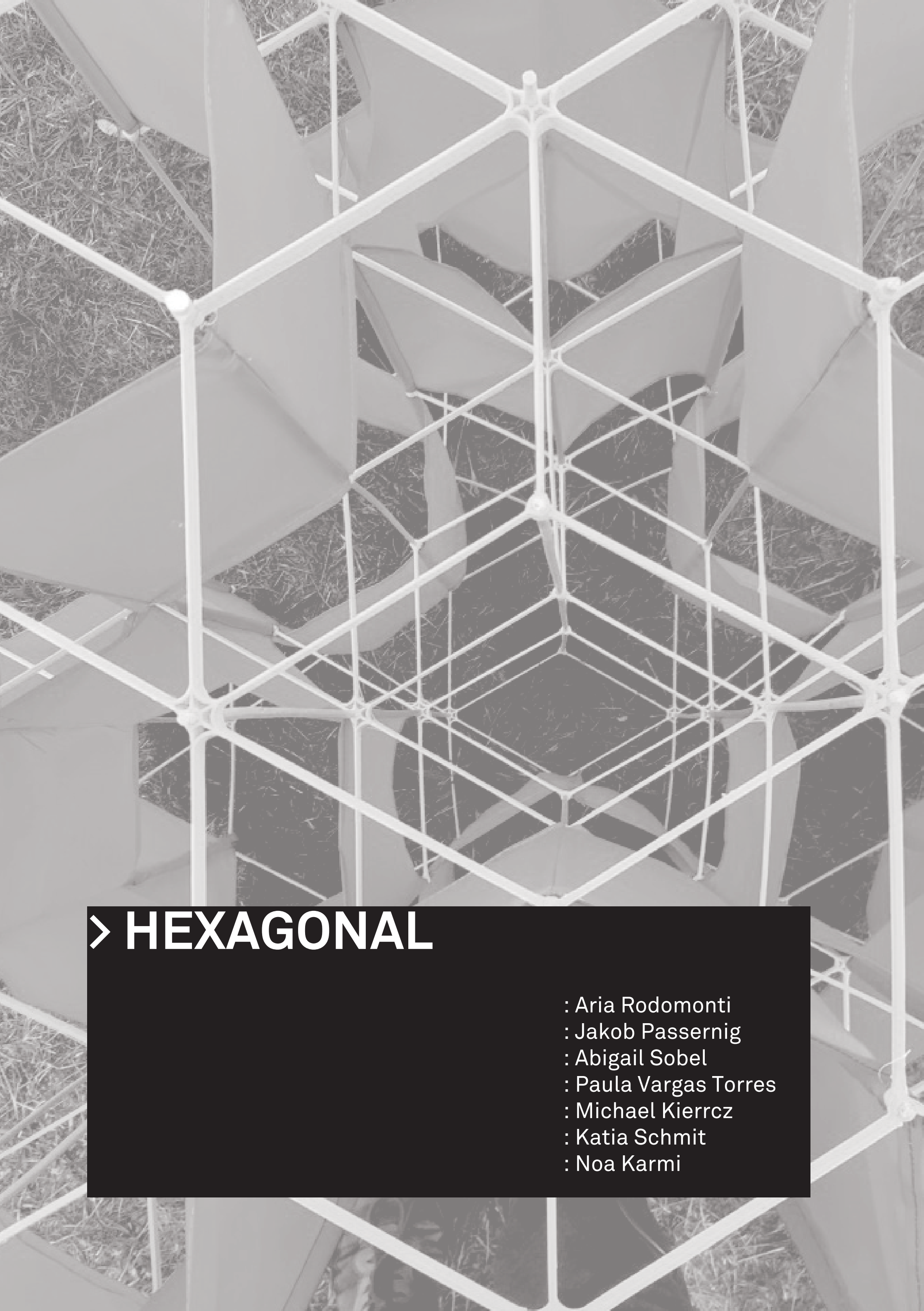








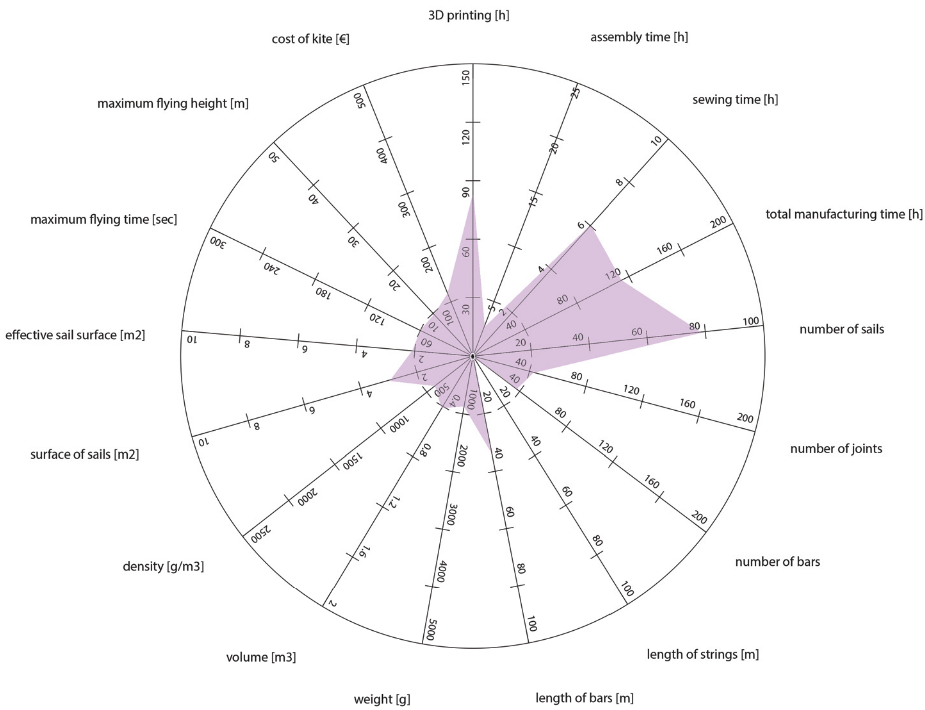

A
B



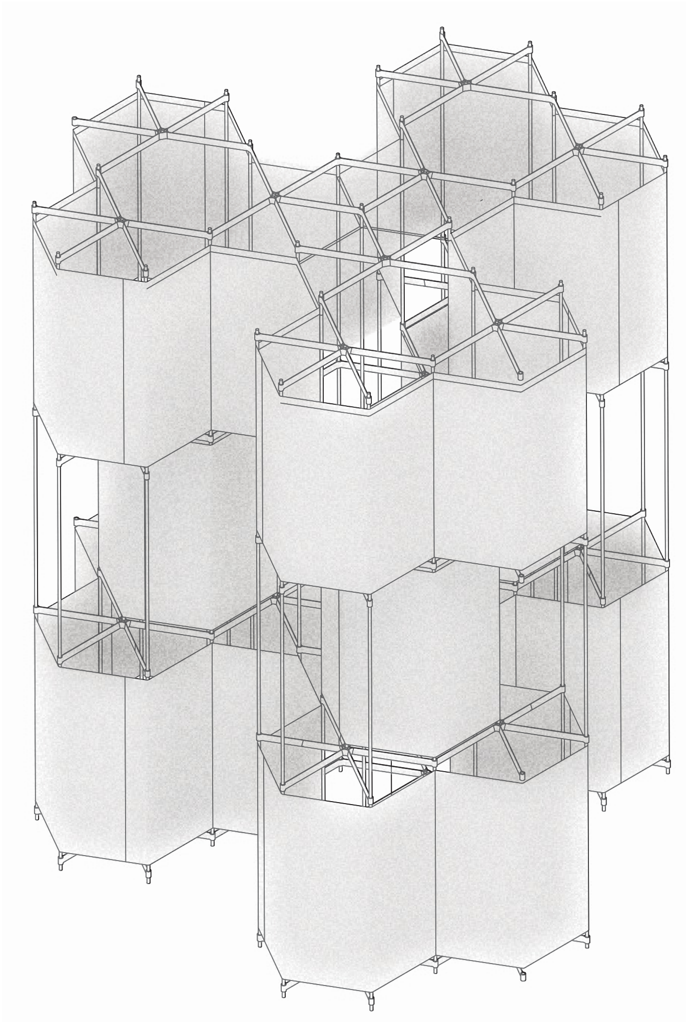
> HEXAGONAL

: Aria Rodomonti
: Jakob Passernig
: Abigail Sobel
: Paula Vargas Torres
: Michael Kierrcz
: Katia Schmit
: Noa Karmi

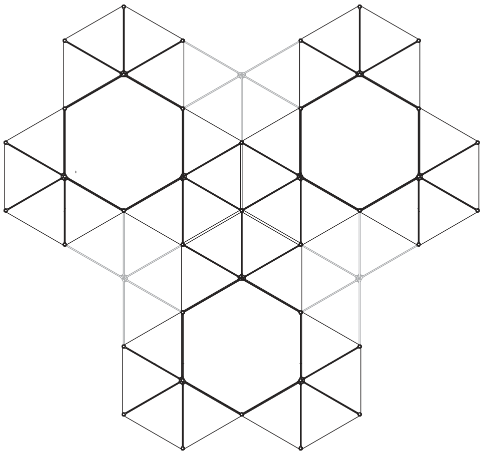
/ PROPERTY CHART

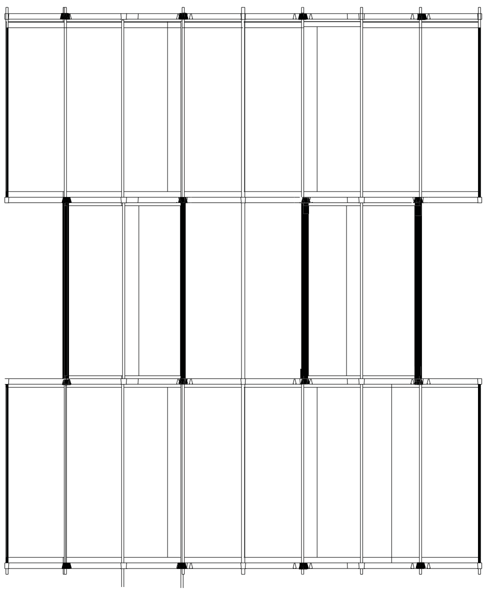


// AXONOMETRY



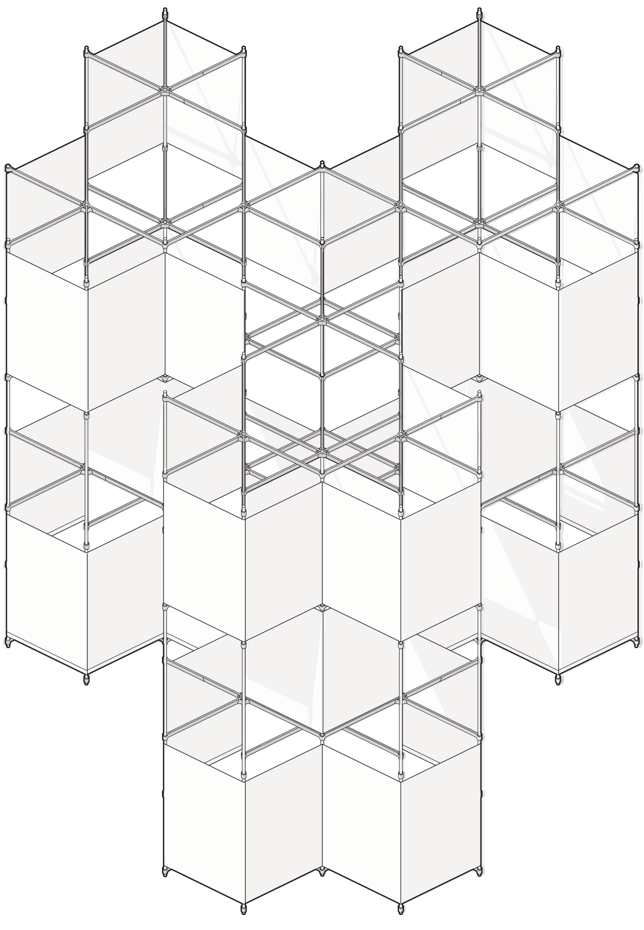
// PLAN | SECTION A

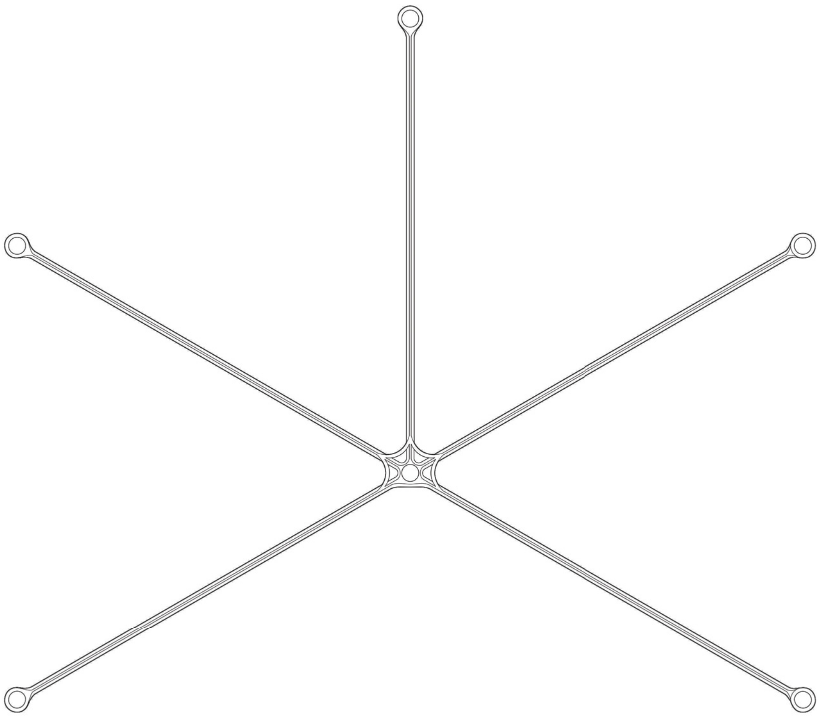


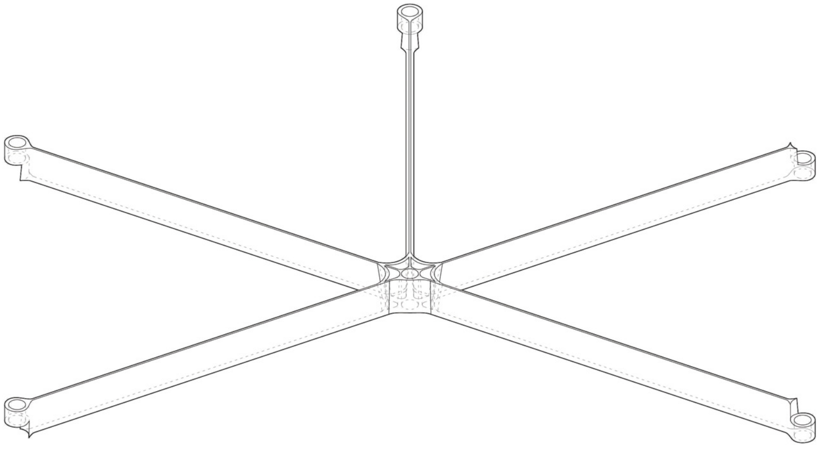


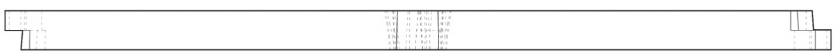
0 100 250 500 mm.

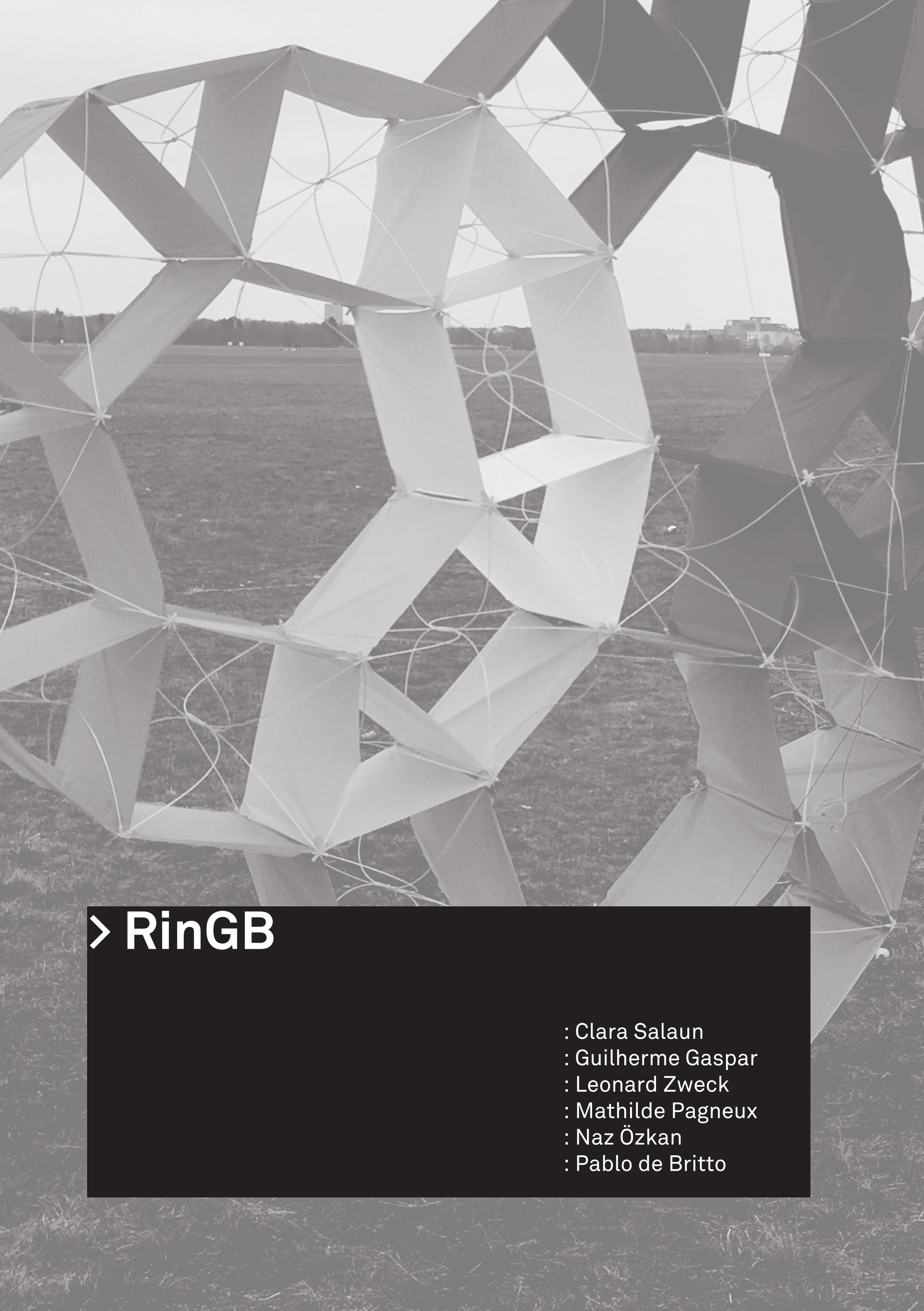
/ ELEVATION







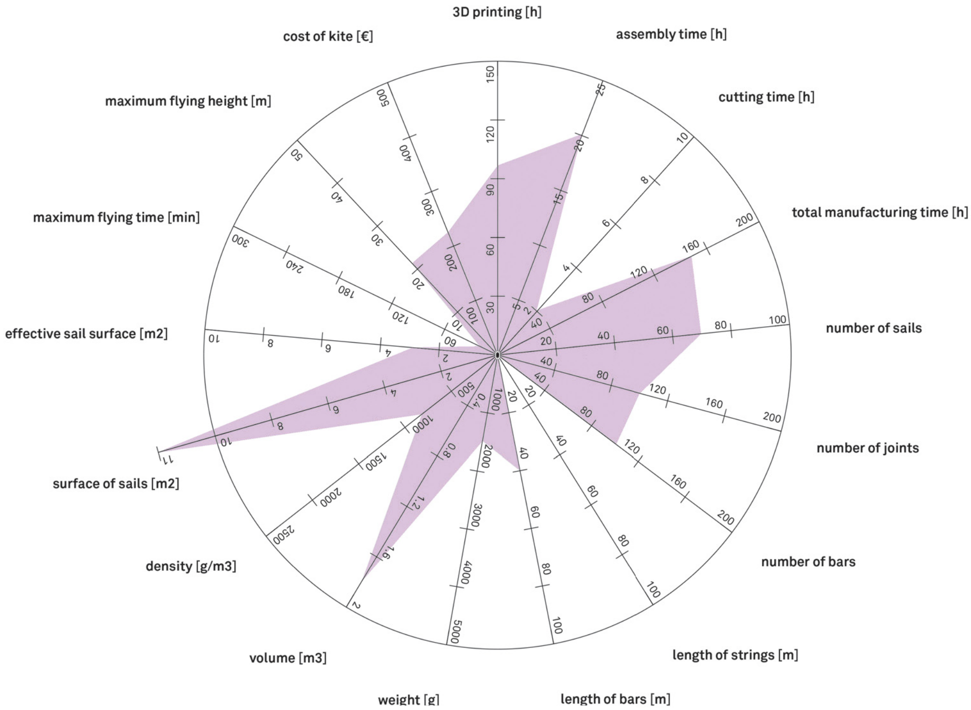




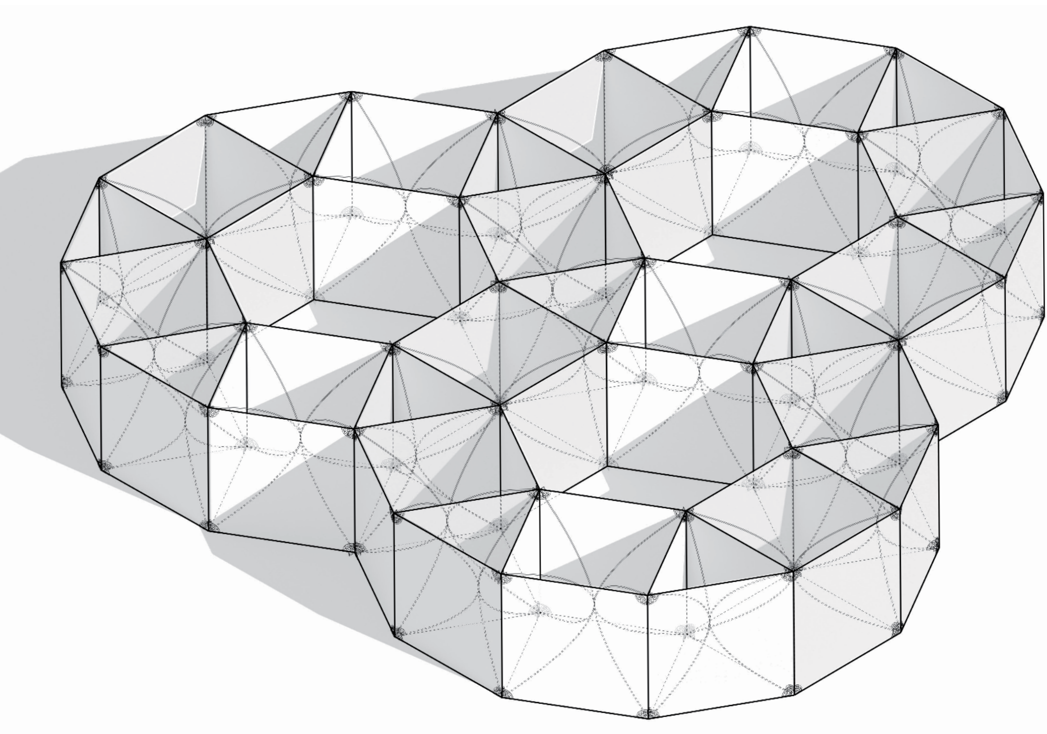
> RinGB

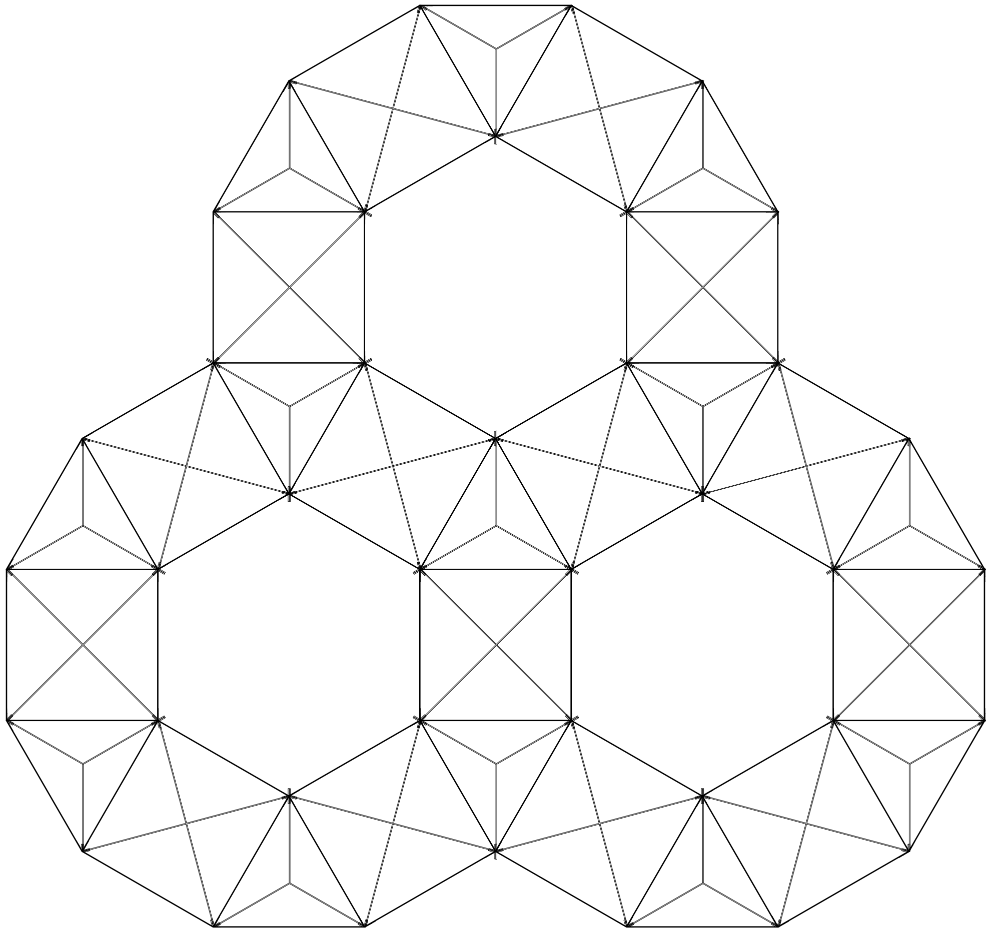
: Clara Salaun
: Guilherme Gaspar
: Leonard Zweck
: Mathilde Pagneux
: Naz Özkan
: Pablo de Britto

/ PROPERTY CHART



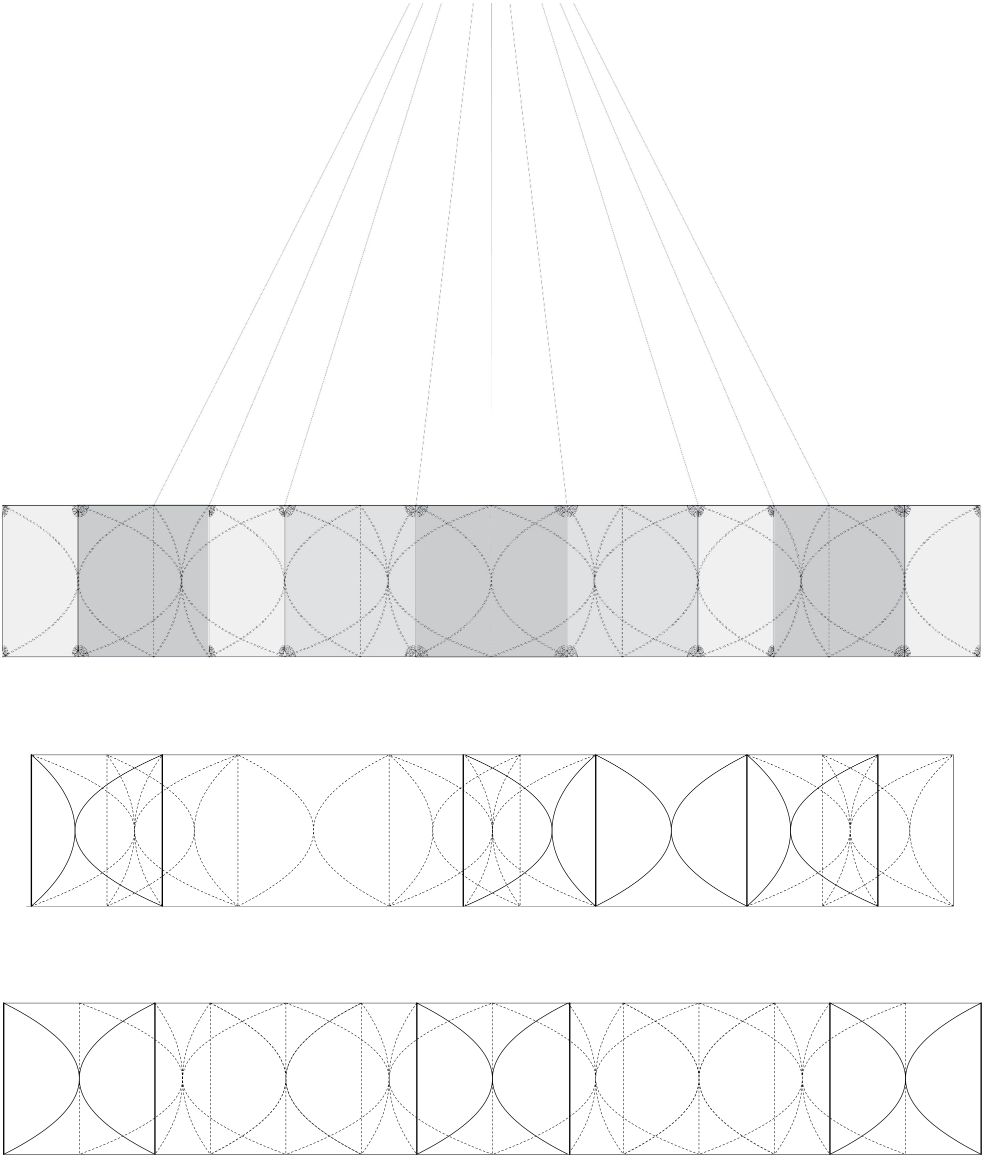
/ AXONOMETRY





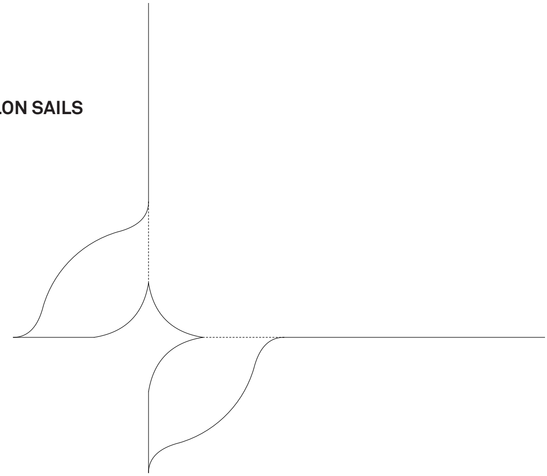
0 100 250 500 mm.

// ELEVATION | SECTION A | B

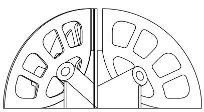


// OVERVIEW PARTS

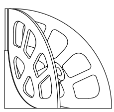
NYLON SAILS
69x



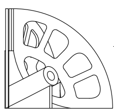
4 CONNECTIONS
42x

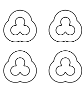


3 CONNECTIONS
28x

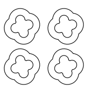


3 CONNECTIONS
29x

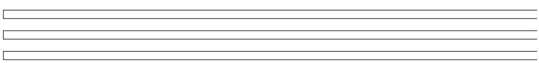




15x



13x

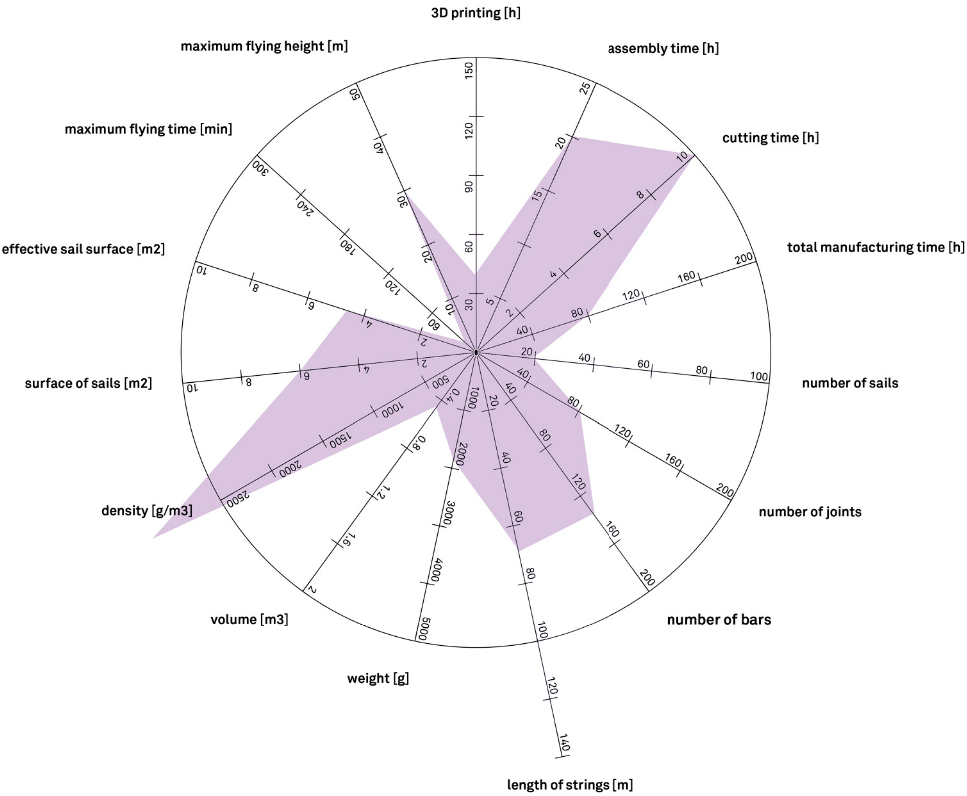


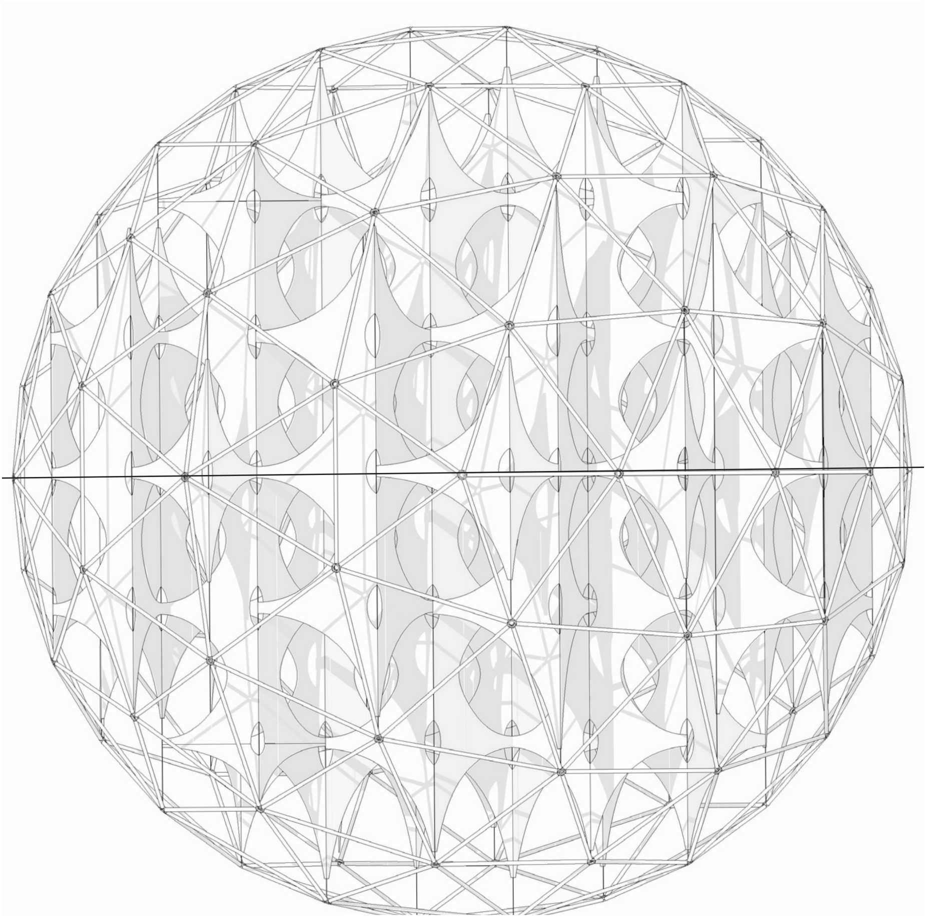
GLASS FIBER BARS
99x

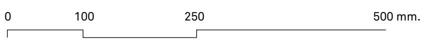
> SPHERE

: Chloe Ozoux
: Daniel Dieren
: Eduardo Brizio
: Esraa Refaat
: Ilaria Abdelmessih
: Julie Laconte

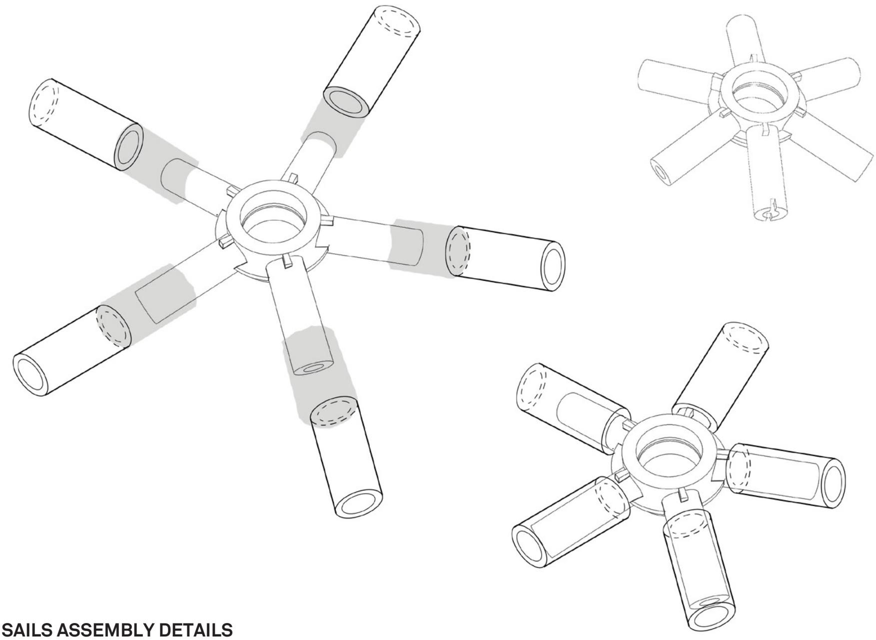
/ PROPERTY CHART



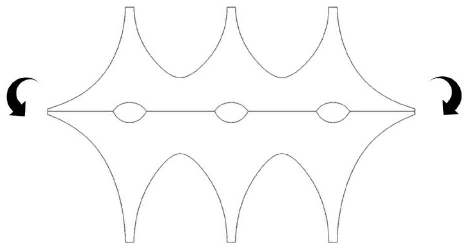


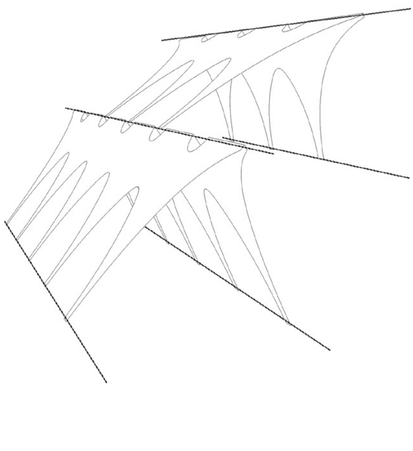

0
100
250
500 mm.

// DETAILS

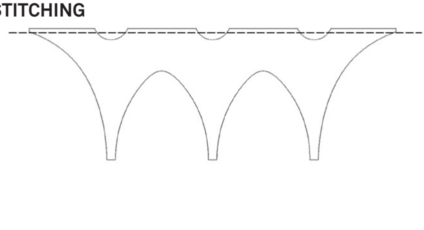


SAILS ASSEMBLY DETAILS

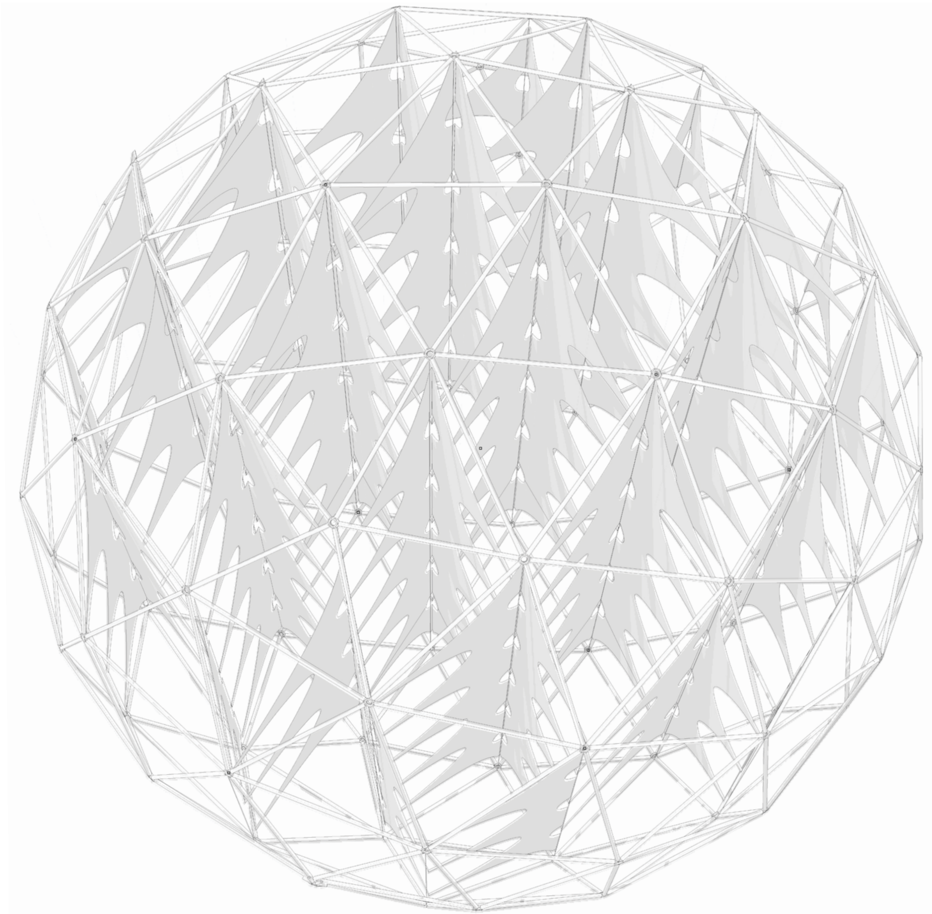


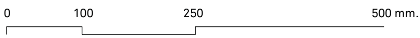


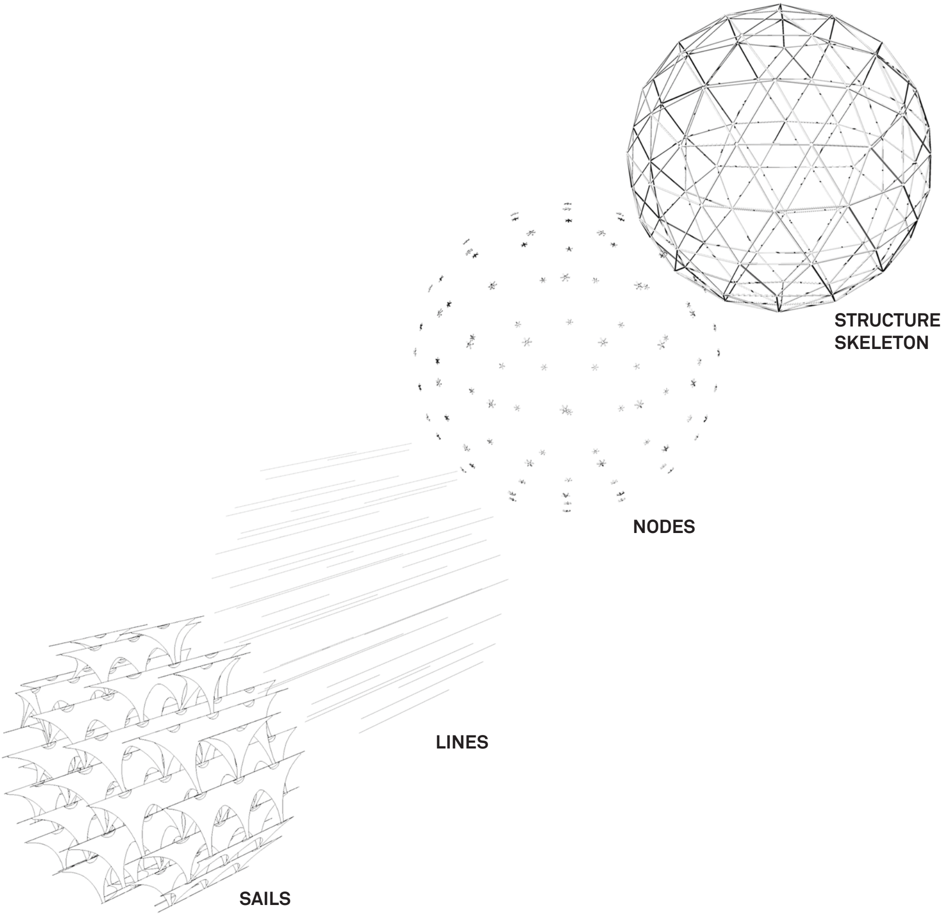
STITCHING

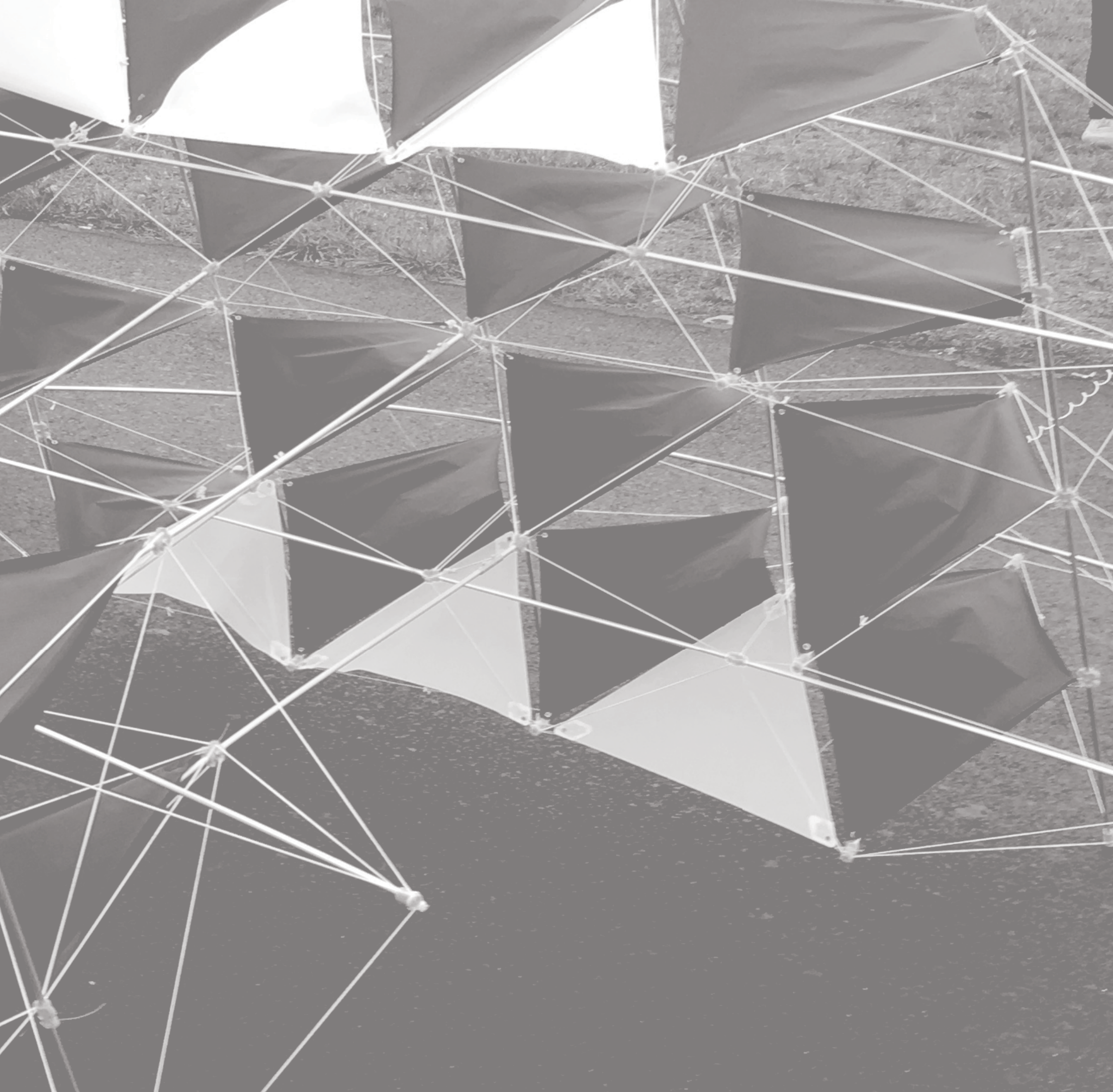


/ ELEVATION





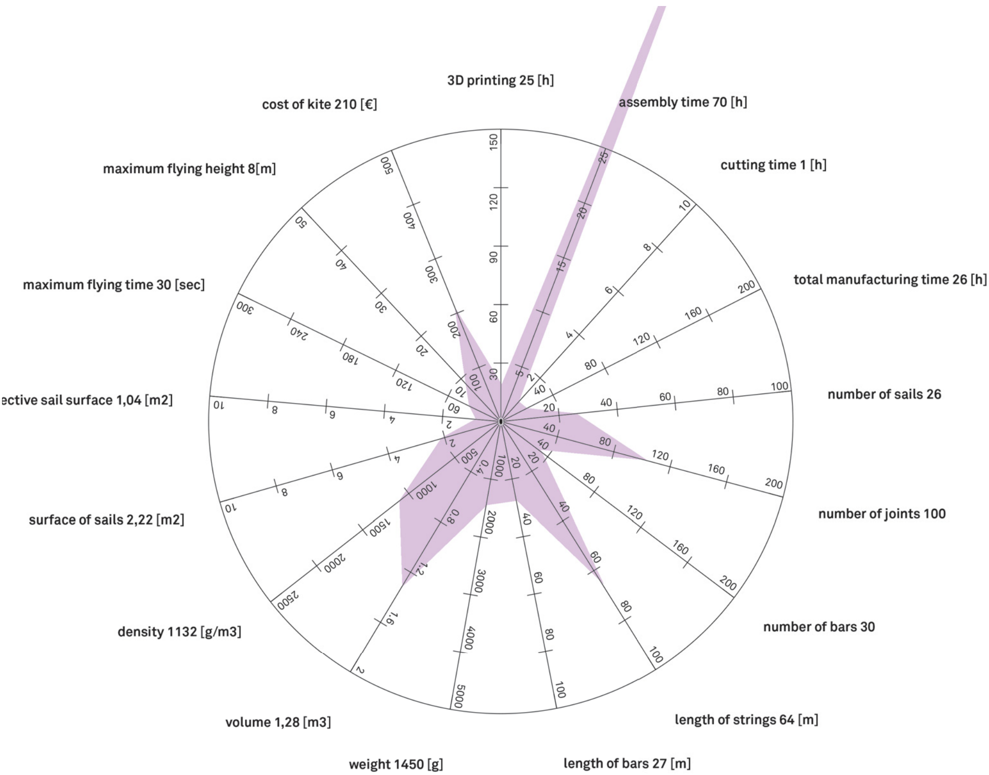

STRUCTURE
SKELETON
NODES
LINES
SAILS



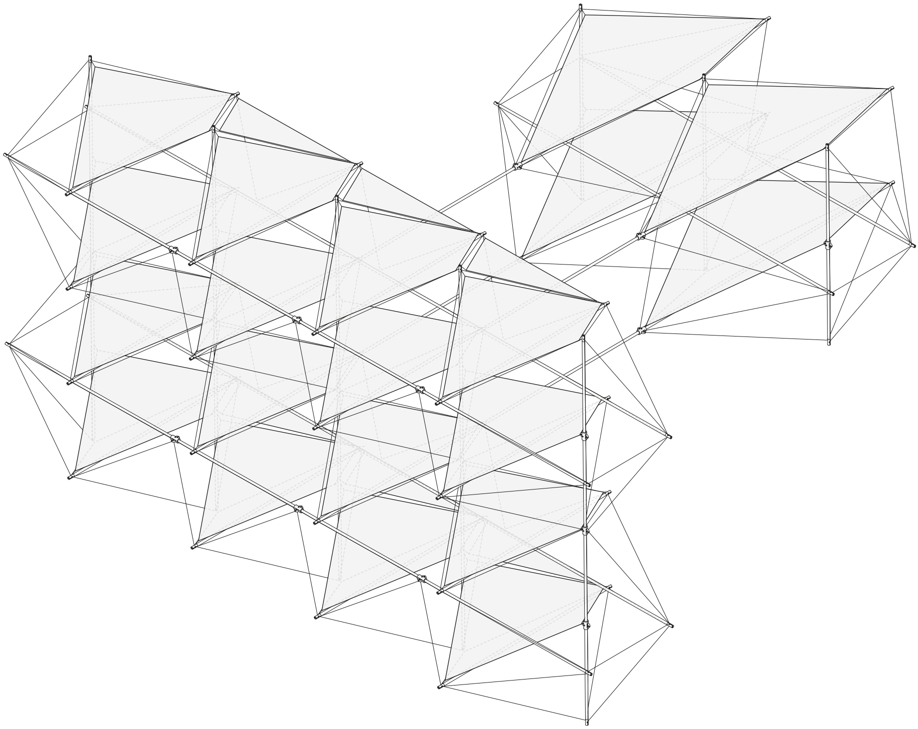
> TENSEGRITY

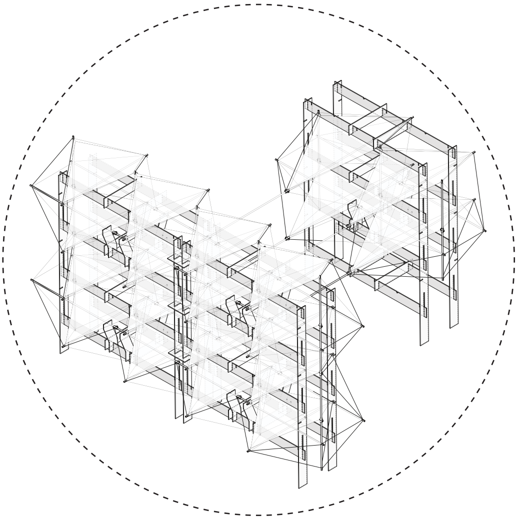
: Alexander Grams
: Jennifer Jiang
: Lukas Kleiter
: Tan Phong Nguyen
: Radoslaw Stanko
: Nicolas Diaz Tamayo

/ PROPERTY CHART

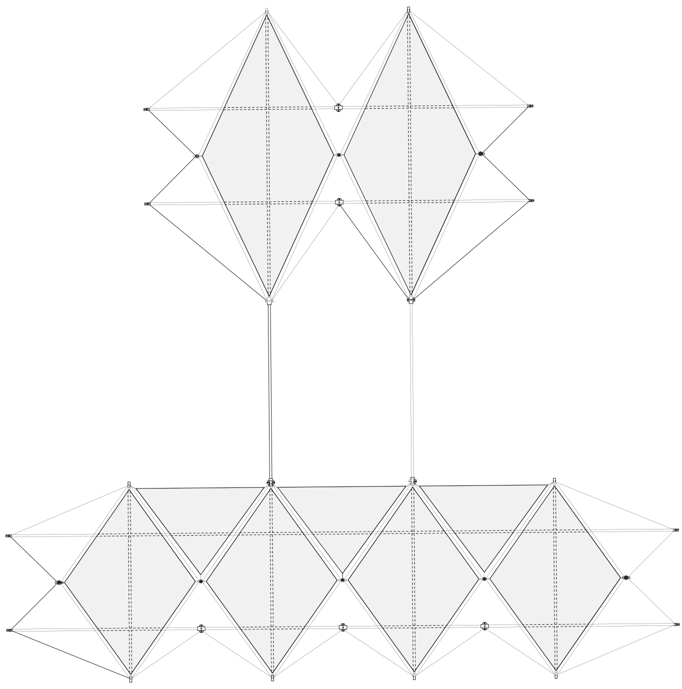


/ AXONOMETRY



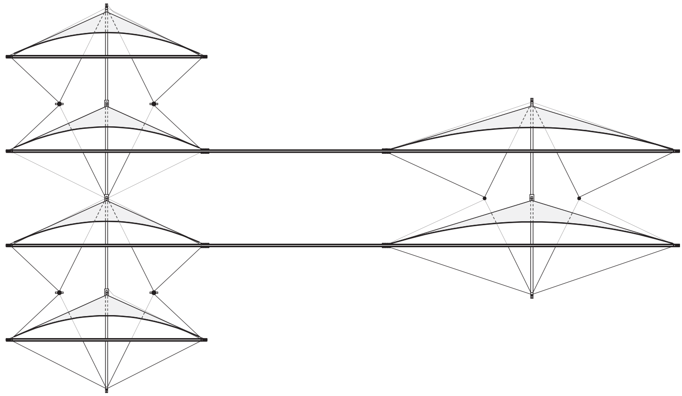


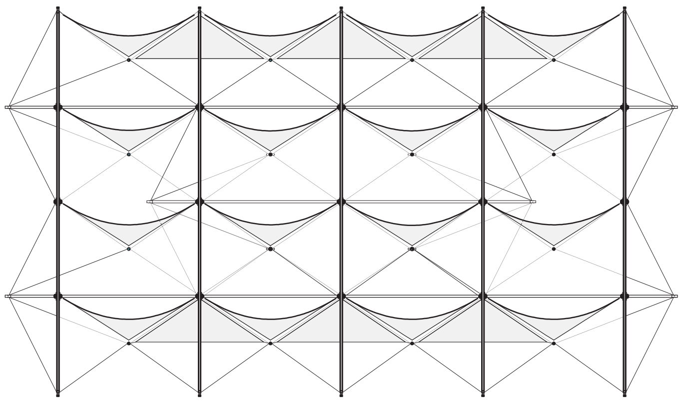
AXONOMETRY SUPPORT STRUCTURE



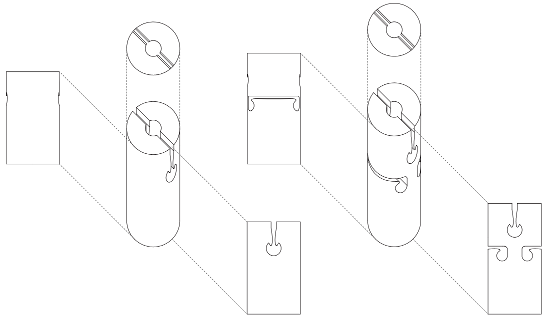
0 100 250 500 mm.

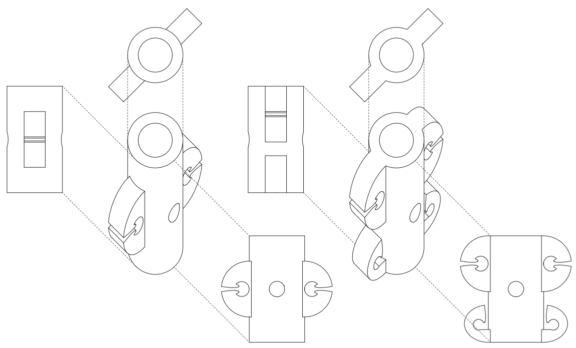
// SECTION A | B

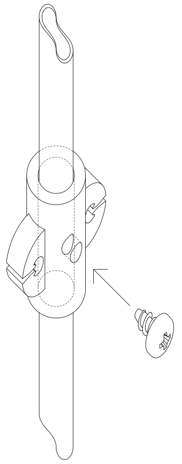


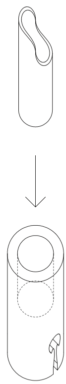


/ DETAILS







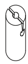
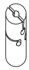
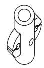


// OVERVIEW PARTS

joints

properties:

material: PLA
type: thermoplastic aliphatic polyester
geometry: spool
material diamiter: 1,75 mm
glass temp: 60~65° C
melting temp: 150~160° C
nozzle temp: 215° C

CAP-1		bounding box: X = 6,00 mm Y = 6,00 mm Z= 15,00 mm	x 20
CAP-3		bounding box: X = 6,00 mm Y = 6,00 mm Z = 20,00 mm	x 40
MID-A		bounding box: X = 20,82 mm Y = 10,40 mm Z = 20,00 mm	x 20
MID-BUTTERFLY		bounding box: X = 20,82 mm Y = 10,40 mm Z = 20,00 mm	x 20

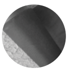
rods

properties:

material: metal
type: alluminium
geometry: round tube, hollow
external diamiter: 6 mm
internal diamiter: 4mm
wall thickness: 1mm
surface treatment: anodised
basic color: silver

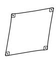
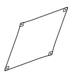
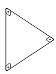
ROD-1		Ø = 6 mm L = 500 mm	x 15
ROD-2		Ø = 6 mm L = 1000 mm	x 7
ROD-3		Ø = 6 mm L = 1750 mm	x 8

fabric



properties:

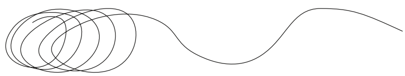
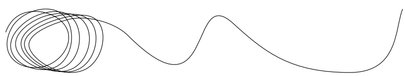
material: polyamide
type: nylon
geometry: roll of fabric
distance between reinforcement threads: 4 mm
thickness: 0,05 mm
other features: tear proof, wind-proof, water-repellent
basic color: various

BASIC		rhombus: a = 415,1 mm × = 51,91˚	x 16
TAIL		rhombus: a = 304,3 mm × = 77,68˚	x 4
TRIANGLE		isosceles triangle: base = 330 mm side = 290 mm	x 6

strings

properties:

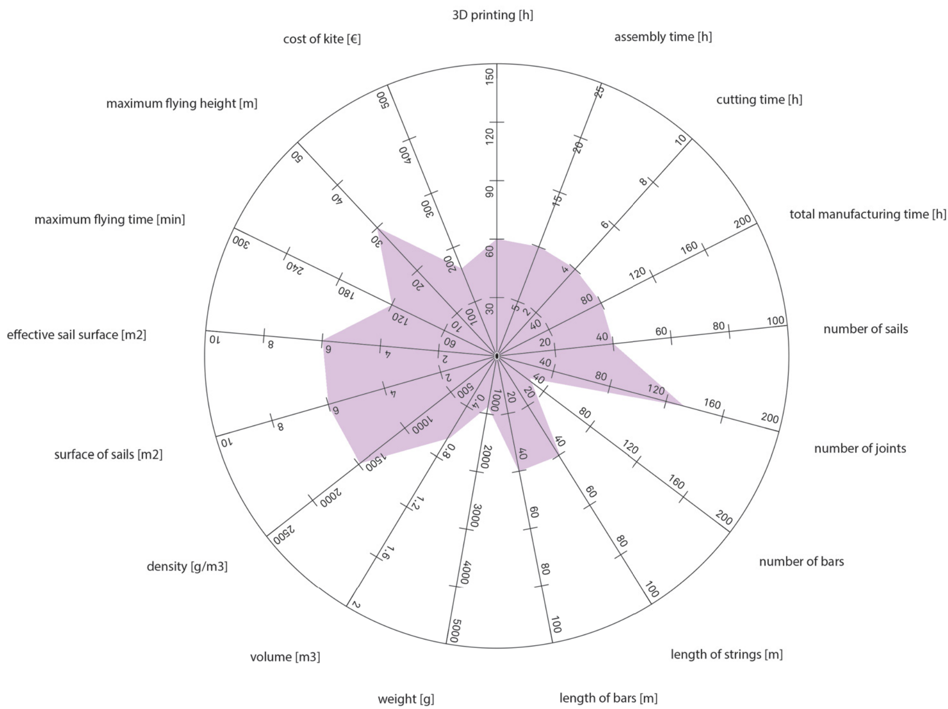
material: varius
core: rubber
shell: polyester
shell type: woven
level of elongation: medium

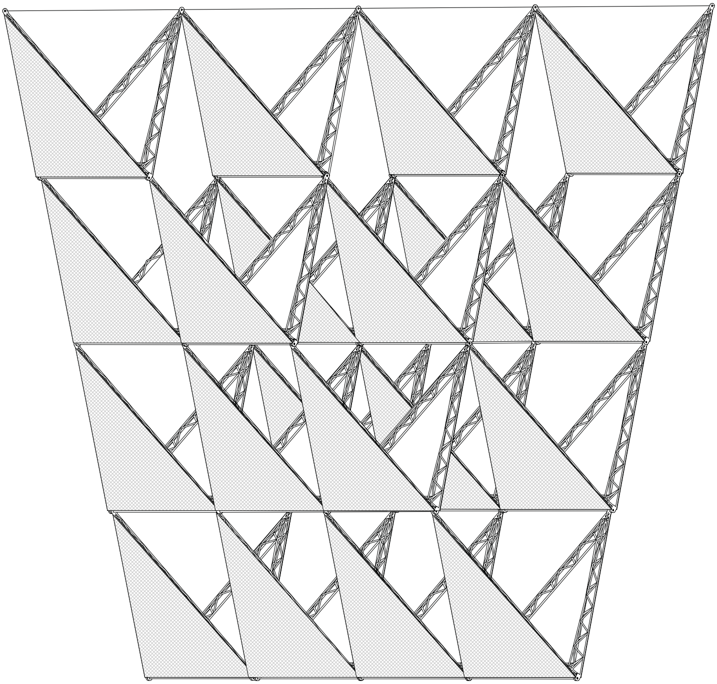
LOOP		varius loops based on elon-gation ratio	x 64 [m]
CONTROL		steering string	x 25 [m]

> UN FOLD

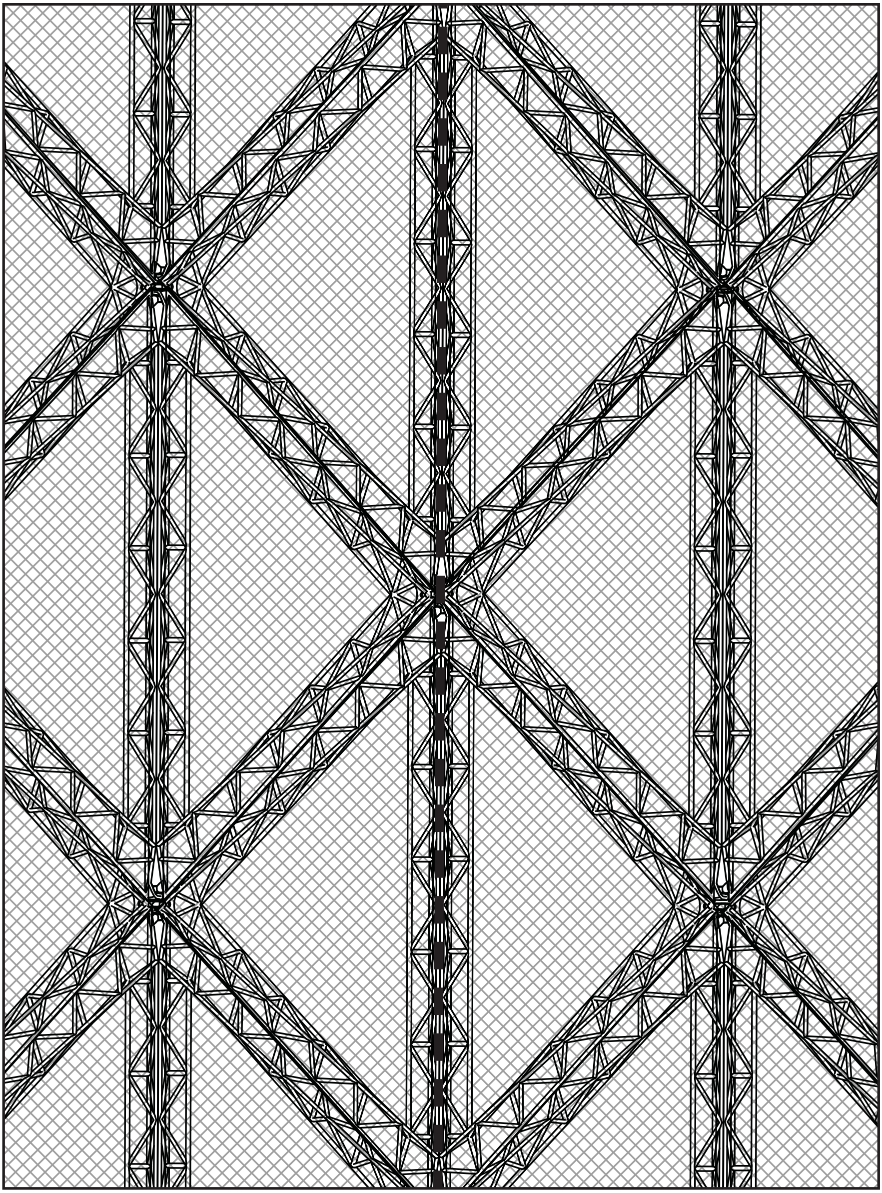
: Tareq Almuhammad
: Nicolas Colman
: Jacqueline Ekteshafi
: Julian Seyda
: Zeki Smajli

/ PROPERTY CHART

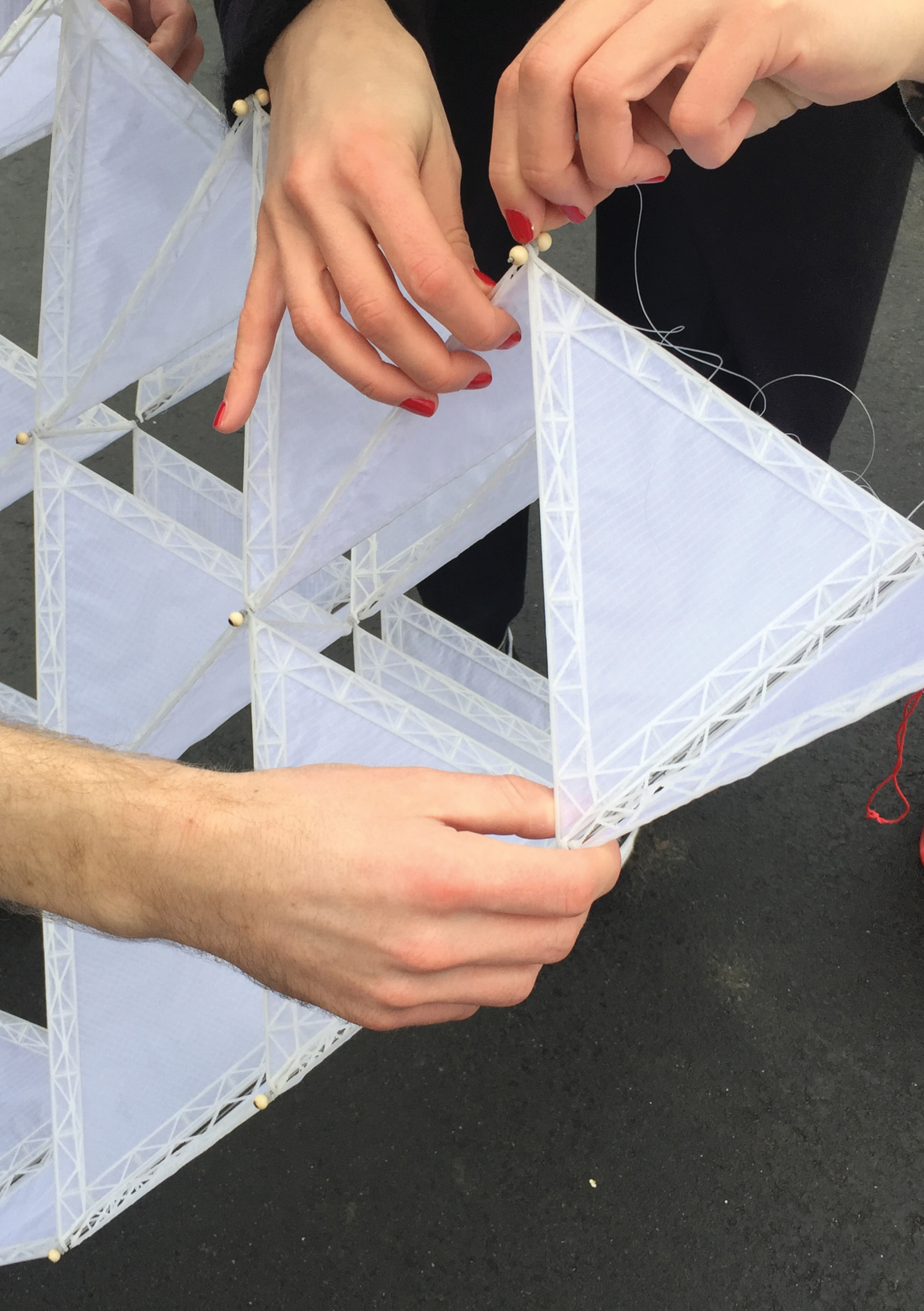


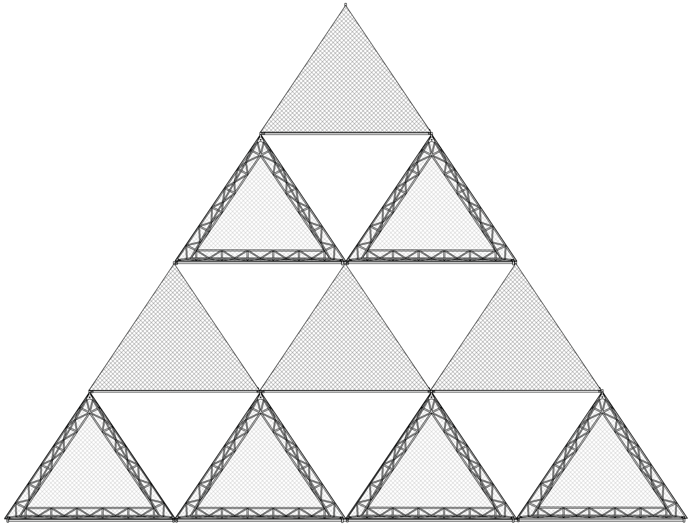


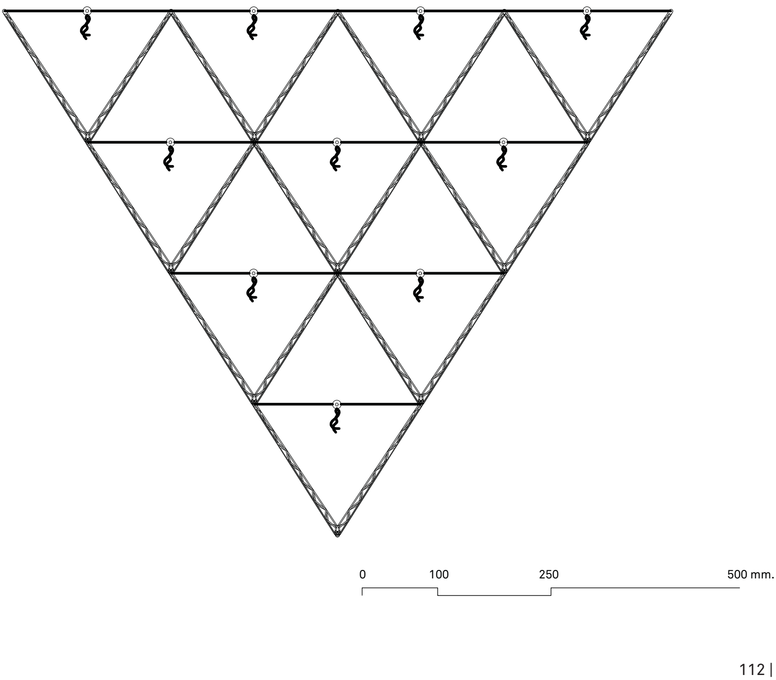
0
100
250
500 mm.



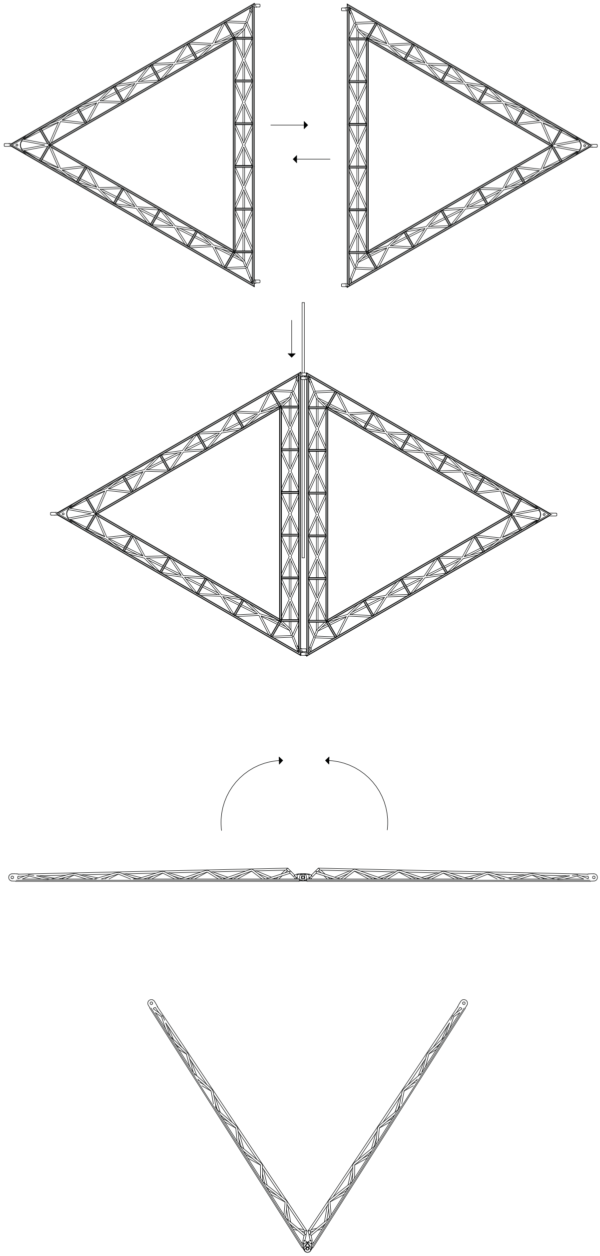
DETAILED STRUCTURE

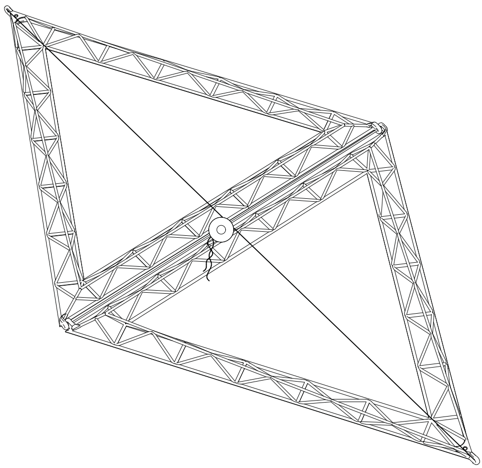


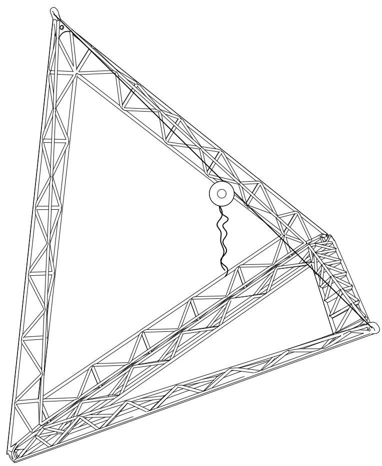



0
100
250
500 mm.

/ CONCEPT







>> DEPLOYABLE & INFLATABLE STRUCTURES

TU Berlin

CoLab

Universidad Politécnica de Cartagena

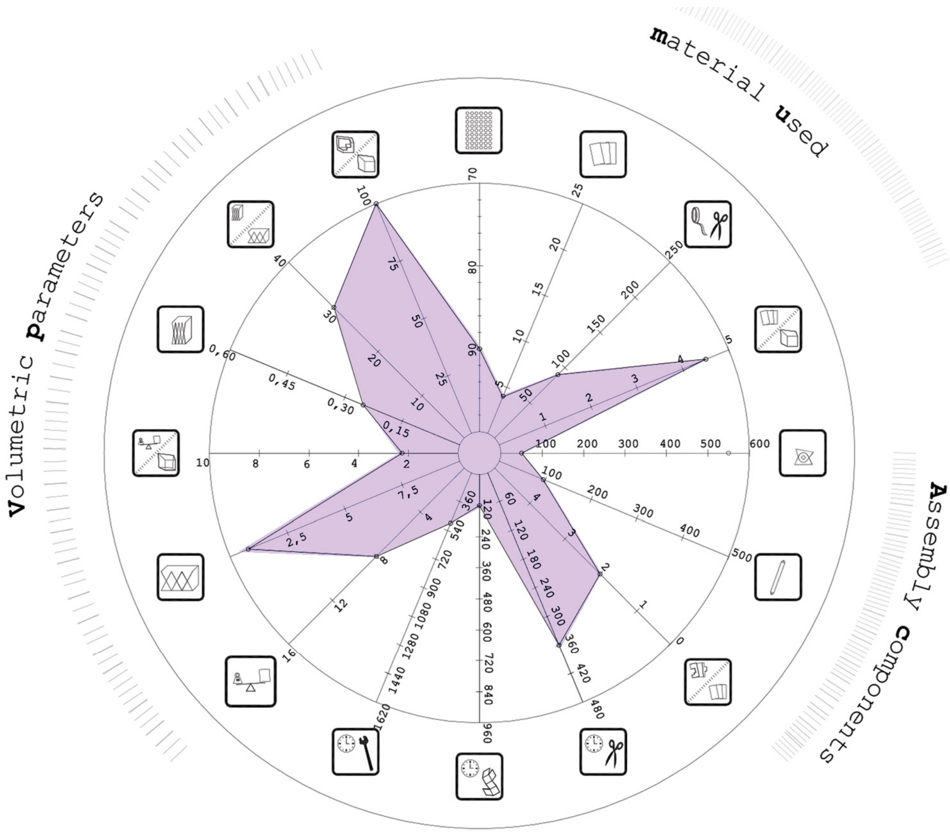
ARQTE

Feng Chia University

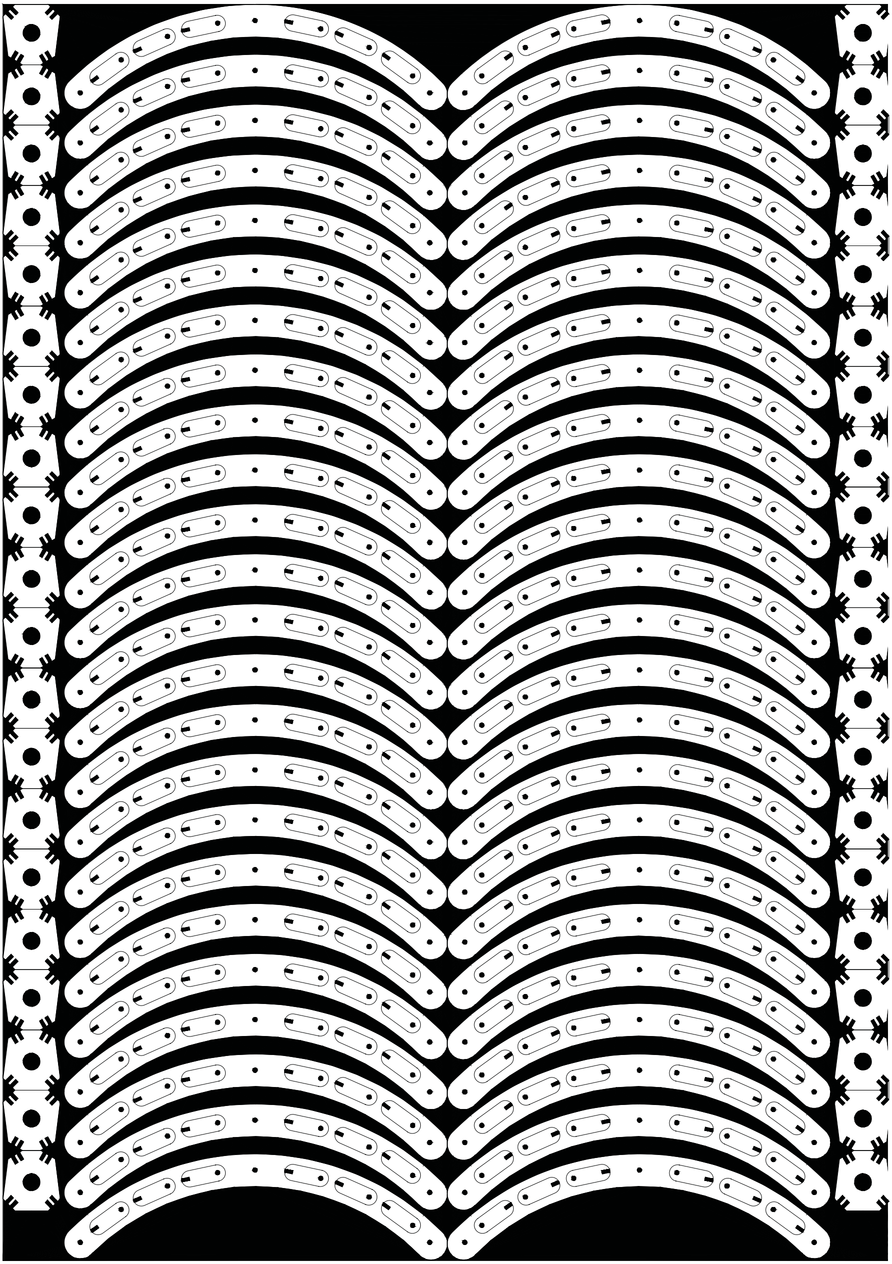
> INFLATABLE SPHERE

: 趙宇涵 Zhao, Zoey
: 賴柏廷 Lai, Jimmy
: 李默菲 Lee, Murphy
: Jakob Passernig
: Mª Catalina García Jiménez

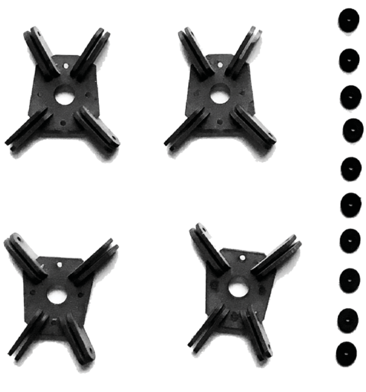
/ PROPERTY CHART



/ PATTERN



>> Inflatable bag version 1.02   (discarder)



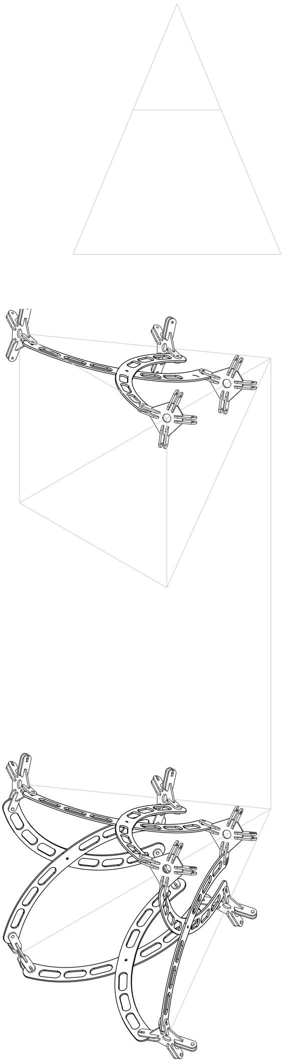
>> Ensambled joint

>> Ensambled scissor

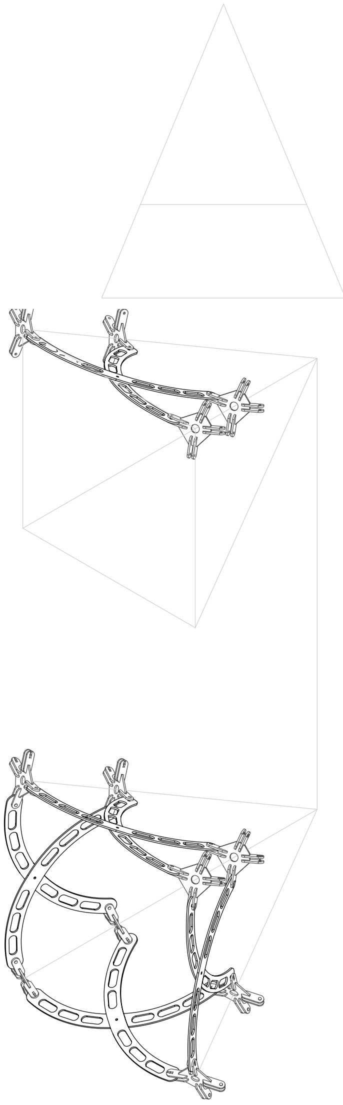
/ MODULE | ASSEMBLY

>> Module//

>> Closed module

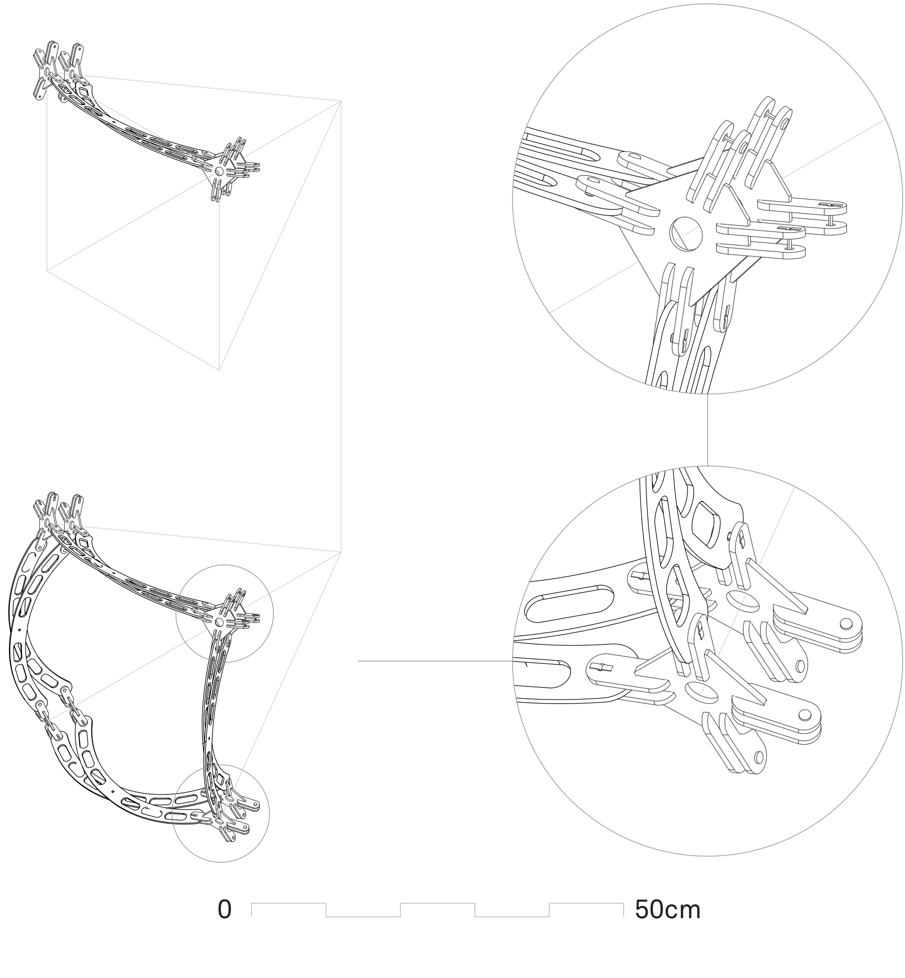


>> Half open module



Scale 1:10 0 50cm

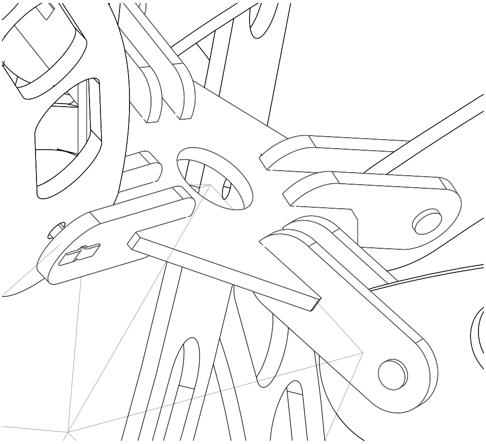
>> Open module



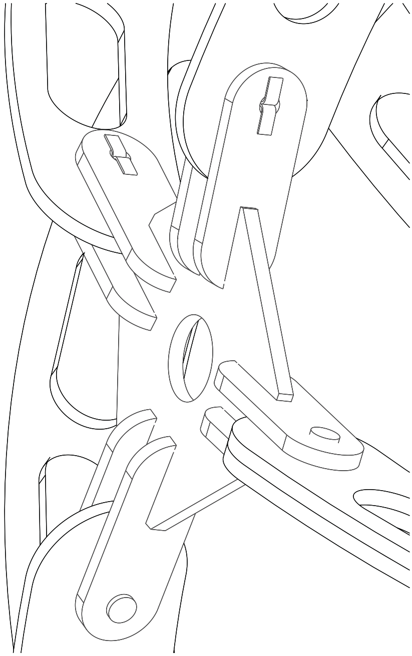
/ MODULE | ASSEMBLY

>> Type of connectors

>> Node // two pieces

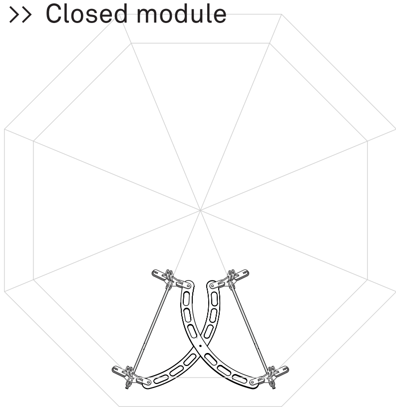


>> Node // two pieces

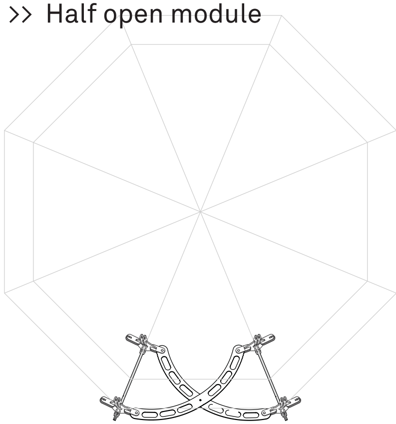


Scale 1:1

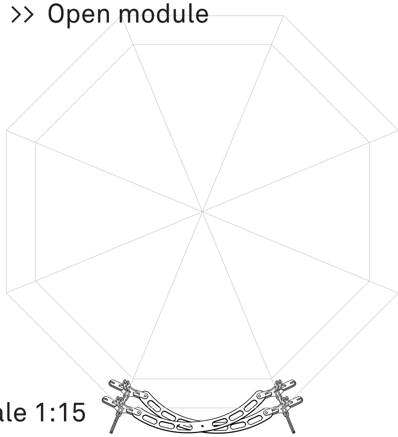
>> Closed module



>> Half open module



>> Open module

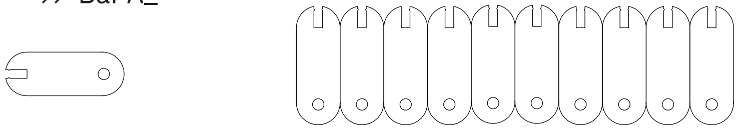


Scale 1:15

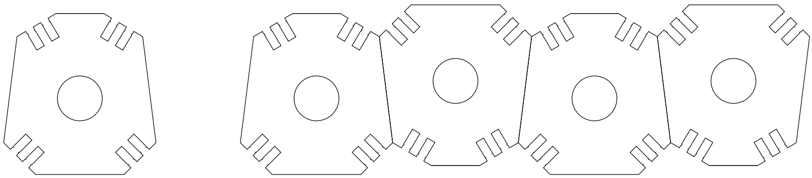
>> Type of bars

>> Pattern bars//connectors

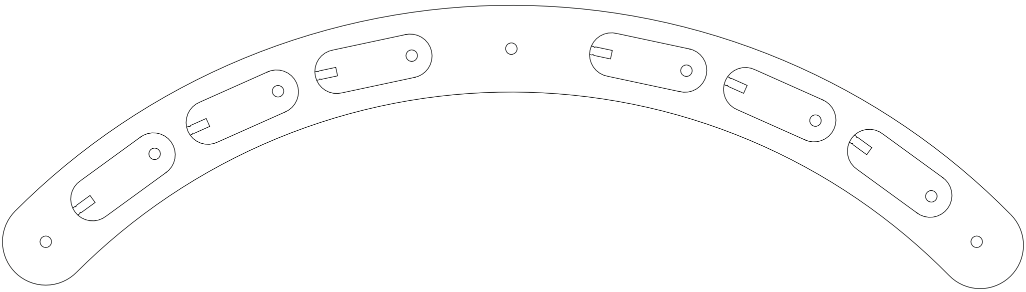
>> Bar A_



>> Bar B_

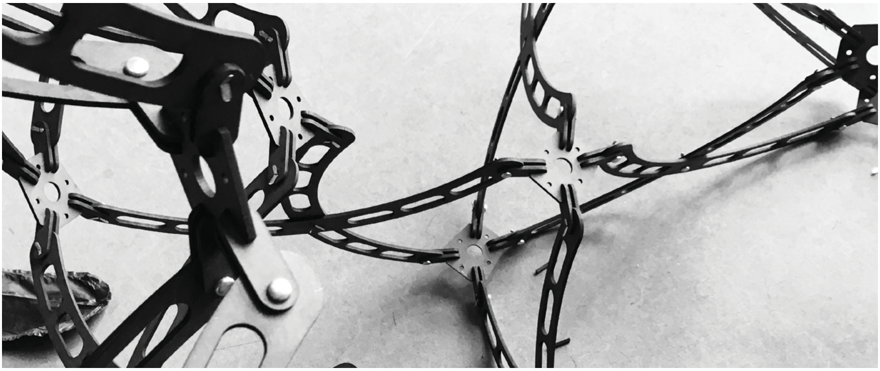


>> Bar C_



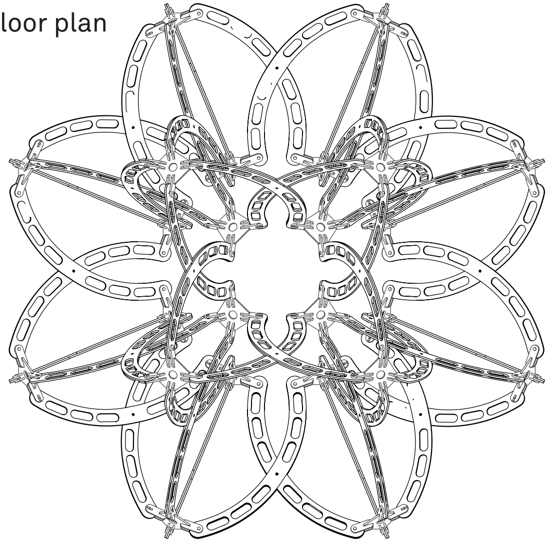
Scale 1:2

>> Detail photos prototype

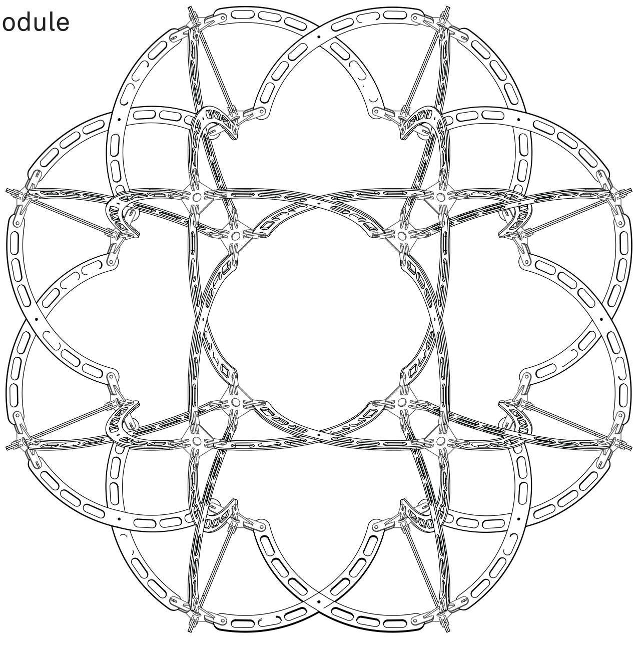


>> Elevation and floor plan

>> Closed module



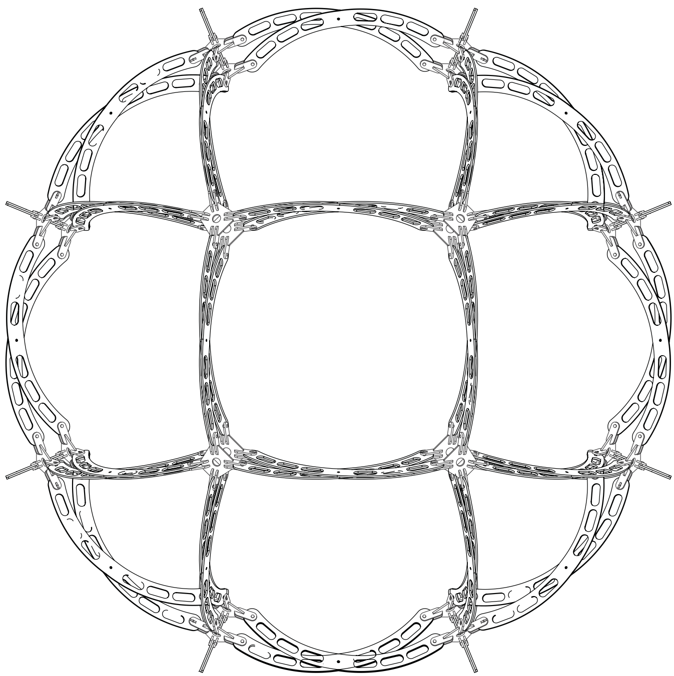
>> Half open module



Scale 1:10

0 50cm

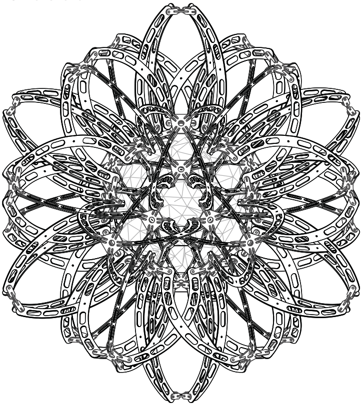
>> Open module



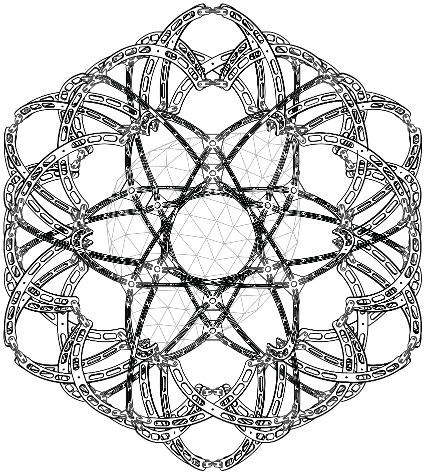
Scale 1:10 0 50cm

/ PROTOTYPE FOLDING | PRODUCTION

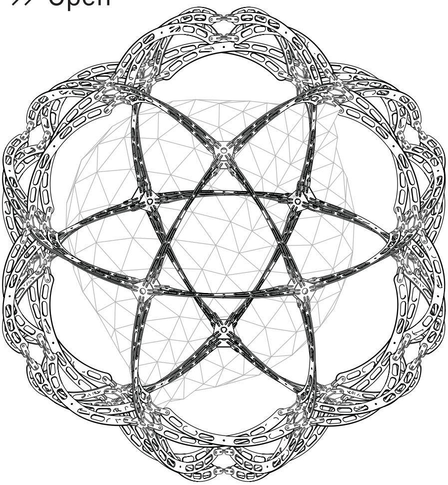
>> Closed



>> Half open

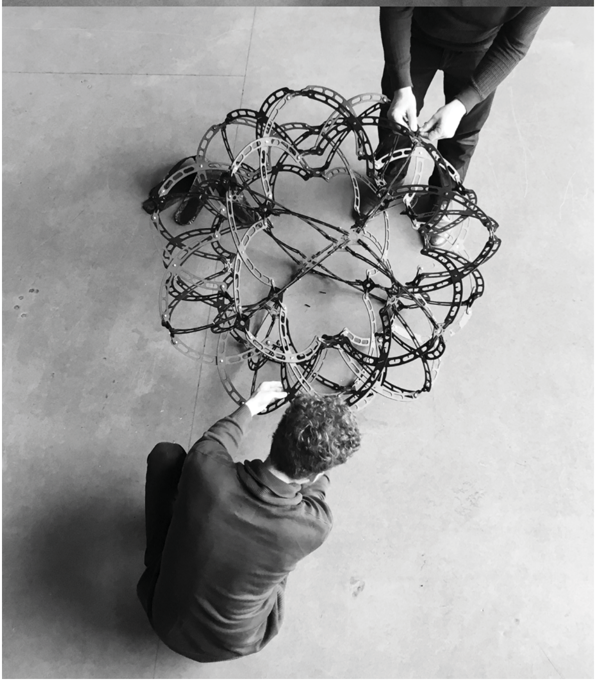


>> Open



Scale 1:15

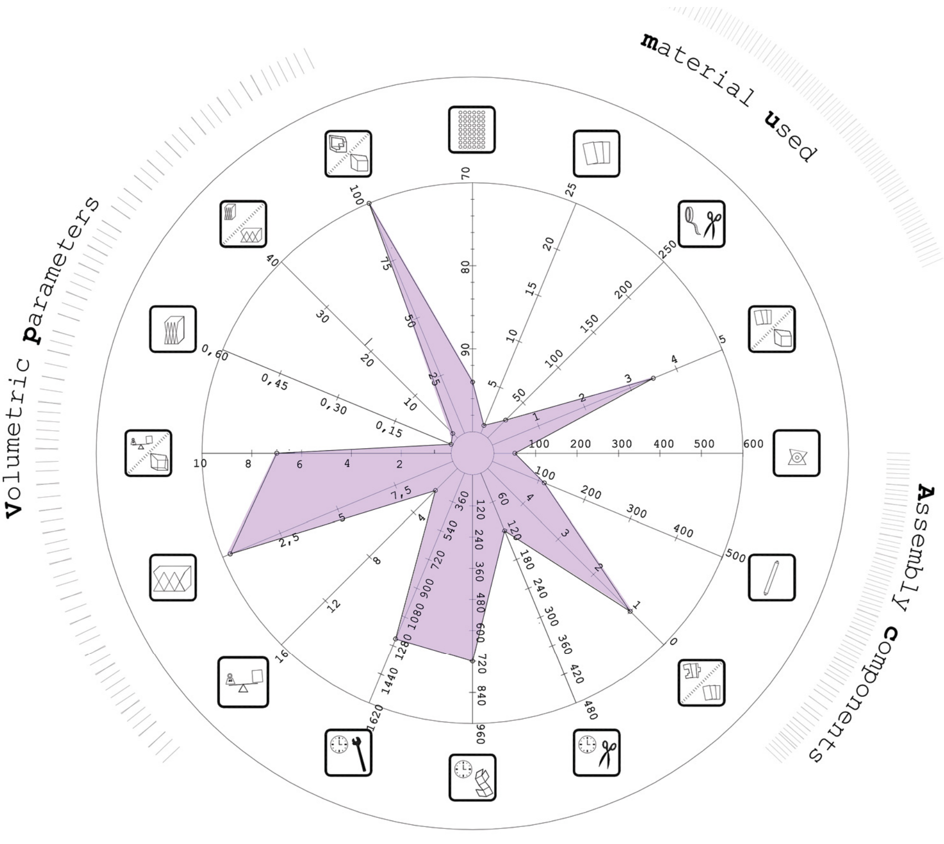
0 50cm

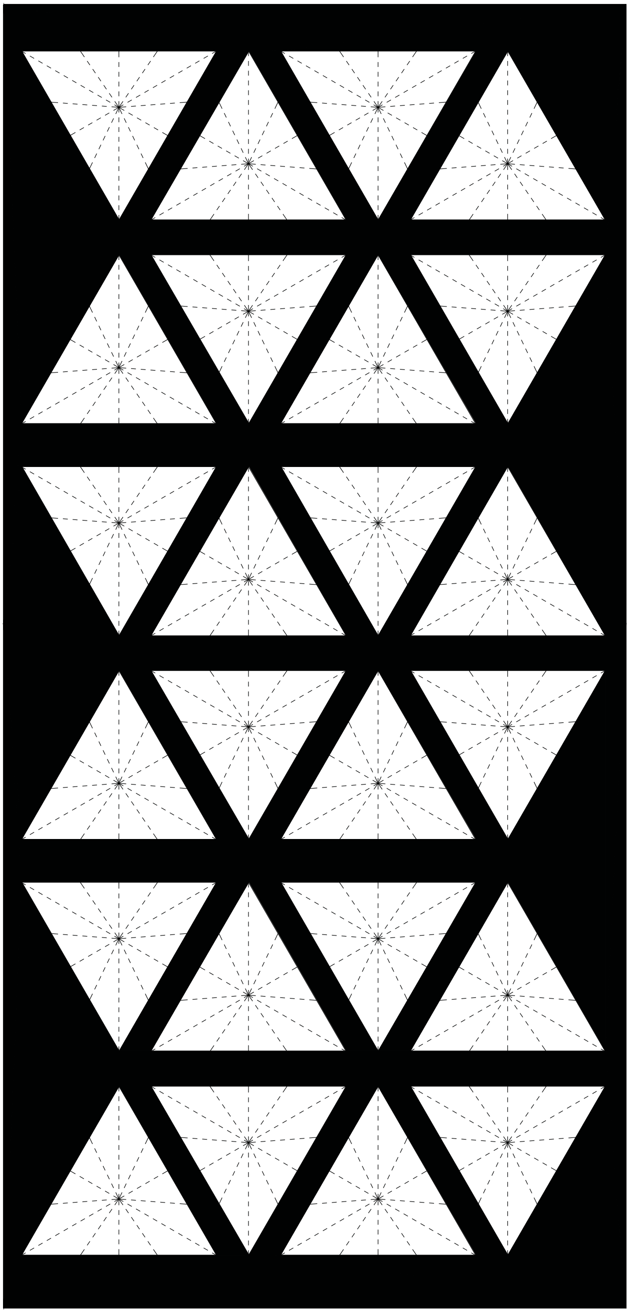


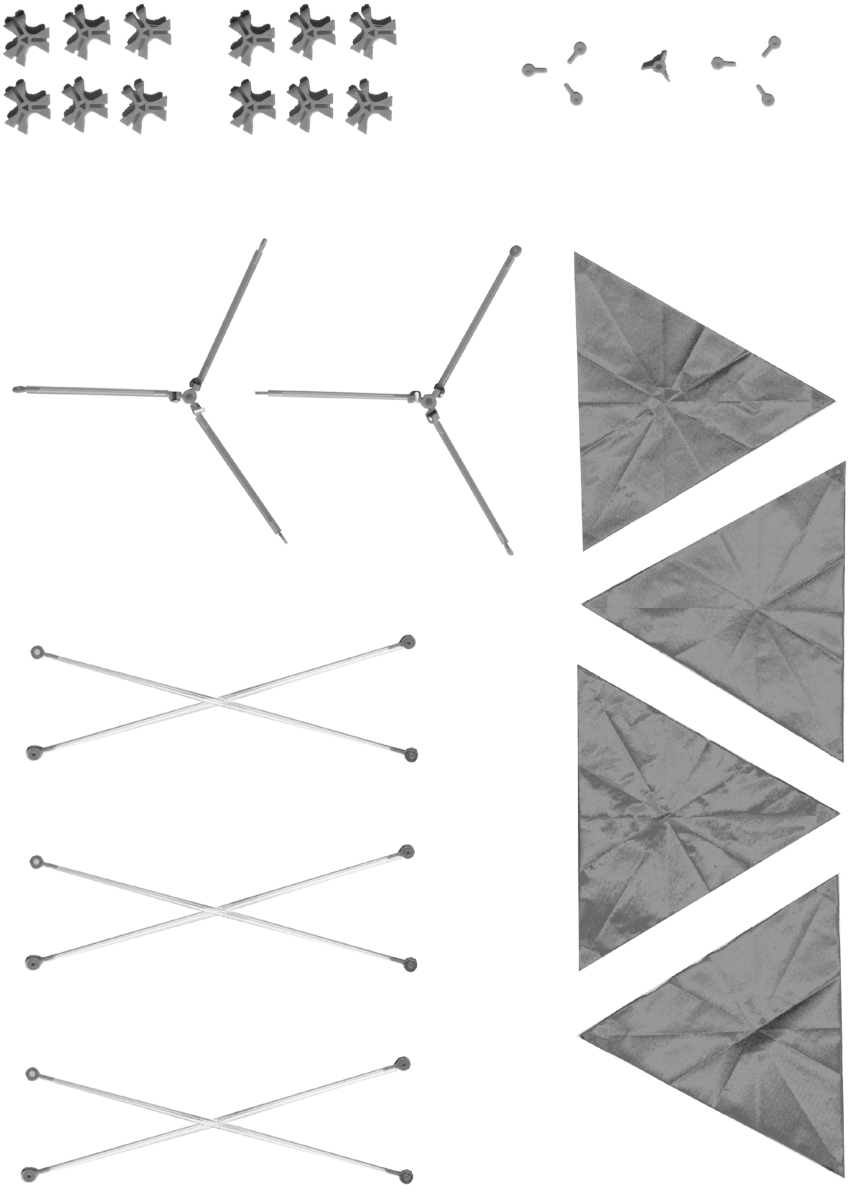
>> Inflatable bag version 0.2

> DEPLOYABLE KITE

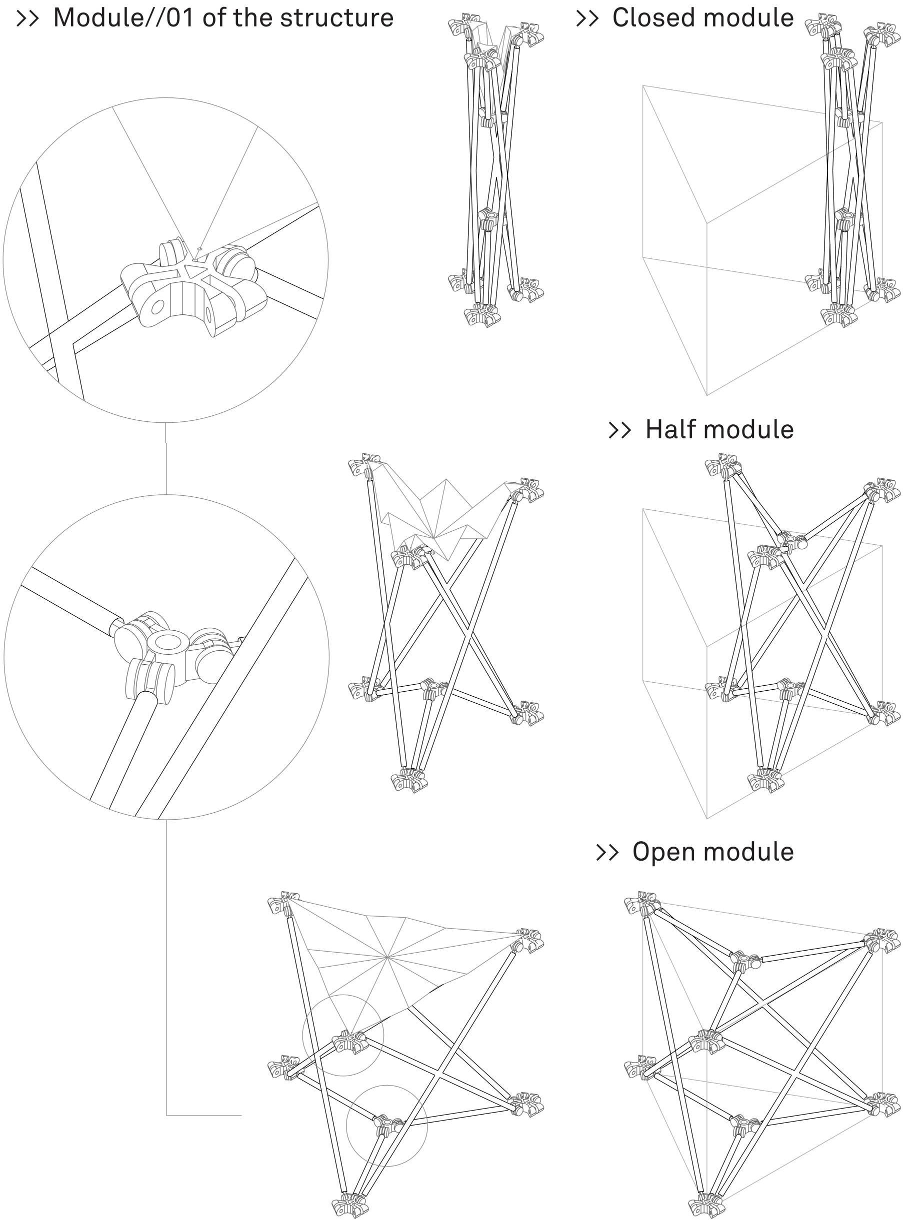
: 廖譔堯 Liao, Ryan
: 陳伊婷 Chen, Cris
: 賴尉齊 Lai, William
: Esraa Refaat
: Aria Rodomonti


material used
Volumetric parameters
Assembly components





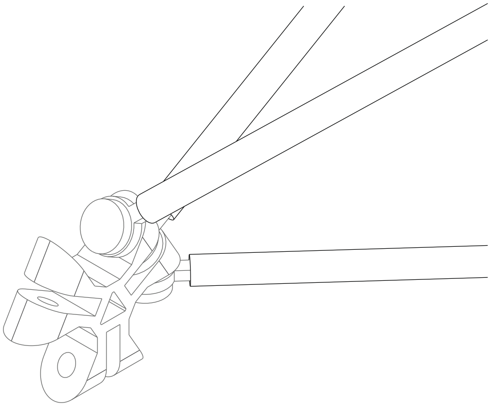
/ MODULE | ASSEMBLY

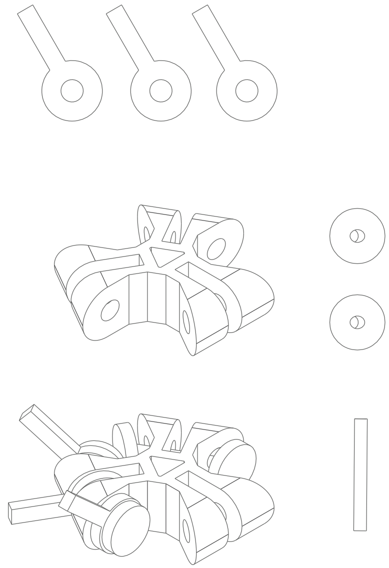


Scale 1:6 0 50cm

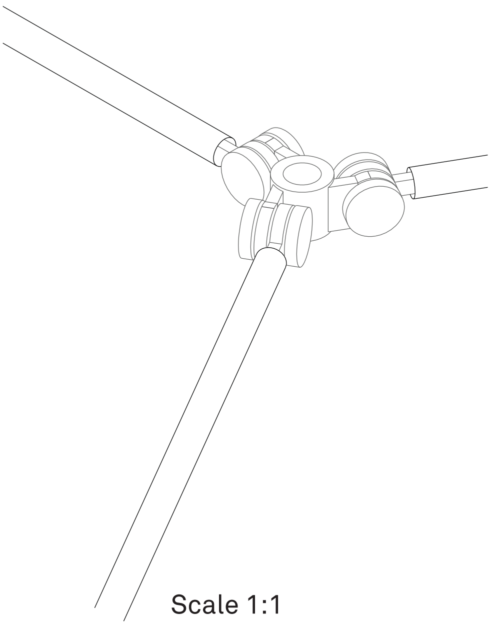
>> Type of connectors

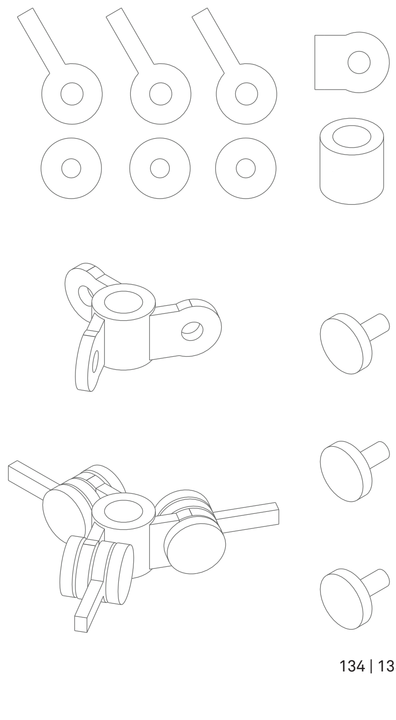
>> Node A// two pieces





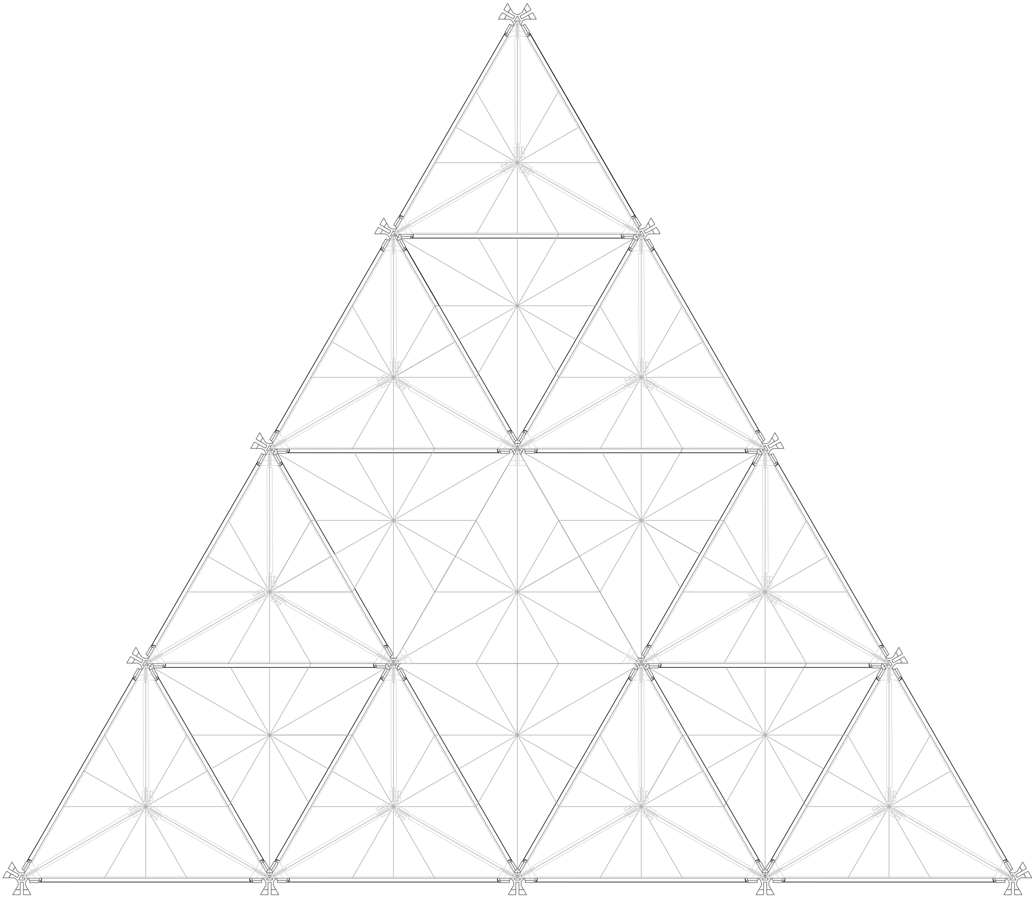
>> Node B// two pieces

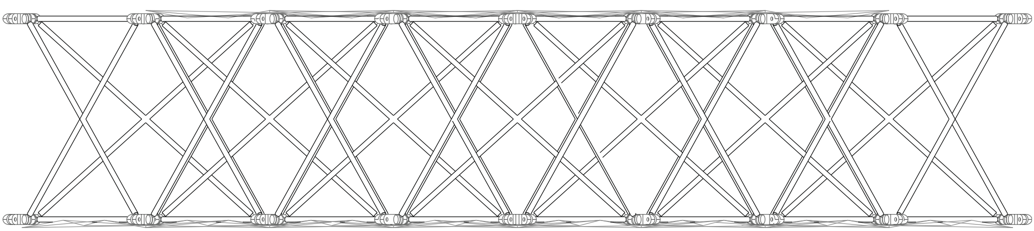




Scale 1:1

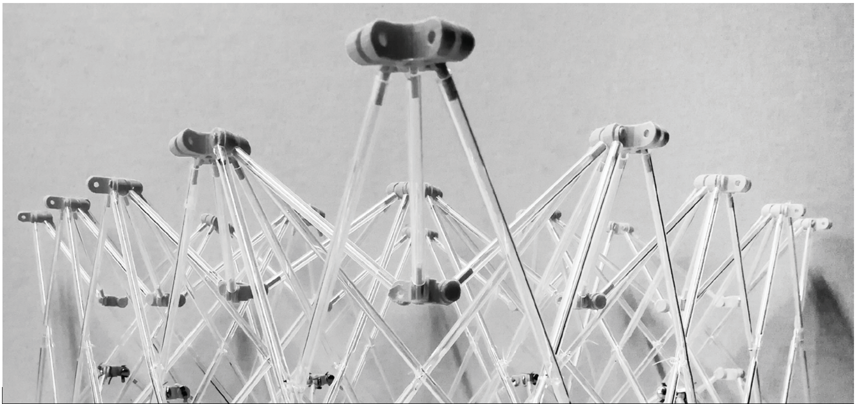
>> Elevation and floor plan

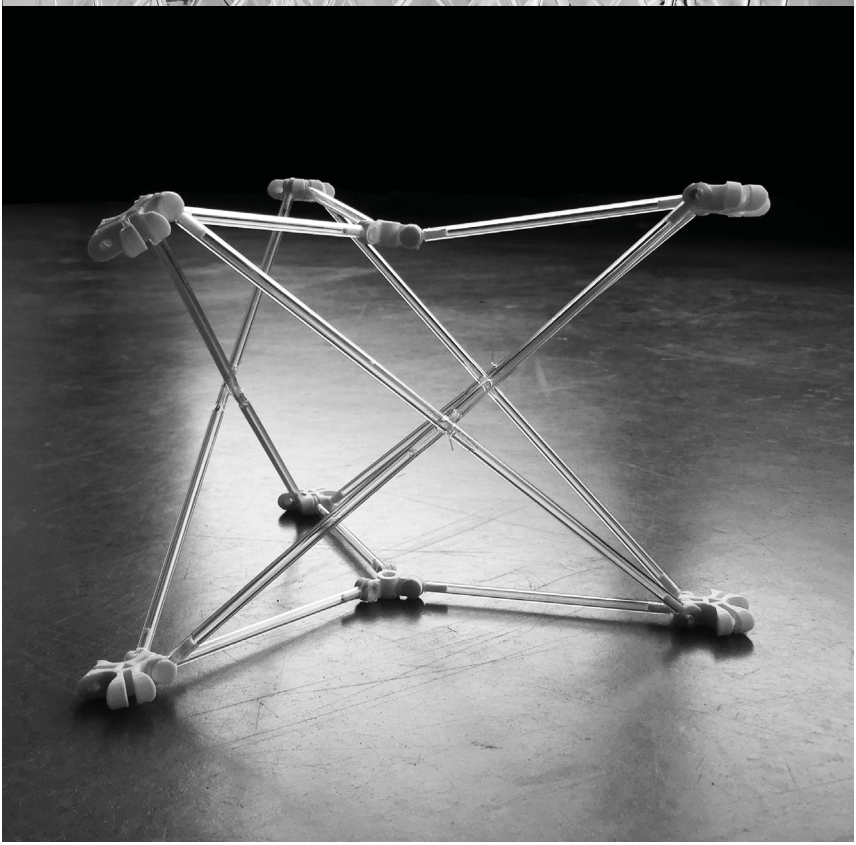




Scale 1:6 0 50cm

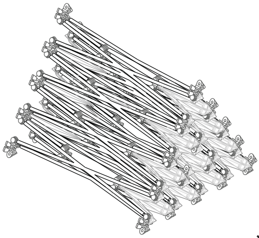
>> Prototype detail photos



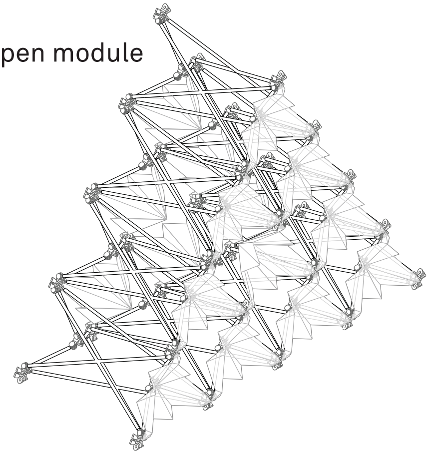


/ PROTOTYPE FOLDING | PRODUCTION

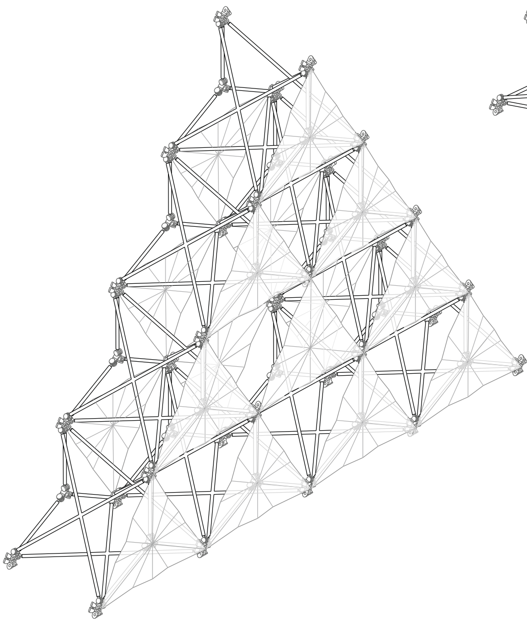
>> Closed module



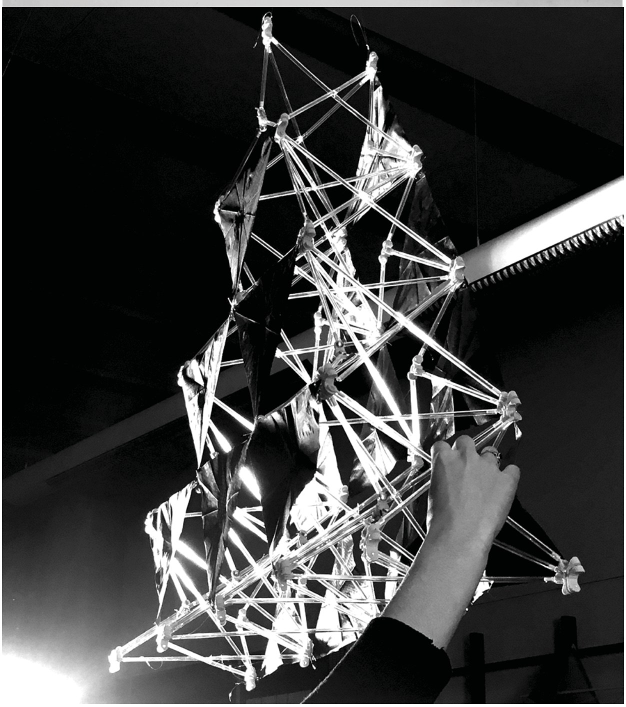
>> Half open module



>> Open module



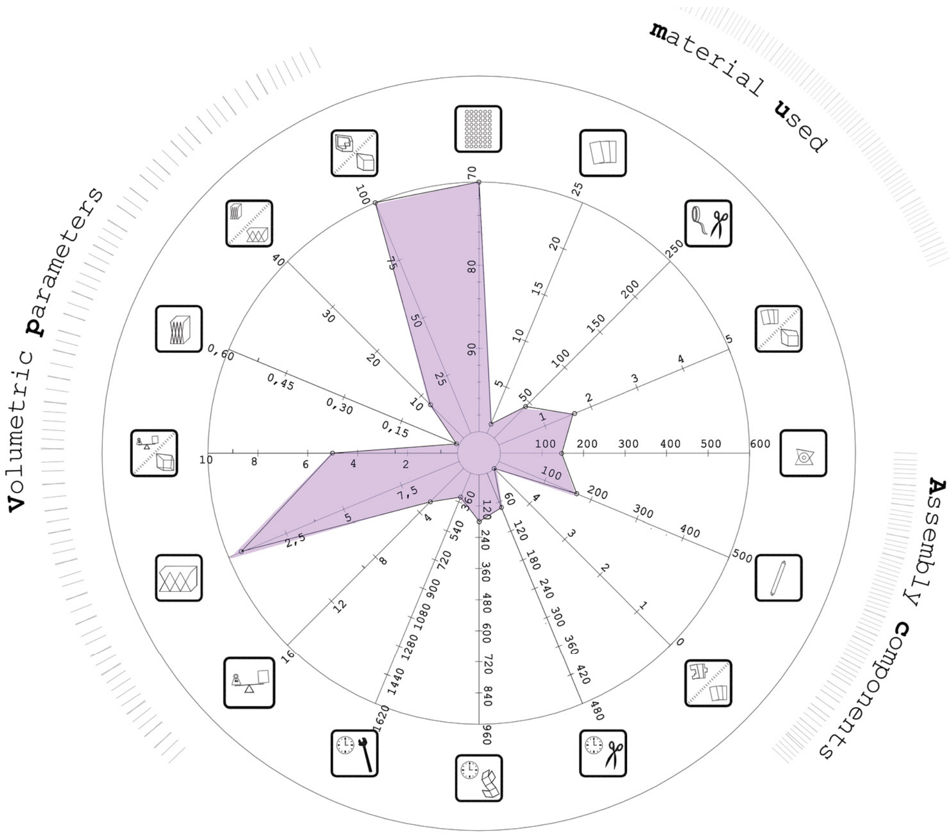
Scale 1:10 0 50cm

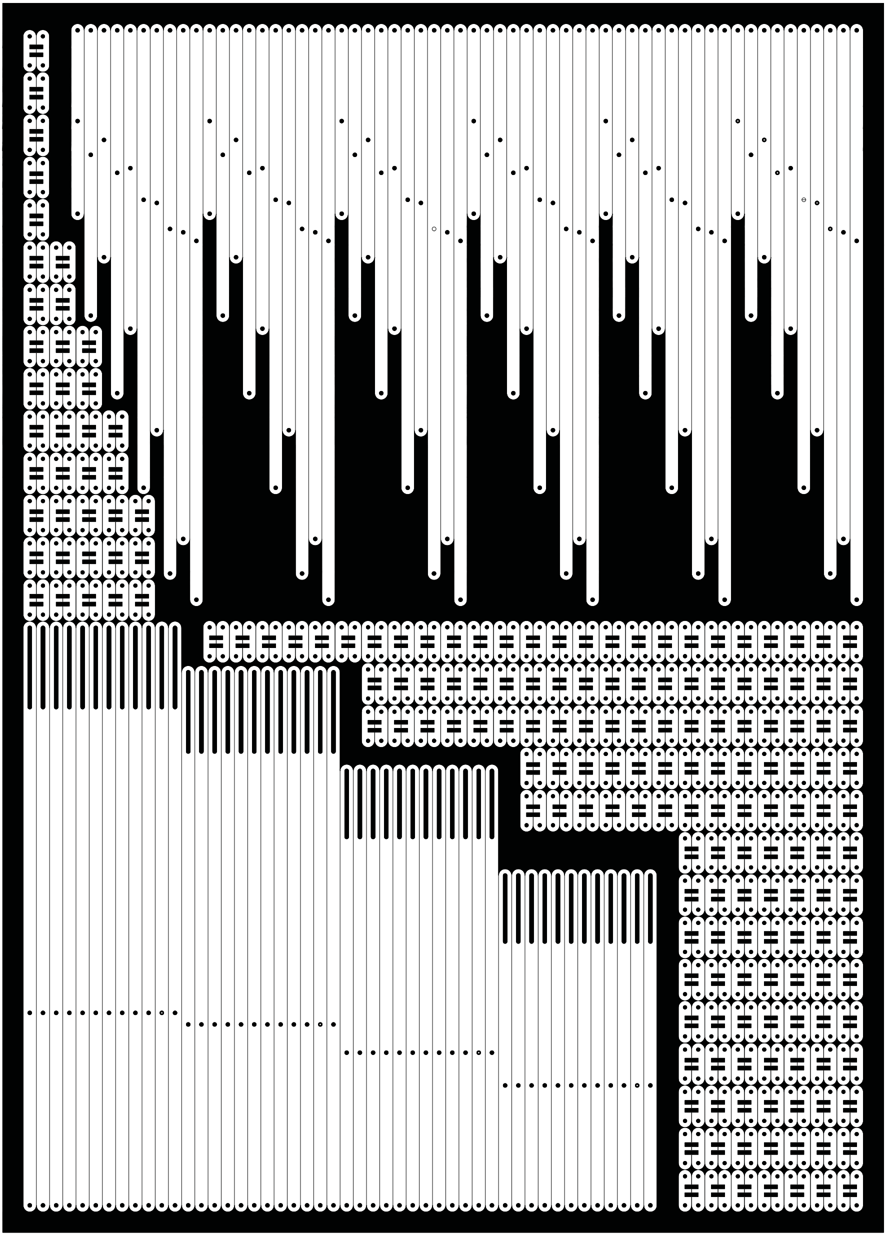


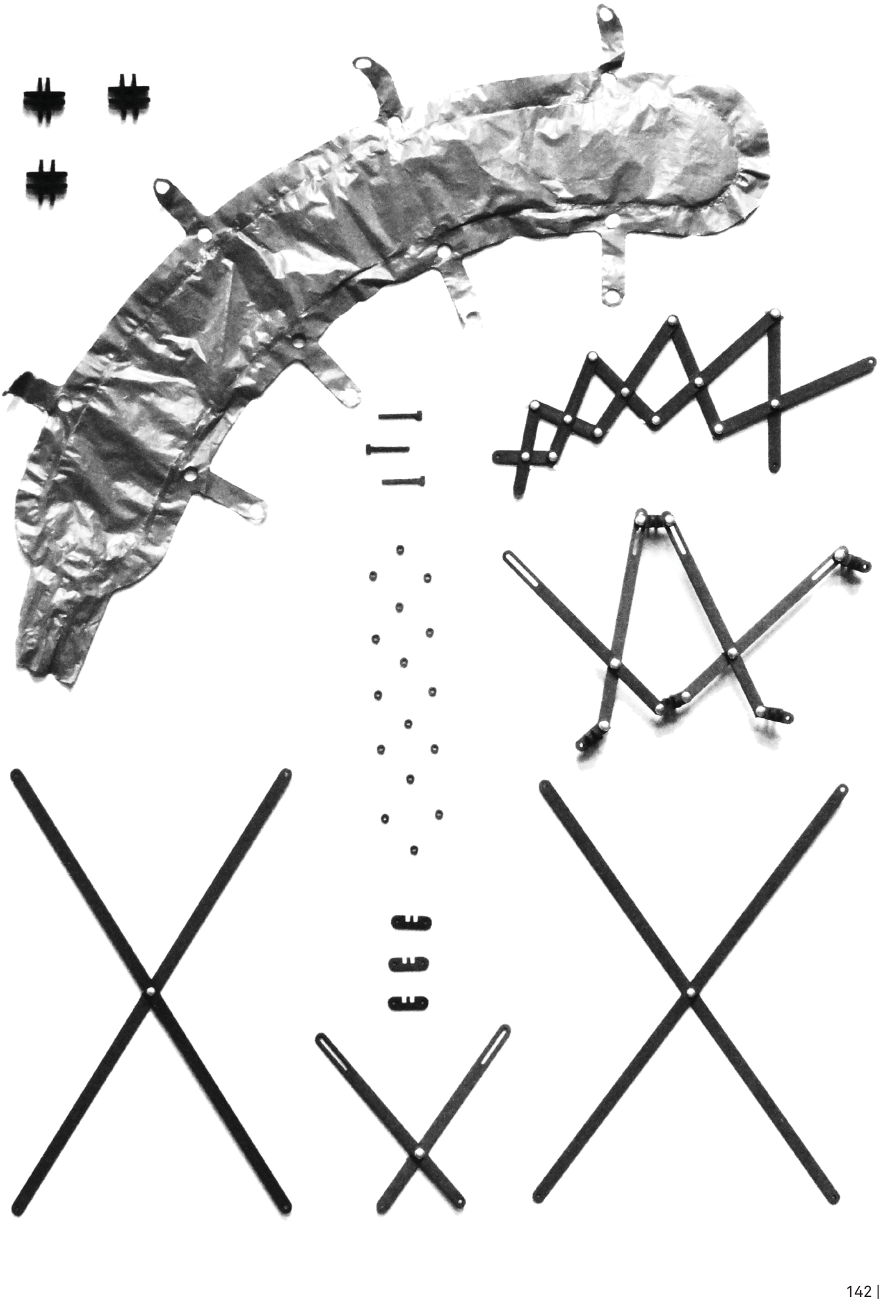
>> Prototype detail photos

> DEPLOYABLE & INFLATABLE KITE I

: 蔡旻家 Tsay, Mingka
: 楊允澤 Yang, Stanley
: 劉兆旻 Liu, Diego
: Krishna N. Patel
: Nicolas Colman

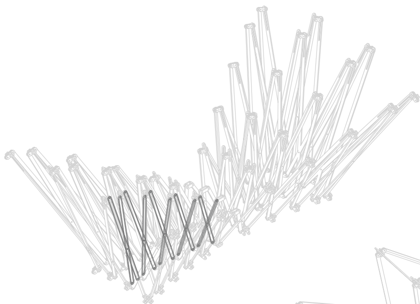

material used
Volumetric parameters
Assembly components



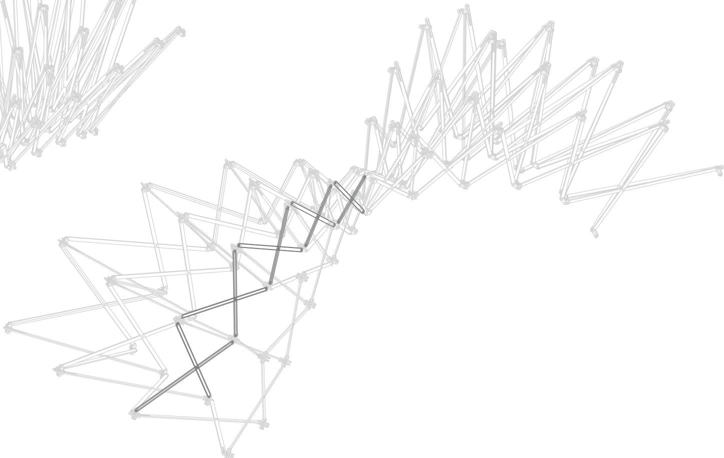


/ MODULE | ASSEMBLY

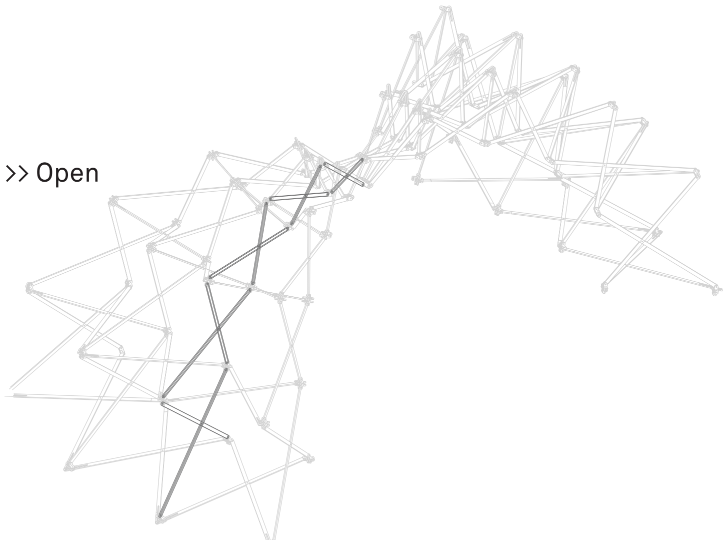
>> Closed



>> Half open

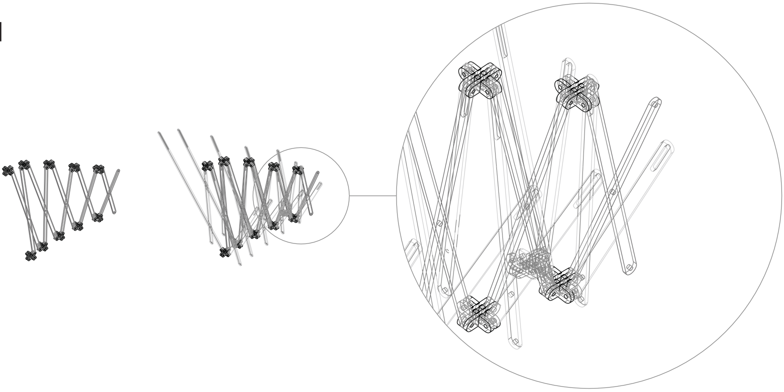


>> Open

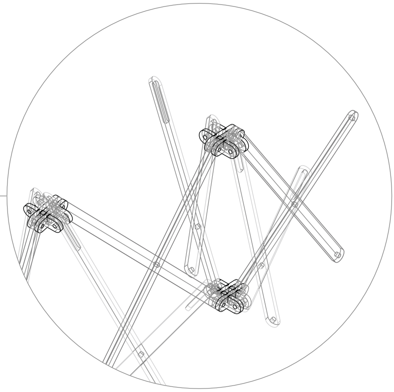


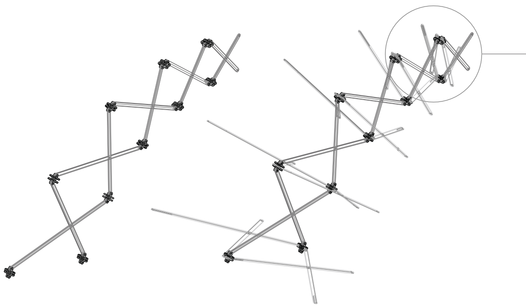
Scale 1:20 0 50cm

>> Closed

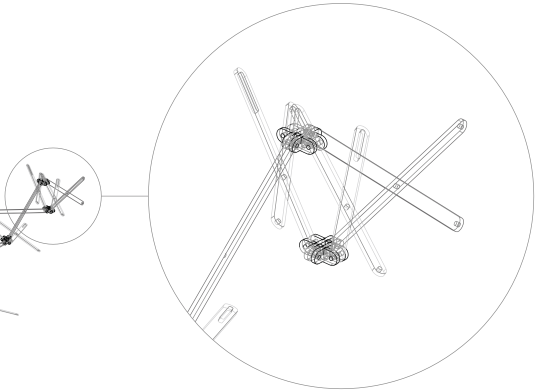


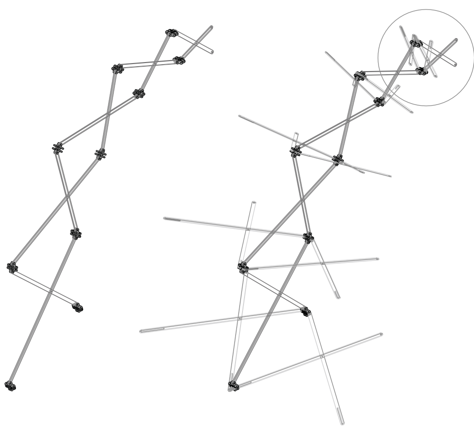
>> Half open





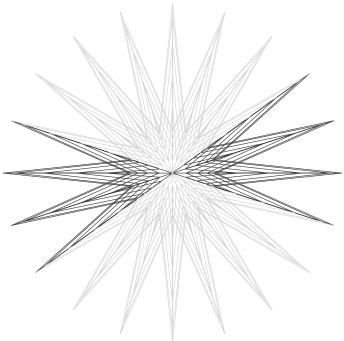
>> Open



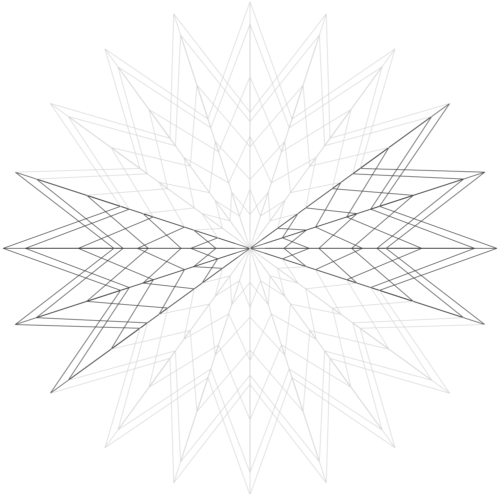


/ MODULE | PLANS

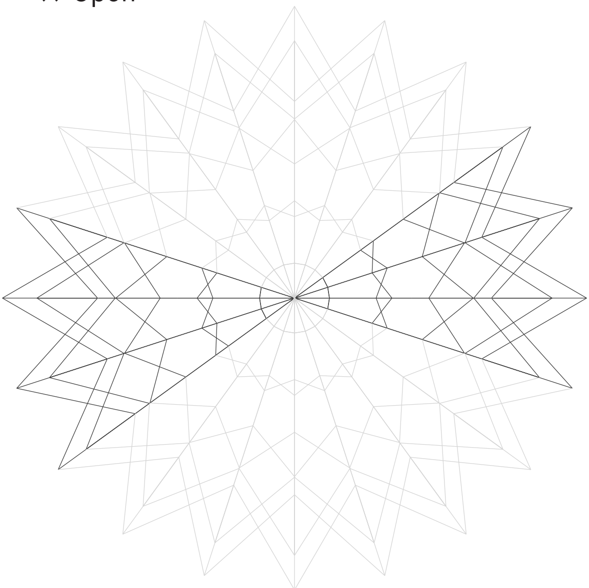
>> Closed



>> Half open



>> Open

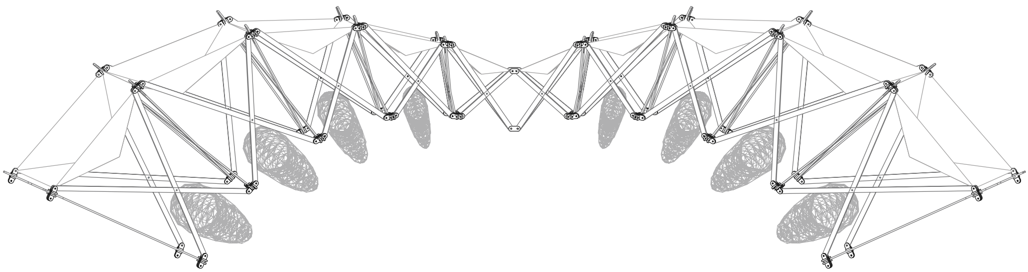


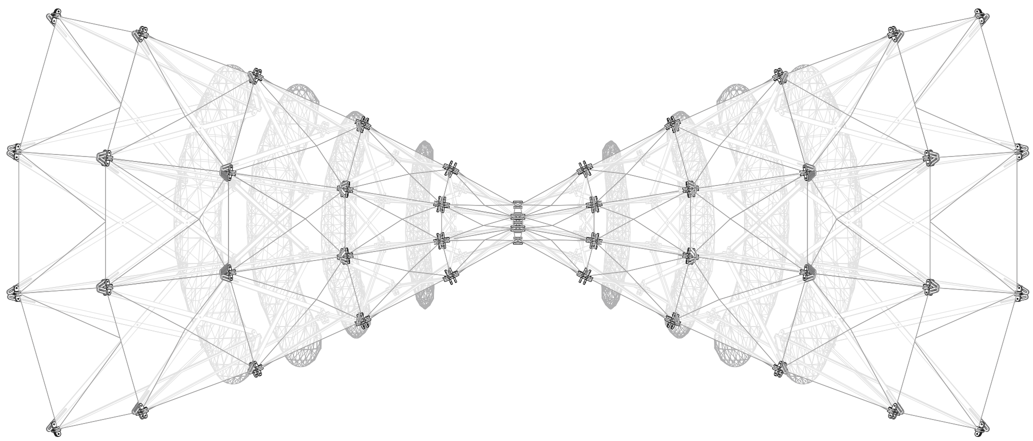
Scale 1:25

0 50cm

>> Elevation and floor plan

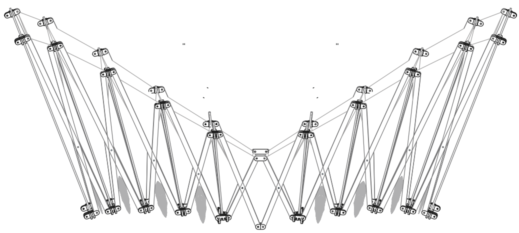
>> Half open

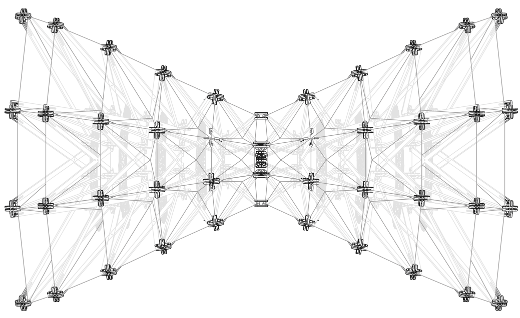




Scale 1:15

>> Elevation and floor plan
>> Closed



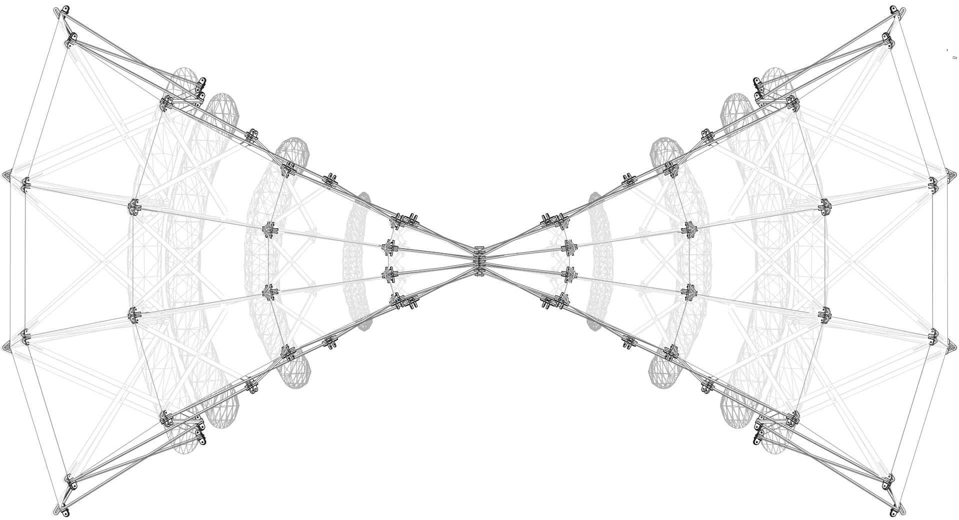


Scale 1:15

0 50cm

>> Elevation and floor plan

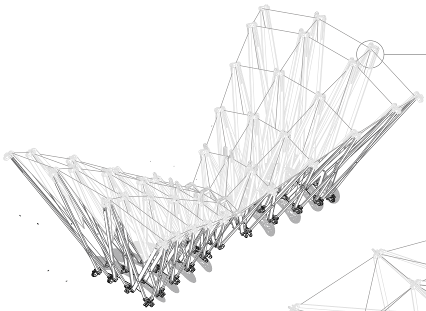
>> Open



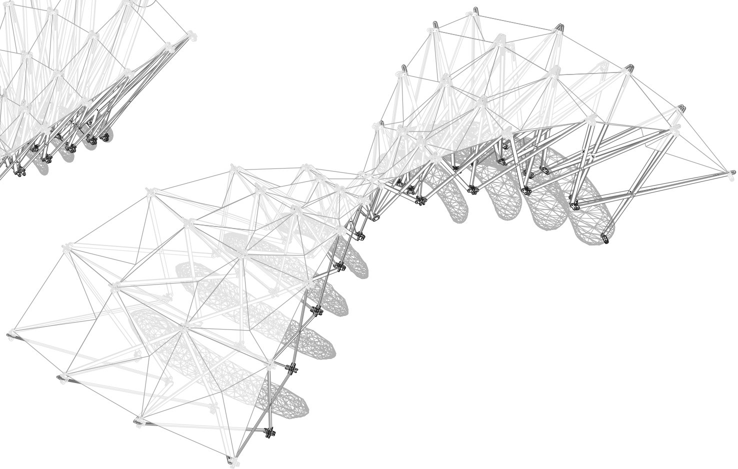
Scale 1:15 0 50cm

/ PROTOTYPE | NODES

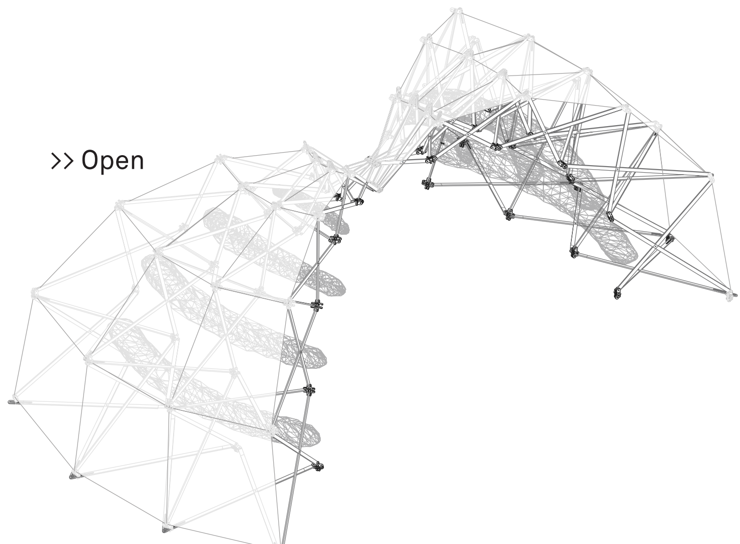
>> Closed



>> Half open



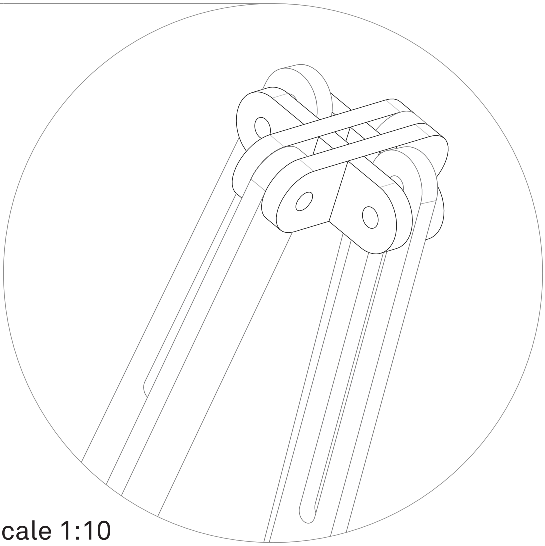
>> Open

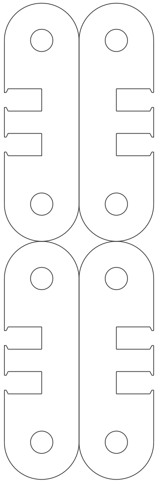


Scale 1:20 0 50cm

>> Type of connectors

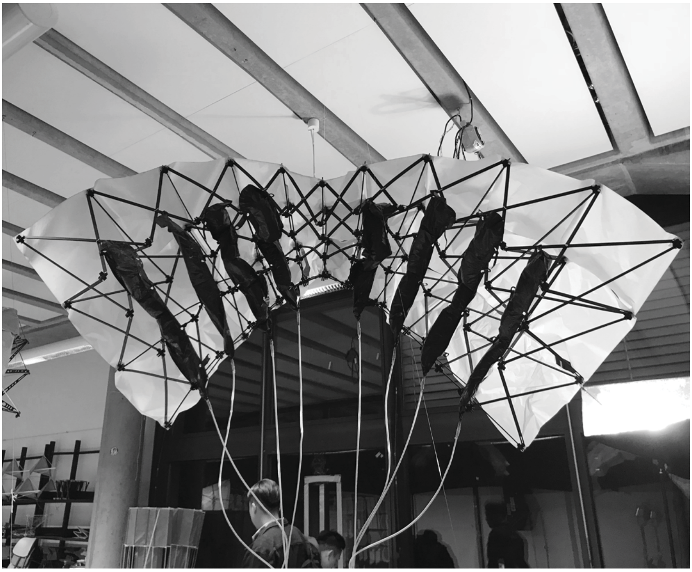
>> Node A// for Module 01//Module 02//





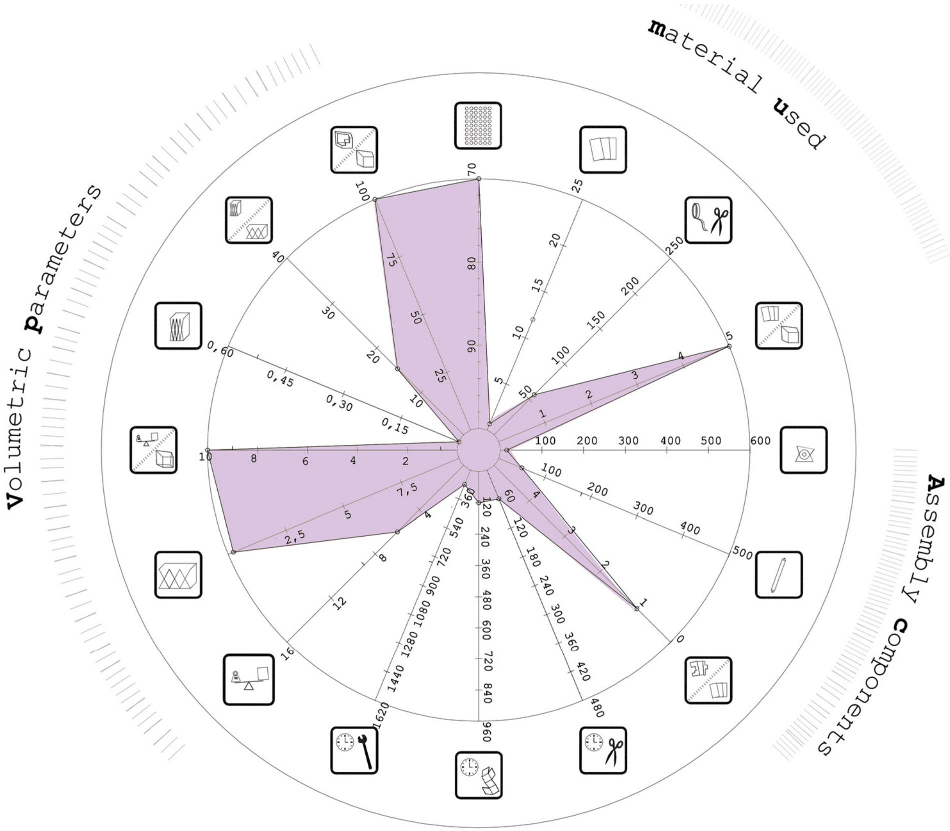
Scale 1:10

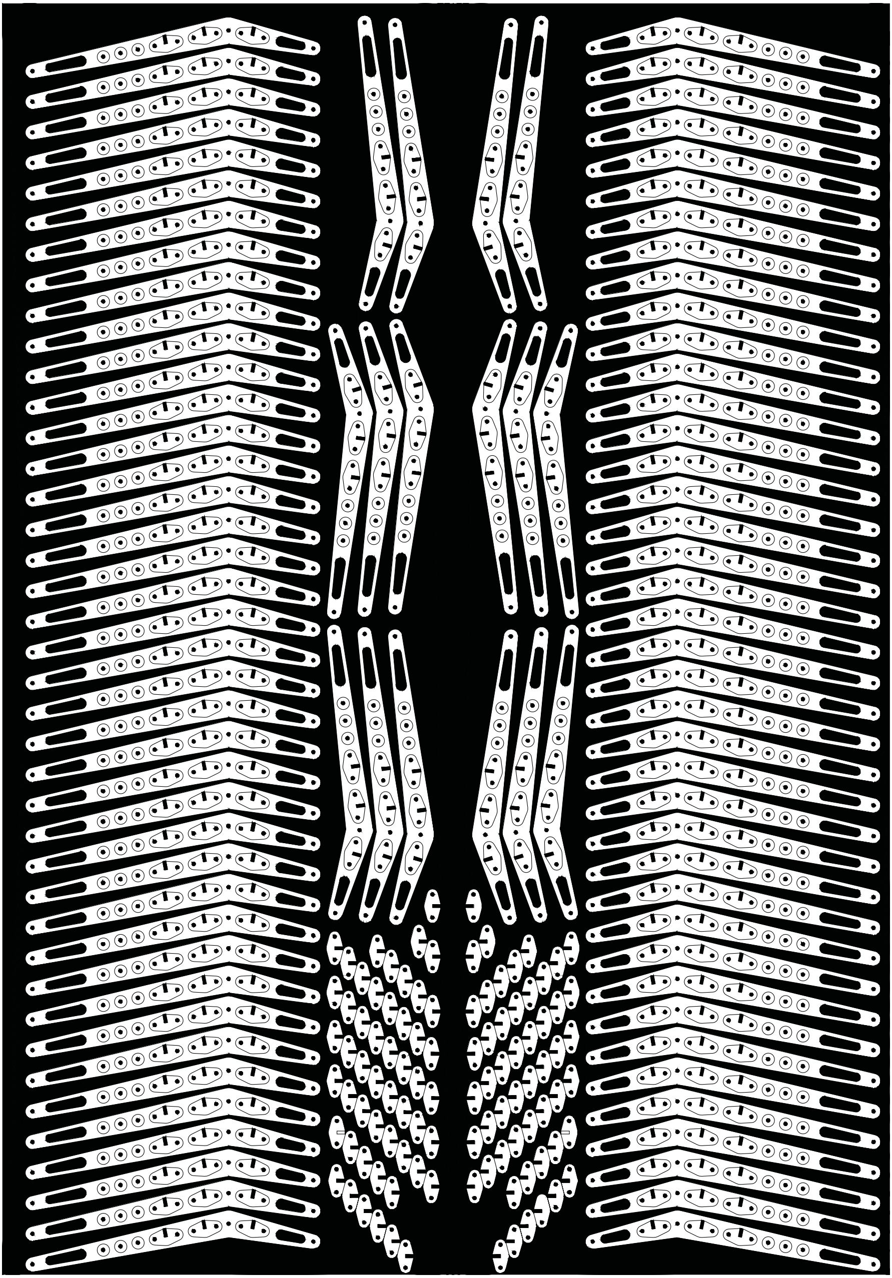
>> Prototype detail photos



> DEPLOYABLE & INFLATABLE KITE II

: 蕭仲筠 Hsiao, Yvette
: 李奇 Lee, Rich
: 蕭仲筠 Cheng, Fred
: Luis Álvarez Ayuso

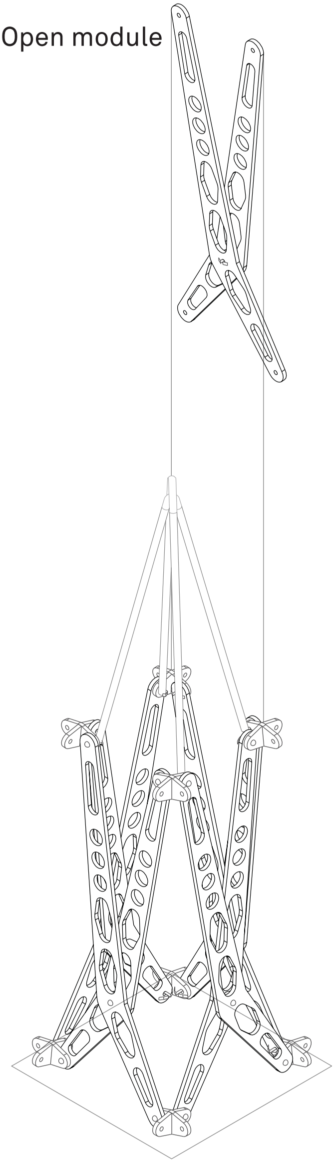

material used
Assembly Components
Volumetric parameters



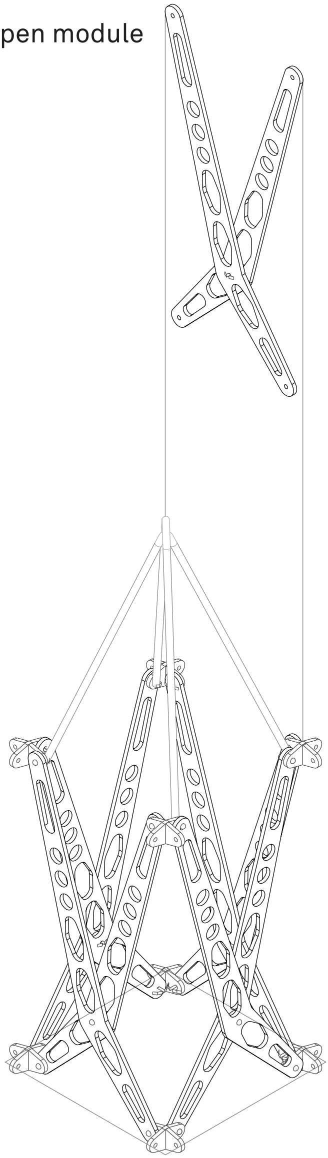
/ MODULE | ASSEMBLY

>> Module//01 of the structure

>> Open module



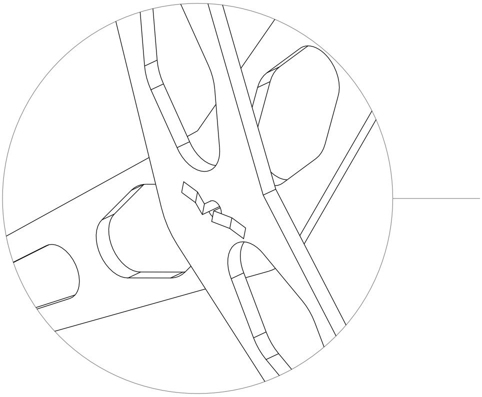
>> Half open module

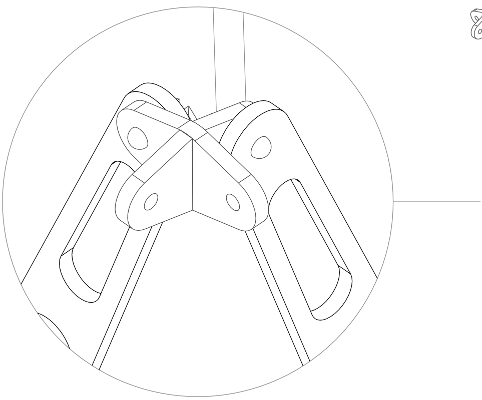


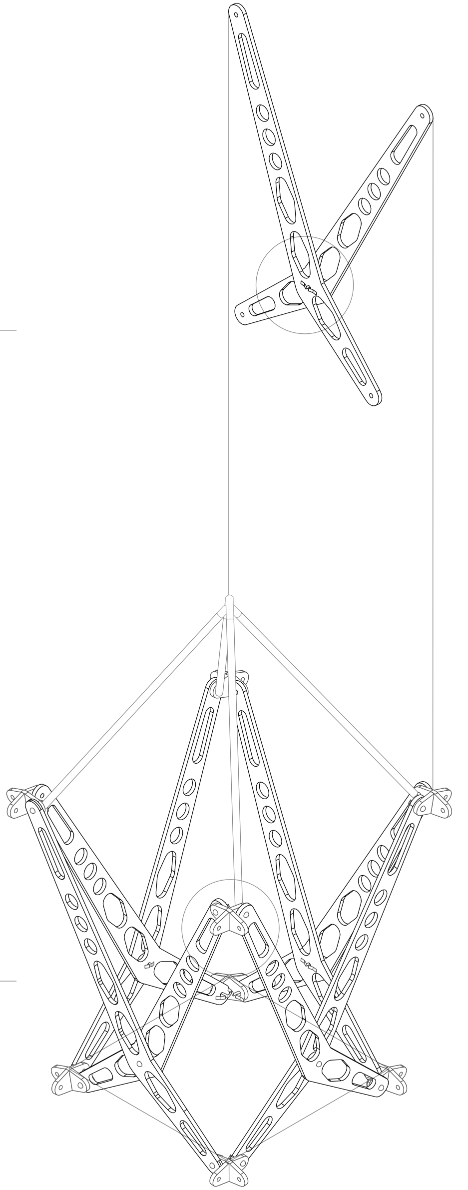
0 50cm

Scale 1:5

>> Closed module







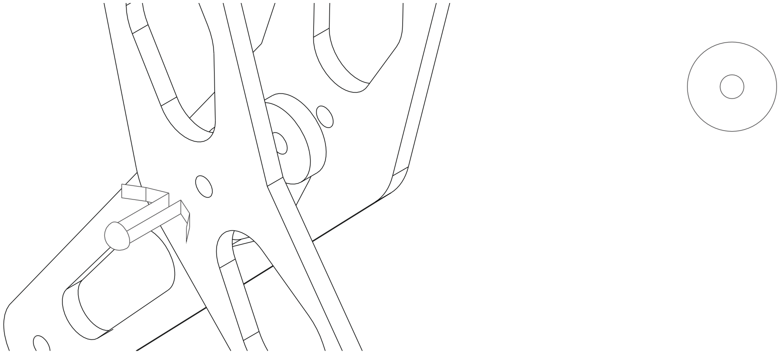
0 50cm

Scale 1:5

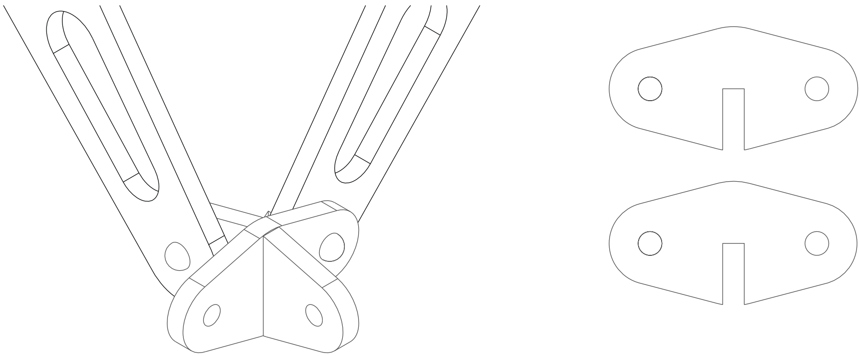
/ NODES

>> Type of connectors

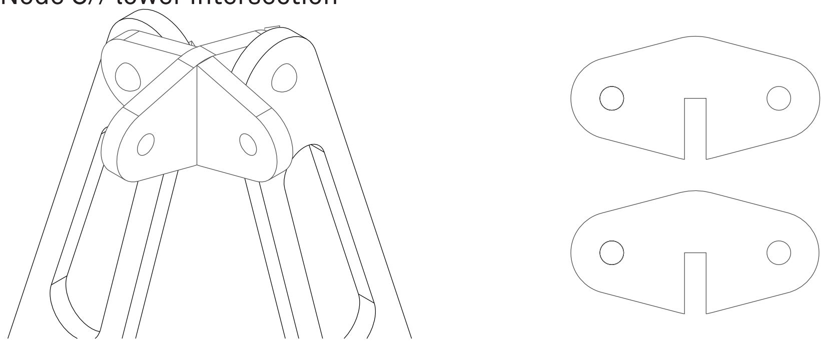
>> Node A// two pieces



>> Node B// one piece



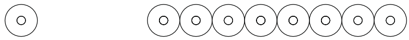
>> Node C// lower intersection



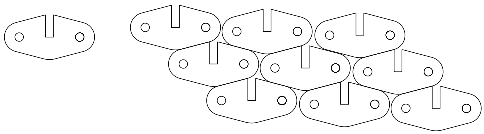
Scale 1:1

>> Type of bars

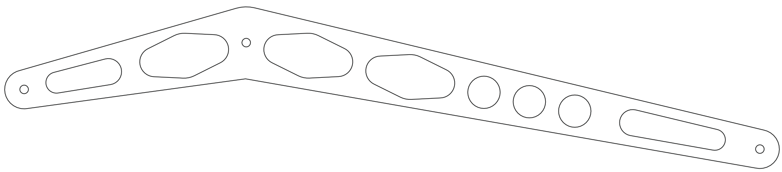
>> Bar A



>> Bar B



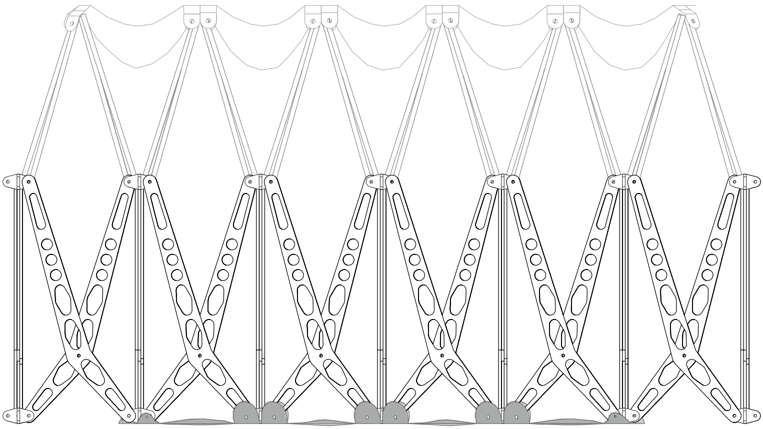
>> Bar C

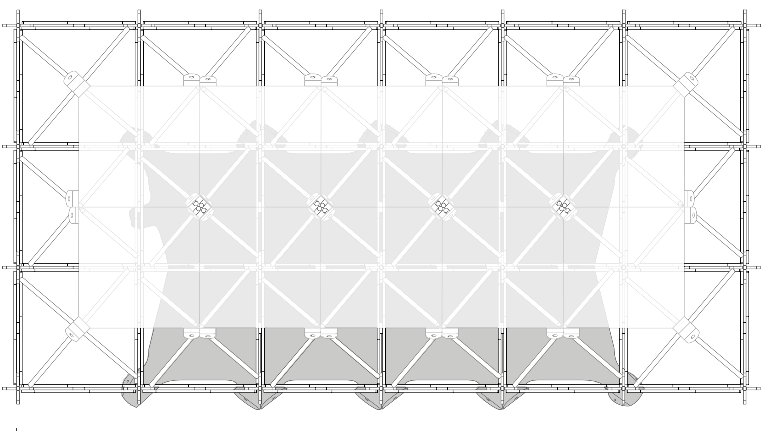


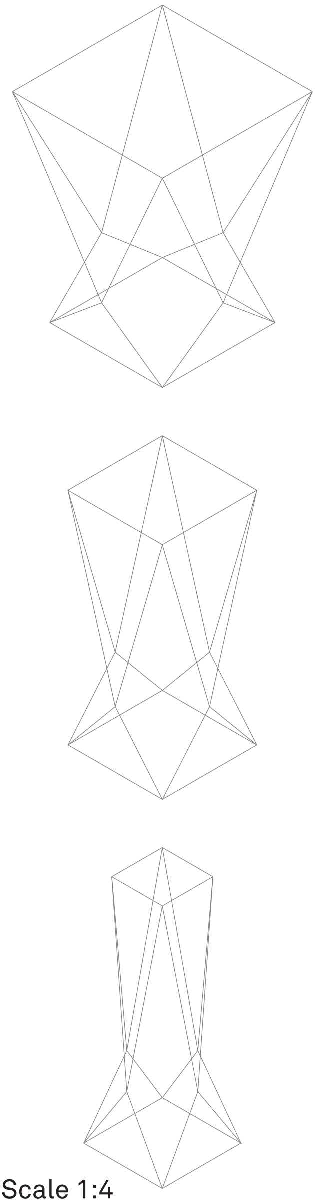
Scale 1:2

>> Prototype detail photo

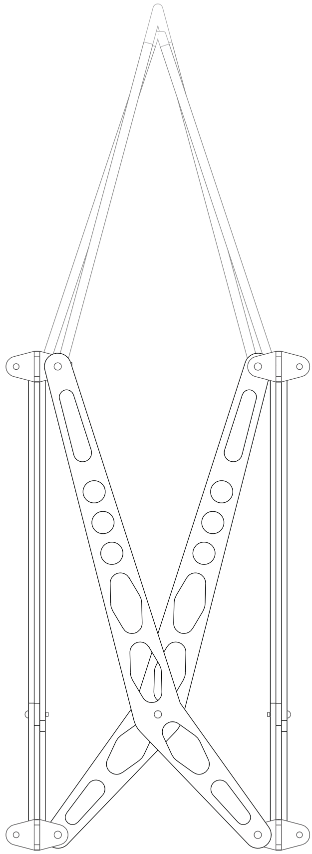
>> Elevation and floor plan

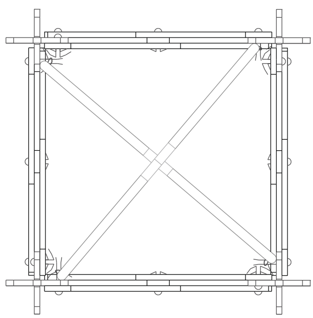




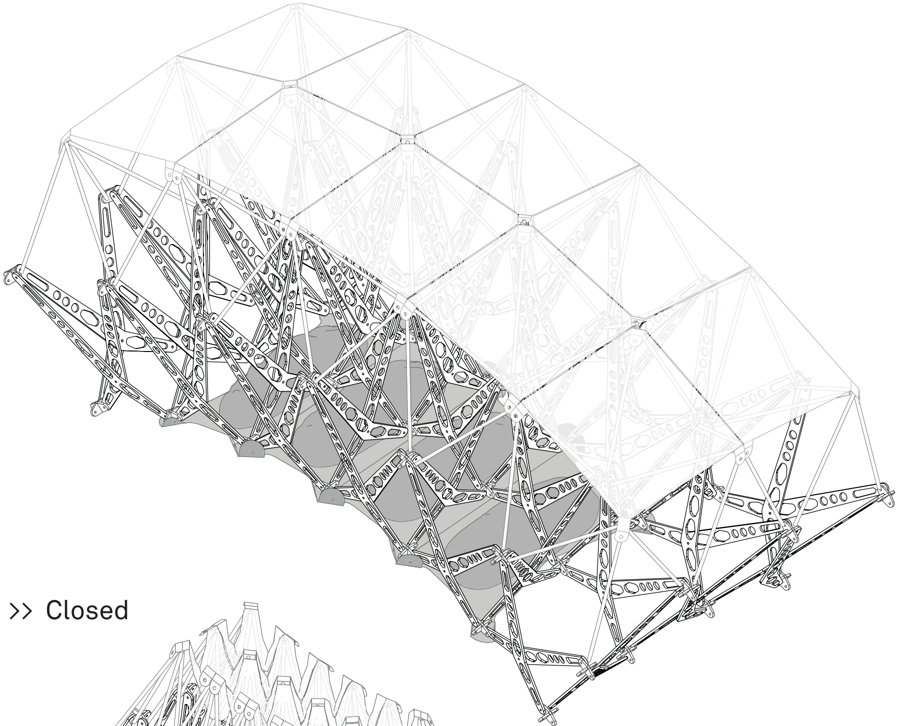


Scale 1:4

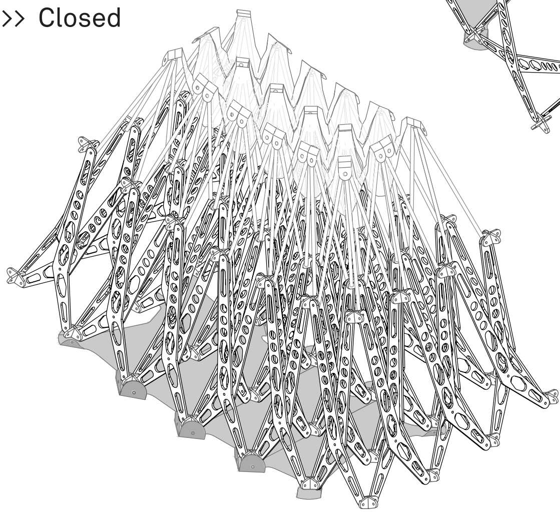




>> Open

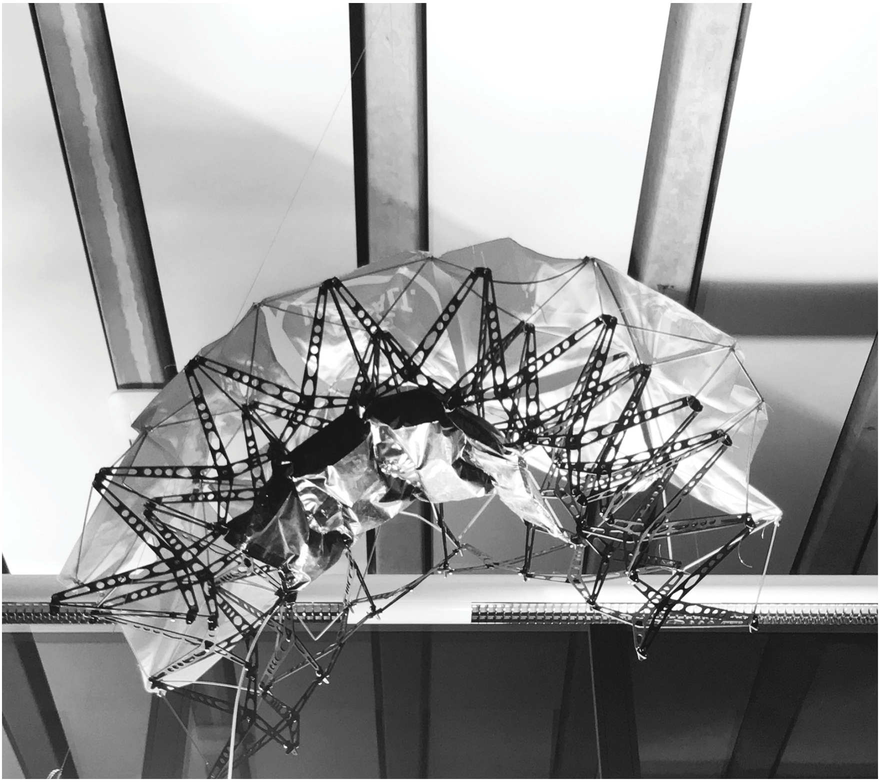


>> Closed



Scale 1:10 0 50cm

>> Prototype detail photos



Imprint

CoLab
Collaborative Design Laboratory

TU Berlin
Fakultät VI Planen Bauen Umwelt
Institut für Architektur
Sekretariat A28, Raum A812
Straße des 17. Juni 152
10623 Berlin
Telefon: +49 (0) 30 314 72730
info@colab.tu-berlin.de
www.colab.tu-berlin.de

Universitätsverlag der TU Berlin, 2020
http://verlag.tu-berlin.de
Fasanenstr. 88, 10623 Berlin
Tel.: +49 (0)30 314 76131 / Fax: -76133
publikationen@ub.tu-berlin.de

Print: docupoint GmbH

ISBN 978-3-7983-3153-2 (print)
ISBN 978-3-7983-3154-9 (online)

ISSN 2568-2865 (print)
ISSN 2568-2873 (online)

Published online on the institutional repository of the
Technische Universität Berlin:
DOI 10.14279/depositonce-9878
http://dx.doi.org/10.14279/depositonce-9878

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data are available on the Internet at http://dnb.dnb.de.

www.colab.tu-berlin.de

Universitätsverlag der TU Berlin
ISBN 978-3-7983-3153-2 (print)
ISBN 978-3-7983-3154-9 (online)