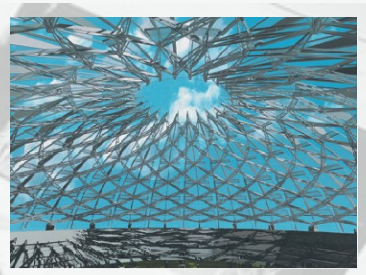
Budapest University of Technology and Economics (BME)

Laboratoire de Mécanique et Technologie
École Normale Supérieure de Cachan

Quick construction by deployable structures

A study on deployable structures enabling a quick constructional method



Noémi FRIEDMAN,
Prof. Adnan IBRAHIMBEGOVIC, Luc Davenne, Prof. György FARKAS

-Scissor-like deployable structures
- Pantograph structures
- Adaptive/interactive kinetic structures

INTRODUCTION

"Deployable structures are prefabricated structures capable of executing large configuration changes thus can be transformed from a usually a closed, compact configuration to a predetermined, expanded form in which they are stable and can carry loads" [Gantes]

Deployable structures in nature

- virus capsids
- leaves
- wing of insects

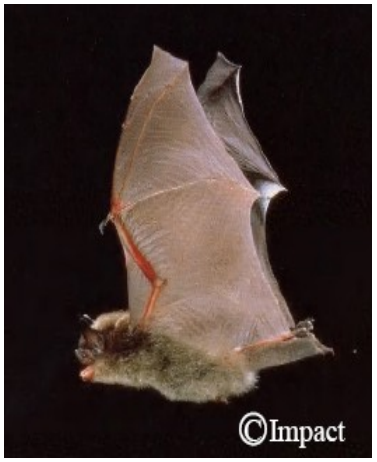


Image from: Kishimoto (et al) - New Deplosable Membrane Structure Models Inspired by Morphological Changes in Nature

Man made deployable structures

- Small and simple deployable structures: chair, umbrella, fans
- Advanced structures in spatial engineering: booms, solar arrays, antennas
- Structures for civil engineering and architecture: tents, portable shelters, retractable roofs, kinetic exhibition displays

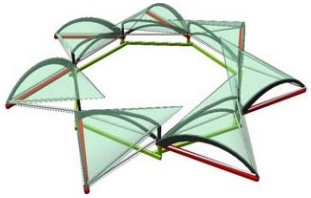


Image from: Carolina Rodriguez

Image from: Giulio Barbieri S.p.A

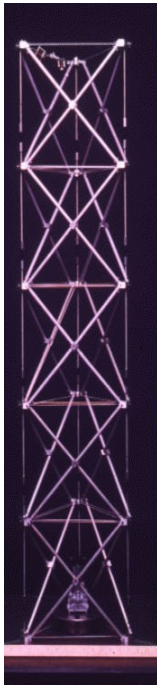
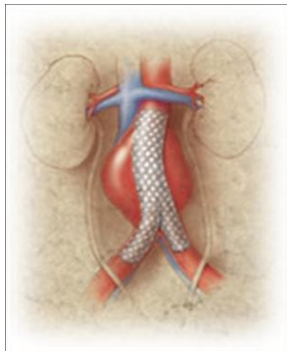


Image from: Deployable Structures Laboratory

!!!Resistance to service loads in the operational configuration + flexibility enabling transformation process

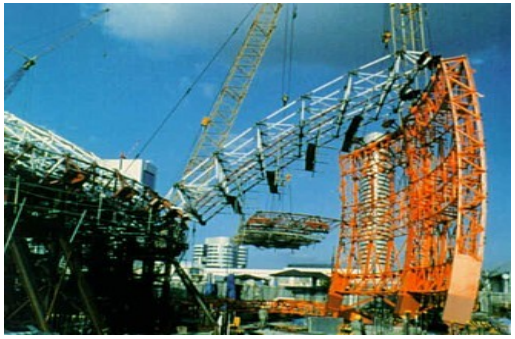
INTRODUCTION

Why to make it deployable?



pop-up Stent

World Memorial Hall



Nara Centennial Hall

Pop up tent by Pinnacle

Deployable exhibition display by Nomadic Display

Hamanizuki Park

- Easy and fast mounting

INTRODUCTION

Why to make it deployable?

- Transformability, transportability

INTRODUCTION

Why to make it deployable?

Oita Main Stadium

BMW 3 convertible

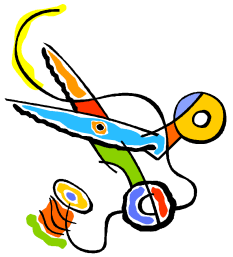
Cardinal Stadium

- Response to external excitations

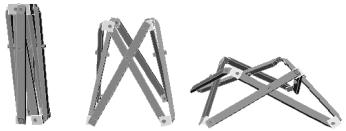
„to design a cabrio is like to design a suspension bridge without cables”

SCISSOR LIKE DEPLOYABLE STRUCTURES – The principle

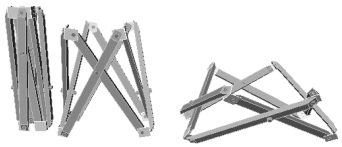
- Basic element: SLE
- Secondary units:



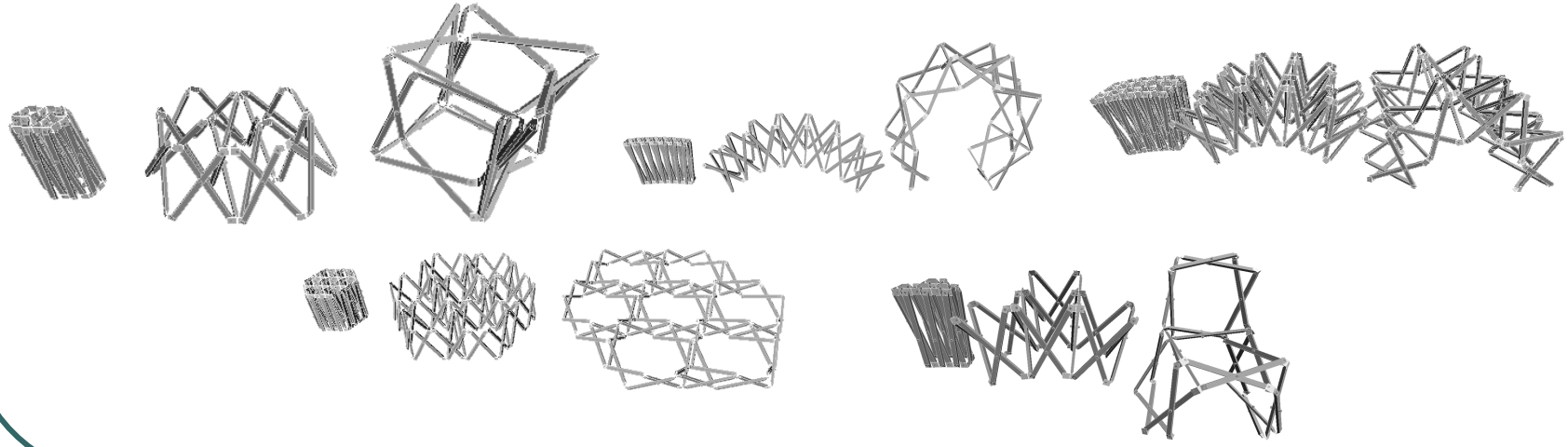
Triangular pyramid unit



Square pyramid unit

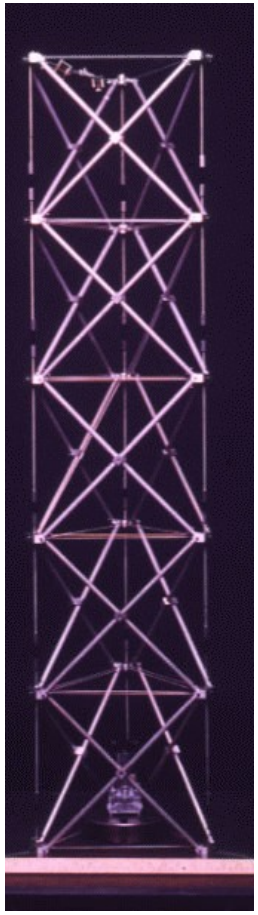


Skew type unit

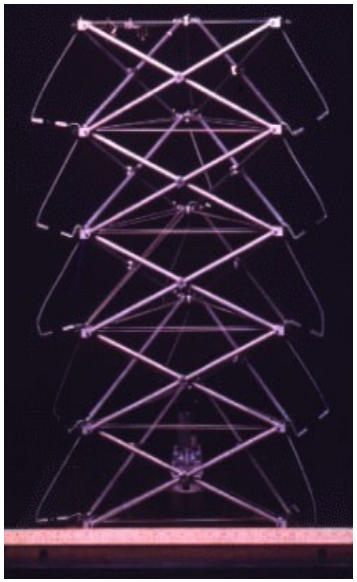


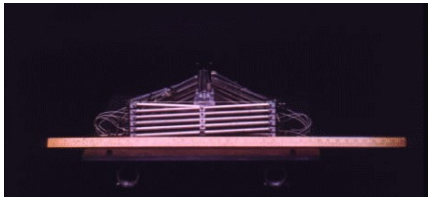
Images from: ATAKE Space Design Laboratory Co., Ltd. Japan - New variations on scissor technique

SCISSOR LIKE DEPLOYABLE STRUCTURES with external control and stabilization



Deployable mast of S. Pellegrino





Deployable bridge in the Hamanizuki Park

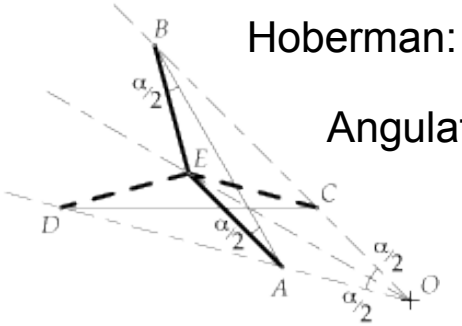
Images from: Deployable Structures Laboratory

Deployable domes

Hamanizuki Park deployable dome

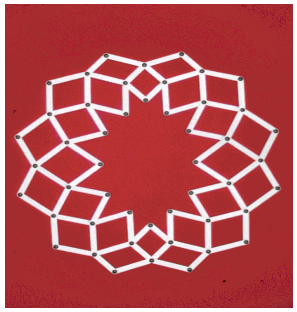
Hoberman magesphere

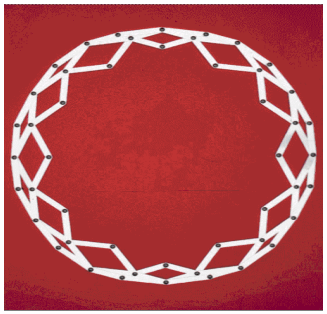
Retractable roof structures



Hoberman:

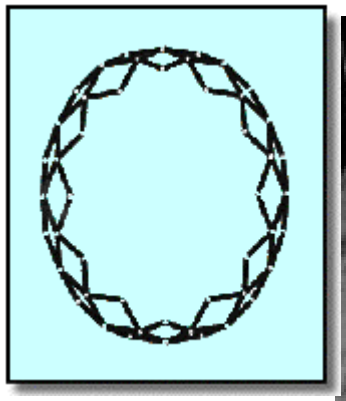
Angulated element

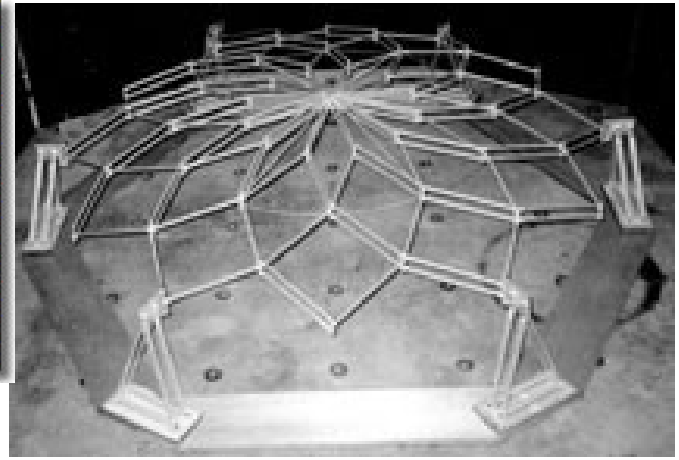


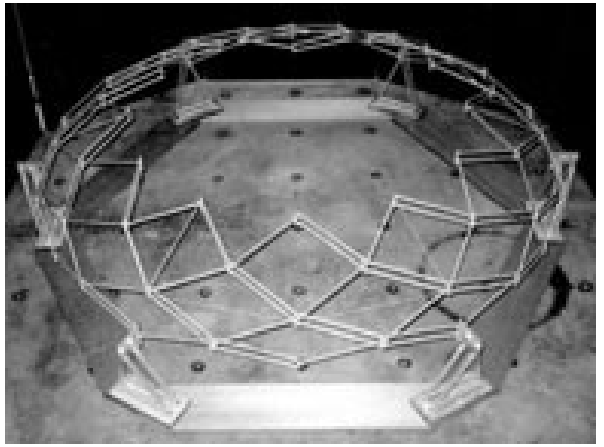


Yris dome

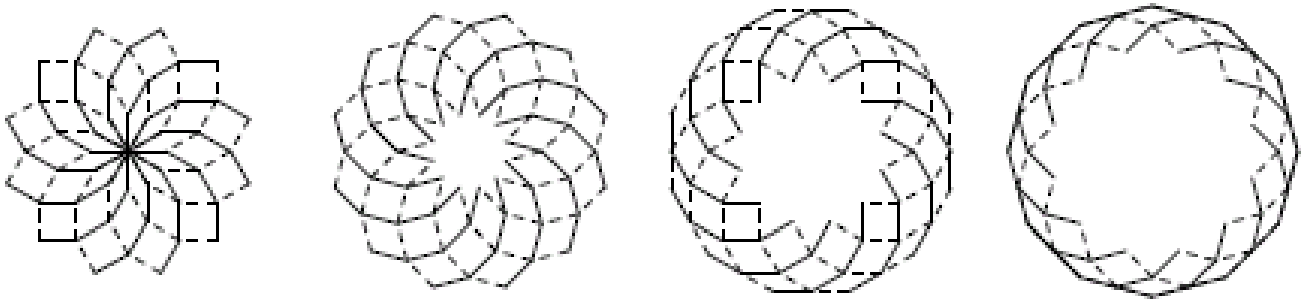
Retractable roof structures



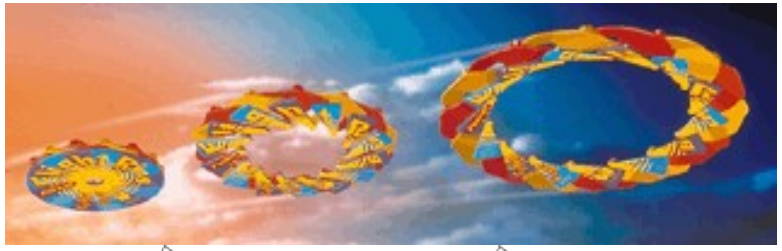


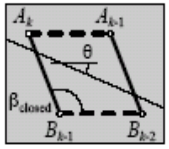


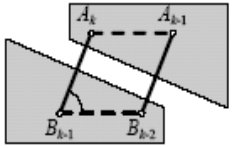
Z. You et S. Pellegrino

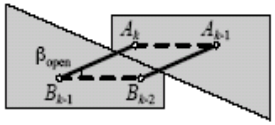


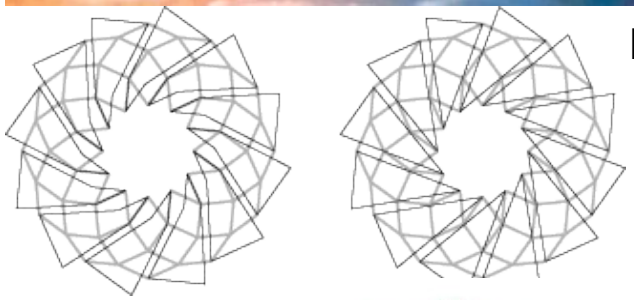
Retractable roof structures



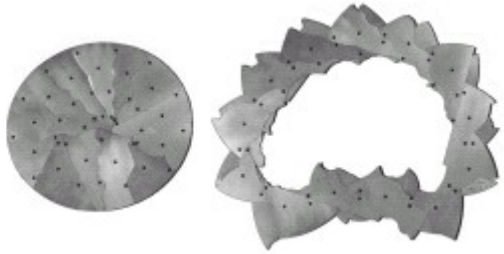




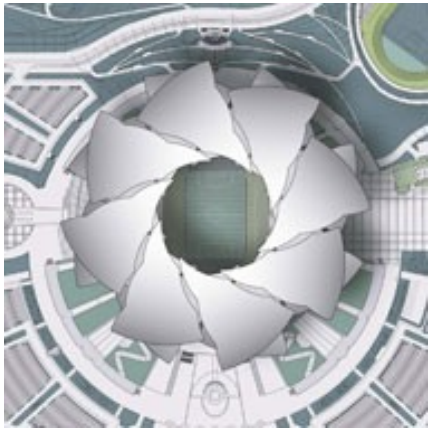


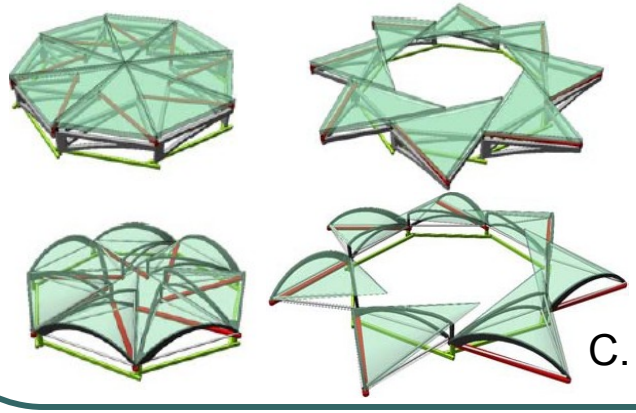


P. E. Kassabian



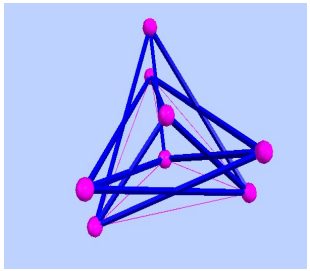
F. Jensen

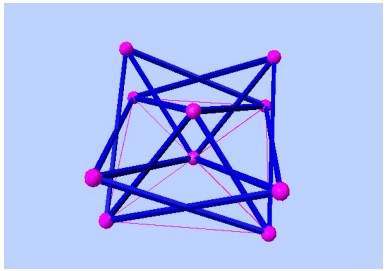


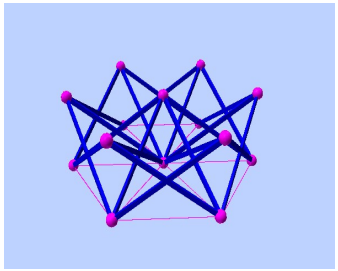


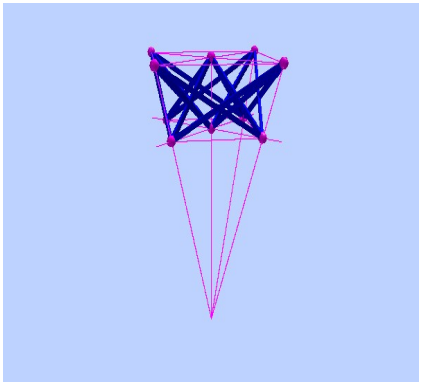
C. Rodriguez

Self-locking SCISSOR LIKE DEPLOYABLE STRUCTURES

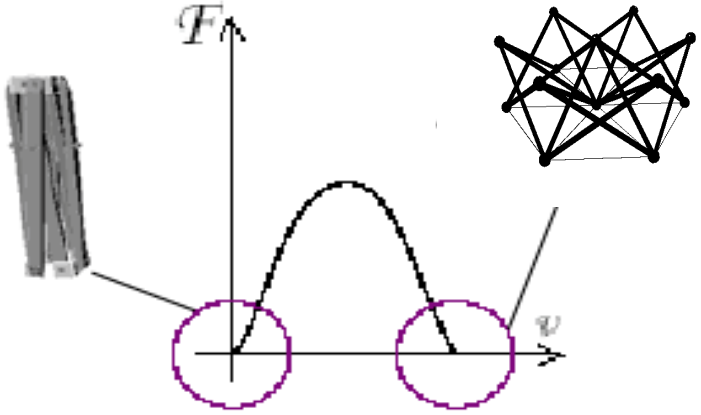


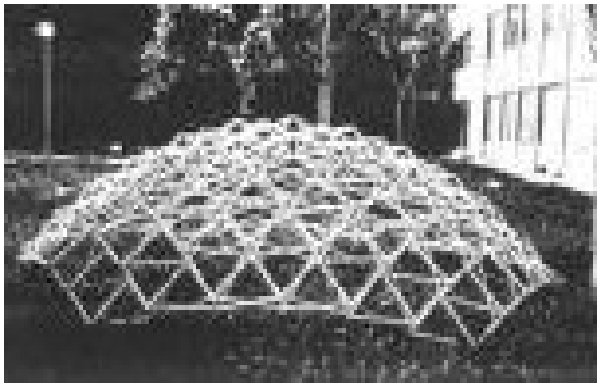






Zeigler, Krishnapillai, Logcher , Rosenfeld, Gantes





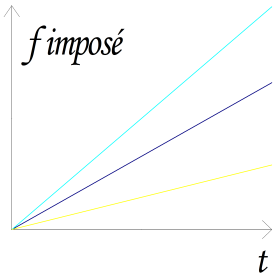
Self-locking SCISSOR LIKE DEPLOYABLE STRUCTURES

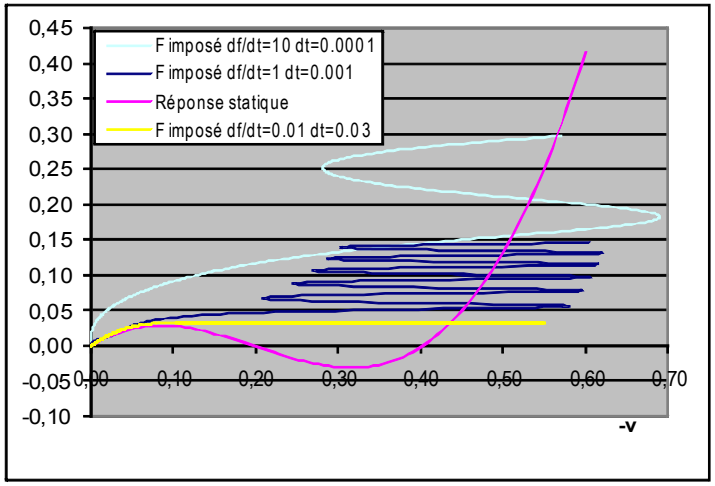
Sable $\quad \Pi(\underline{\varphi} + \underline{\omega}) > \Pi(\underline{\varphi}) \Rightarrow \underline{\omega} \cdot \underline{K} \cdot \underline{\omega} > 0 \Leftrightarrow$ $\underline{K}$ positif definit $\quad \exists \underline{\omega} \neq 0$

Not stable $\quad \Pi(\underline{\varphi} + \underline{\omega}) < \Pi(\underline{\varphi}) \Rightarrow \underline{\omega} \cdot \underline{K} \cdot \underline{\omega} < 0 \Leftrightarrow$ $\underline{K}$ negative definit $\quad \exists \underline{\omega} \neq 0$

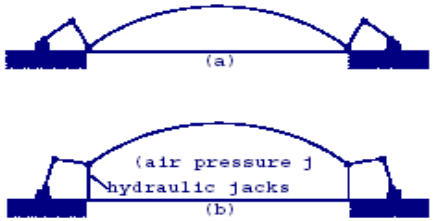
Critique: $\quad \Pi(\underline{\varphi} + \underline{\omega}) = \Pi(\underline{\varphi}) \Rightarrow \underline{\omega} \cdot \underline{K} \cdot \underline{\omega} = 0 \Leftrightarrow$ $\underline{K}$ singular $\quad \exists \underline{\omega} \neq 0$

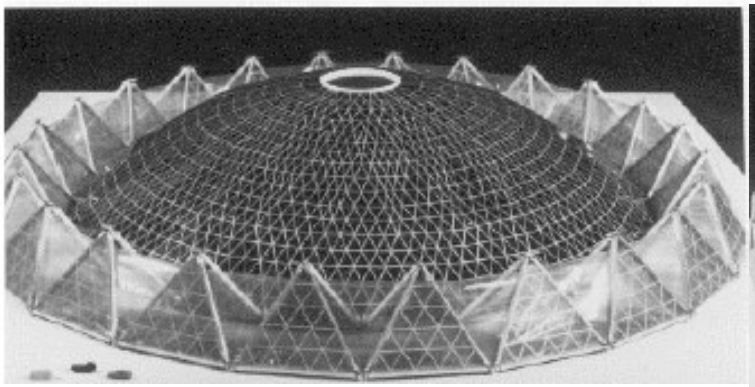
$$\underline{\omega} = \underline{\Psi} \Rightarrow \underline{0} = \left\{ \underbrace{\underline{K} - \lambda \underline{I}}_{=0} \right\} \cdot \underline{\Psi} = \underline{K} \cdot \underline{\Psi}$$

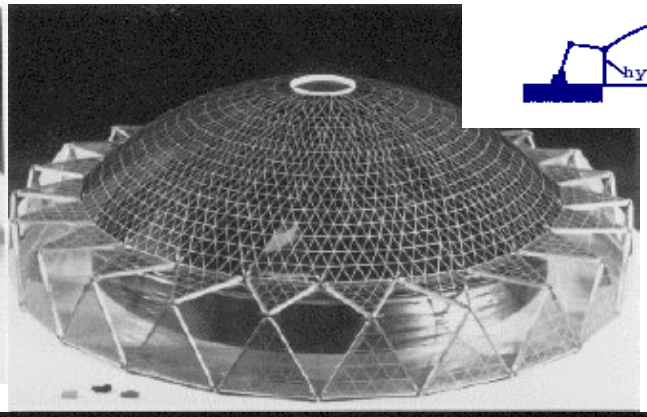


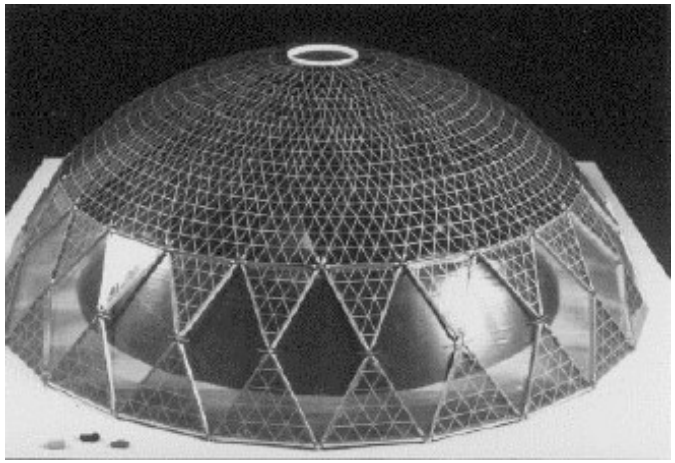


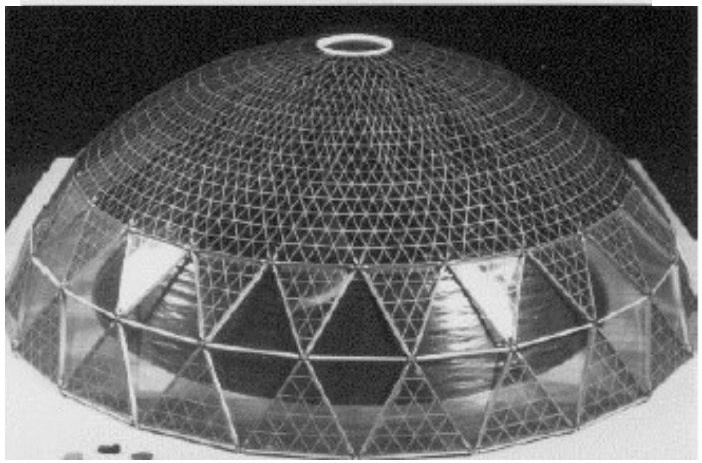
The „pantograph” erection by M. Kawaguchi



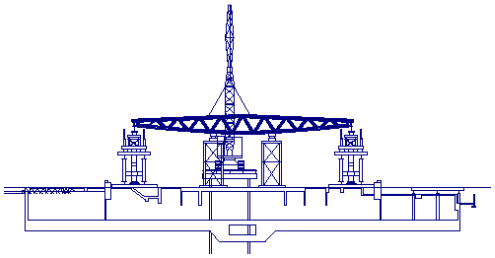




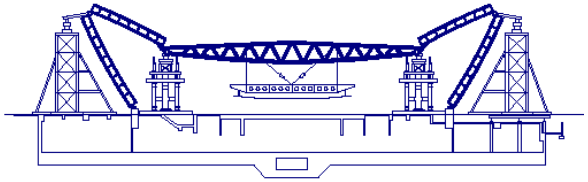


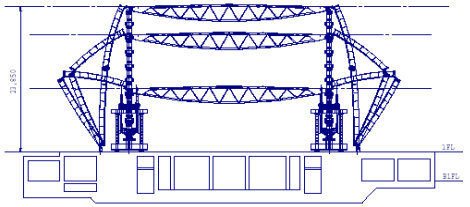


The „pantograph” erection



Nara Centennial Hall (138x42m)– A. Isozaki 1998





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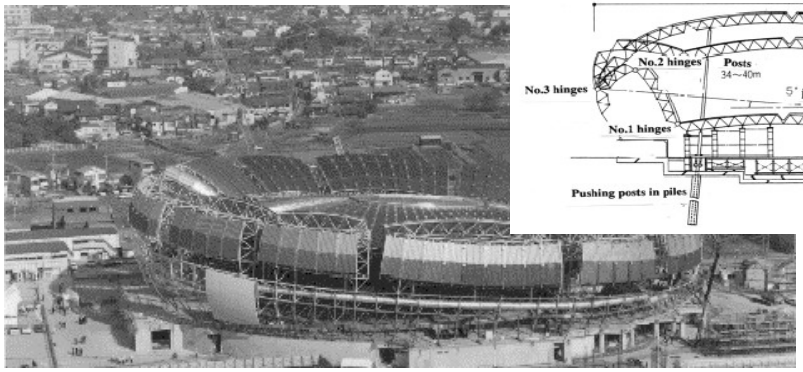
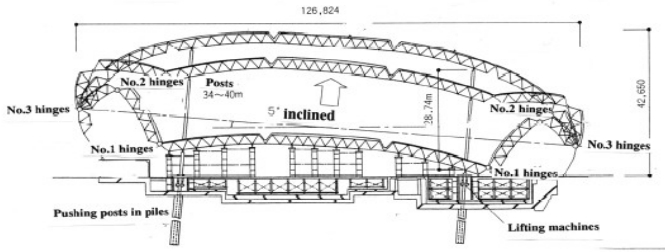
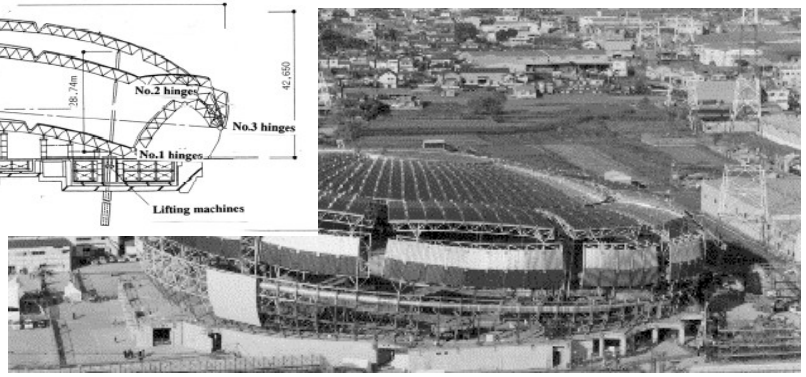
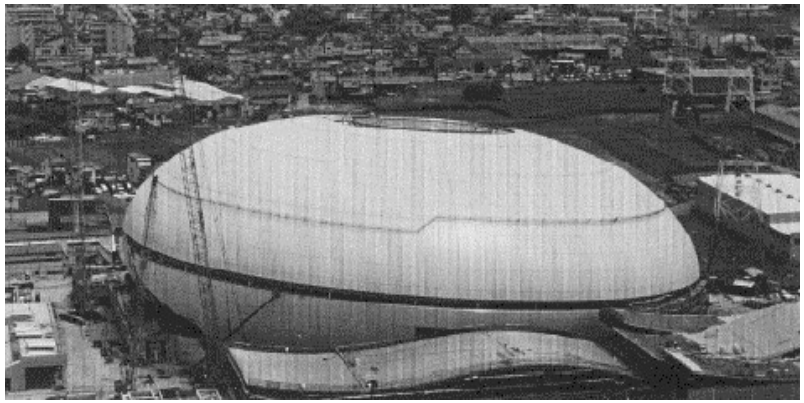








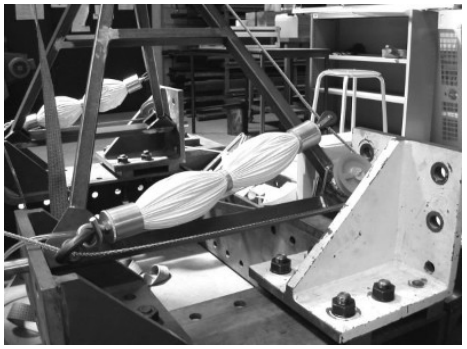
Namihaya Dome (~127x111m) 1997 Osaka - Showa Sekkei Co.

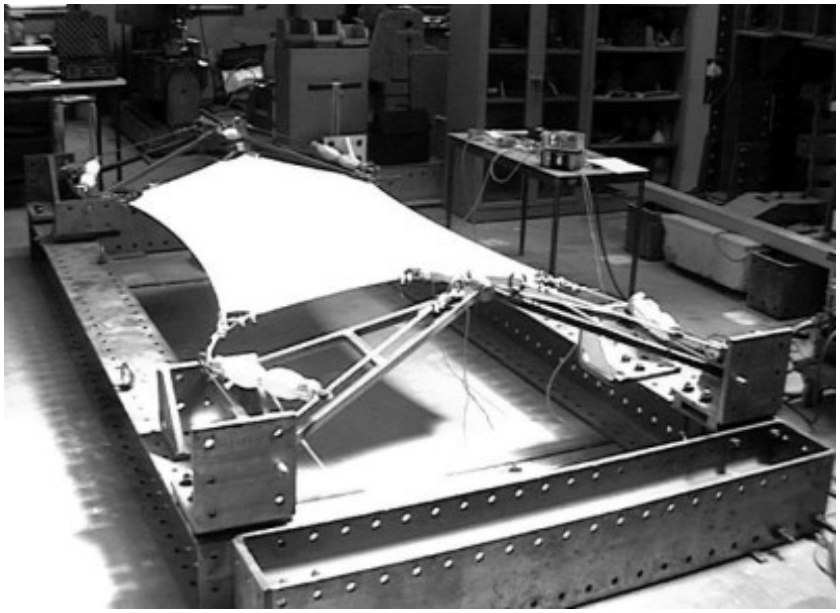
Adaptive/interactive kinetic structures

Resistance in infinite number of configurations - changing of shape, mechanical and physical properties and overall behavior as a response to external excitations and requirements.

Three integral component

- Sensors
- Processors
- Actuator





Adaptive structure introducing artificial muscles (PPAM) in the structure
Massachusetts Institute of Technology

Philippe Block

Summary and research perspectives

Deployable structures are promising structures that can be easily adapted to the new concepts of the XXI. century:

- Light structures with economical material use;
- Fast and prefabricated construction;
- Option for reutilization;
- Light and transparent architecture with minimal environmental damages.

High level difficulties in the design process:

- Complex joints and difficult control;
- Calculation problems;
- Highly immature structures without engineering routine: realized structures with very specific need.