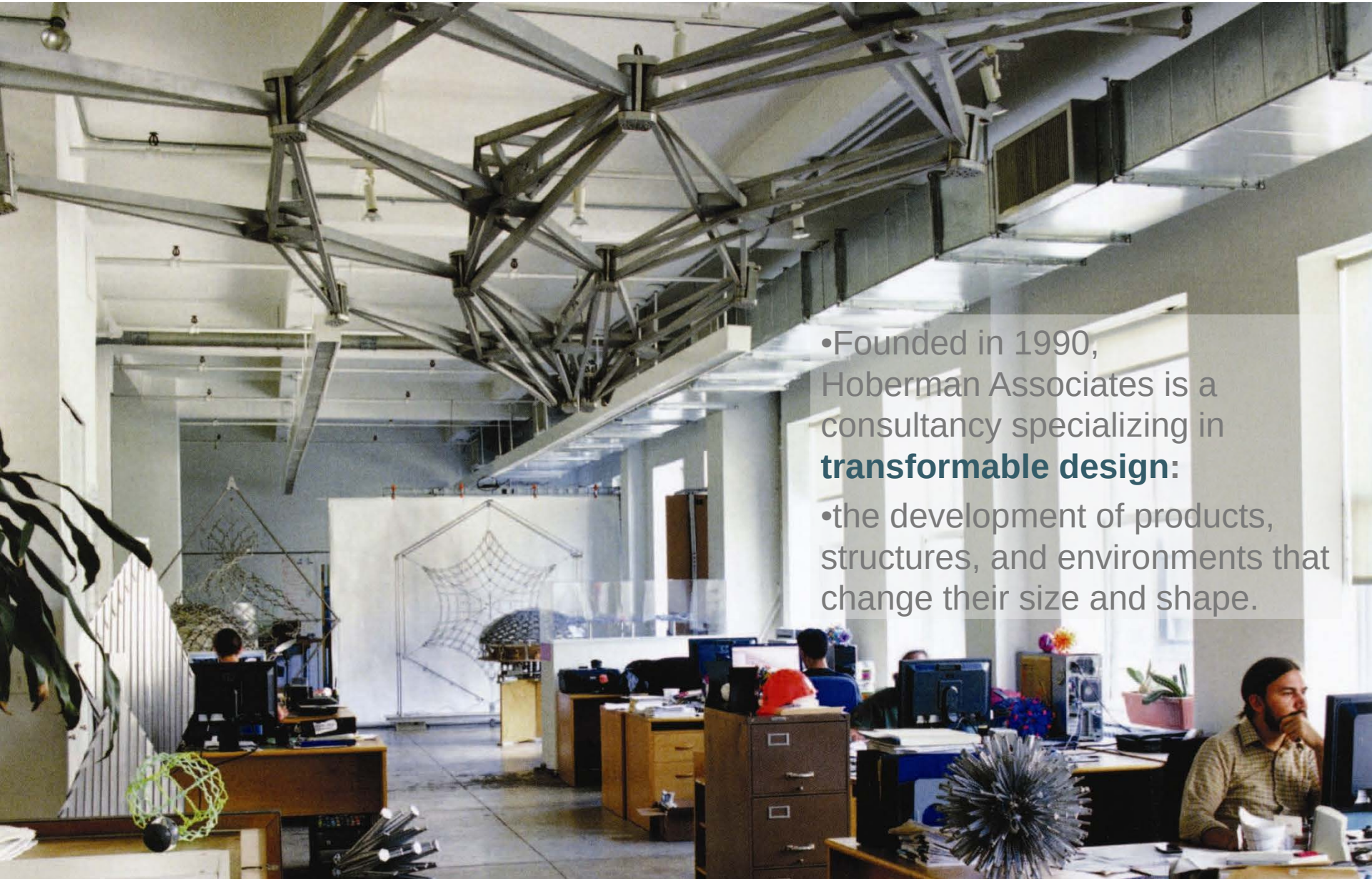
MIT Class 6.S080 (AUS)

Mechanical Invention through Computation

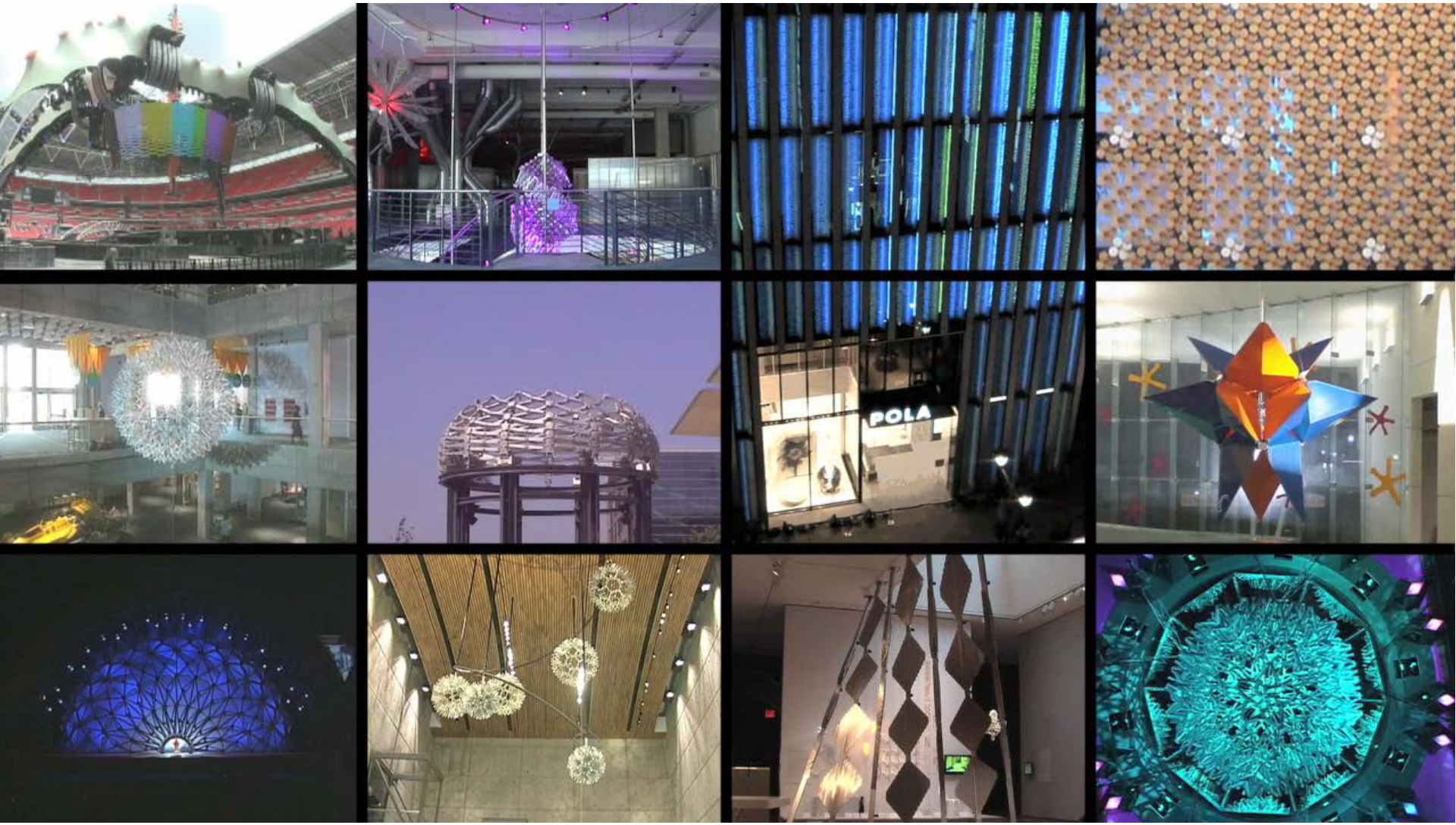
Introduction

Background



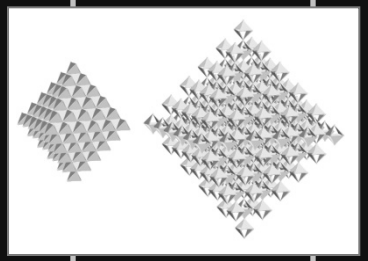
- Founded in 1990, Hoberman Associates is a consultancy specializing in **transformable design:**
- the development of products, structures, and environments that change their size and shape.

Background

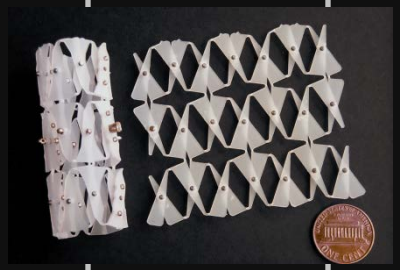


Scale

nano



medical



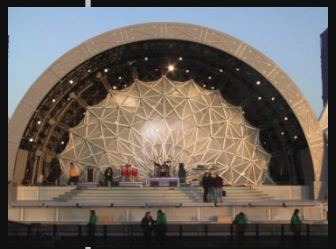
toys

furniture

tents

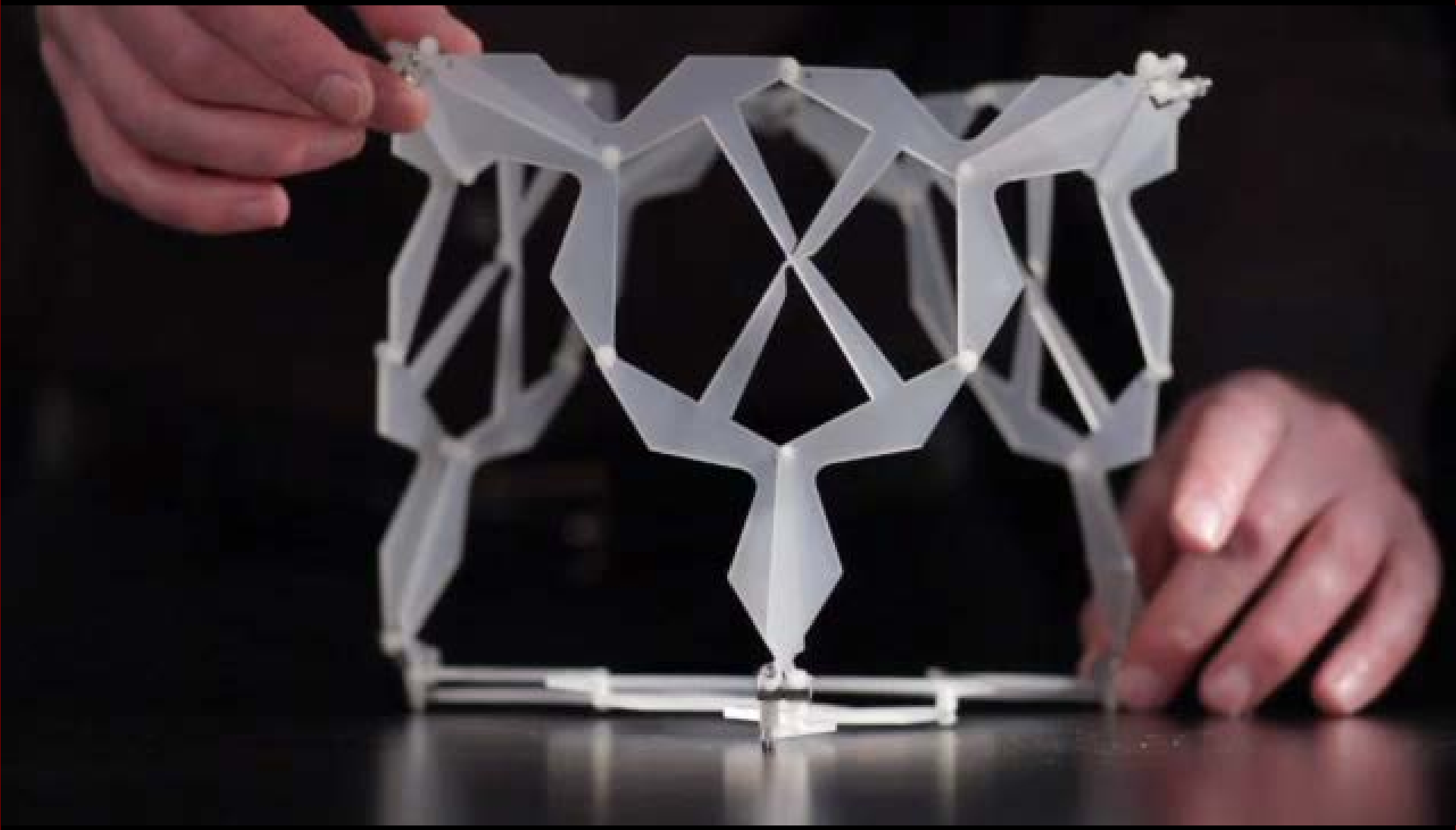
shelter

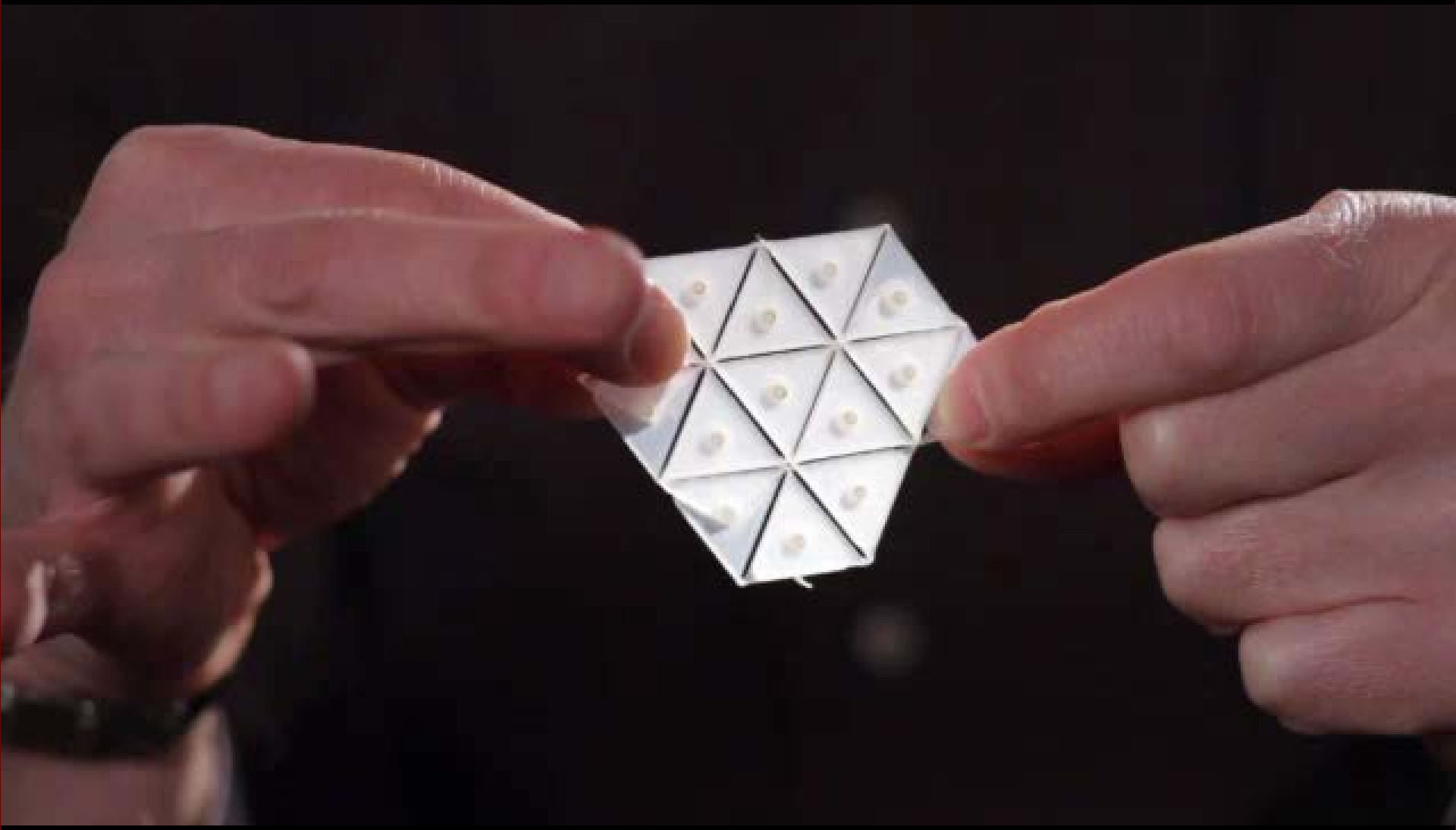
architecture

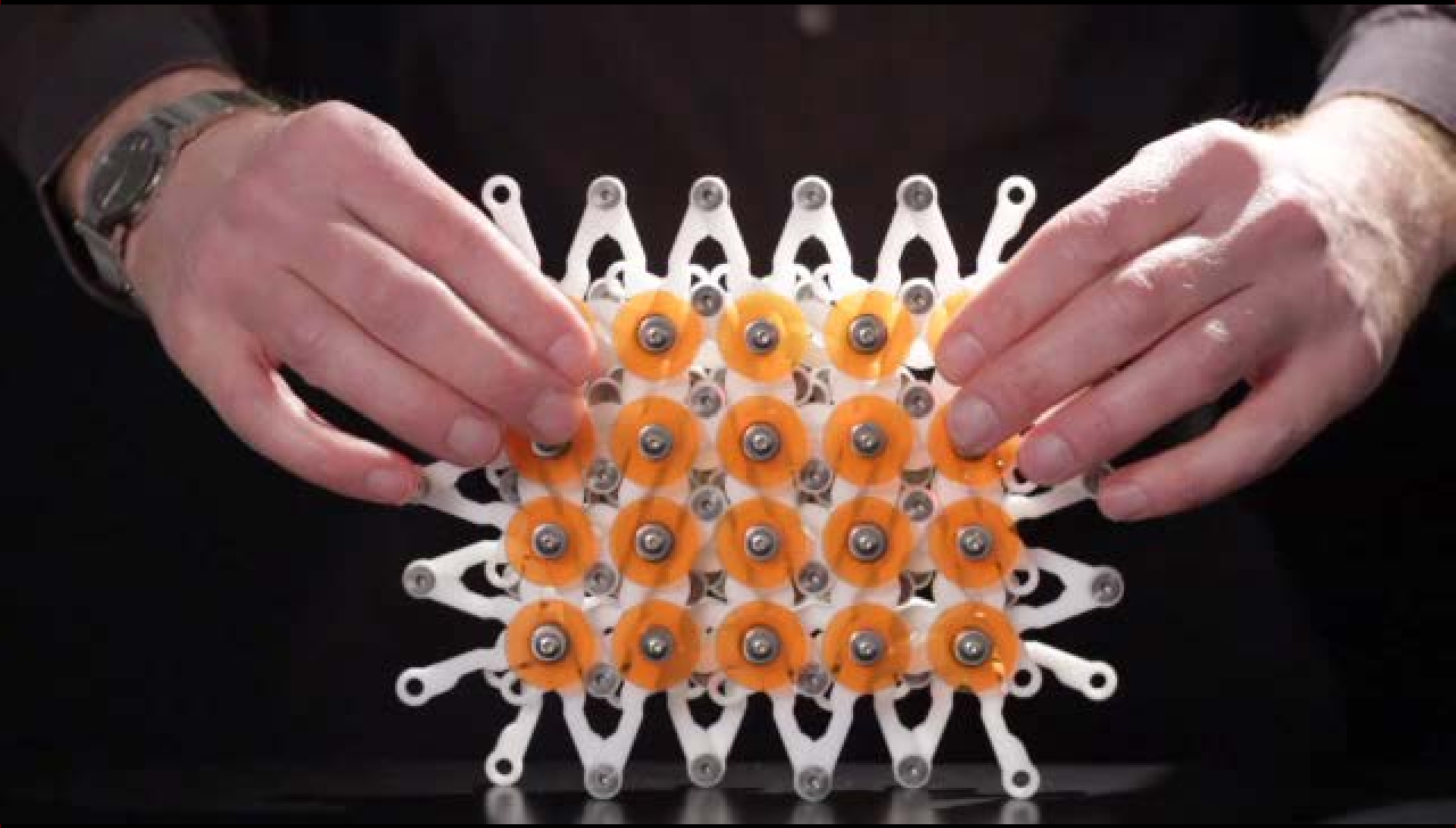


0.001m | 0.01m | 0.10m | 1.0m | 10m | 100m | 1000m

Prototypes







spectrum of creativity

objective ..... expressive

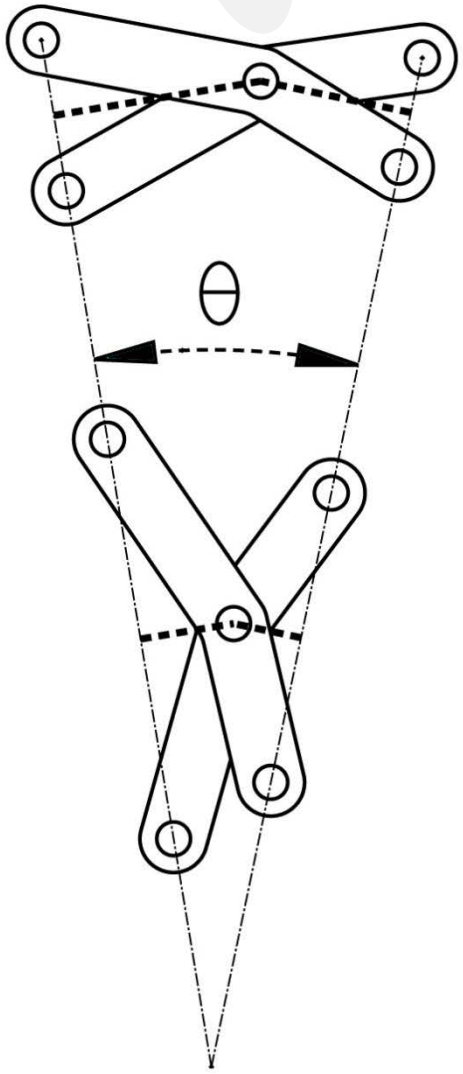
science ..... art/design

“Thought is only a flash between two long nights, but this flash is everything.”

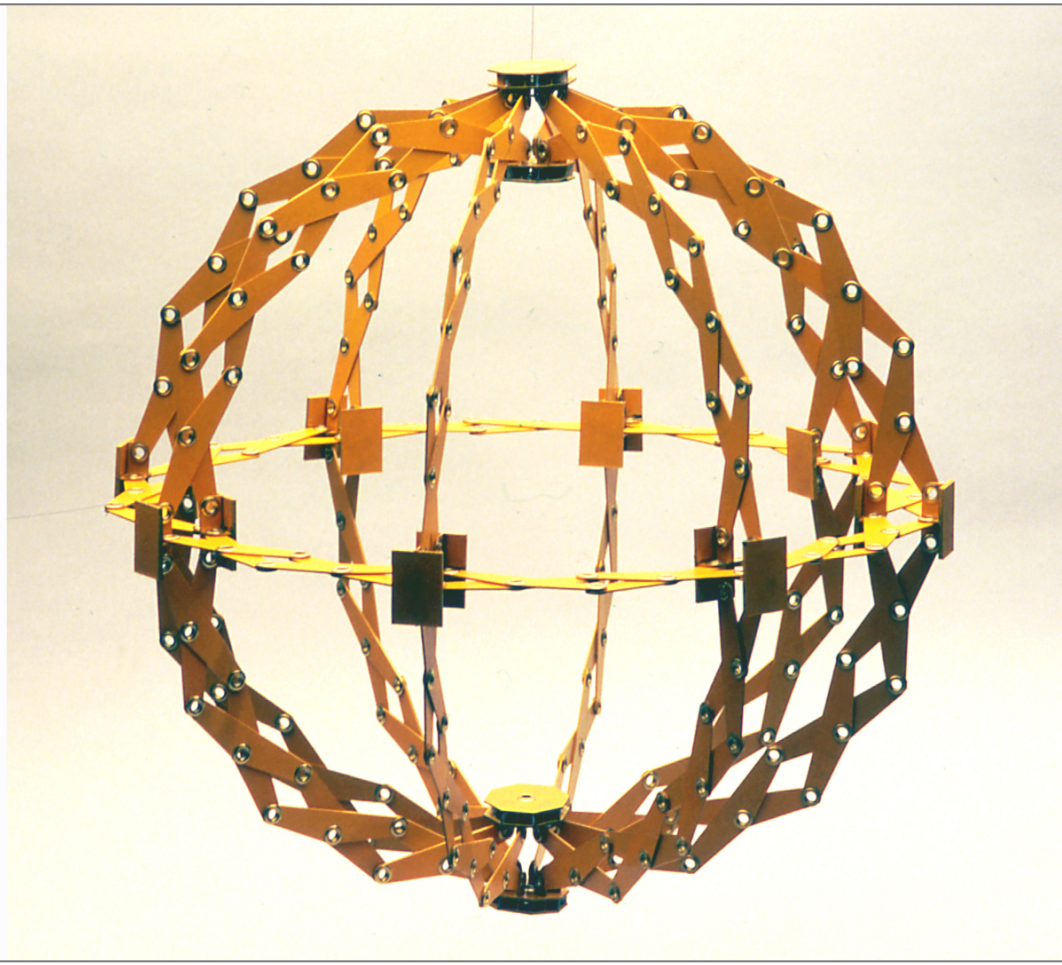
Henri Poincare

1854 - 1912

I had a flash in 1988.



1989



United States Patent [19]

Hoberman

[11] **Patent Number: 4,942,700**

[45] **Date of Patent: Jul. 24, 1990**

[54] **REVERSIBLY EXPANDABLE DOUBLY-CURVED TRUSS STRUCTURE**

[76] Inventor: **Charles Hoberman,** 472 Greenwich St., New York, N.Y. 10013

[21] Appl. No.: **263,582**

[22] Filed: **Oct. 27, 1988**

[51] **Int. Cl.**[5] **E04B 1/52**

[52] **U.S. Cl.** **52/81;** 52/109; 52/646

[58] **Field of Search** ..... 52/109, 646, 81; 135/29 R

[56] **References Cited**

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23,503	4/1859	Selden	135/25 R
1,255,182	2/1918	Krupski	135/25 R
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3,700,070	10/1972	King	52/109
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Primary Examiner—Henry E. Raduazo

Attorney, Agent, or Firm—Sprung Horn Kramer & Woods

57]

A loop-a comp

least three scissors-pairs, at least two of the pairs comprising:

two essentially identical rigid angulated strut elements each having a central and two terminal pivot points with centers which do not lie in a straight line, each strut being pivotally joined to the other of its pair by their central pivot points,

each pair being pivotally joined by two terminal pivot points to two terminal pivot points of another pair in that,

(a) the terminal pivot points of each of the scissors-pairs are pivotally joined to the terminal pivot points of the adjacent pair such that both scissors-pairs lie essentially in the same plane, or

(b) the terminal pivot points of a scissors-pair are each pivotally joined to a hub element which is small in diameter relative to the length of a strut element, and these hub elements are in turn joined to the terminal pivot points of another scissors-pair, such that the plane that one scissors-pair lies in forms an angle with the plane that the other scissors-pair lies in, the axes passing through the pivot points of one of the scissors-pair not being parallel to the axes of the other scissors-pair,

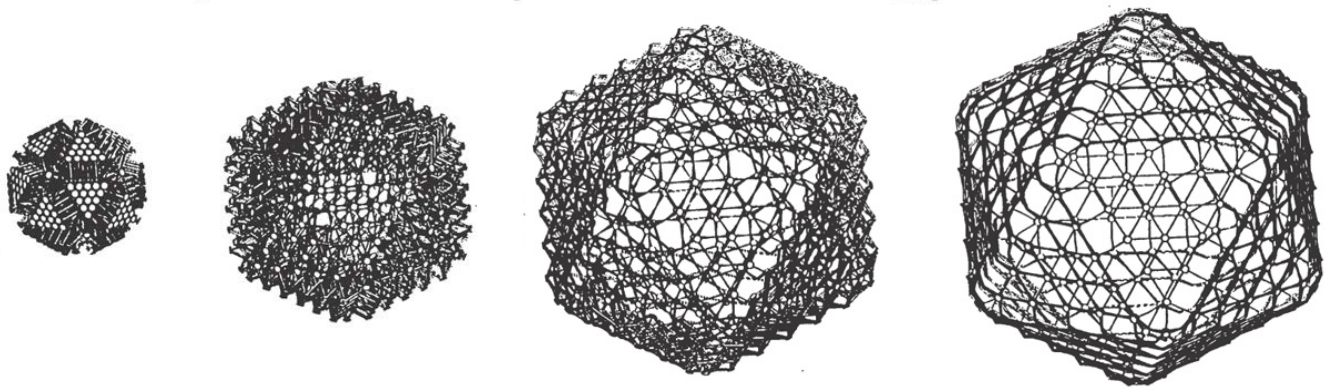
where a closed loop-assembly is thus formed of scissors-pairs, and this loop-assembly can freely fold and unfold without bending or distortion of any of its elements, and

a line that intersects and is perpendicular to the axes of any two terminal pivot points is non-parallel with at least two other similarly formed lines in the assembly,

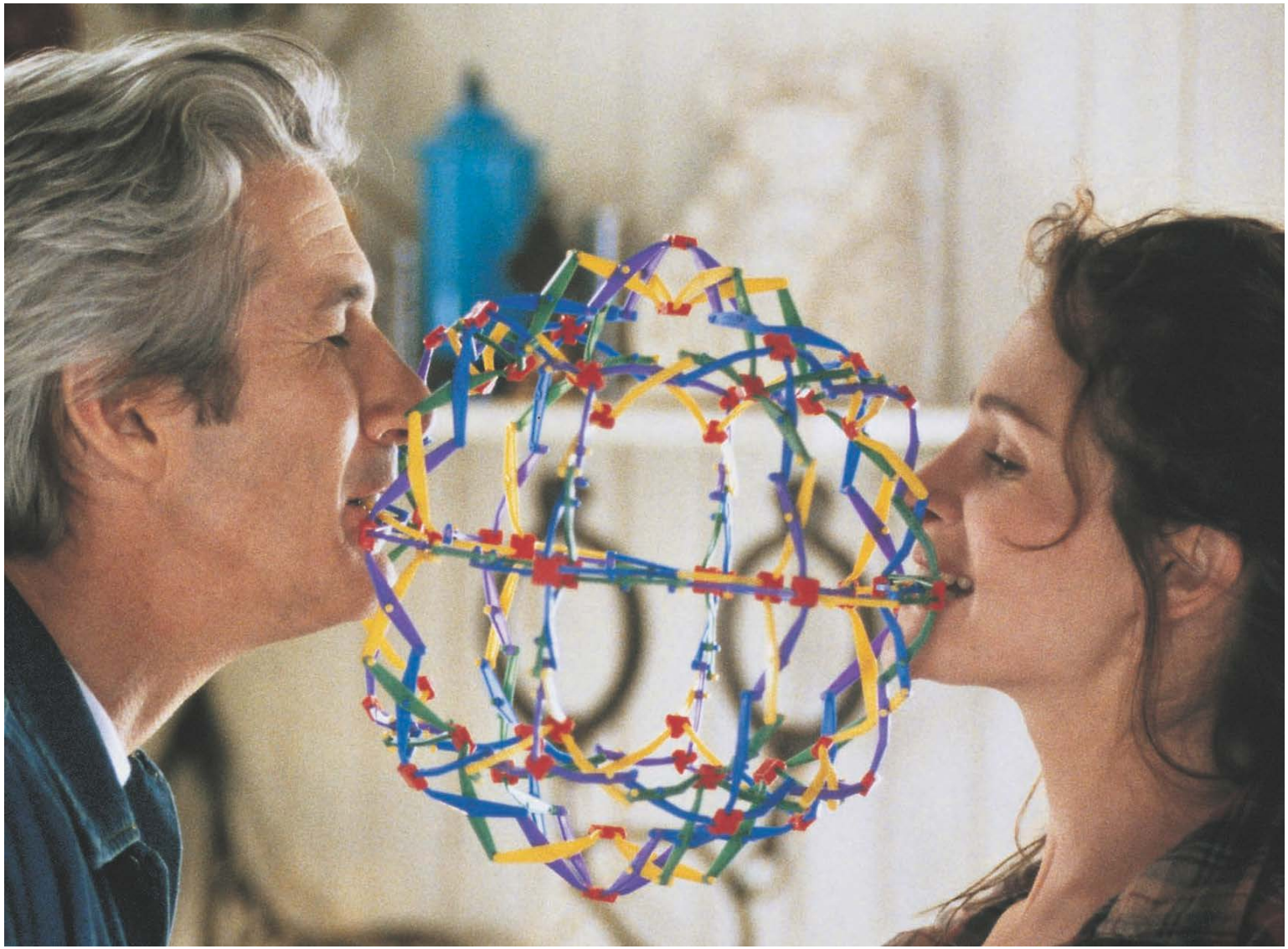
the angles formed between said lines remaining constant

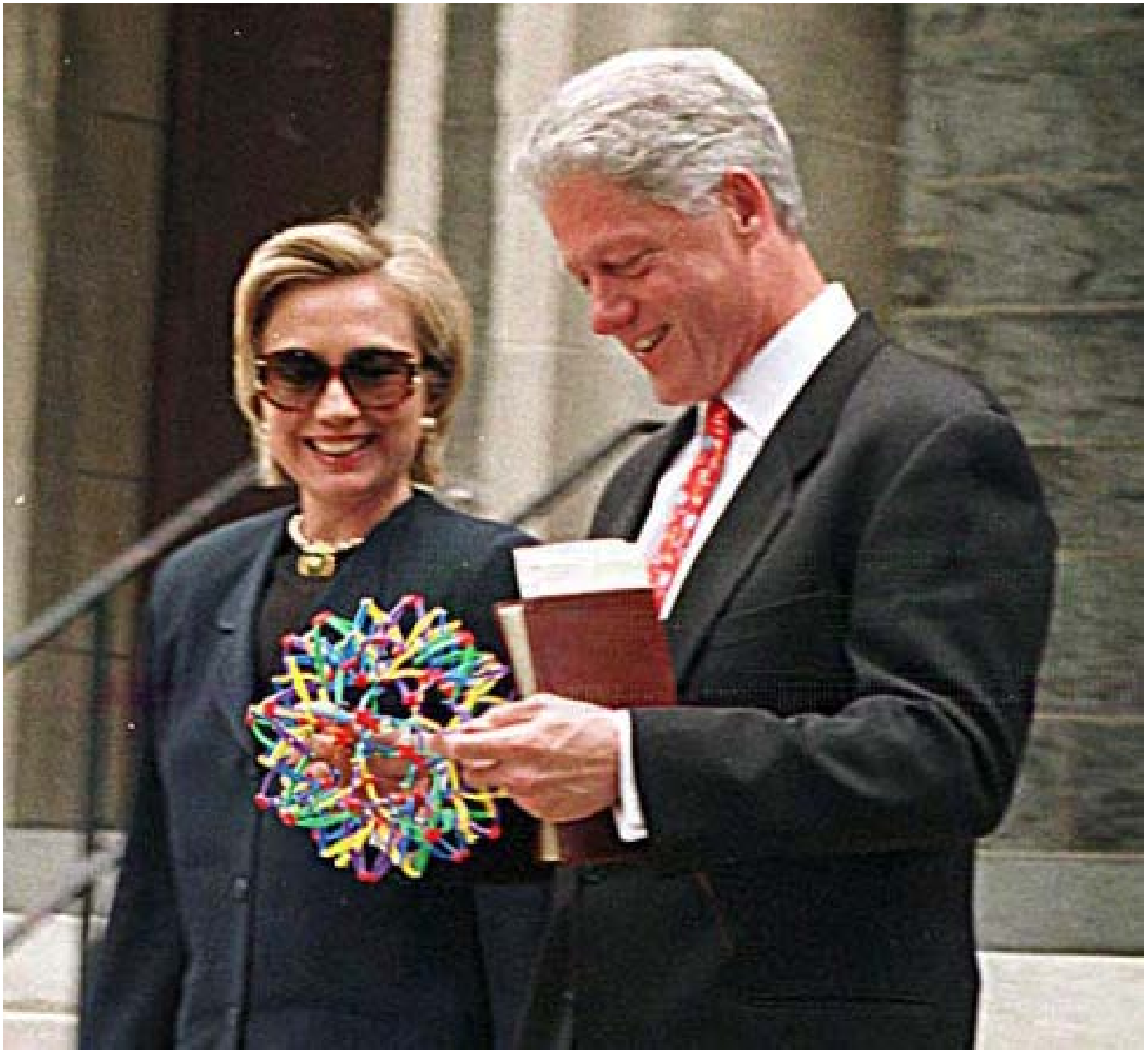
ded an

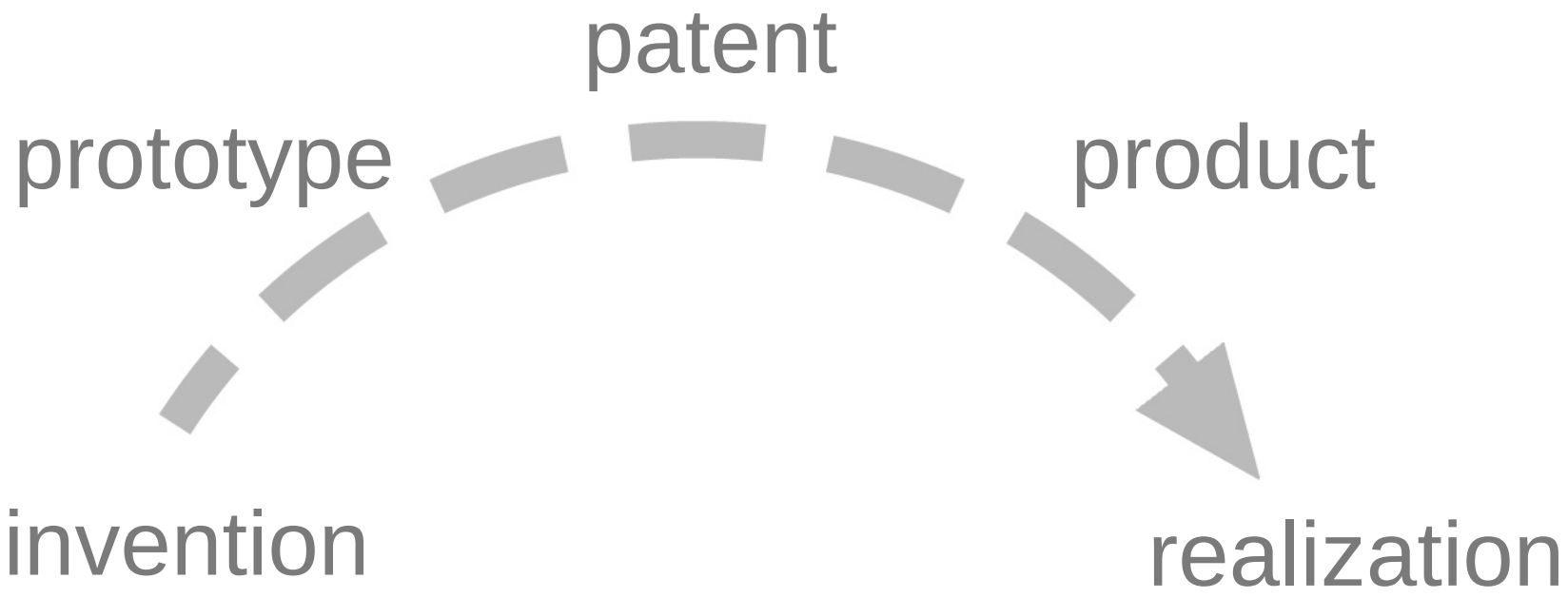
awing



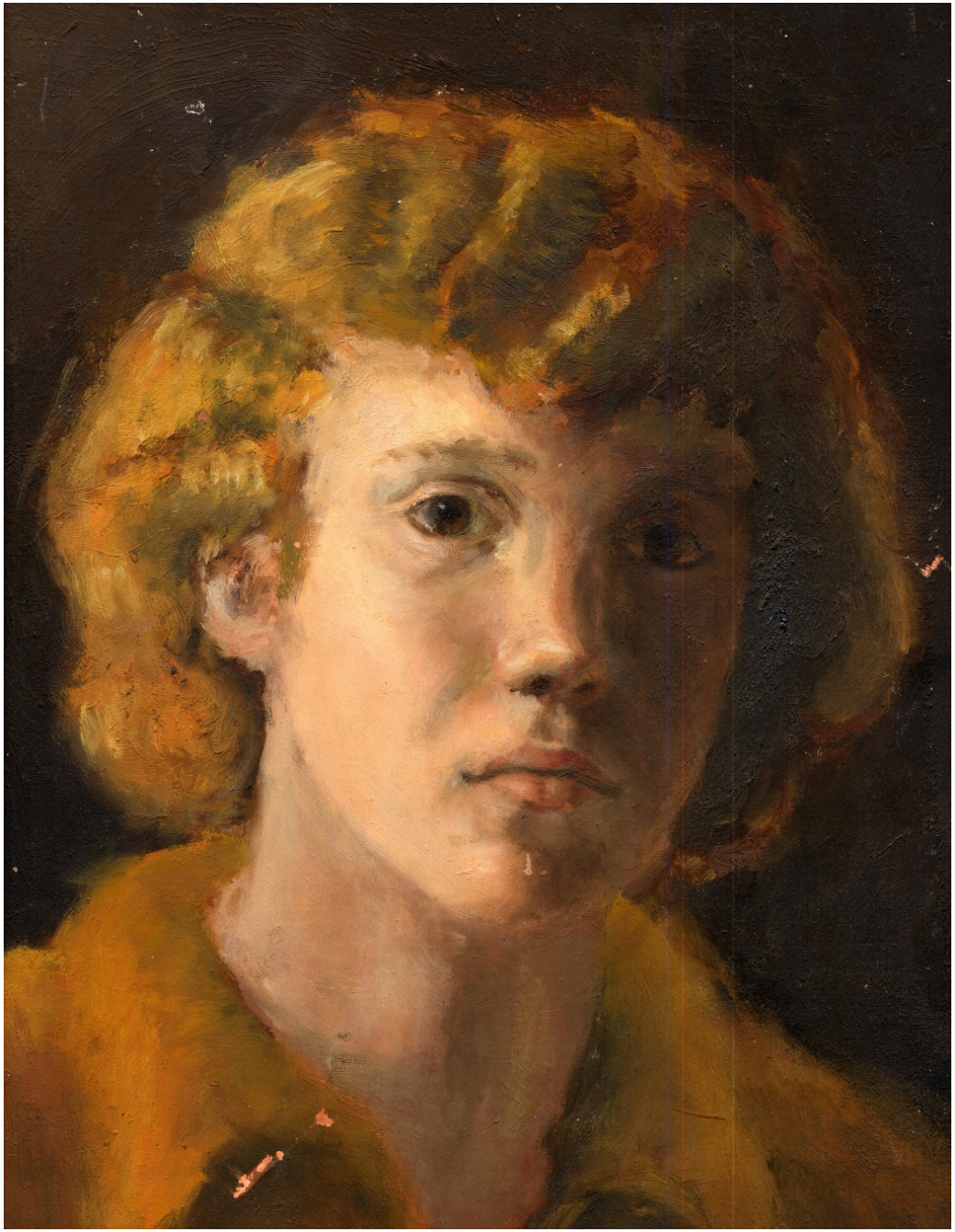

WORLD'S
BEST
BOSS



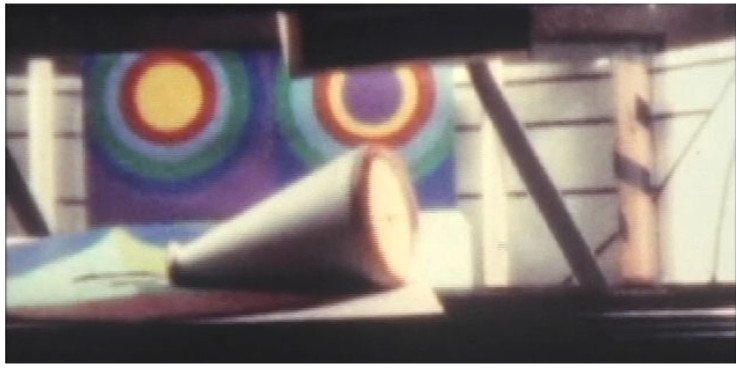



patent
prototype
product
invention
realization

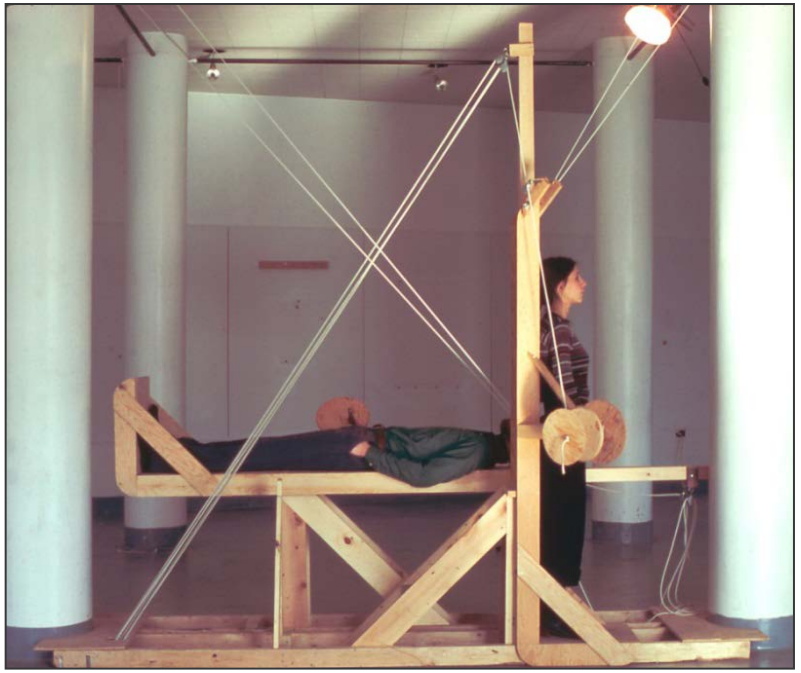
Where
does the
flash come
from?

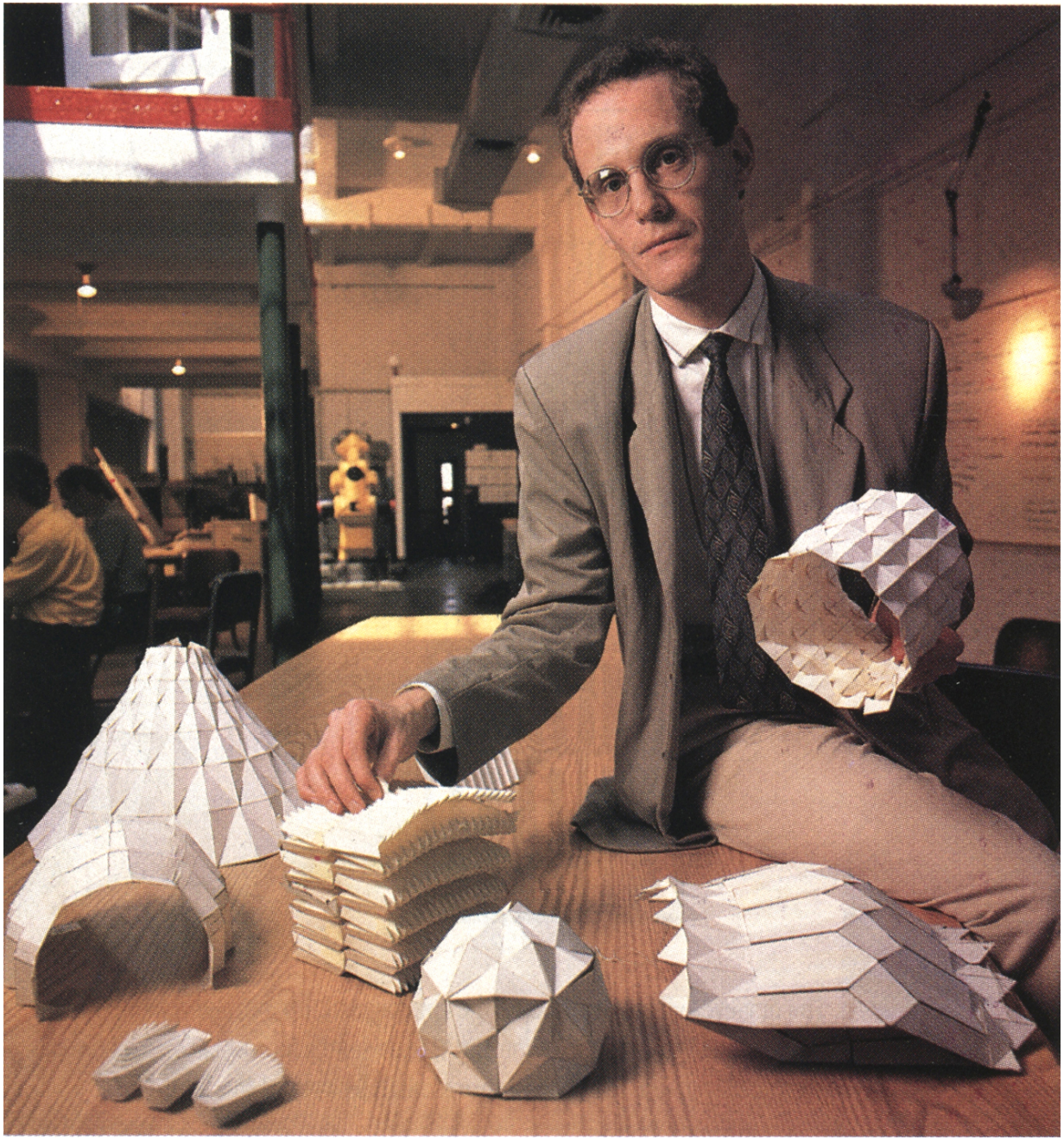


Early work (Cooper Union)

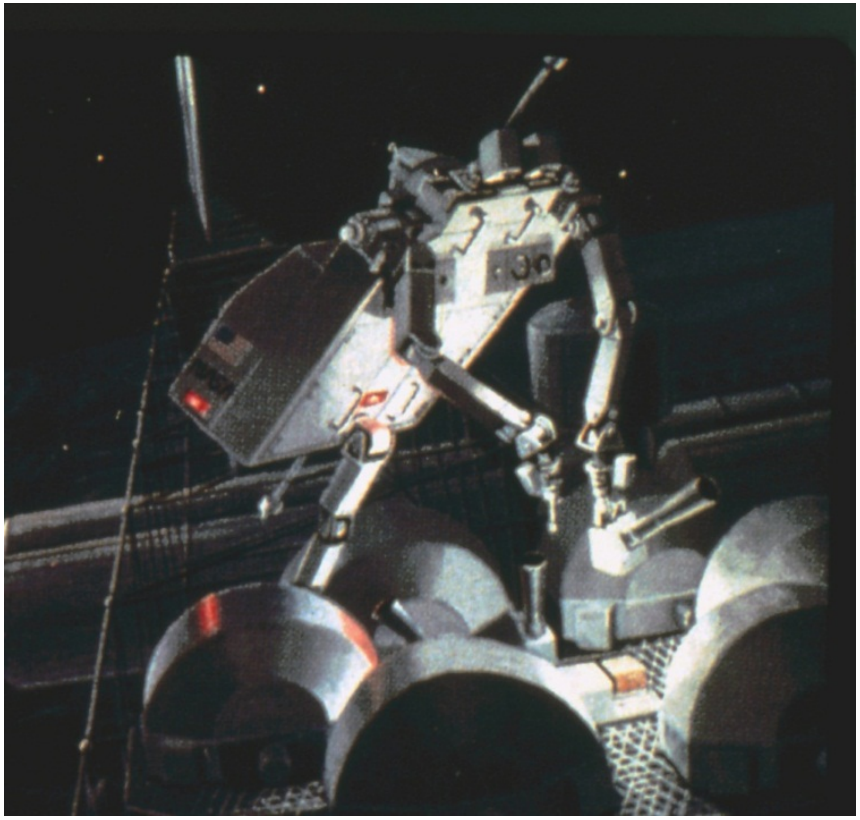


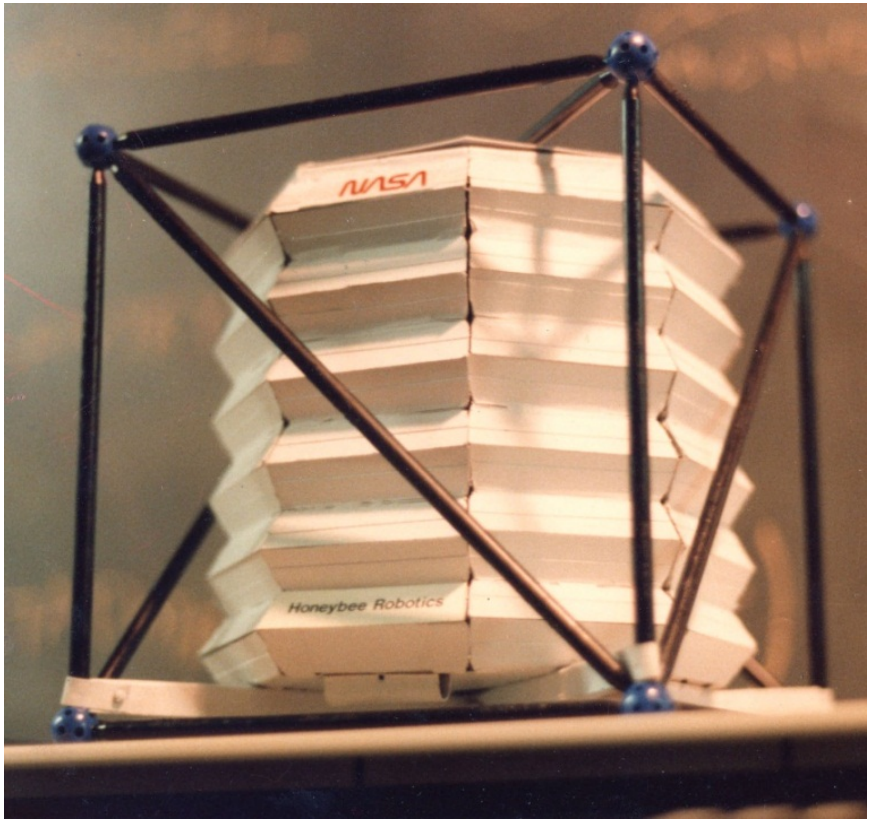
Early work

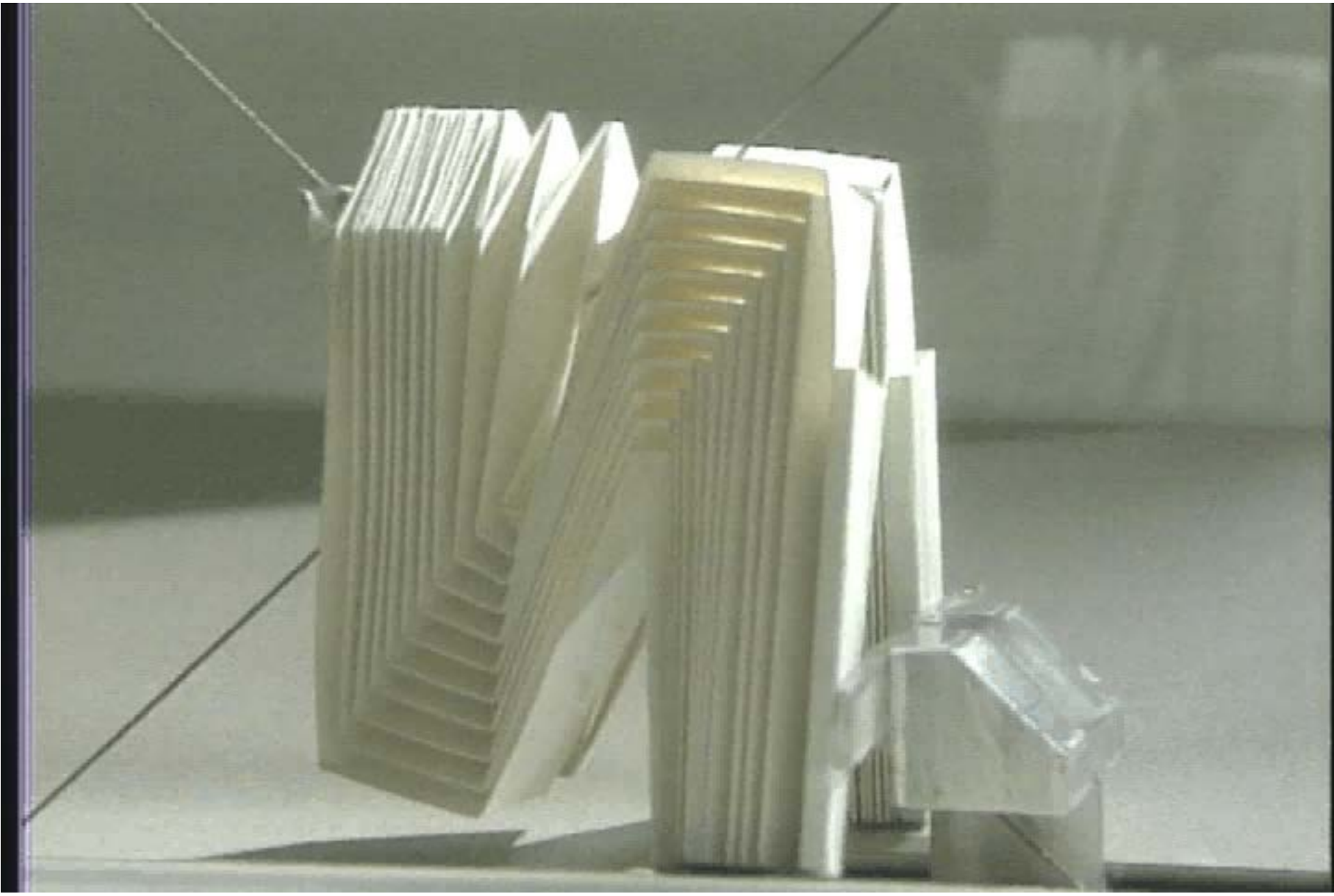




Early work with:

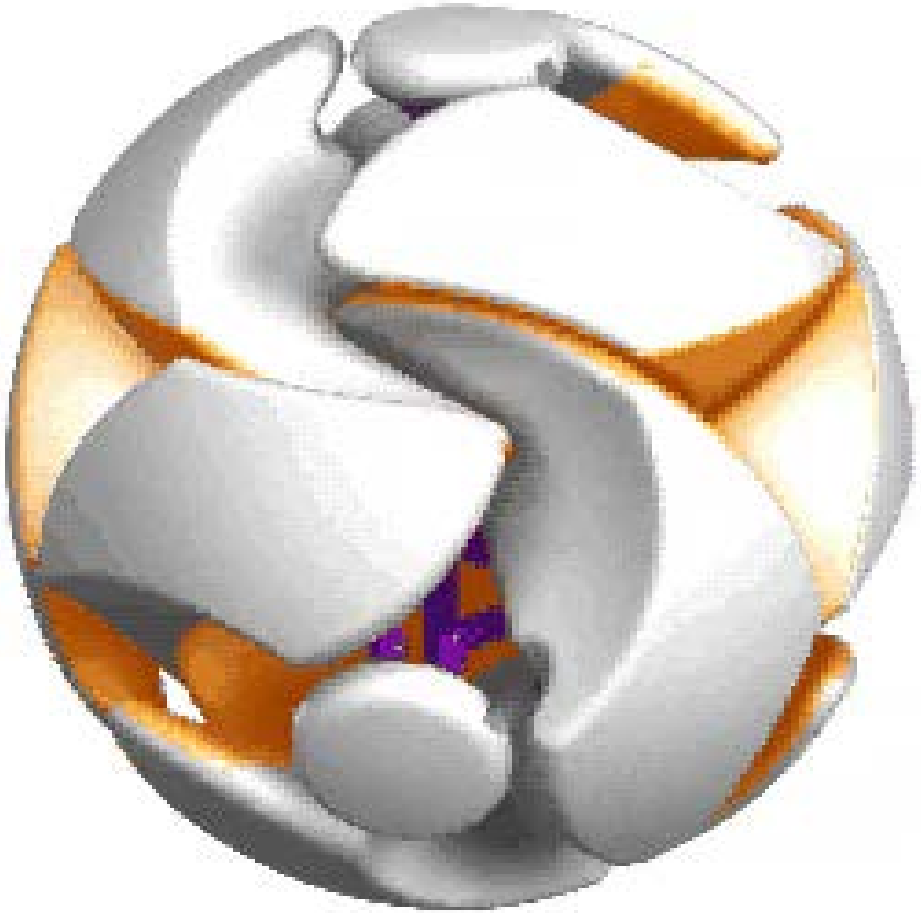


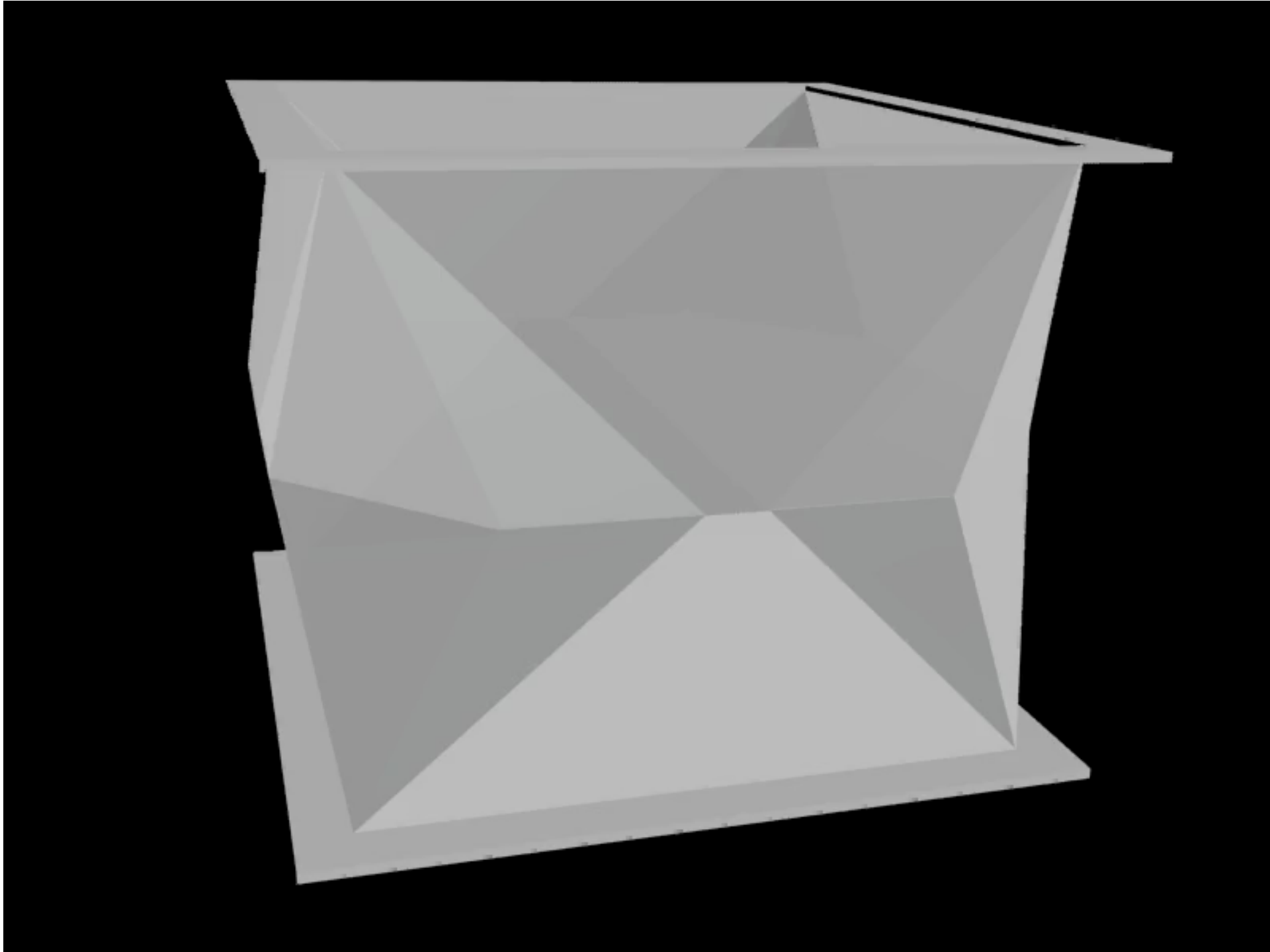




Finding your problem:

How do you make an object transform?

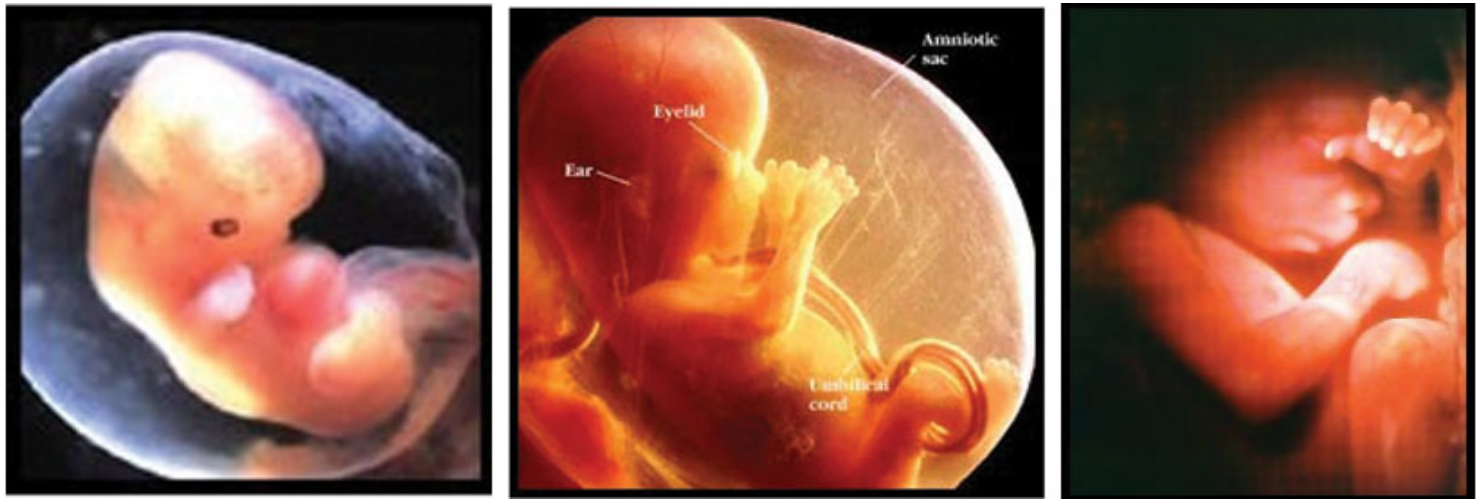




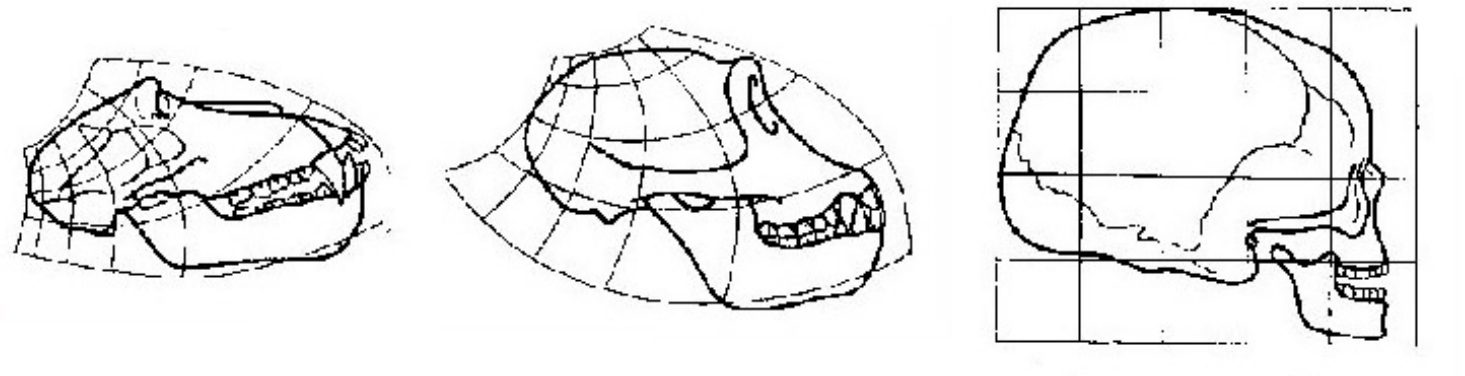
transformable toys
transformable shelters
transformable stage sets
transformable medical devices
transformable sculptures
transformable buildings
transformable furniture

Principles of Transformation

Transformation in nature



Nine months →

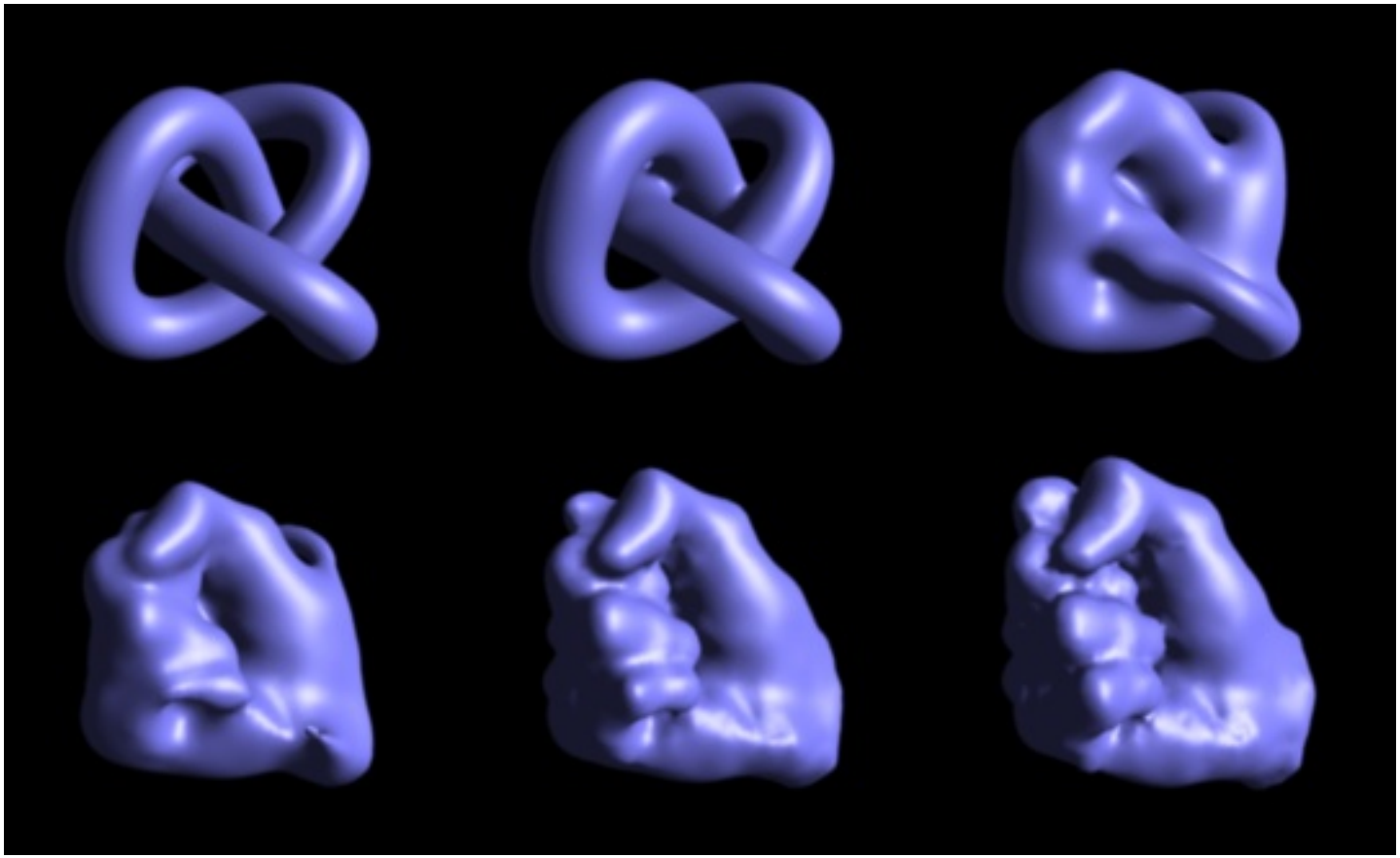


100 million years →

Transformation in nature

10 Seconds →

Transformation in digital media



Transformation in Designed Objects

	Physical	Designable
Natural	X	
Digital		X
Transformable Objects	X	X

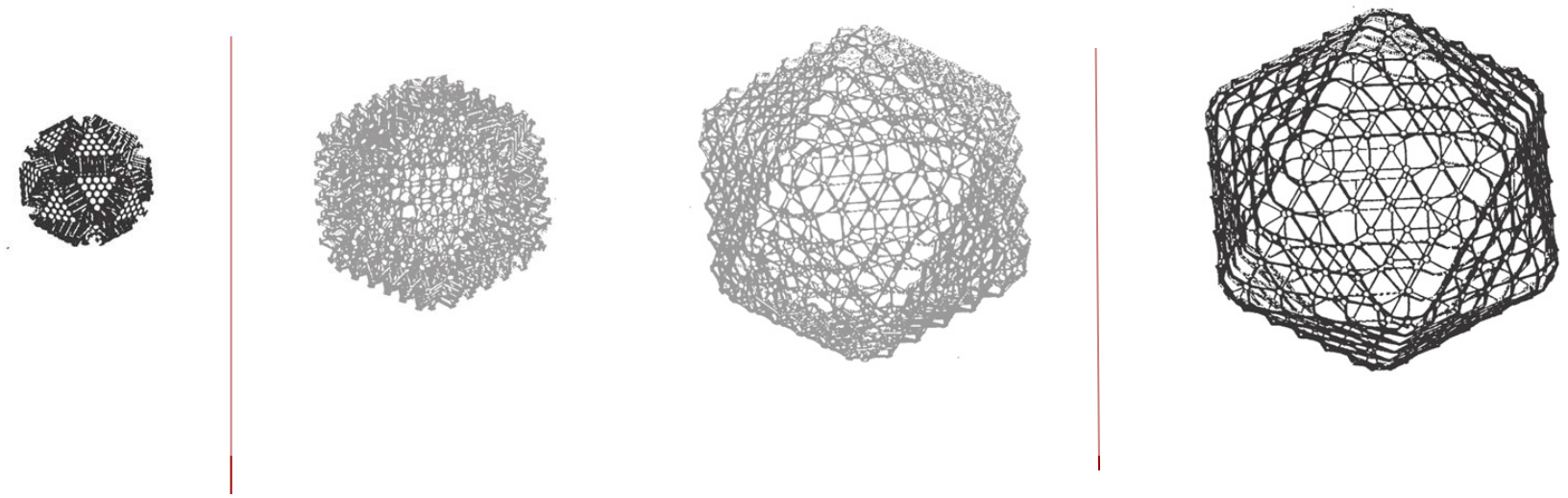
Transformation Process

A specified sequence of forms

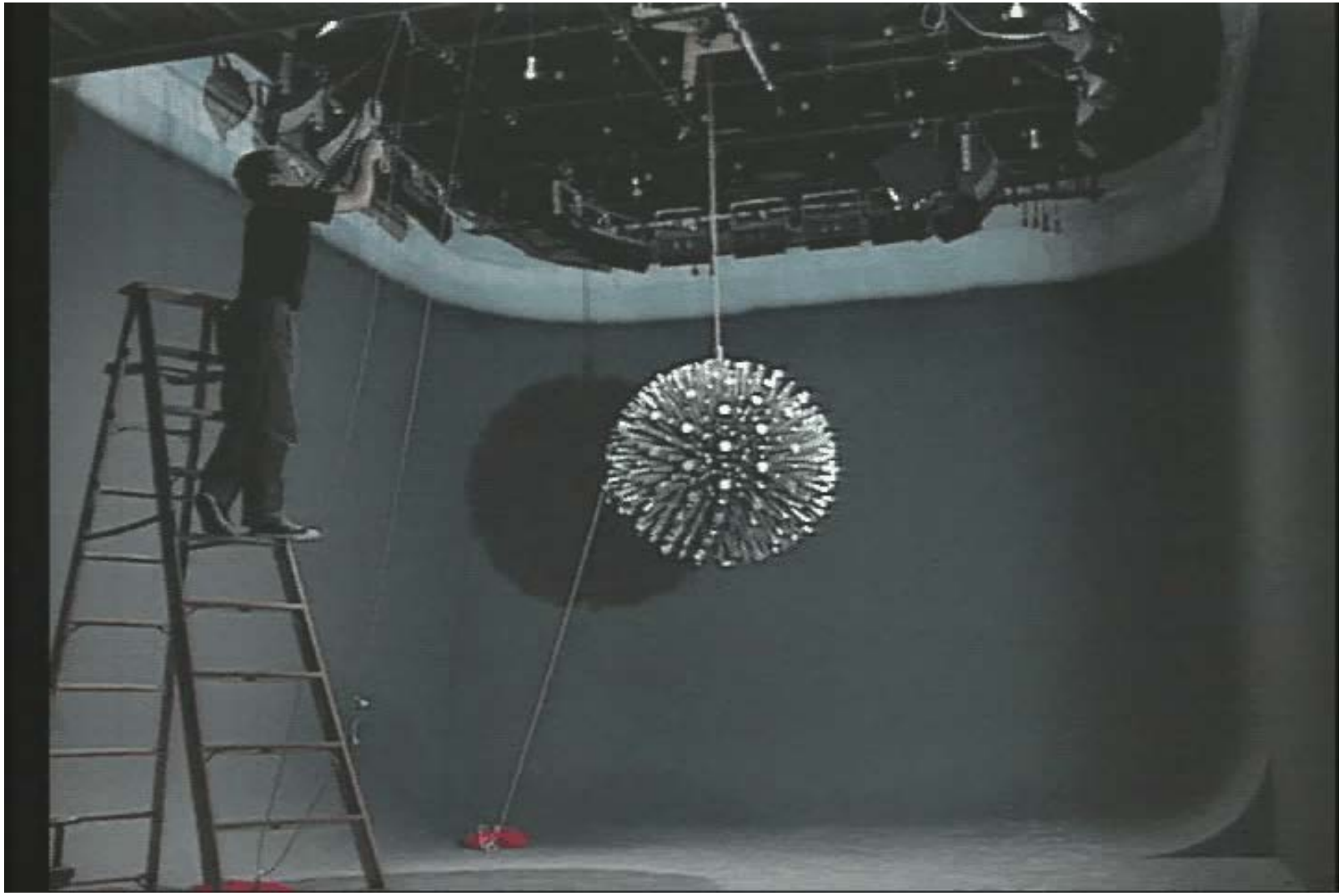
+

A means to achieve that sequence

FORM 1 → TRANSFORMATION PROCESS → FORM 2



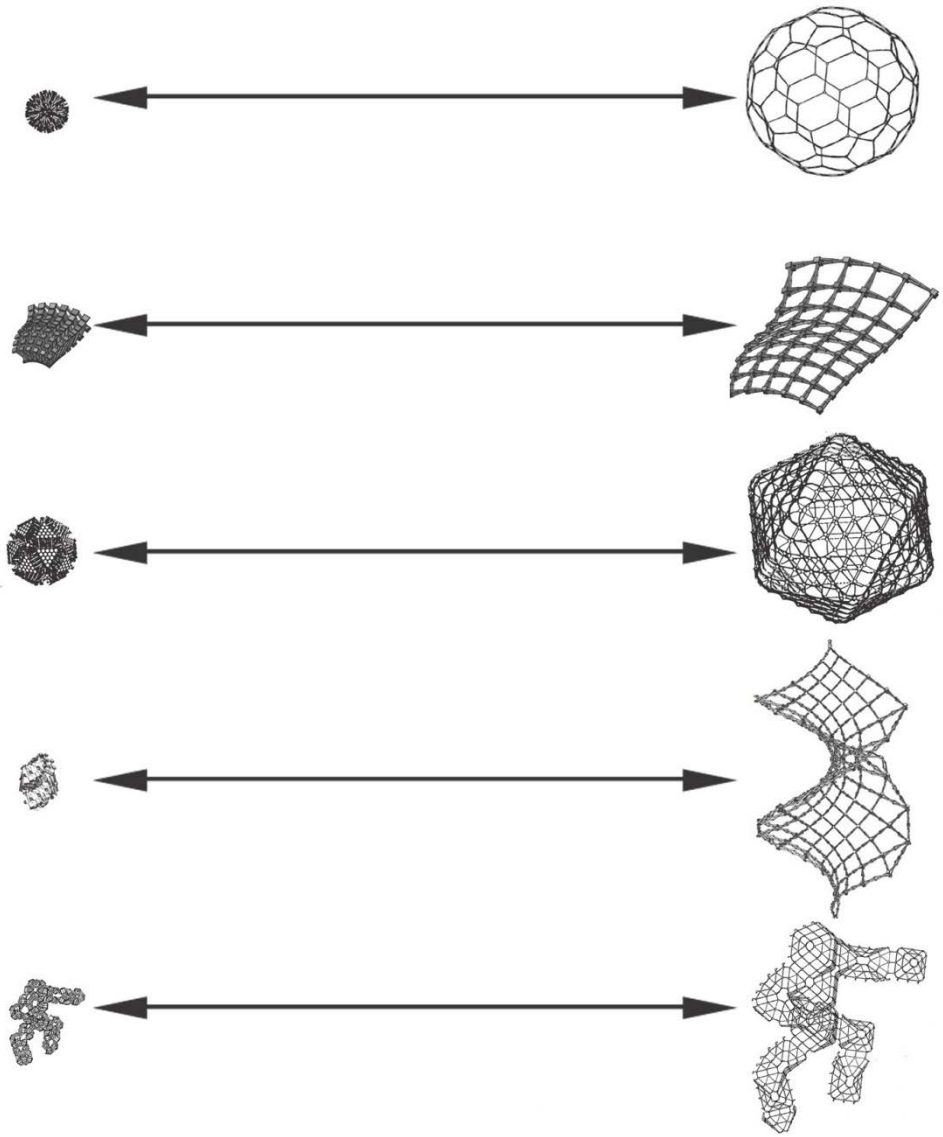
Physical Interaction



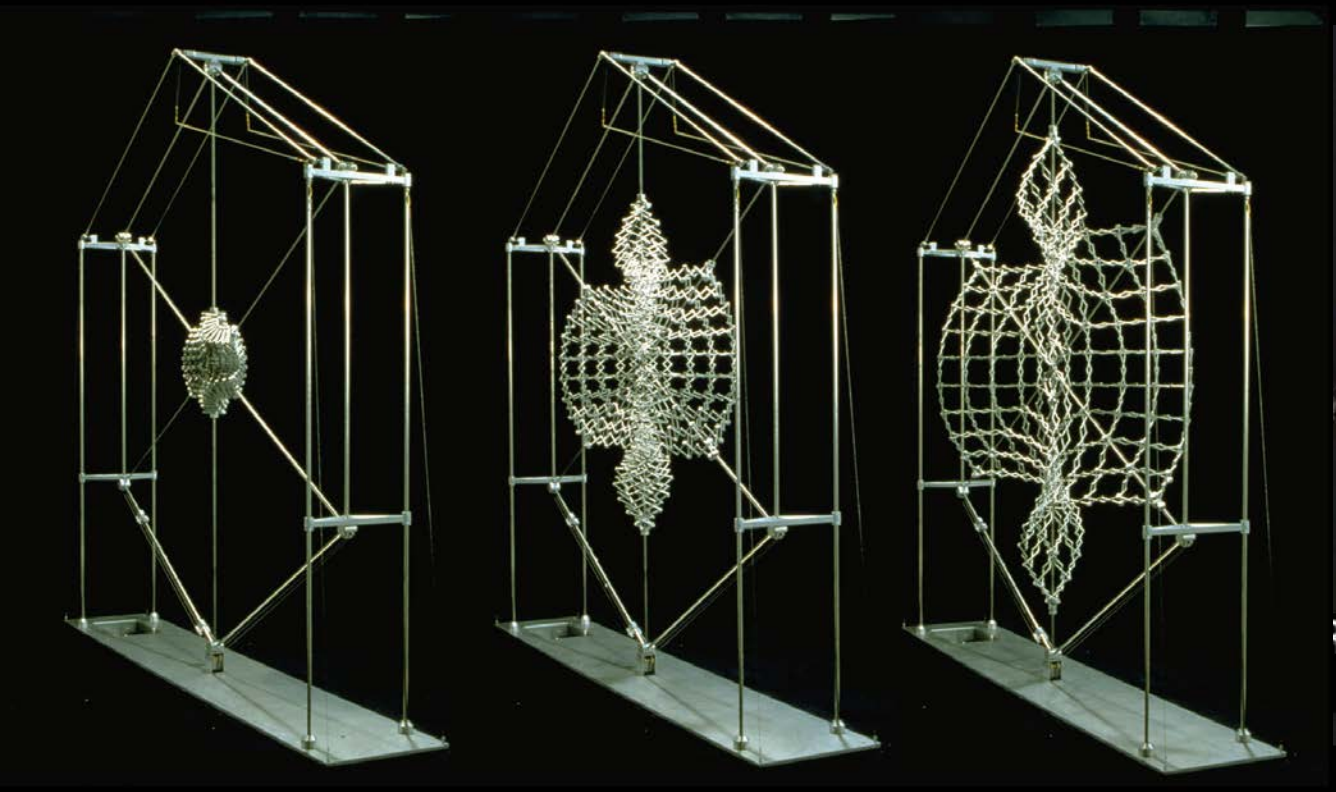
Transforming Size

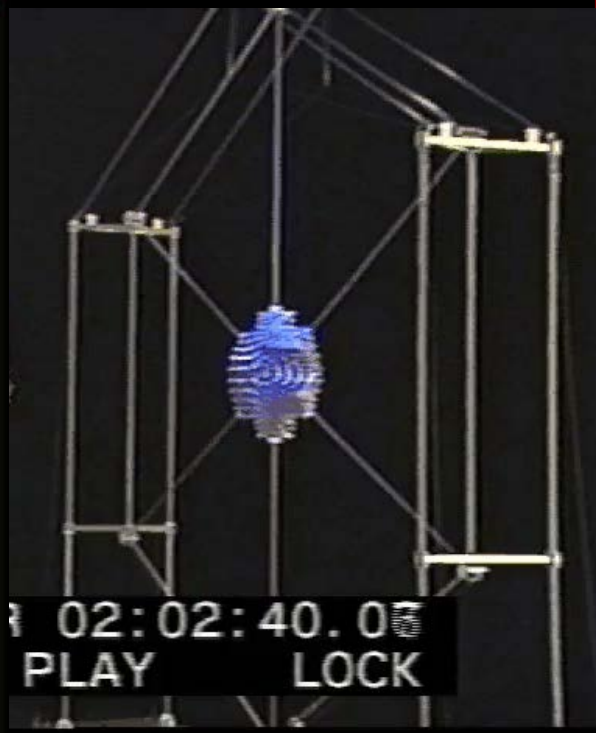
Expanding Structures

Shape invariant expanding structures

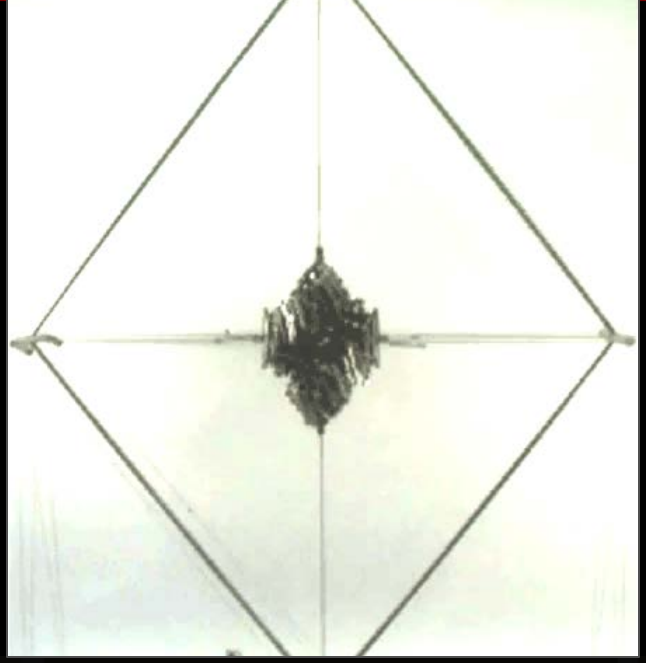


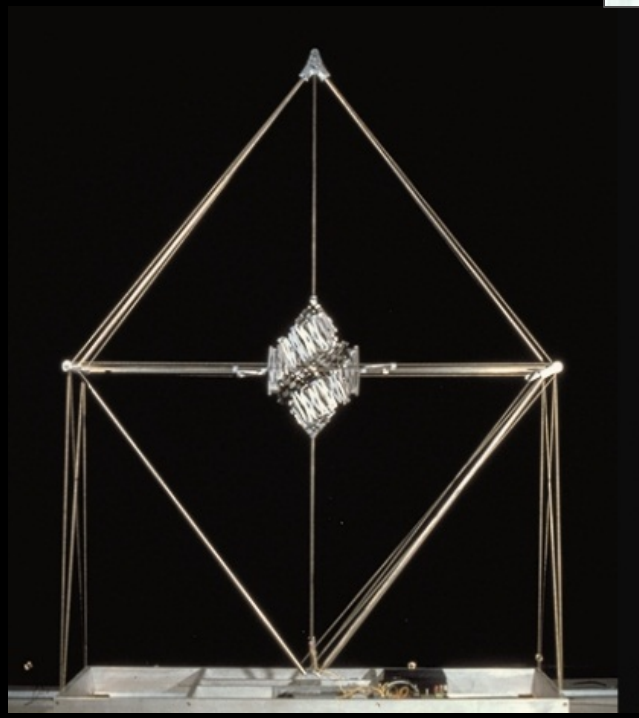
Hypar

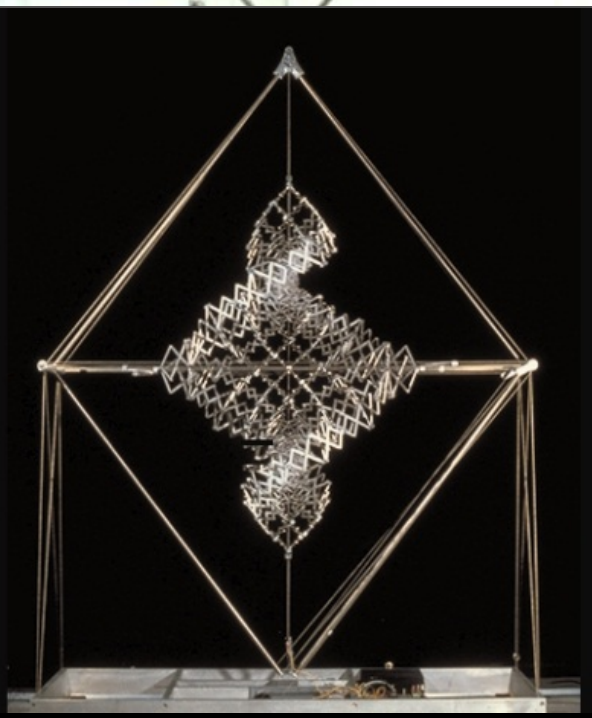


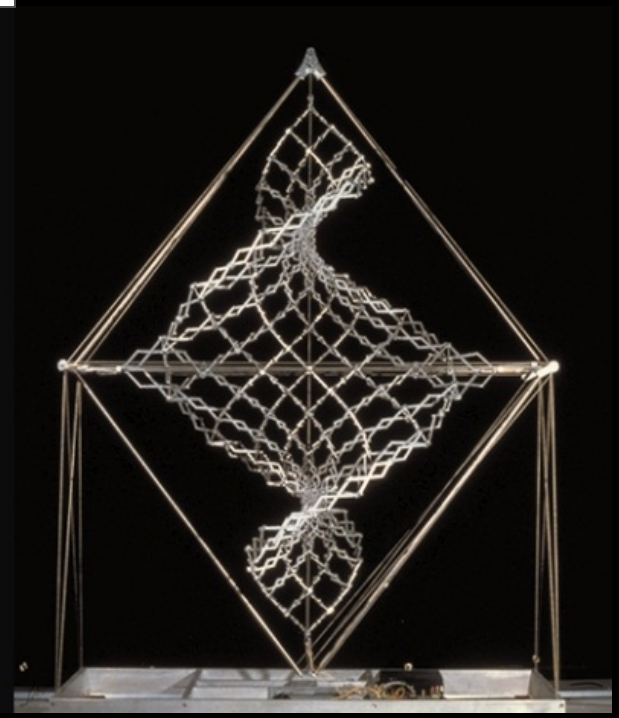


Helicoid



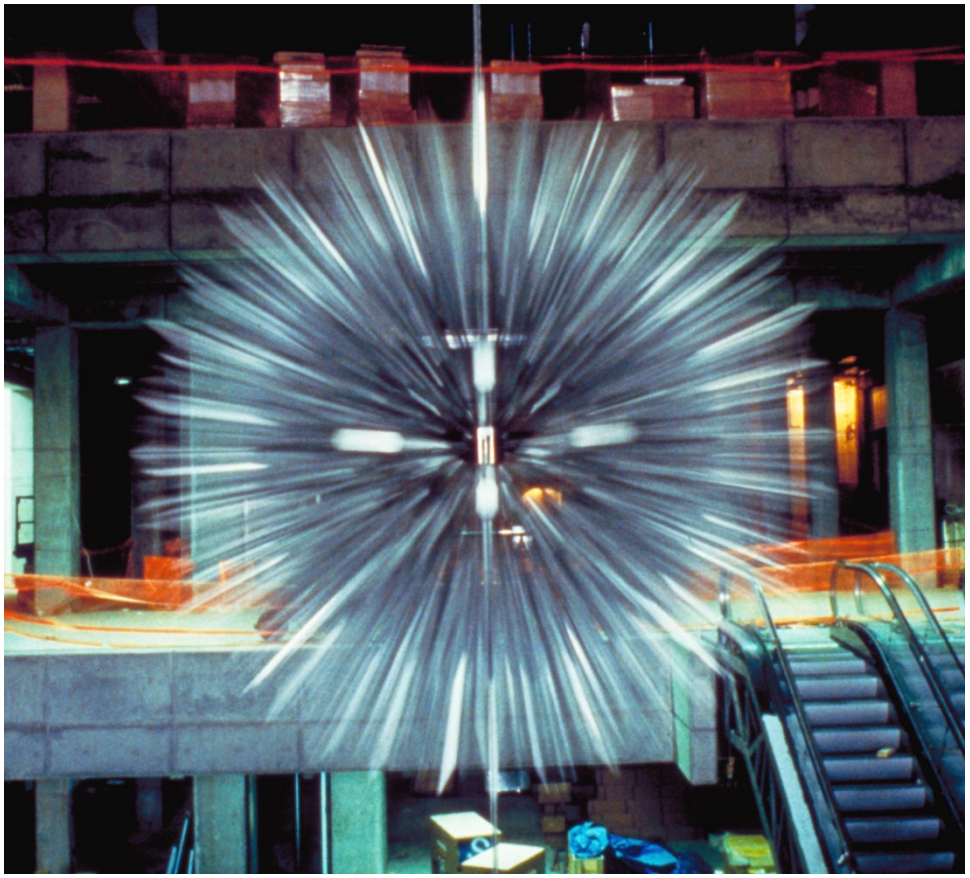


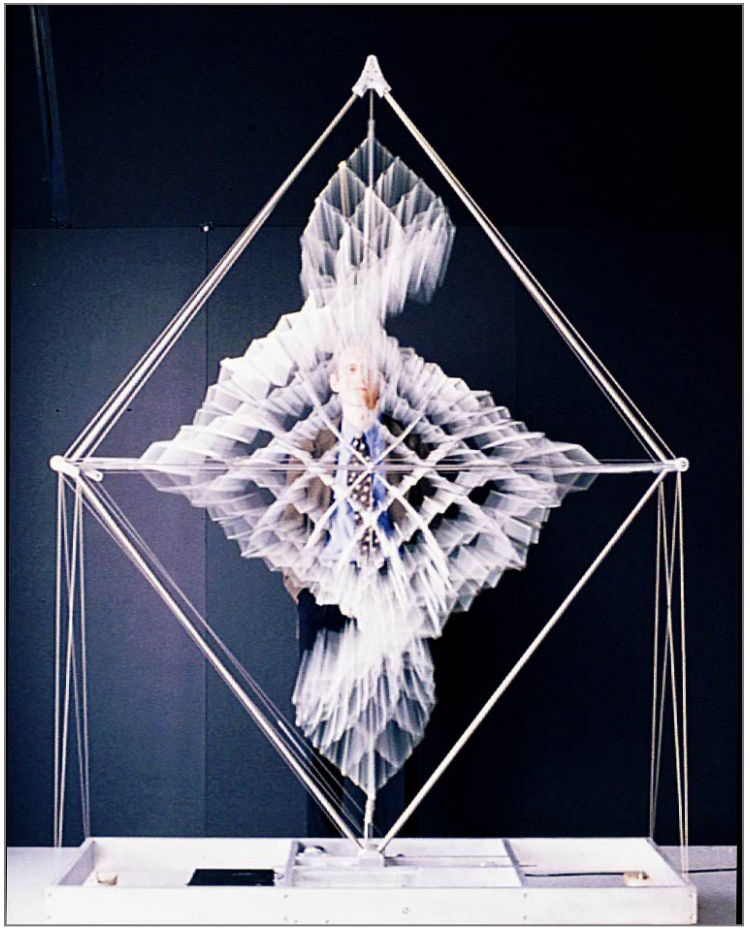




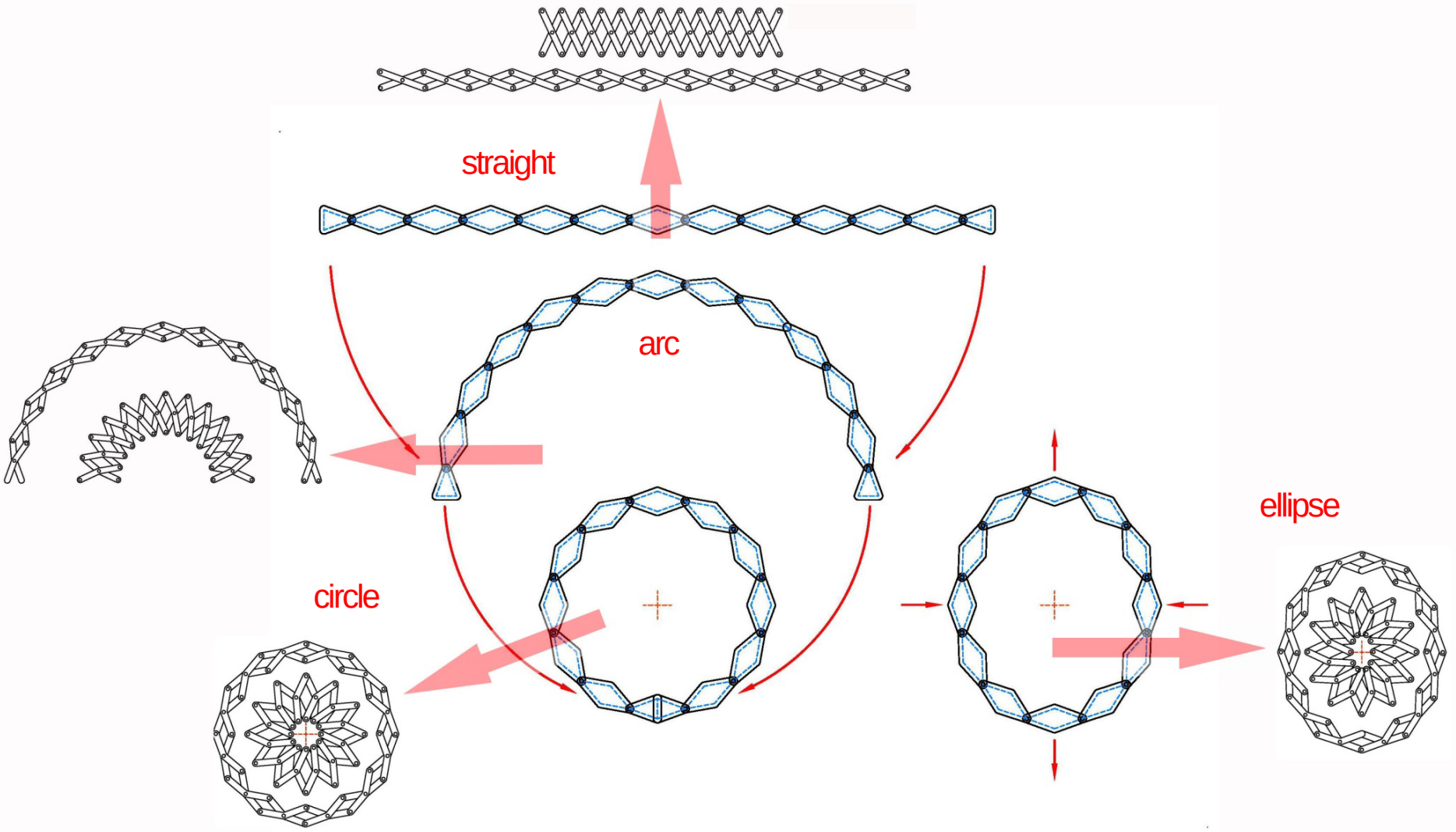
Radial expansion

Points on expanding shape move radially outwards.

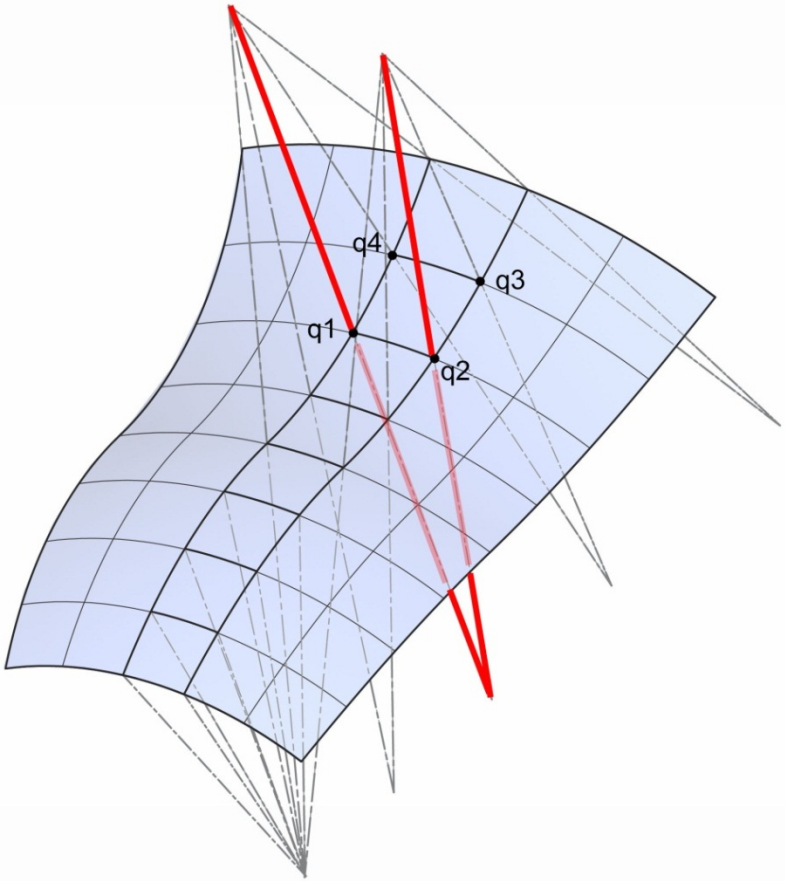


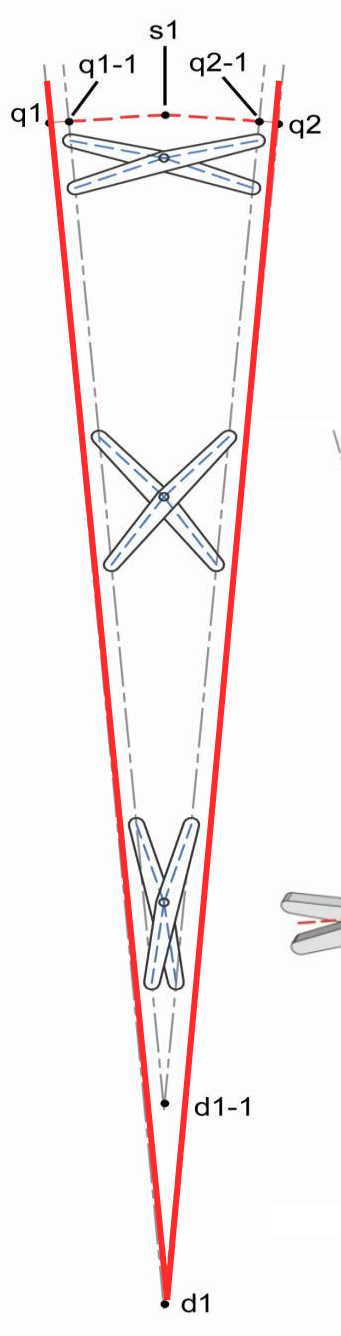


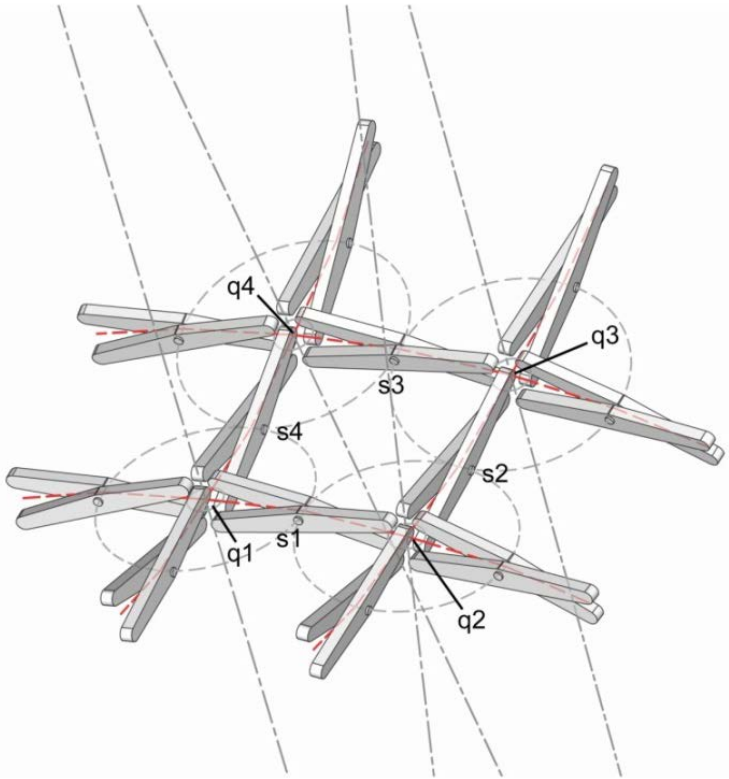
‘Shaping’ technique to create expanding linkages



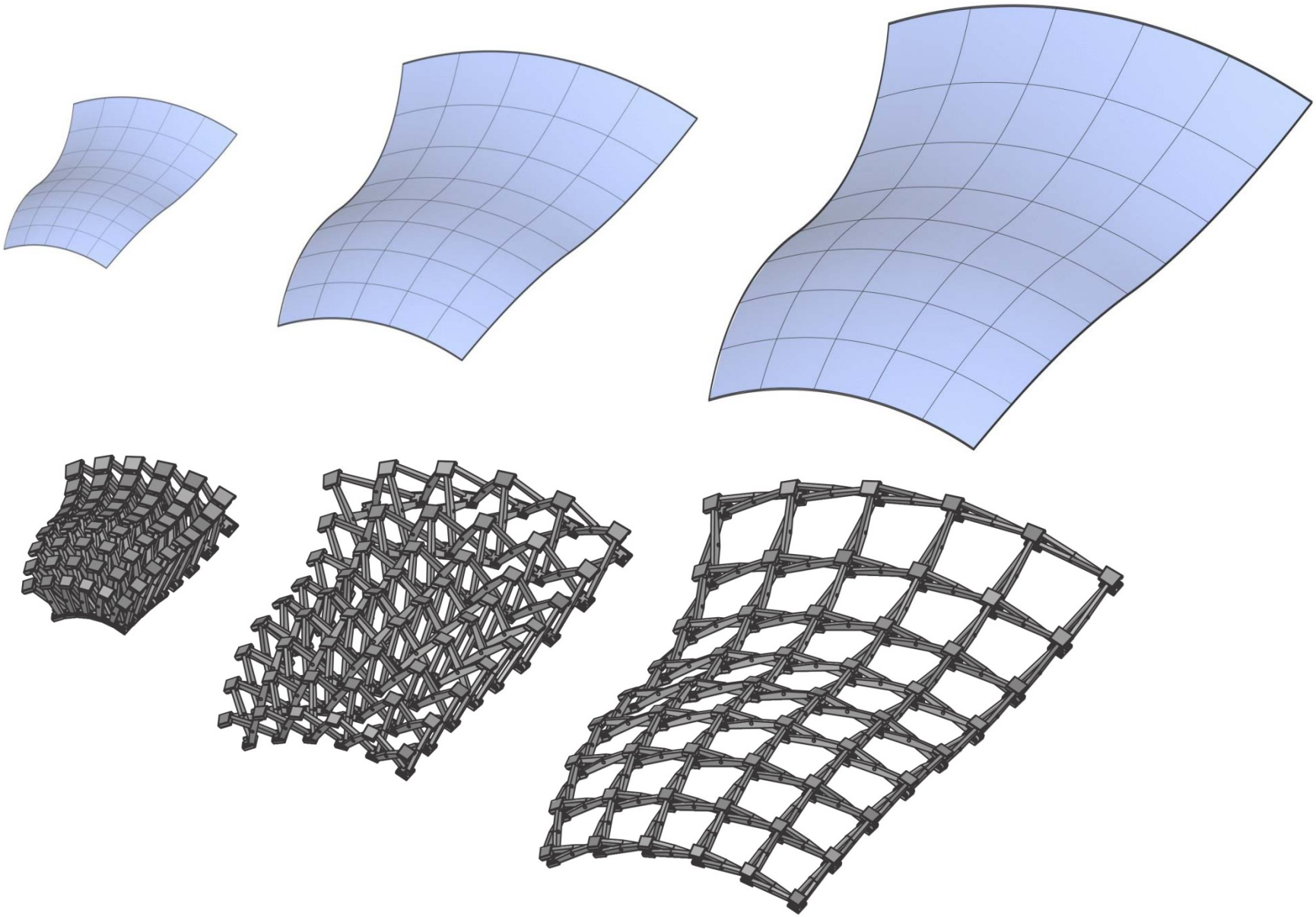
Surface geometry => structura



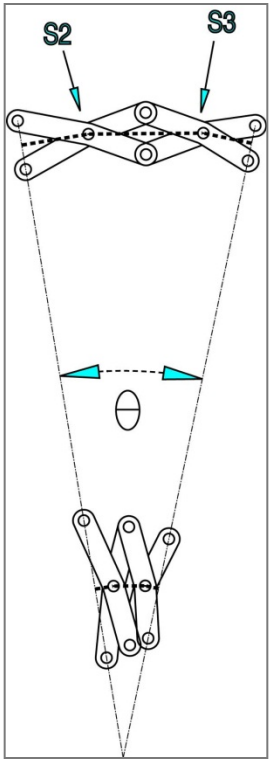


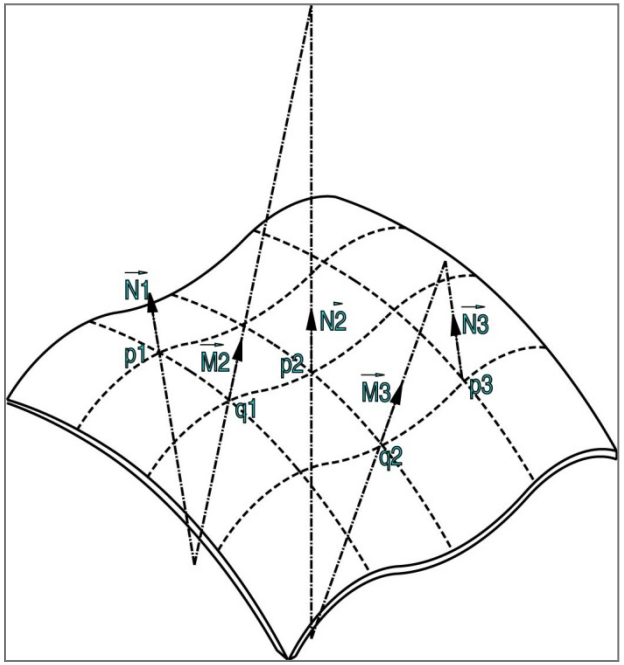


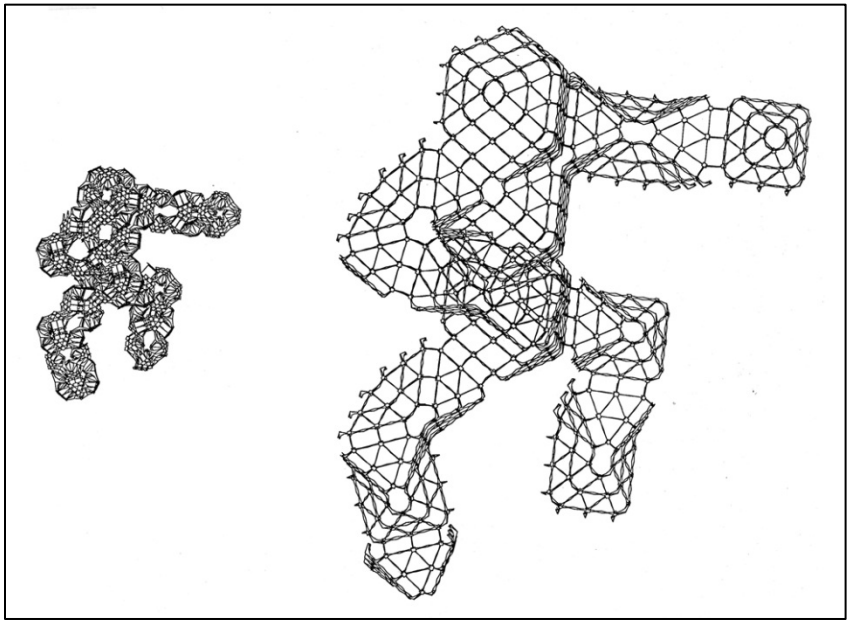
Surface geometry => structural mechanism



Shape + Movement



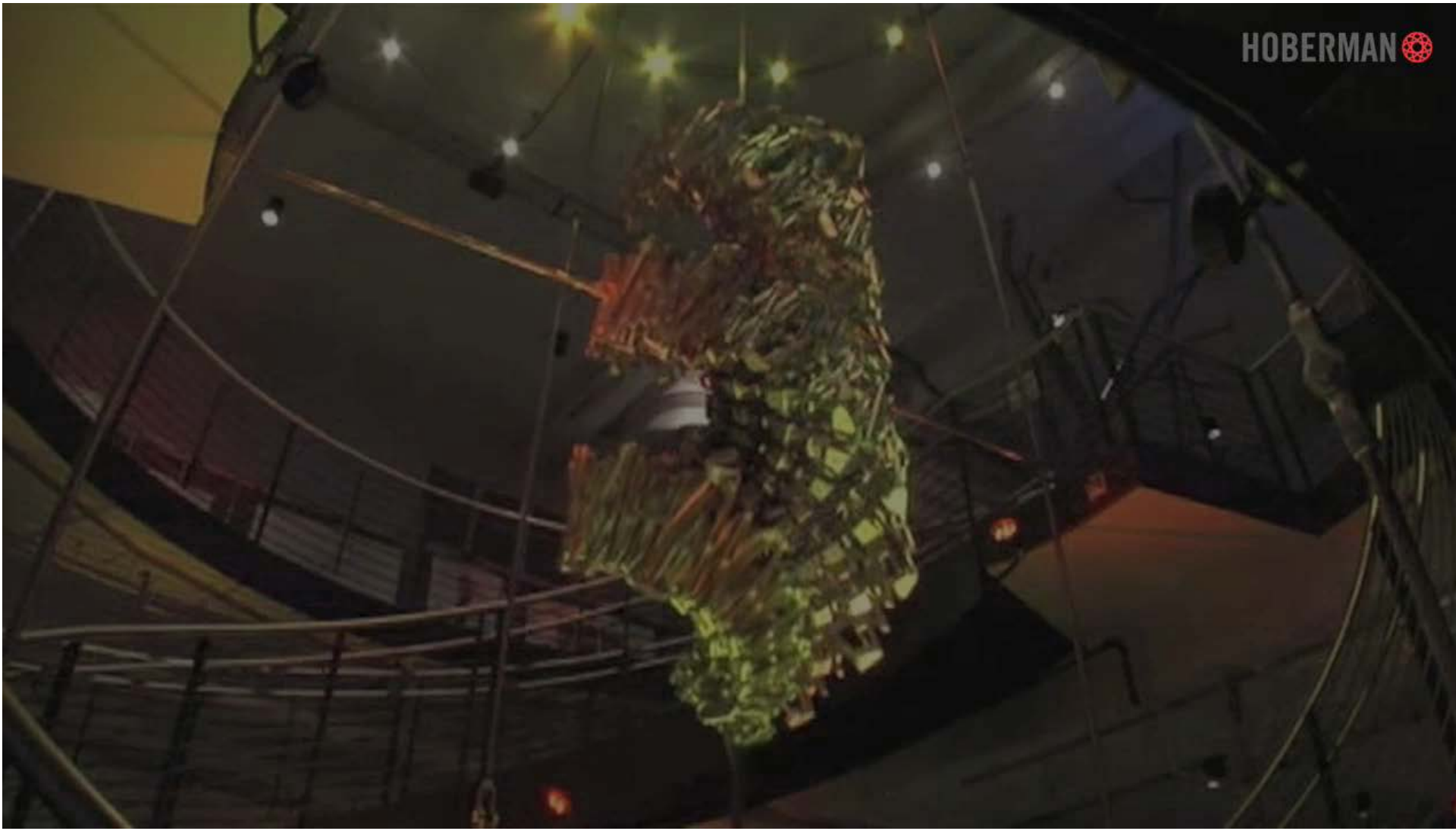




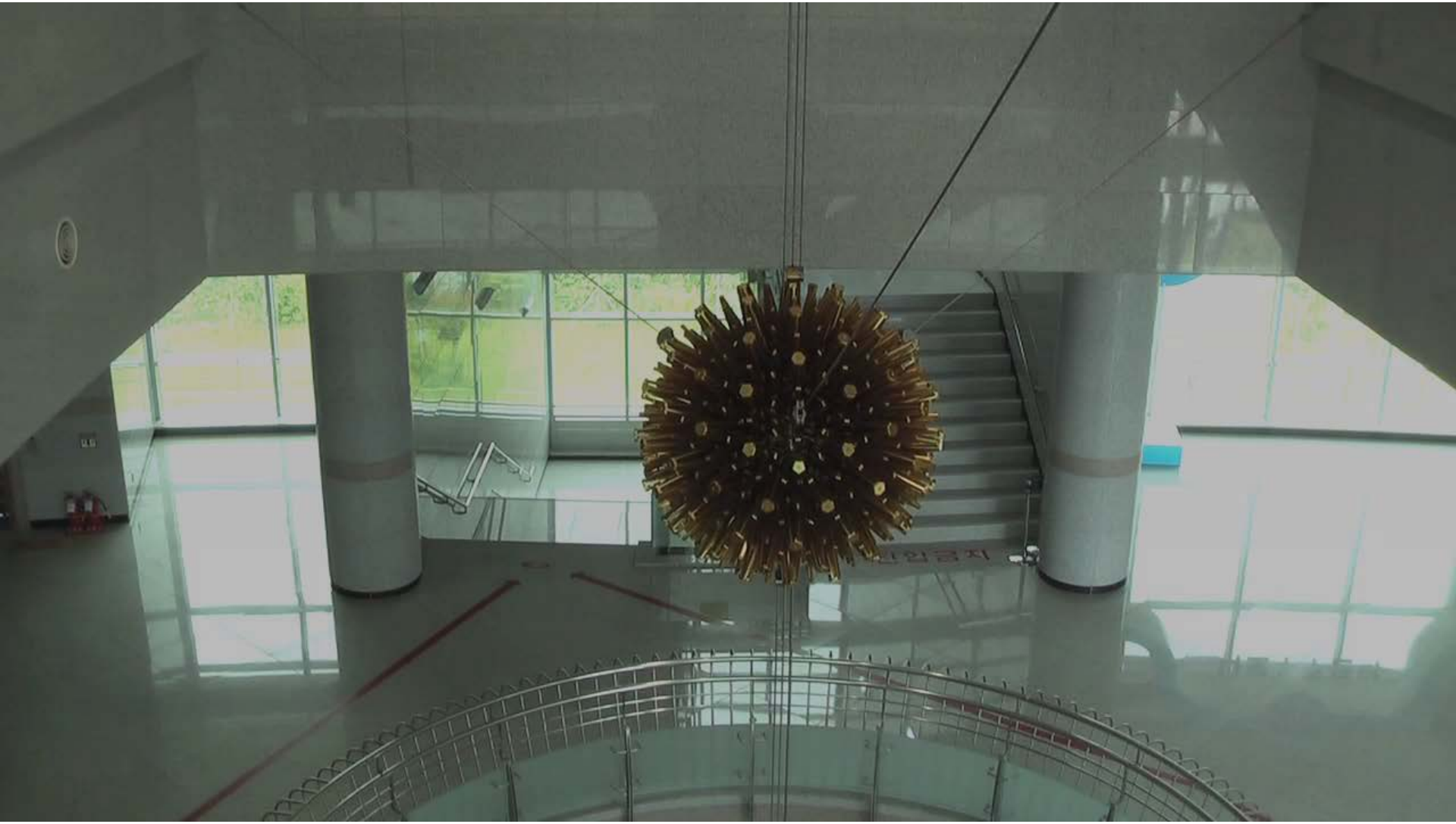
Surface properties are translated into linkage properties.

Expanding Helicoid

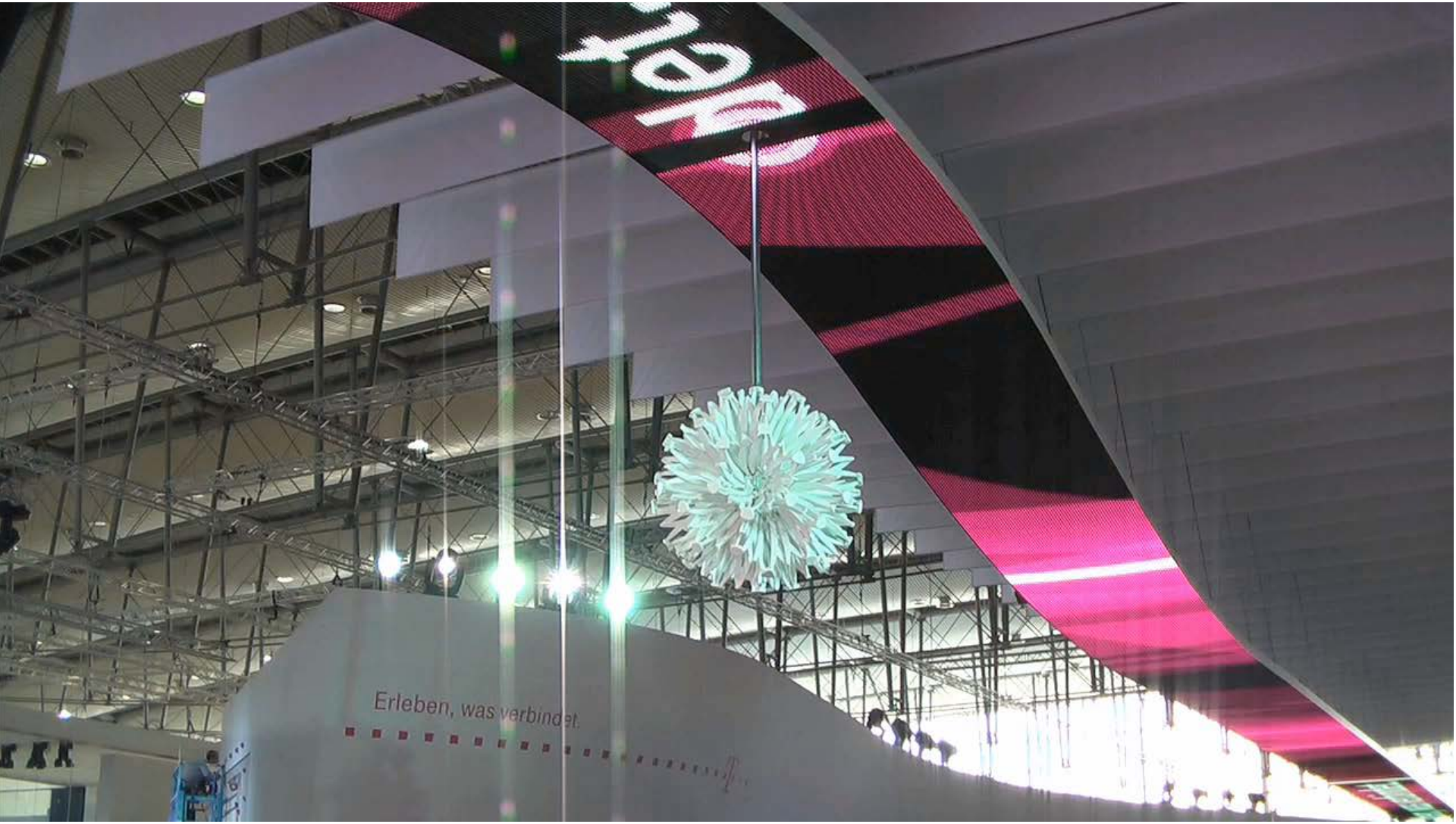
Expanding Helicoid



Korean Aerospace Institute

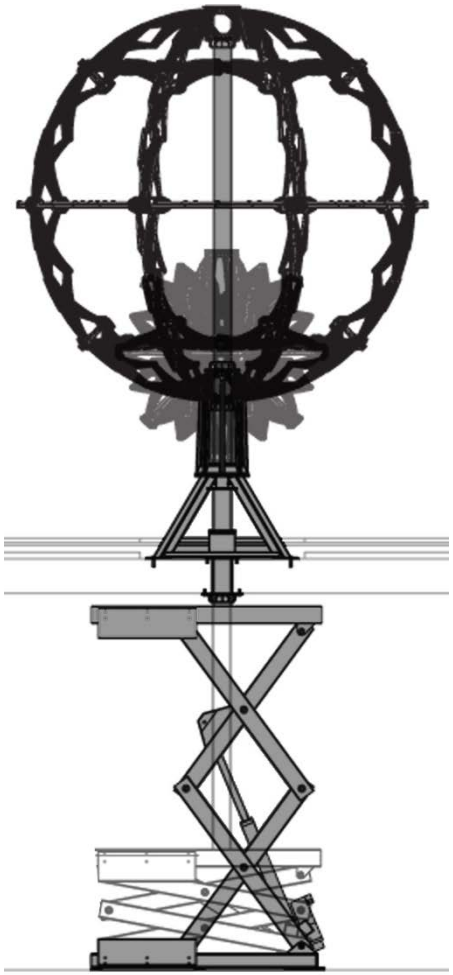


Expanding Sphere, CBIT Conference, Hanover, 2010



Smith Haut Lafitte

Bordeaux, France



Smith Haut Lafitte

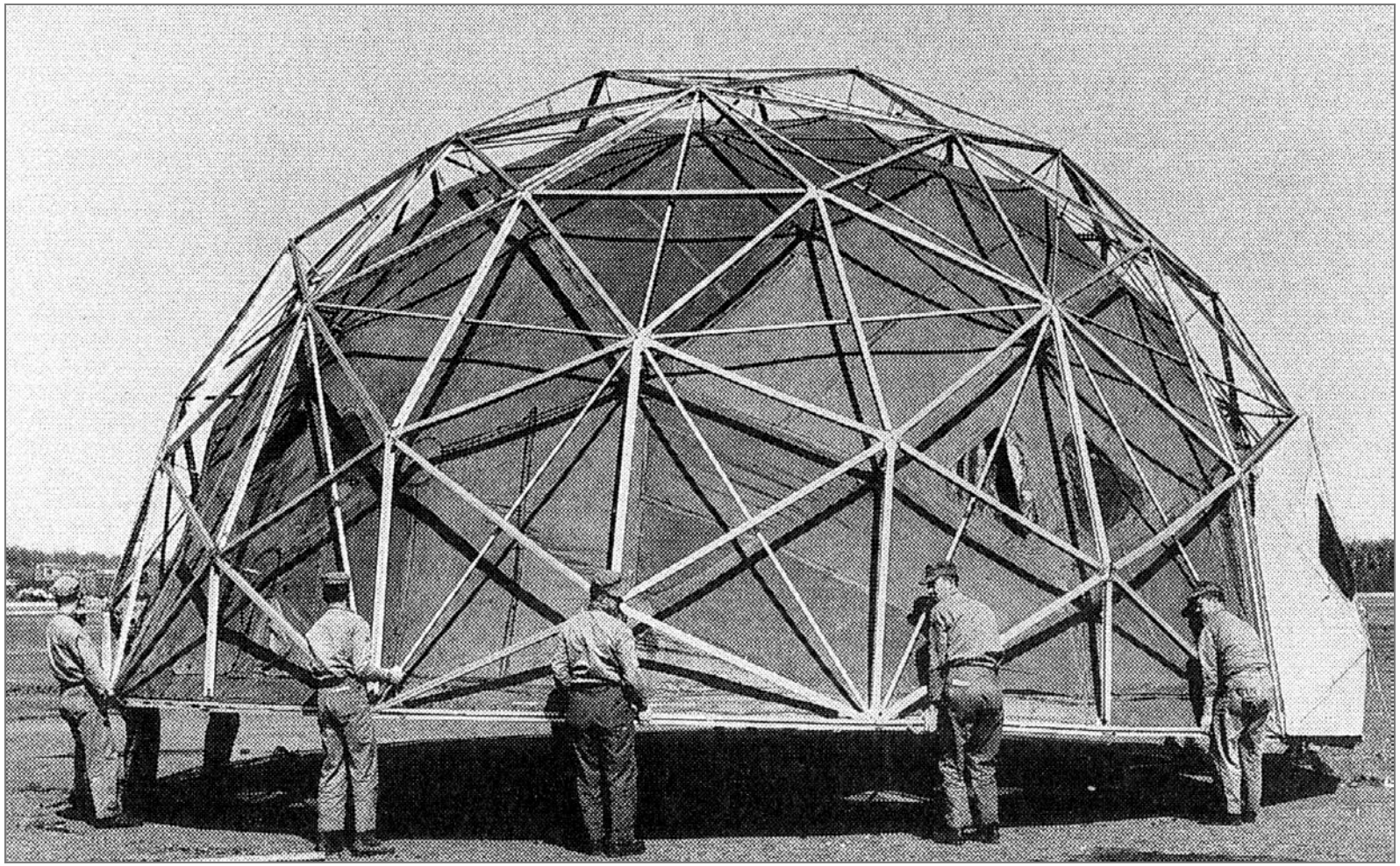
Bordeaux, France


Smith Haut Lafitte
Bordeaux, France

Structural Principles

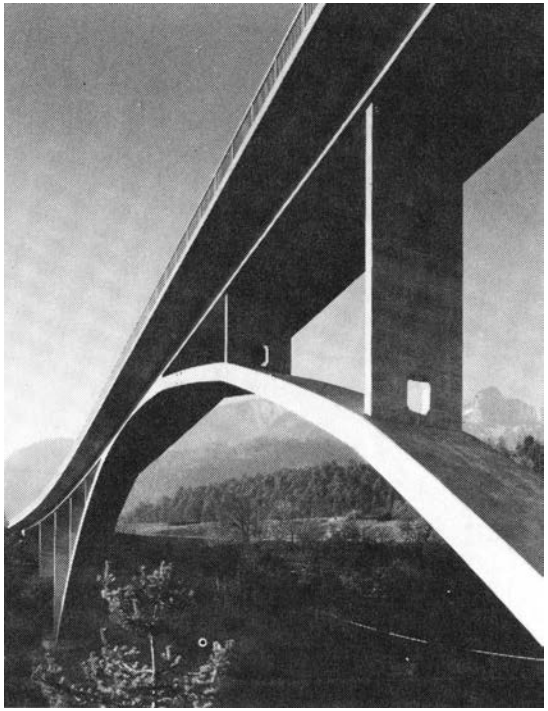
Kinematic mode

Structural mode



Structural mode

Design Principles
Structure and Mechanism



Structure:

Force is resisted

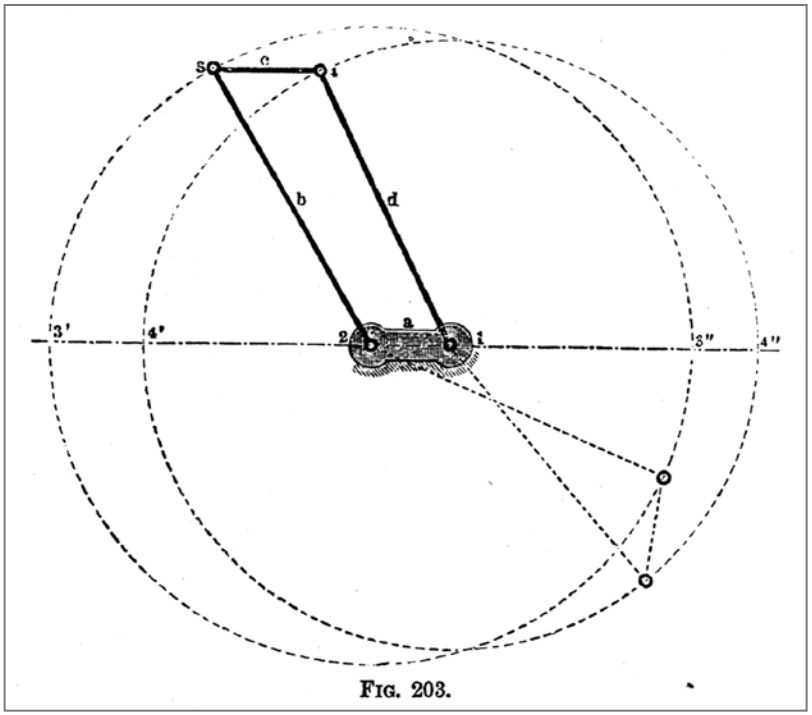


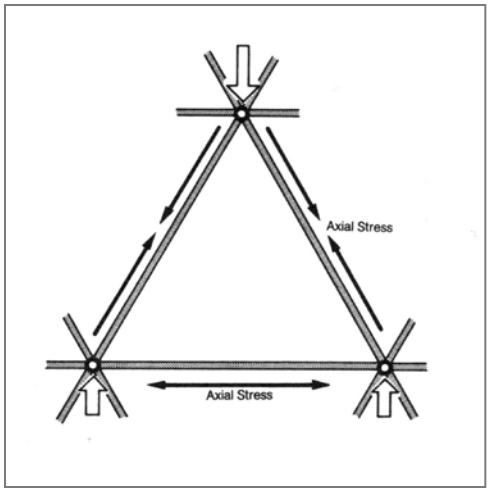
FIG. 203.

Mechanism:

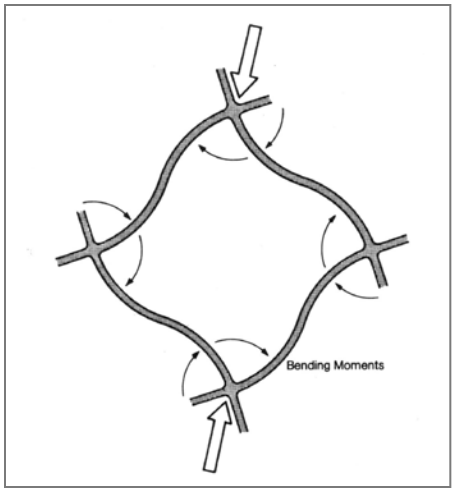
Force flows into movement

Design Principles
Structure and Mechanism

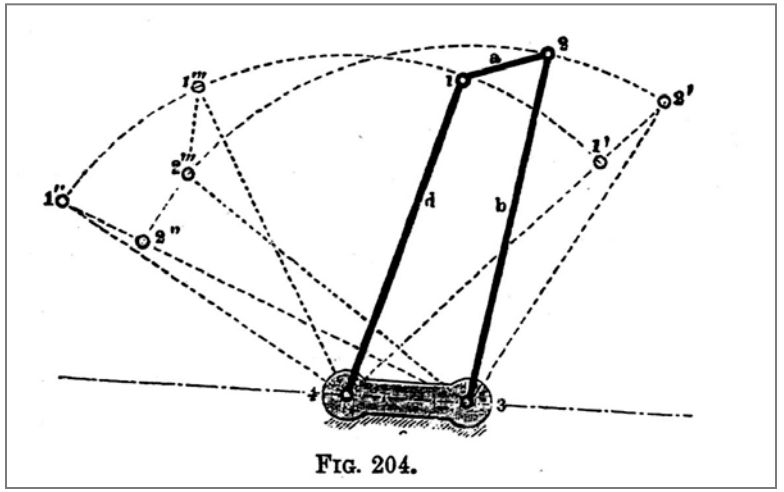
Possible Responses to Applied Force



Structural Resistance

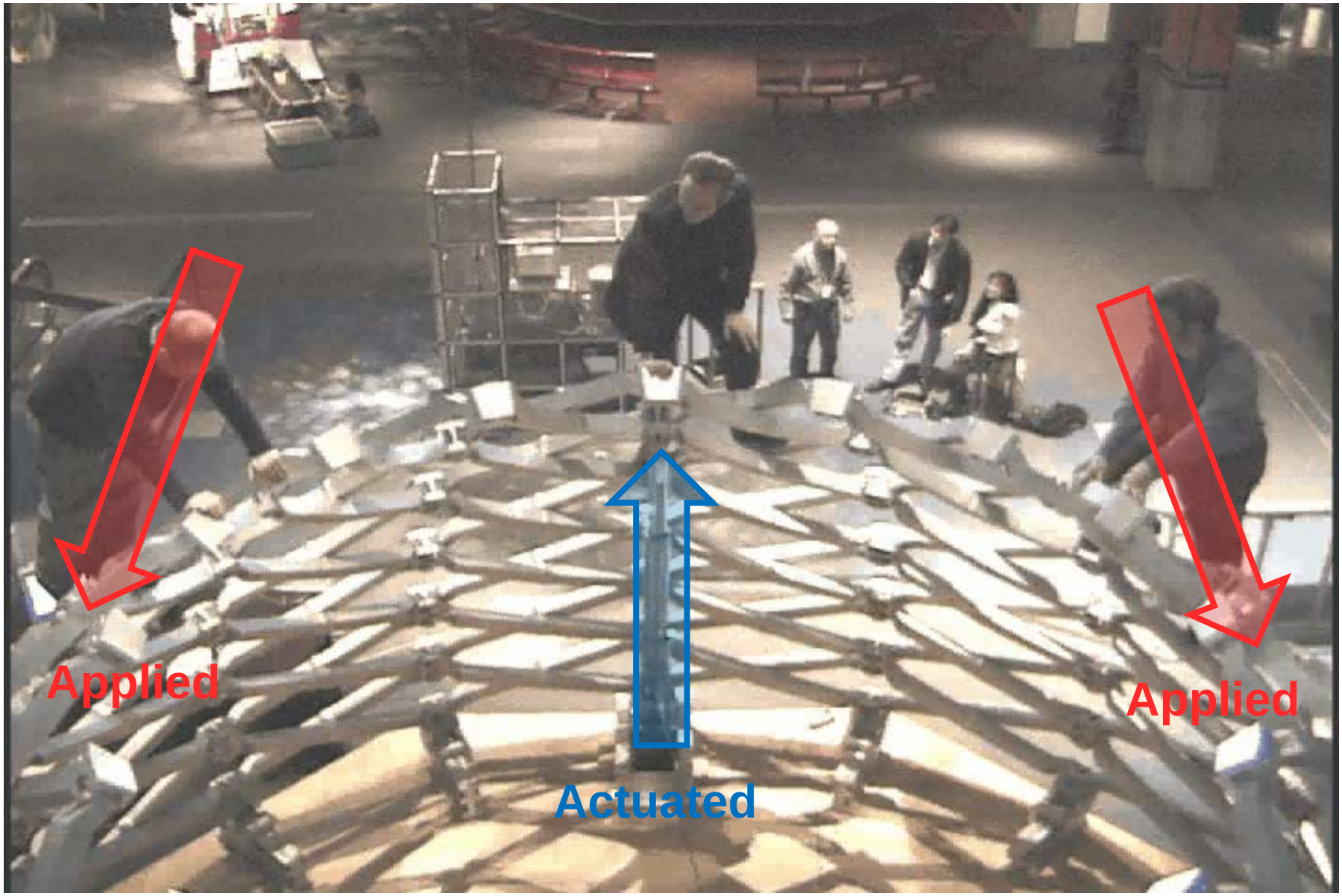


Structural Deflection (elastic or Inelastic)



Kinematic deflection

Resolving forces between kinematic and structural modes

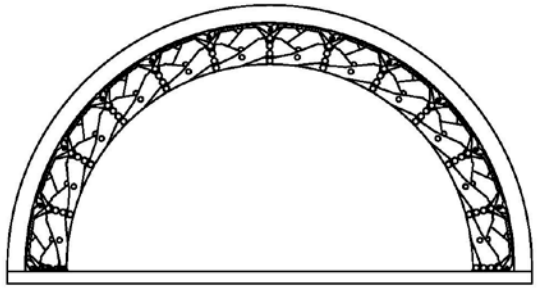


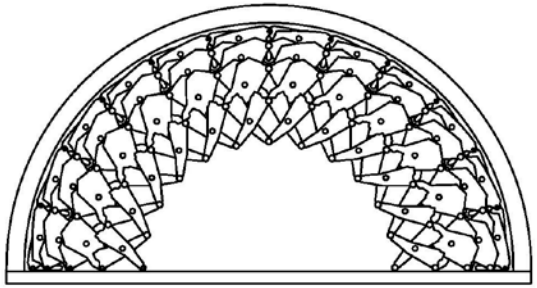
Stability defined as a process, not a state

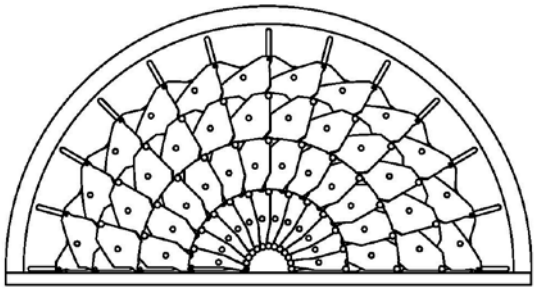
Design Principles
Structure and Mechanism

Expo 2000, Hannover

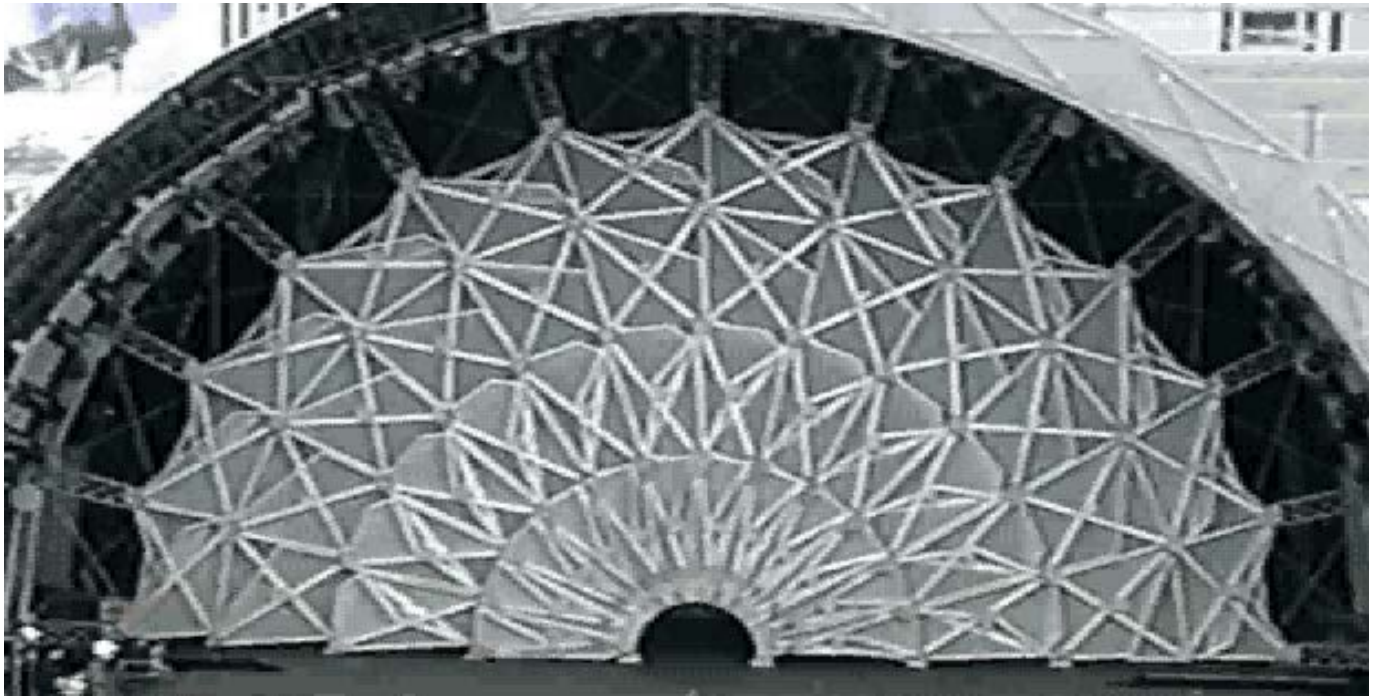
Olympic Arch, Salt Lake City 2002



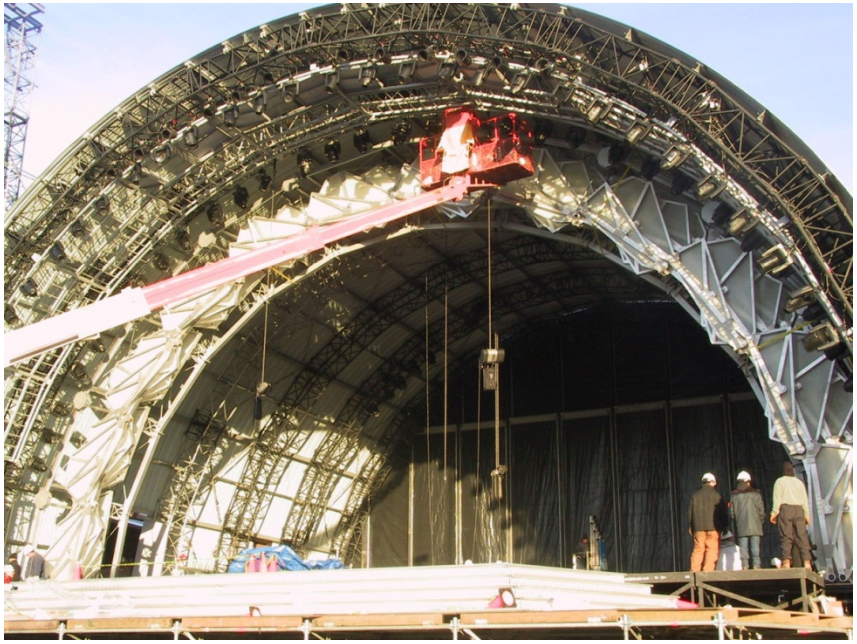




2002 Winter Olympics, Salt Lake City



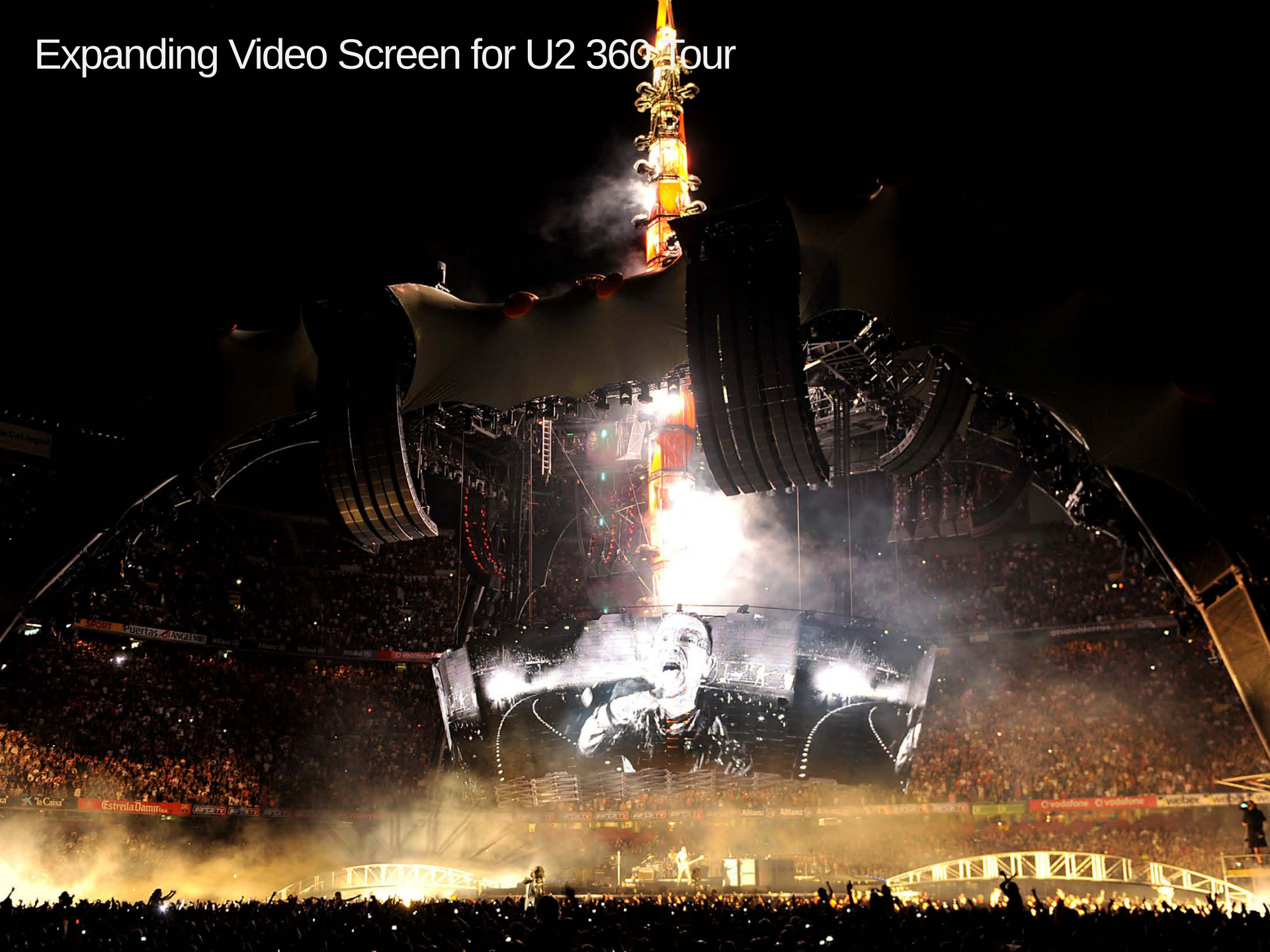
Olympic Arch



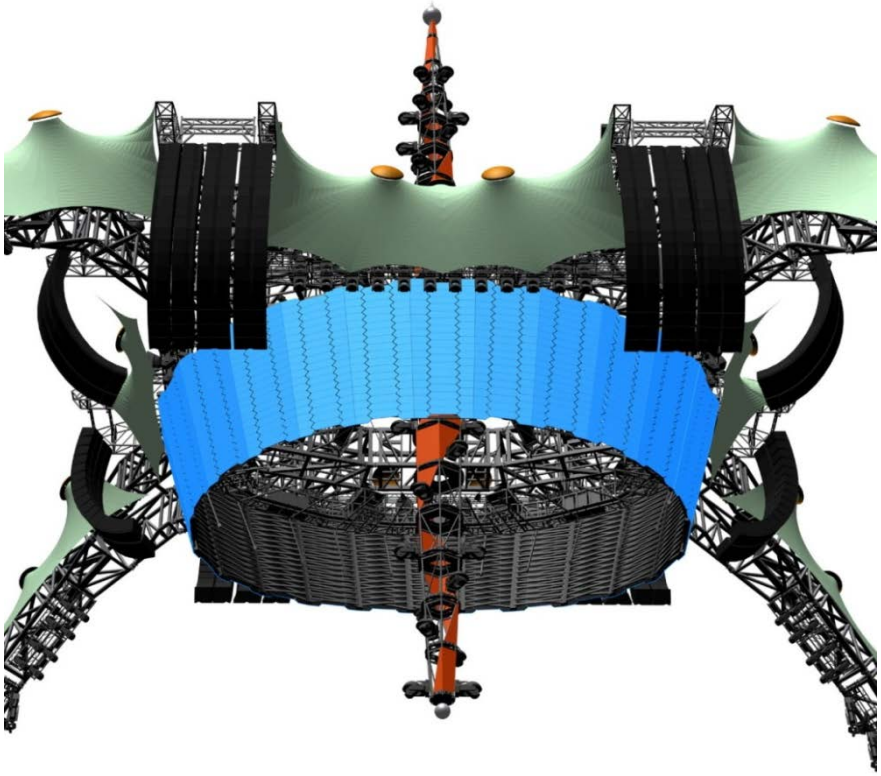
Olympic Arch, Salt Lake City 2002

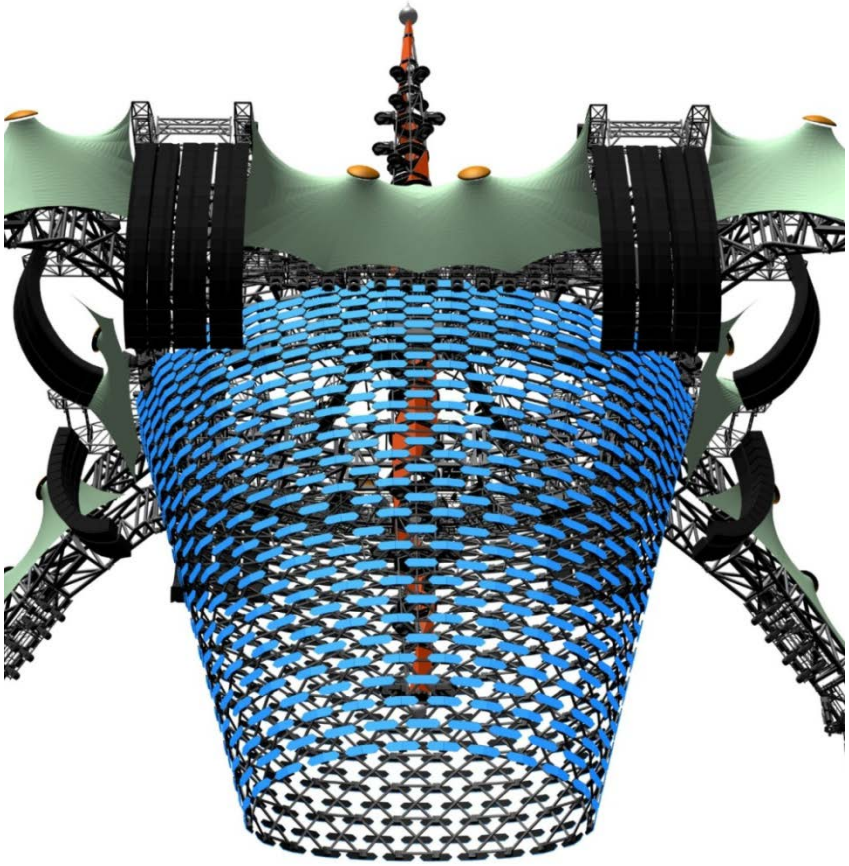
Olympic Arch

Expanding Video Screen for U2 360 Tour



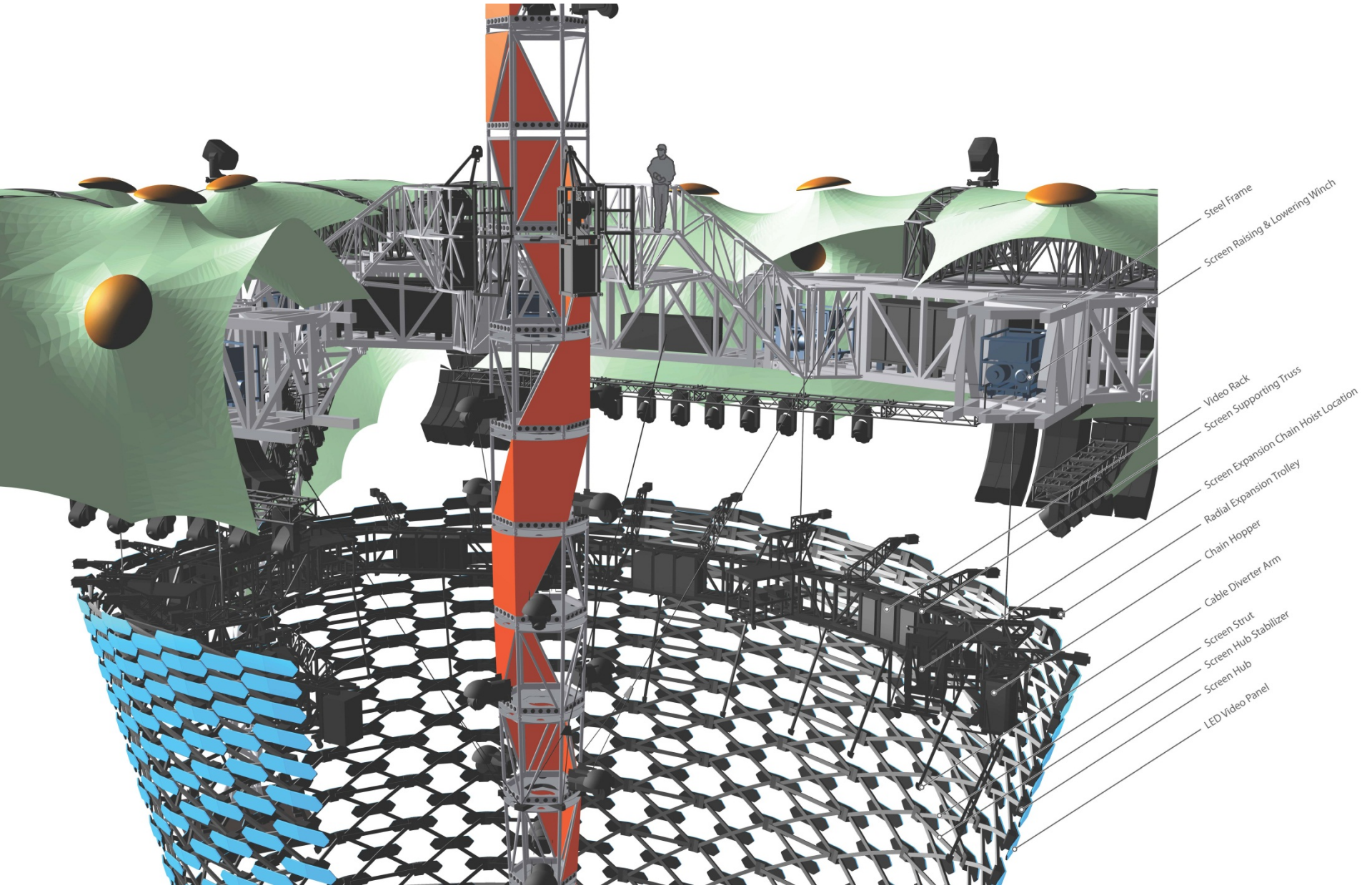
Scale: 25m X 17m X 25m (expanded)



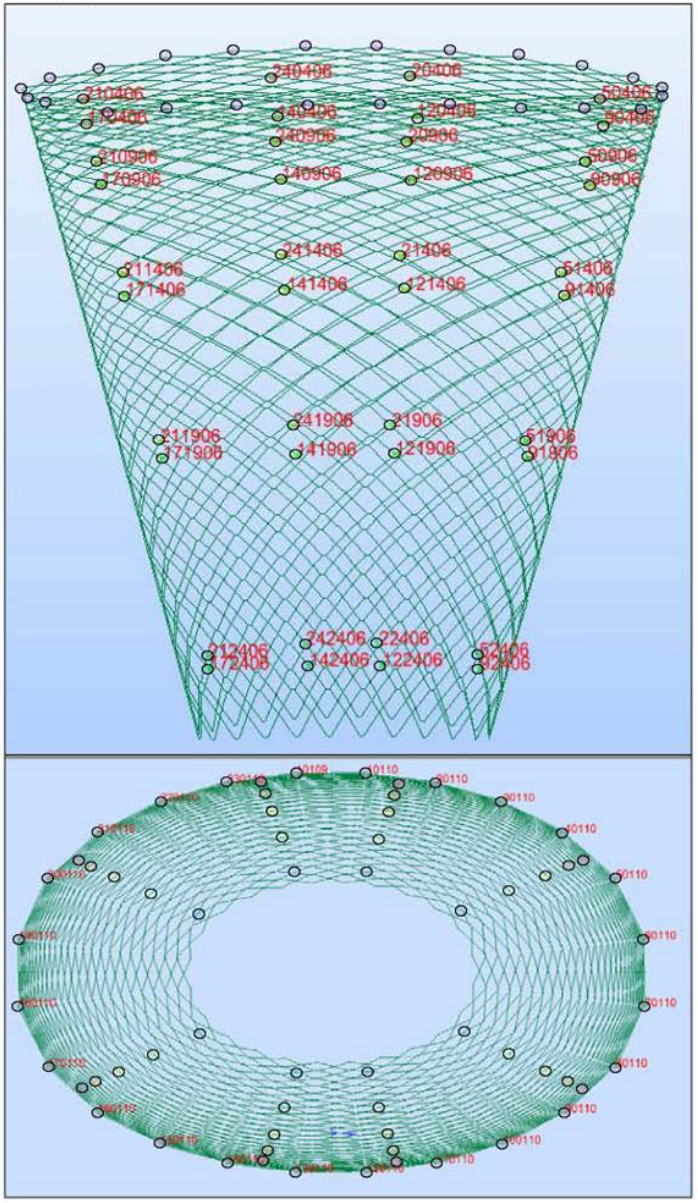


ROLL OVER ILLUSTRATION FOR DETAILS

Technology


Steel Frame
Screen Raising & Lowering Winch
Video Rack
Screen Supporting Truss
Screen Expansion Chain Hoist Location
Radial Expansion Trolley
Chain Hopper
Cable Diverter Arm
Screen Strut
Screen Hub Stabilizer
Screen Hub
LED Video Panel

U2 360 Tour (2009-2011)



Node	Dead Load Only 0% FZ (lbs)	50% FZ (lbs)	100% FZ (lbs)	90 MPH Wind (Side) + DL 0% FZ (lbs)	50% FZ (lbs)	100% FZ (lbs)	90 MPH Wind (Front) + DL 0% FZ (lbs)	50% FZ (lbs)	100% FZ (lbs)
10109	364.26	416.61	452.2	145.48	170.27	253.48	513.95	636.92	499
10110	363.82	404.67	437.01	251.19	249.63	312.9	507.58	598.24	483.94
120110	362.91	416	453.13	219.48	237.26	333.02	959.62	996.68	849.81
130110	365.78	406.03	437.68	139.41	172.37	261.6	897.94	920.74	800.8
20110	221.83	239.4	266.06	192.12	177.4	224.84	328.19	365.76	306.3
110110	258.38	302.5	339.64	188.31	187.64	261.56	778.89	806.95	669.68
140110	224.31	241.03	266.69	-2.87	19.3	95.22	594.47	595.11	509
230110	260.79	303.61	338.49	5.78	40.07	147.25	389.55	491.99	381.61
30110	314.53	303.99	299.92	319.34	303.91	302.82	300.7	268.2	239.42
100110	246.31	254.94	277.8	230.78	222.36	256.57	514.73	518.76	476.68
150110	315.38	304.53	300.3	211.09	205.7	221.27	469.76	462.84	435.68
220110	248.86	256.79	278.4	90.76	99.27	159.89	277.94	290.4	252.01
40110	528.58	503.56	444.5	545.82	534.91	464.85	373.83	291.36	241.04
90110	450.08	420.64	374.33	476.35	454.89	389.9	417.93	416.23	417.82
160110	528	503.07	444.02	591.26	574.68	516.34	476.13	482	469.32
210110	449.58	420.27	374.41	476.98	458.58	412.19	320.24	238.12	210.58
50110	275.19	279.48	274.19	274.39	285.28	280.38	168.68	143	126.68
80110	389.28	372.22	325.89	405.72	393.83	324.85	309.88	334.13	349.91
170110	274.65	279.02	273.59	326.72	328.71	317.99	264	300.48	319.18
200110	388.59	371.79	326	473.53	462.44	399.89	244.78	184.6	160.47
60110	-3.63	17.88	60.16	-15.37	5.18	57.35	-21.75	2.47	31.01
70110	53.46	66.72	94.28	46.98	59.3	88.51	54.92	88.86	124.25
180110	-3.92	17.65	59.93	3.52	14.83	45.92	22.15	61.76	99.55
190110	53.15	66.5	94.23	77.32	83.42	98.05	14.2	25.39	49.43
20406	1616.92	1730.12	1977.99	1265.7	1205.28	1253.65	2014.63	2216.38	1977.27
120406	1550.55	1745.57	2045.97	1061.9	1050.27	1167.53	3475.99	3708.26	3848.37
140406	1627.48	1737.33	1981.21	1027.34	1179.82	1679.57	3126.22	3250.83	3427.71
240406	1561.66	1752.61	2045.02	897.63	1057.82	1575.05	2052.91	2484.15	2193.36
50406	2382.43	2252.21	1936.05	2561.44	2524.86	2085.56	1440.44	1003.87	815.95
90406	2449.41	2280.85	1936.62	2679.25	2560.73	1973.64	859.08	814.35	841.02
170406	2378.74	2249.09	1931.2	3364.56	3356.75	3194.78	852.92	809.39	762.57
210406	2448.26	2281.35	1942.15	3386.1	3365.95	3154.34	1556.72	1080.82	974.99
20906	1869.55	2016.44	2638.18	1403.12	1206.11	1270.45	2362.93	2757.72	2585.56
120906	1835.91	2036.59	2671.4	1328.29	1149.59	1173.69	3393.4	3855.39	4787.69
140906	1881.82	2026.4	2644.76	1358.96	1435.57	2384.42	3311.67	3671.36	4587.48
240906	1837.29	2034.1	2658.98	1365.32	1426.46	2295.63	2284.18	2873.68	2746.41
50906	2928.7	2711.23	2127.31	3116.35	3053.63	2153.15	1858.38	1033.95	176.83
90906	2952.26	2718.11	2133.06	3159.12	3018.42	1935.08	1744.13	1404	1446.01
170906	2924.9	2707.27	2120.92	3908.03	3984.86	4020.6	1631.18	1243.21	1109.76
210906	2949.23	2715.96	2136.93	3809.21	3870.85	3806.12	2011.36	1217.55	532.19
21406	1675.92	2020.13	2776.2	1292.82	943.53	1556.19	2106.32	2917.7	1694.52
121406	1699.57	2060.17	2760.08	1326.48	945.38	1367.63	2575.41	3922.62	4141.75
141406	1704.08	2047.34	2796.91	1396.9	1594.26	3206.33	2611.69	3894.43	4041.41
241406	1651.02	2011.92	2699.35	1471.2	1628.62	3005.73	1937.65	2928.07	1820.49
51406	2786.78	2439.81	1658.47	2915.28	2834.3	1152.69	1970.16	215.58	-402.43
91406	2782.41	2429.8	1625.07	2941.58	2792.15	918.41	2111.93	1372.71	2570.95
171406	2784.89	2436.67	1651.81	3497.74	3944.49	3745.7	2024.07	1141.15	2159.87
211406	2773.95	2421.47	1623.94	3338.57	3725.45	3377.82	2082.41	428.9	-55.96
21906	1833.52	2172.62	2769.89	1520.14	825.24	1628.67	2133.38	3211.26	1511.49
121906	1875.27	2180.15	2691.39	1592.49	778.57	1295.99	2057.47	3102.85	2051.92
141906	1837.98	2198.85	2788.66	1649.71	1755.72	3081.25	2058.18	3114.25	1902.18
241906	1844.25	2153.73	2649.41	1799.67	1802.59	2823.18	1945.56	3154.87	1607.32
51906	2921.75	2361.81	1794.11	2985.72	2542.94	269.64	2309.32	-150.72	916.93
91906	2877.82	2333.88	1713.4	2991.34	2528.89	56.54	2520.14	1687.6	4378.02
171906	2906.67	2344.43	1778.53	3330.55	3475.31	2445.67	2484.74	1494.29	4146.66
211906	2868.94	2323.41	1709.75	3132.51	3222.74	2072.45	2372.55	44.91	1196.86
22406	1262.79	1785.11	2083.1	1139.32	1449.58	3023.2	1413.91	1904.5	-1096.8
122406	1246.61	1701.98	1934.71	1146.02	1295.16	2641.42	1377.16	2344.06	1041.25
142406	1197.77	1724.48	2014.72	1194.82	1853.96	3346.35	1354.45	2247.35	825.43
242406	1142.27	1609.74	1833.7	1224.3	1770.27	3012.35	1174.79	1684.46	-1101.15
52406	2132.85	1865.13	1740.09	2163.87	1813.13	418.64	1936.41	705.86	1555.15
92406	2042.51	1752.64	1551.66	2100.13	1719.2	112.28	2237.47	3558.95	7222.95
172406	2085.9	1811.32	1684.62	2361.19	2945.33	3320.34	2244.84	3463.71	6931.34
212406	2035.42	1745.53	1546.04	2217.41	2721.21	2867.88	1901.83	760.96	1719.7

Support Case 2

Cable Loads

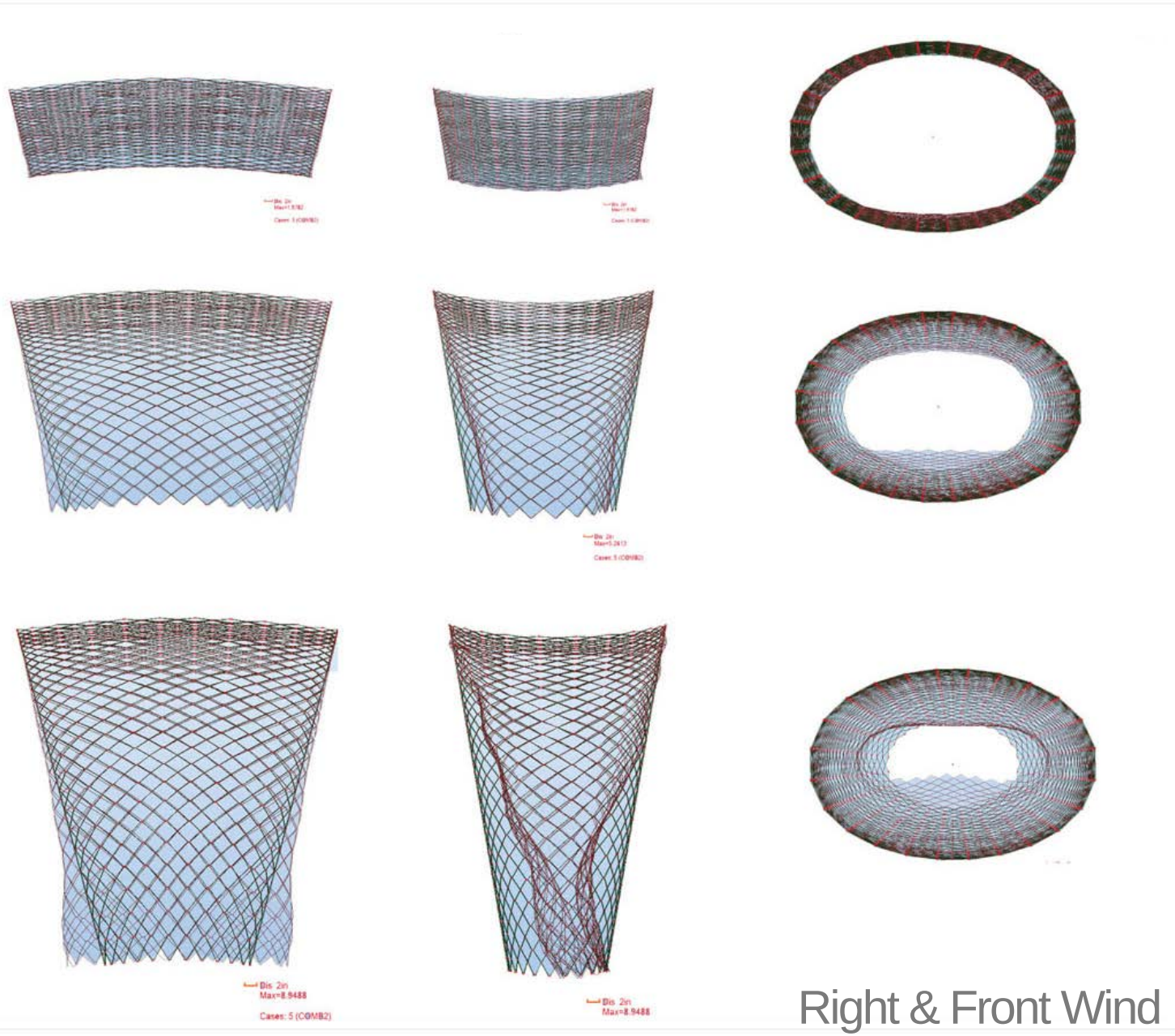
Notes

HOBERMAN
Hoberman Associates, Inc.
40 South Street
Suite 1680
New York, NY 10013
USA
p (+1) 212.349.7919
f (+1) 212.349.7930
www.hoberman.com

Drawn by BW
Checked by

Status

Project Barco U2009
Architect Hoberman Associates, Inc.
Drawing No. 116_Hub_Assembly_Detail
Revision 01
Date 2008.10.01



HOBERMAN

Right & Front Wind Loading (90 MPH)

U2 360 Tour

Expanding Video Screen Development

ADAPTIVE BUILDING INITIATIVE

Concept / Patent

Prototype

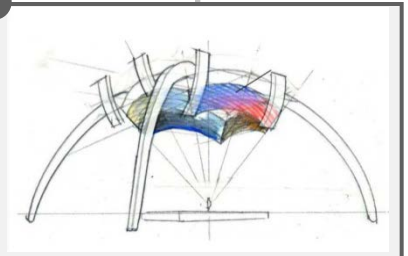
Engineering Development

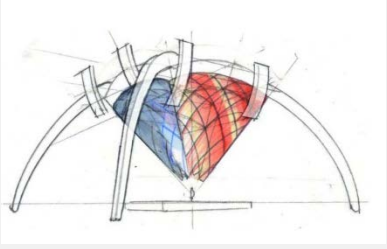
Manufacturing Relationships

Construction & Assembly

Testing

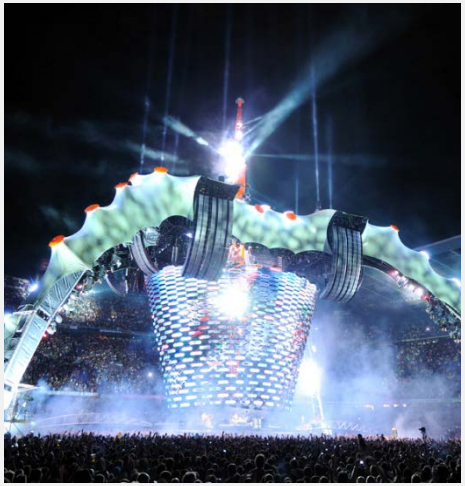
Full-Scale Implementation

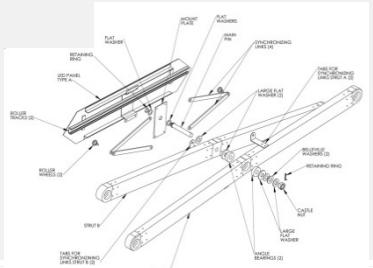


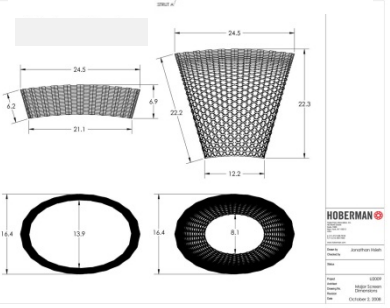


BARCO Visibly yours

INNOVATIVE DESIGNS







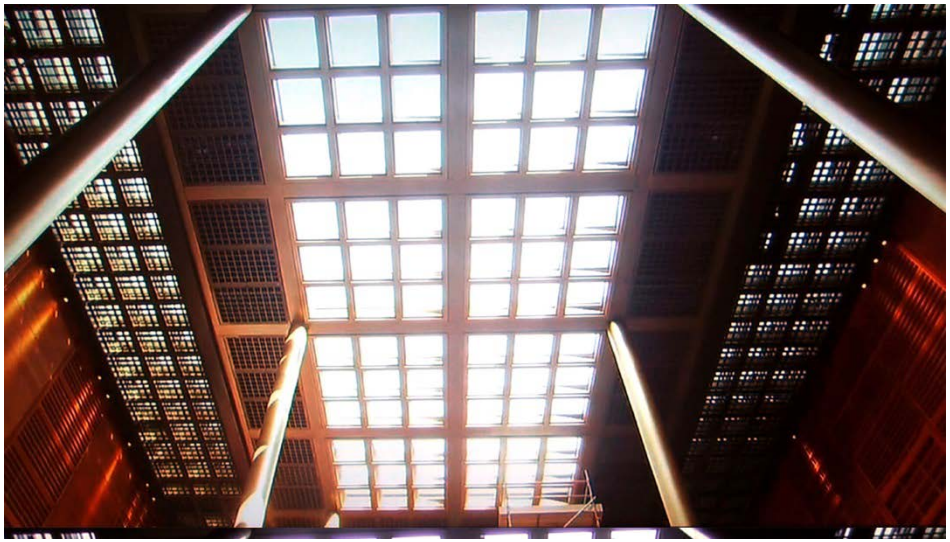
Other interesting directions…

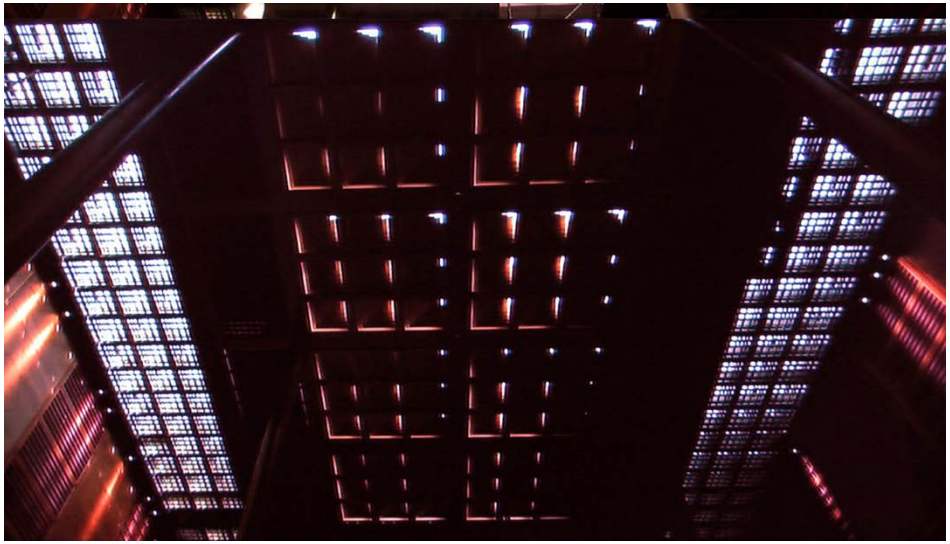
Architecture

Pola Ginza 2009, Yasuda Atelier + Nikken Sekkei

Architecture

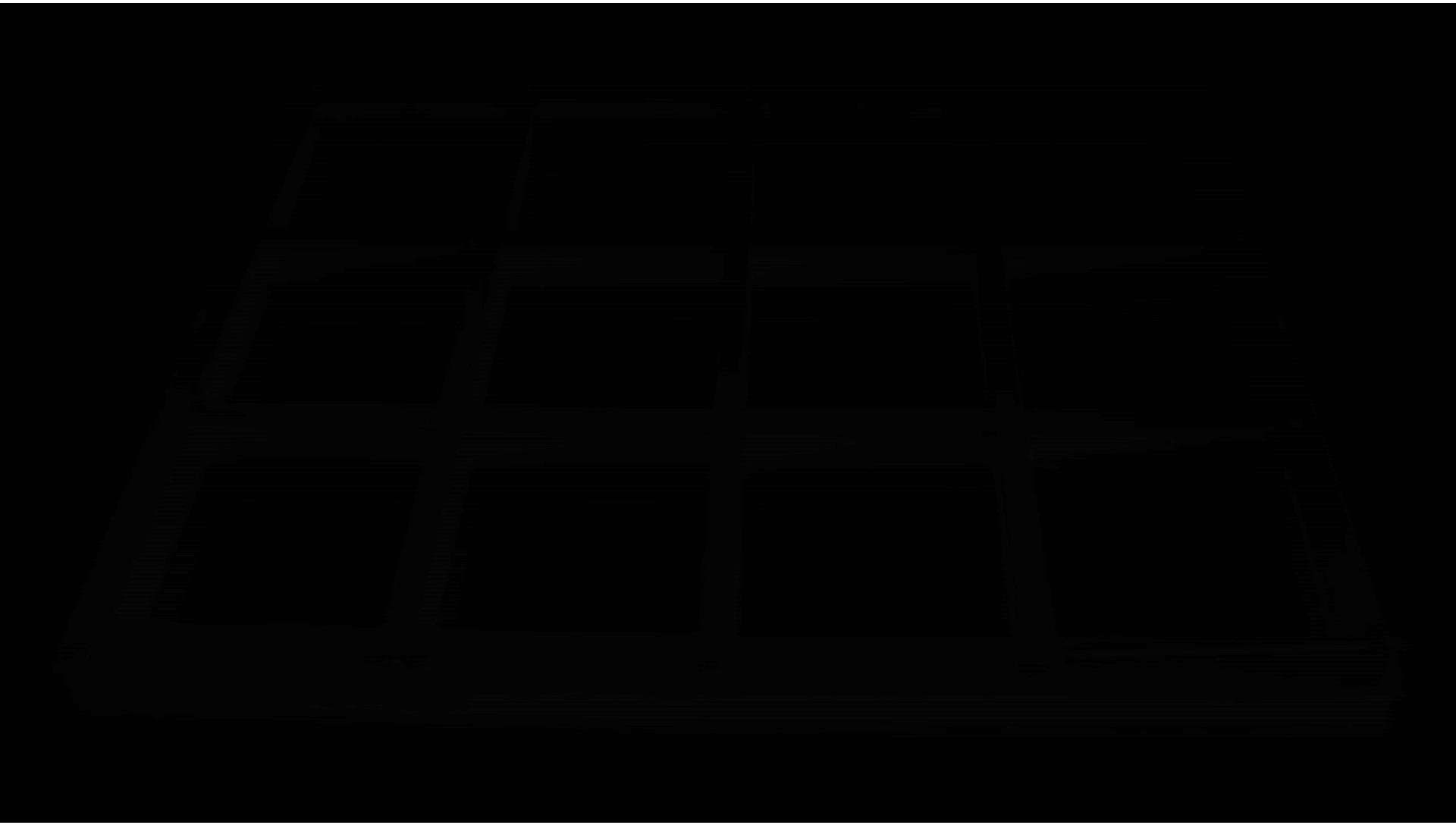
Aldar Central Market 2010, Foster + Partners





Architecture

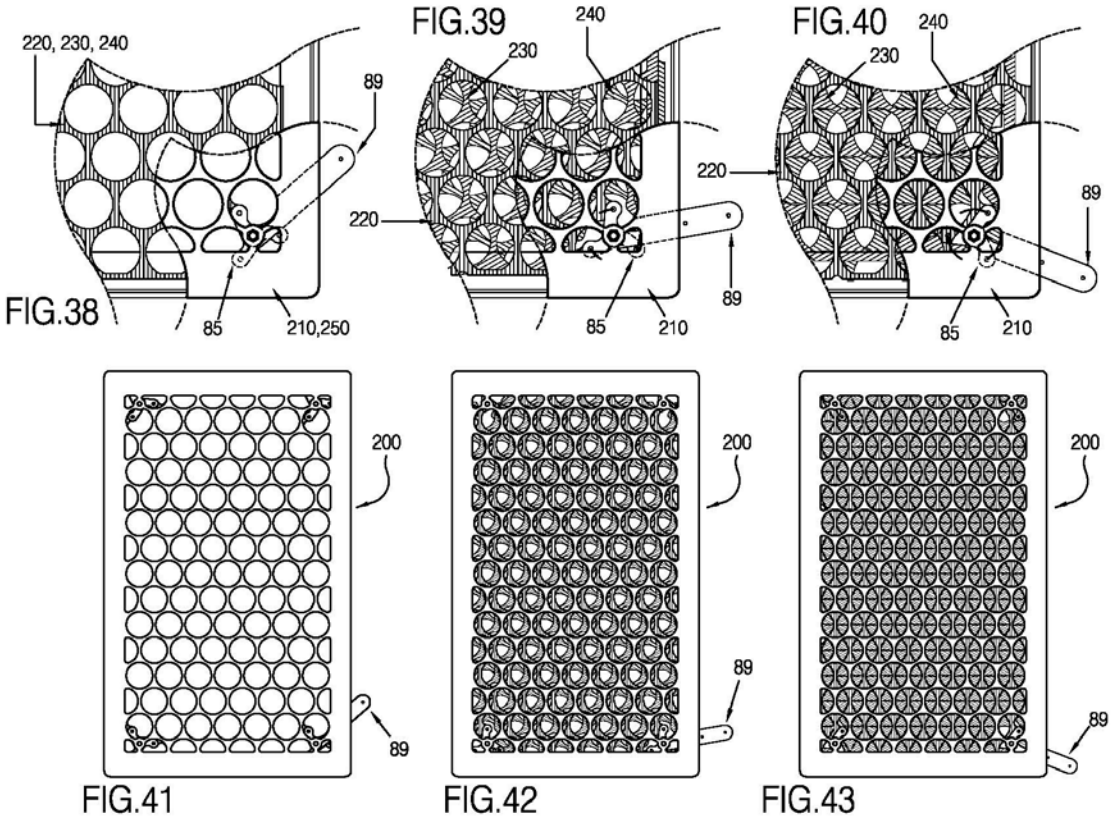
Aldar Central Market 2010, Foster + Partners



Intelligent façade technologies

Adaptive Fritting

Intelligent façade technologies
Tessellate (dynamic screens)



Harvard Graduate School of Design

Transformable Design Methods

(Fall 2012)

NOTE! – EXHIBIT OPENING TONIGHT 2/11 6:30PM

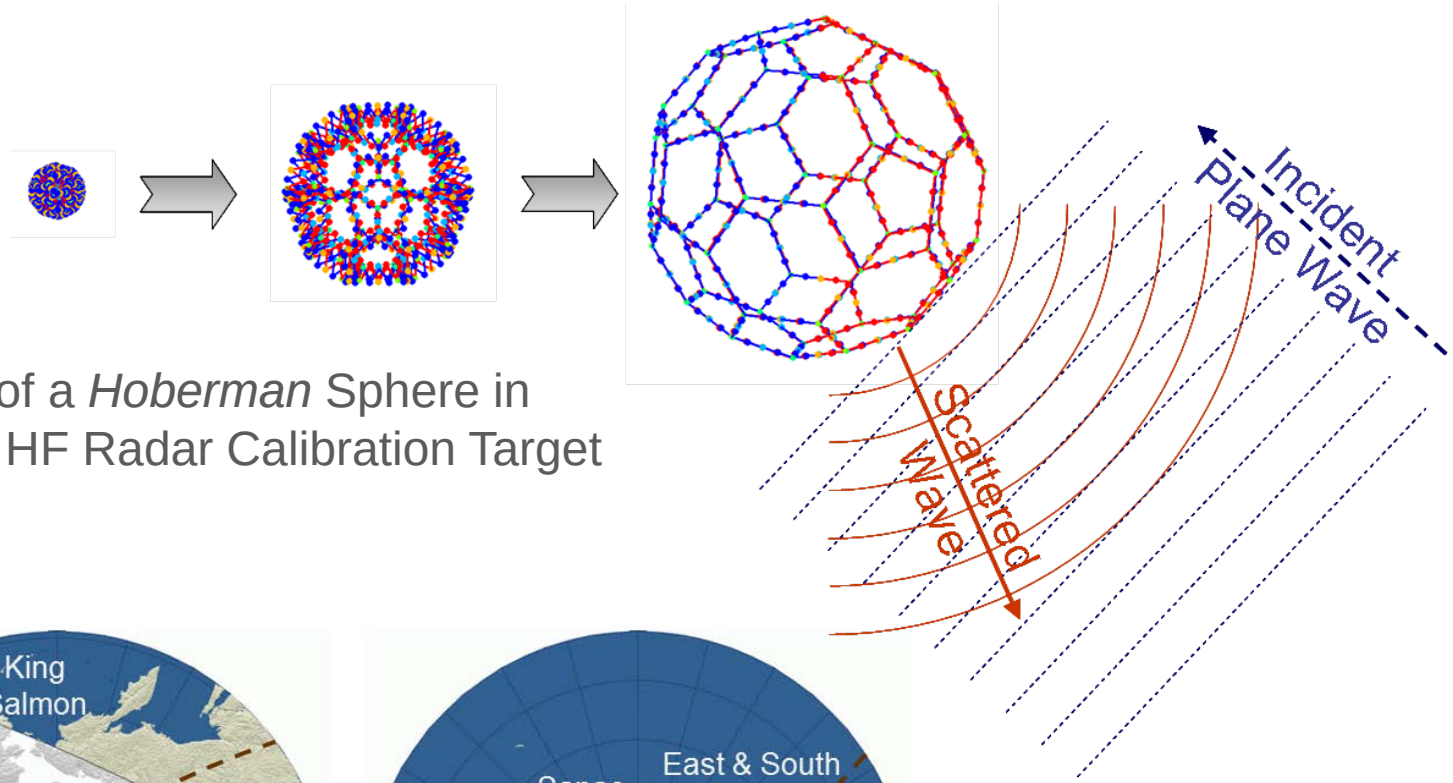
Space structures

PERCS (Precision Expandable Radar Calibration Sphere)

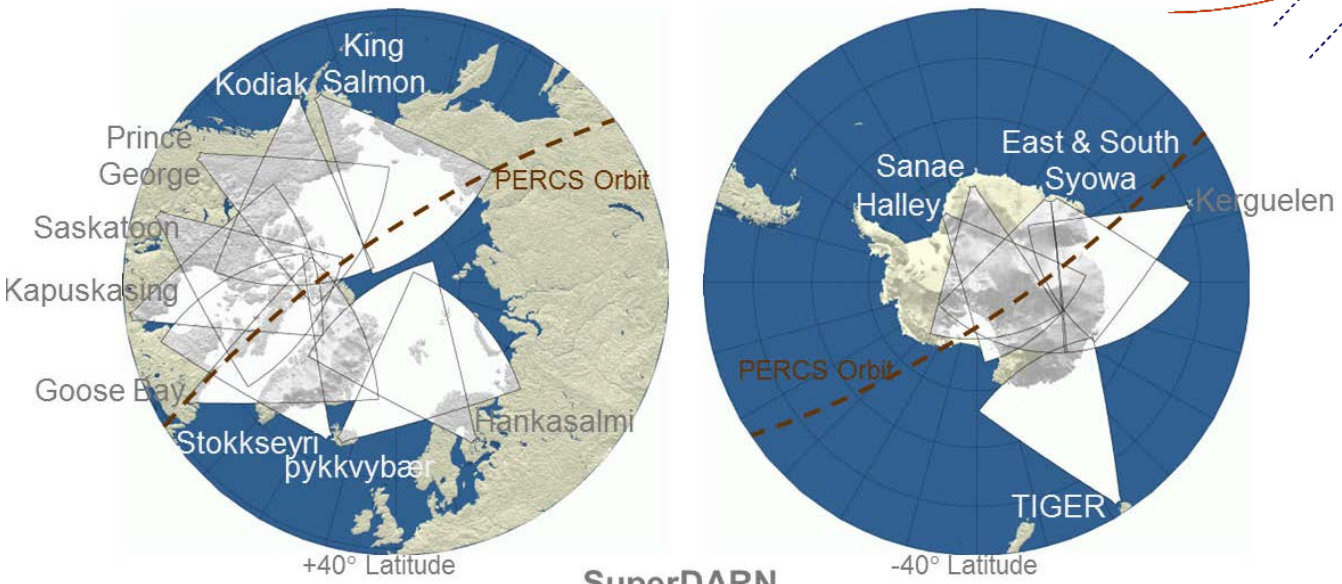
Concept: Dr. Paul A. Bernhardt
Plasma Physics Division
Naval Research Laboratory

Hoberman Sphere in Space as an HF Radar Calibration Target

PERCS



Deployment of a *Hoberman* Sphere in Space as an HF Radar Calibration Target



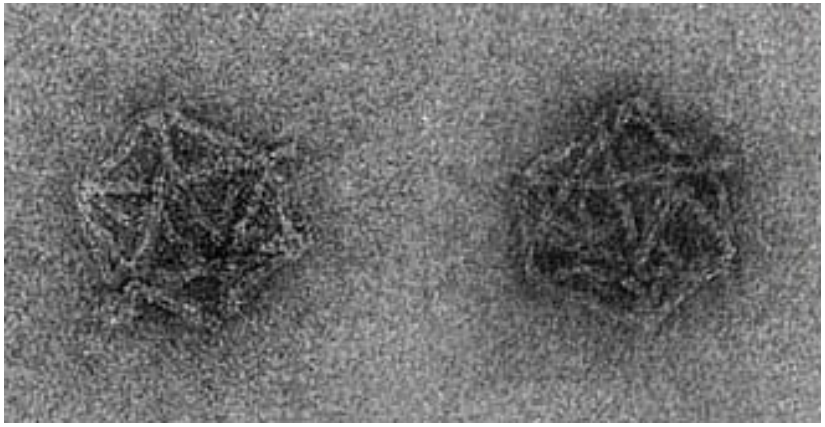
SuperDARN

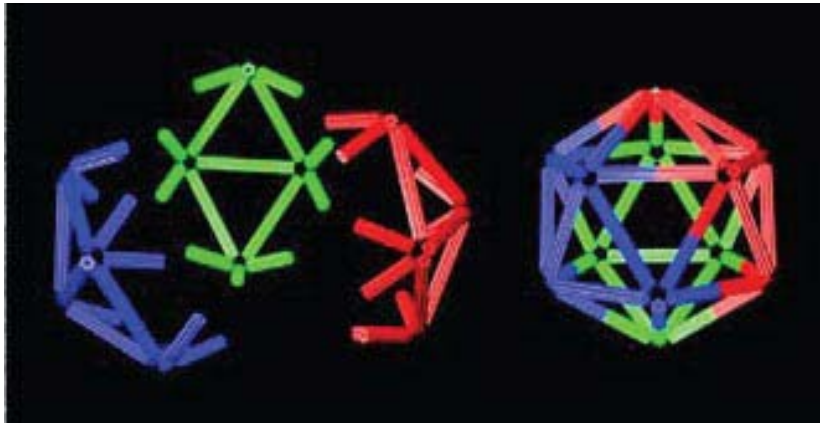
An International Radar Network for Studying the Earth's Upper Atmosphere, Ionosphere, and Connection into Space

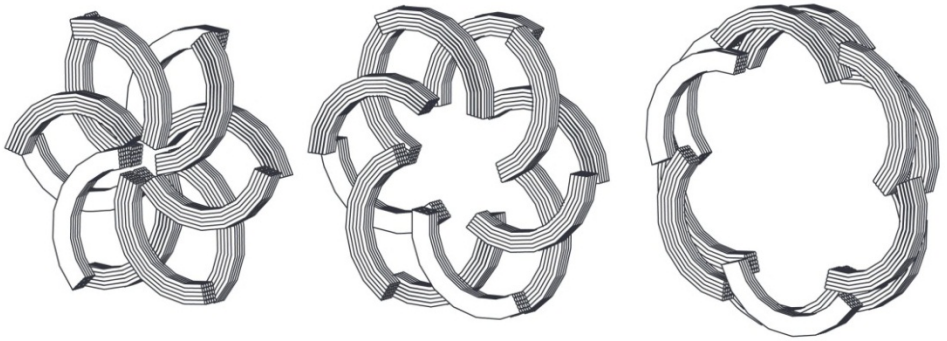
Folding structures made from DNA

Research Collaboration, Dr. William Shih

WYSS INSTITUTE for Biologically Inspired Engineering at Harvard University

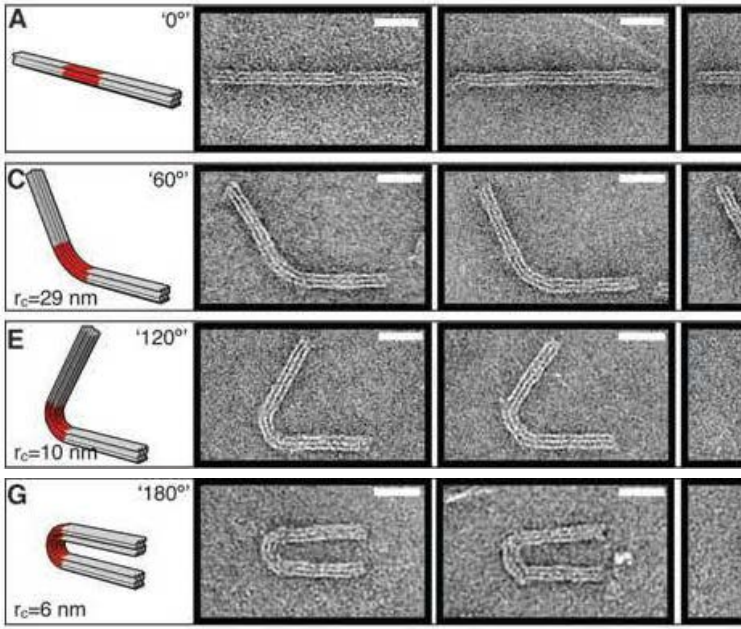


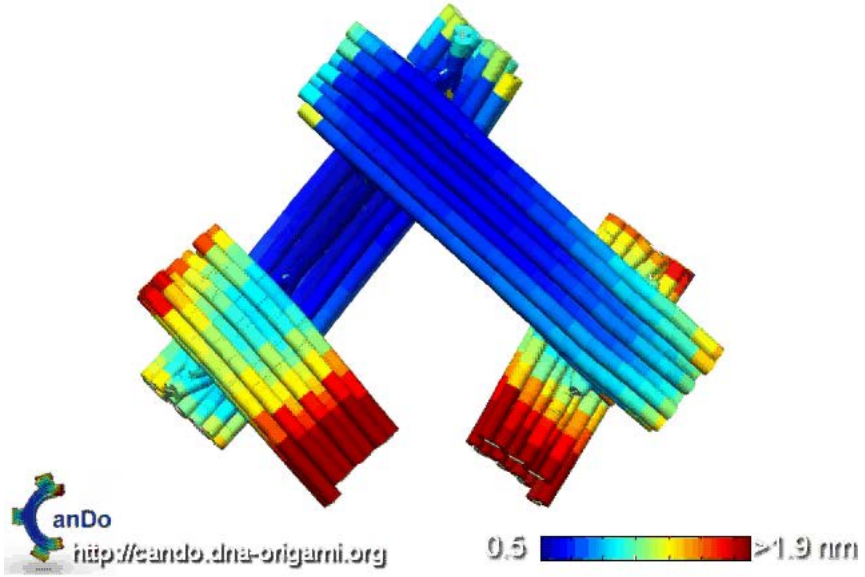


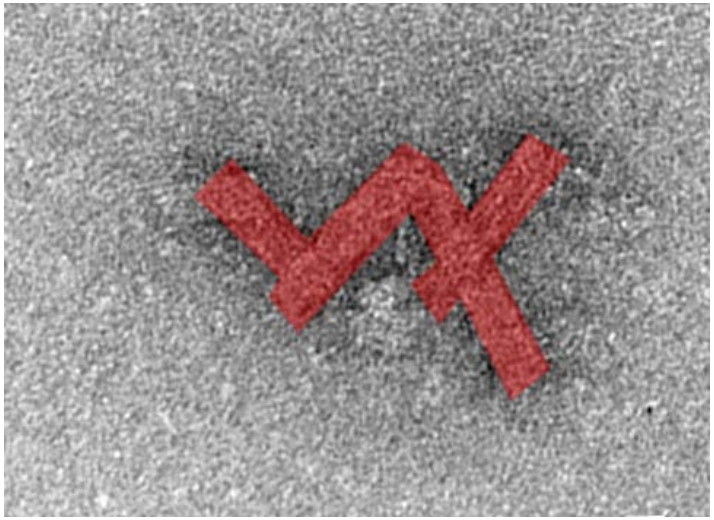


Folding structures made from DNA

WYSS INSTITUTE

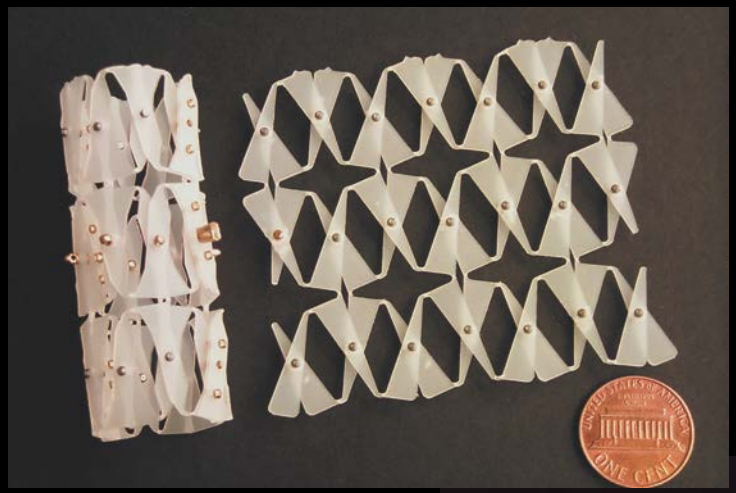


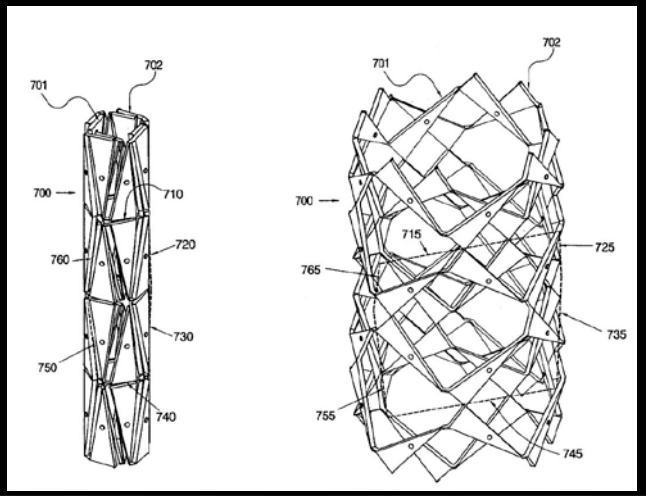


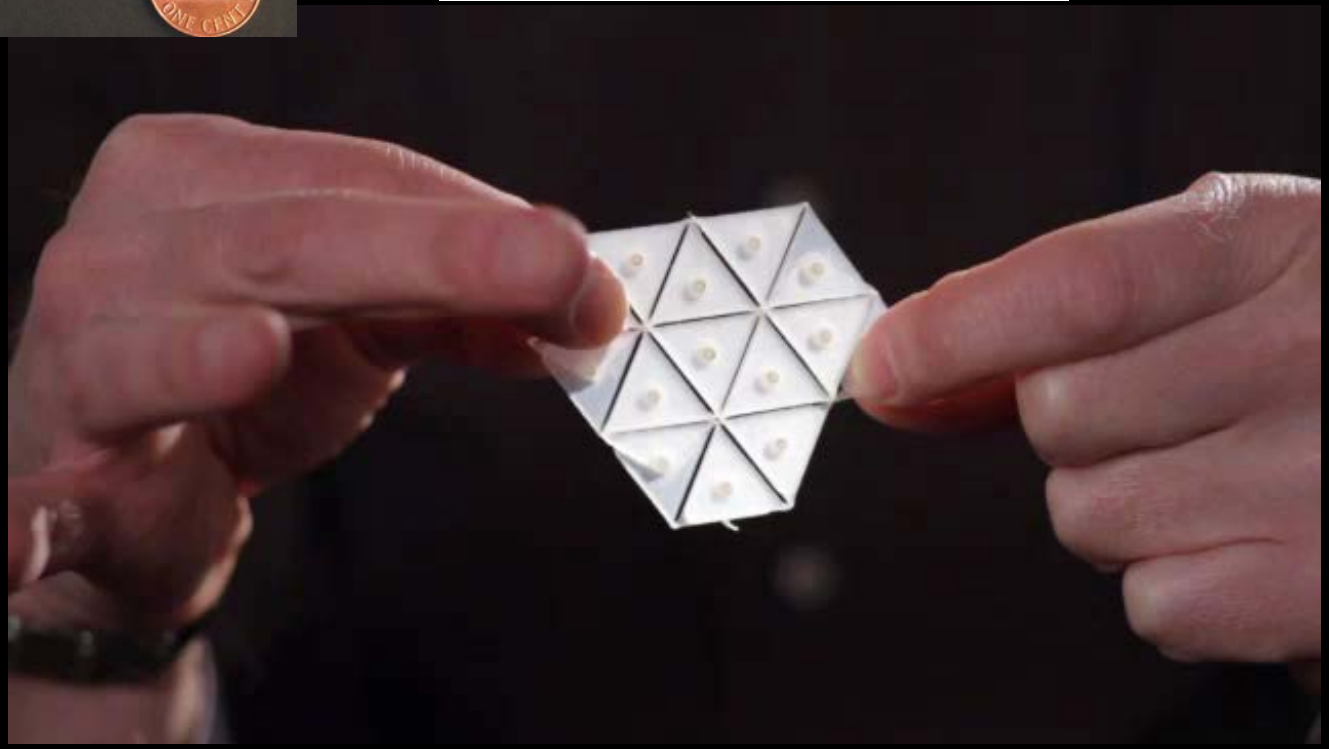


Medical devices

Flexures (living hinges)

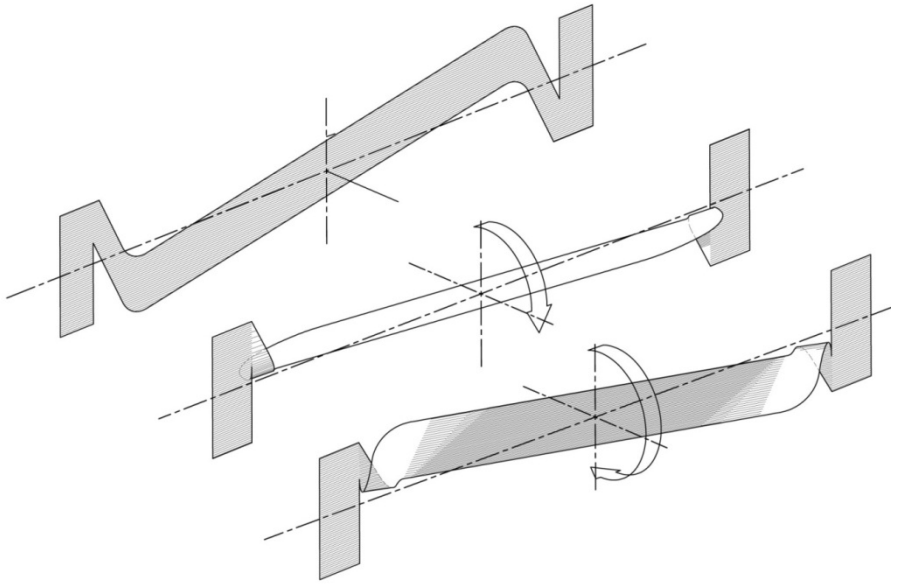




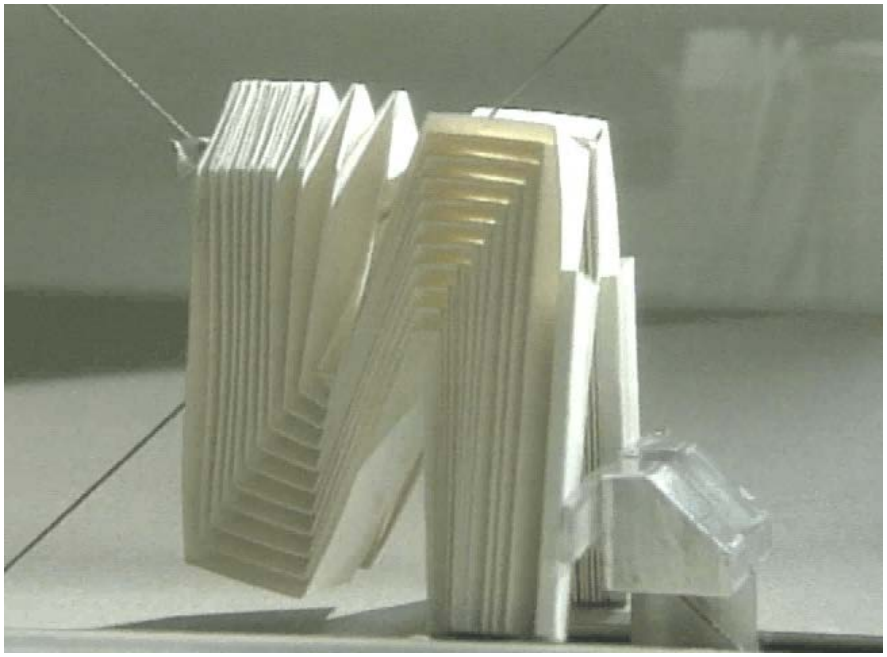


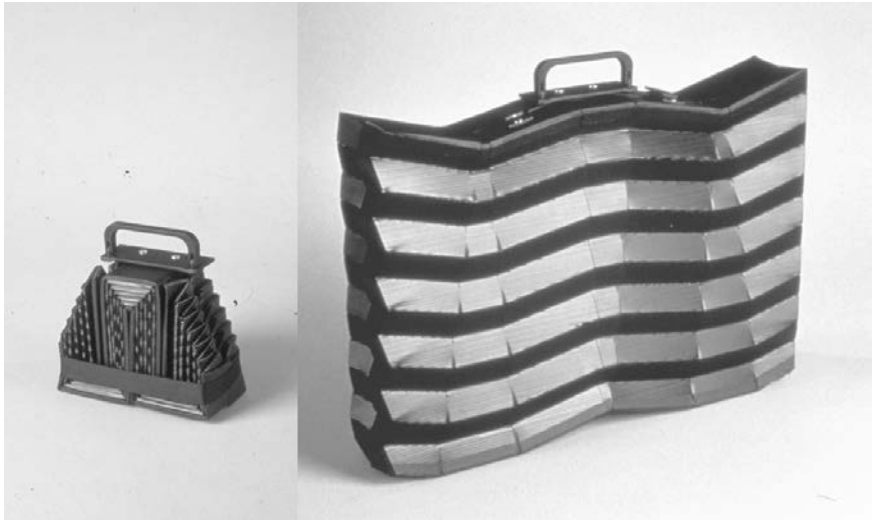
Sheet based mechanisms

Flexures: tension activated

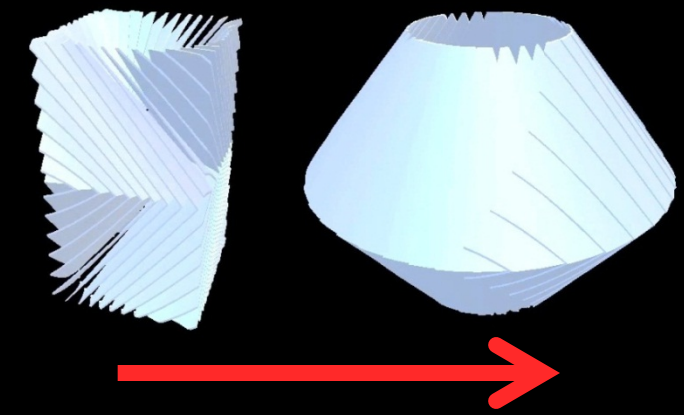


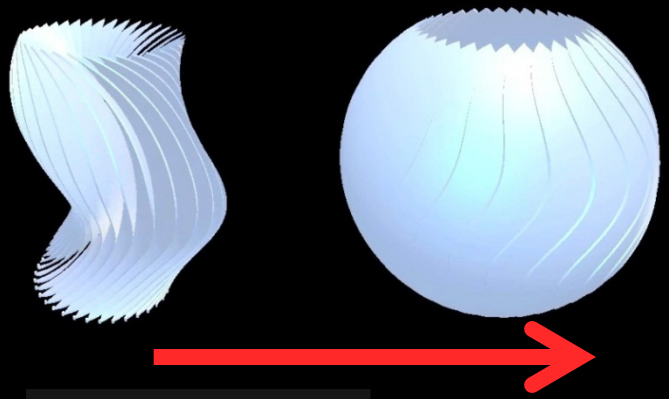
Origami Mechanisms

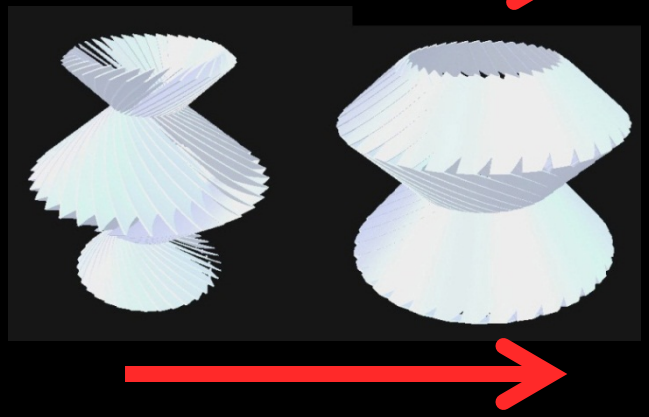


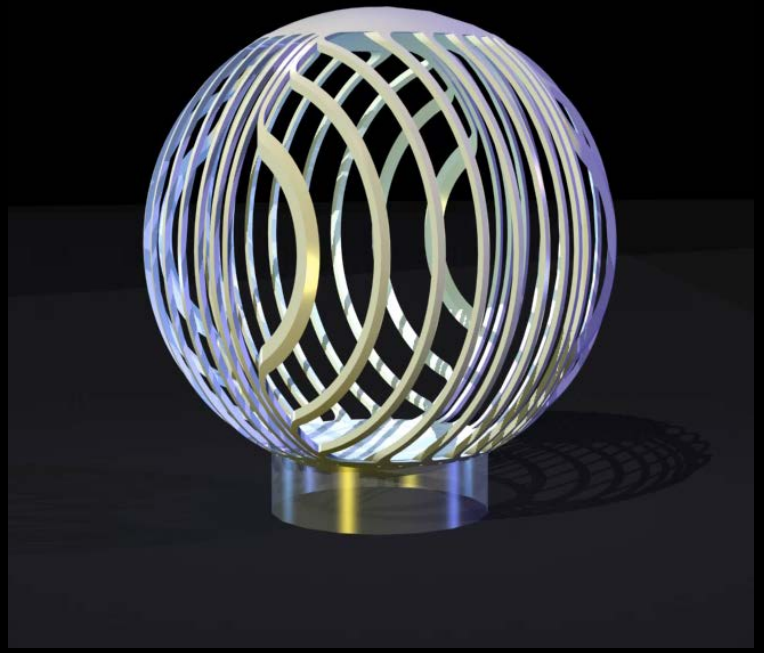


Morphing Structures

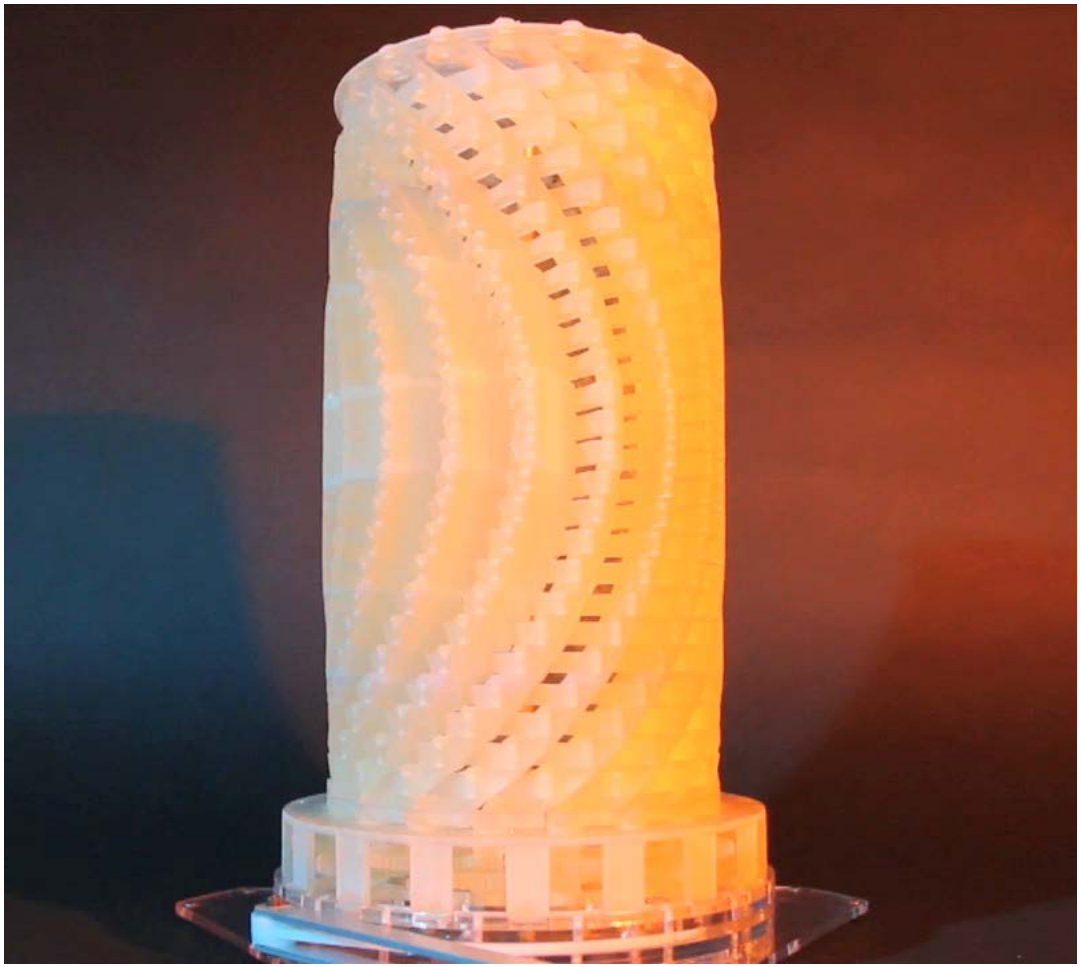


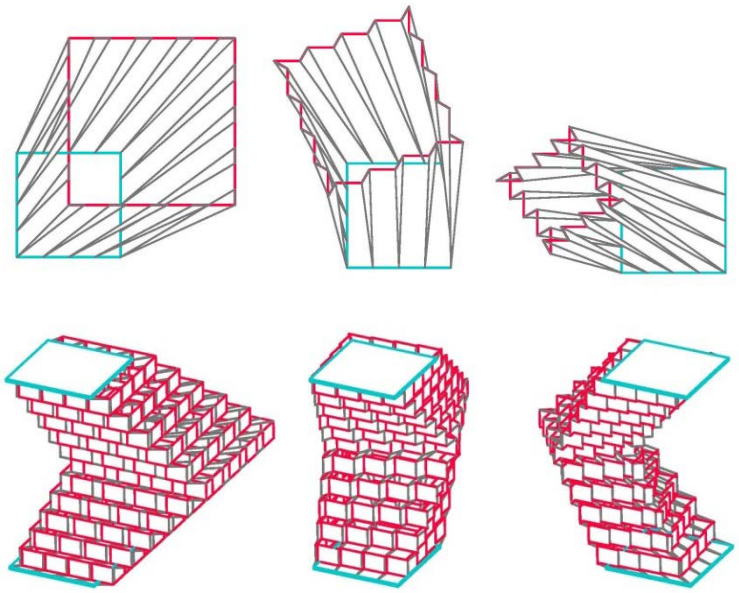


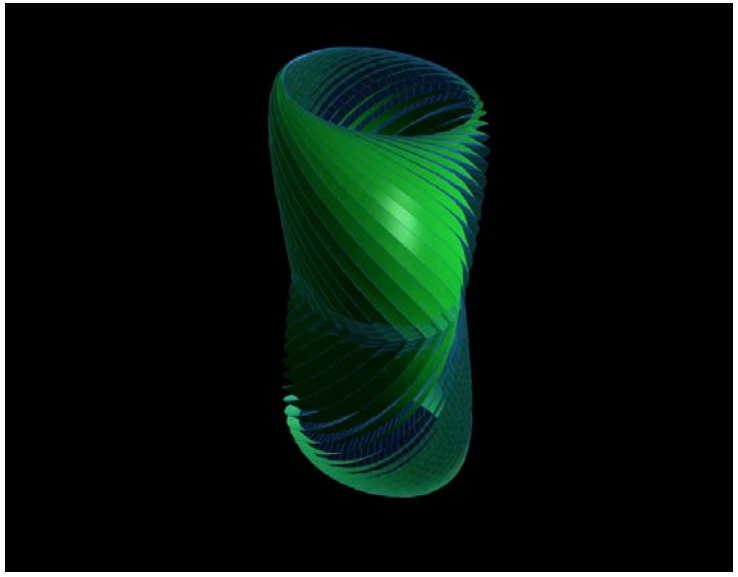




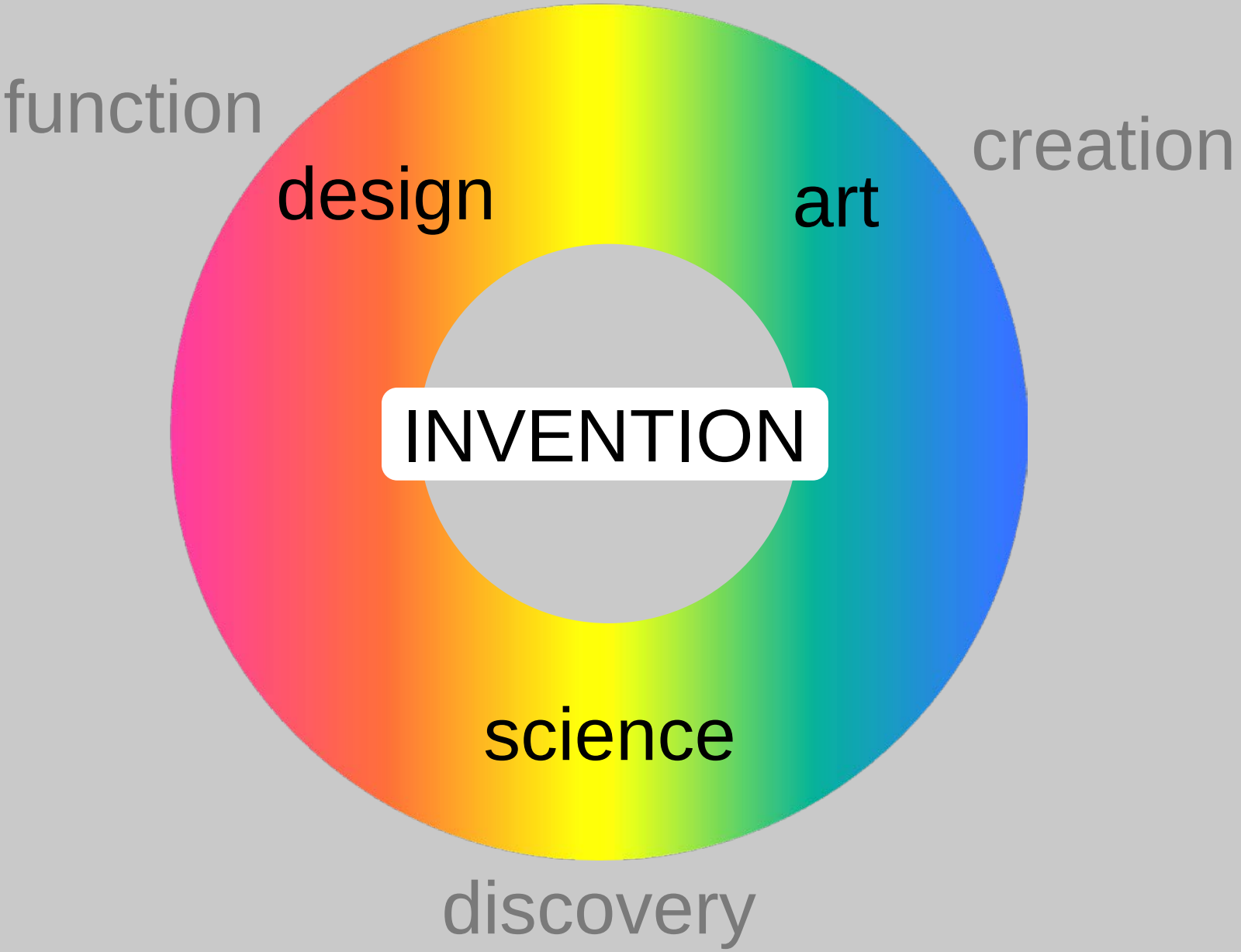
Morphing Structures







Forms of Creativity



US Patent Law

Invention criteria

1. New (easy)
2. Useful (easy)
3. Non-obvious (sometimes hard)

Mechanical Invention

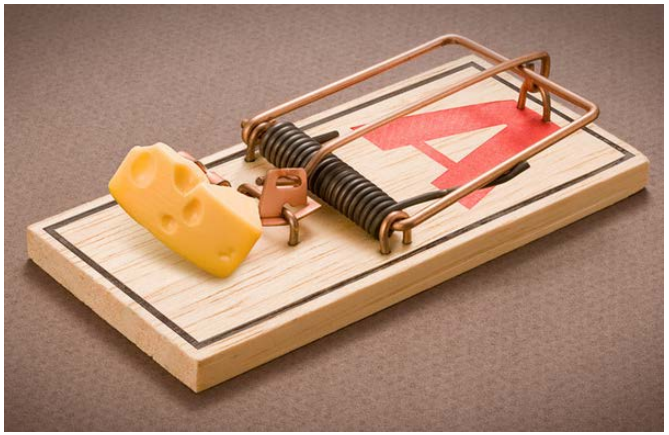
Functional parameters

- Use
- Behavior
- Interaction
- Markets

Technical parameters

- Geometry / topology
- Degrees of freedom
- Trajectory
- Joint types
- Integration with other systems

Is Necessity the mother of invention?



Or is Invention is the mother of necessity?

Inventive development (alternate routes + motivations)

FUNCTIONAL

DEVELOPMENT

TIMELINE

TECHNICAL

“Invention consists… in constructing the useful combinations, which are in infinite minority.

Henri Poincare

Useful combinations

art vs. science

physical vs. virtual

natural vs. man-made

The boundaries are blurring…