



UNIVERSITY OF PENNSYLVANIA/ SCHOOL OF DESIGN/ DEPARTMENT OF ARCHITECTURE.

Arch 732-001 / Architectural Technology/ spring 2024

## DEPLOYABLE STRUCTURES

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THURSDAY: 8:30-11:30

LOCATION: MEYERSON 321 COMPUTER LAB 8:30-10:00 / FABRICATION LAB 10:00-11:30

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### Description:

The objective of this course is to introduce the rapidly growing field of deployable structures through hands on experiments conducted in workshop environments. Students develop skills in making deployable structures.

The course provides an introduction to the history, theory and application of deployable structures, the course is divided into two parts.

I. The first part is a series of workshops that examine the following:

- a. Geometric studies of Platonic and Archimedean solids and space filling geometries.
- b. Topology and morphological transformations.
- c. Studies of different mechanical joints.
- d. Computer visual analysis of the structural behavior of deployable structures
- e. Computer simulation of the deployment using Solid Works
- f. Build basic deployable structures with link, skeletal, and continuous members.

II. The second part of the semester will focus on the research and development of student's individual or group projects. Each student or group will develop and examine a deployable

structure to build architectural applications. The final assignment will be a to-scale physical working model.

**Course Requirements:** Attendance for virtual workshops and assignments are of paramount importance. Assignments are intended to practice techniques learned.

**Readings:** TBD

**Assignments:** Students will complete weekly assignments related to the topic discussed that week. Some assignments involve building physical models and others involve computer simulation. The final report requires the inclusion of all assignments in addition to the final project. The final project includes the physical realization of a deployable system and the testing of that deployment using computer simulation and physical modeling.

**Grading:** the course will be graded as follows:

- 1- Attendance and participation 30%
- 2- Weekly assignments 30%
- 3- Final report 40% (20% will be assigned to the report document and 20% to the physical model)

Penn Design instructors, with the exception of the Department of Fine Arts, apply a grading system of letter grades:

A+	=	4.0	A	=	4.0	A-	=	3.7
B+	=	3.3	B	=	3.0	B-	=	2.7
C+	=	2.3	C	=	2.0	C-	=	1.7
F	=	0.0	Failure	=	0.0	Incomplete		

This course is expected to abide by the rules set by the University, including but not limited to the University Code of Academic Integrity, which can be found in Penn book.

There will be two versions of the career fair: (1) Thursday, February 8, 2024, 12 – 4pm and Tuesday, February 13, 2024, 12 – 4pm. Students can find additional information here: <https://careerservices.upenn.edu/2024-design-career-fairs-student-page/>.

## 1. Introduction and Historic Background

### a. Lecture:

- a.i. Introduction to the concept of mobile architecture.
- a.ii. Military architecture in medieval and renaissance (Leonardo De Vinci, Francesco De Giorgio).
- a.iii. Scaffolding and building apparatus before mechanization.

### b. Reading:

- b.i. Fitchen, John. Building Construction before Mechanization. The MIT Press, Cambridge, Massachusetts 1996.

## 2. Piñero and the development of deployable structures in modern sense

- a. Lecture:
  - a.i. Piñero
- b. Workshop:
  - b.i. Building simple 2D skeletal scissors action deployable structures.
- c. Readings and references:
  - c.i. Pinero, E.P., Project for a Mobile Theater, Architectural Design, 31 (12), 1961.
  - c.ii. Tzonis Alexander. Ed. Santiago Calatrava's creative Process Fundamentals. Birkhauser Publishers for Architecture. Basel, Switzerland. 2001

### 3. The Geometry of Deployable Structures

- a. Lecture:
  - a.i. Introduction to polyhedron
  - a.ii. Space filling geometry
  - a.iii. Form finding
- b. Workshop:
  - b.i. Building solid polyhedron
  - b.ii. Building skeletal polyhedron.
- c. Readings and references:
  - c.i. Critchlow. Keith. Order In Space. Thames and Hudson, Inc. New York, 1987.
  - c.ii. Pearce, Peter. Structure in Nature is a Strategy for Design. Cambridge: The MIT Press. Cambridge, 1990.

### 4. Trans-polyhedron and conformal Mapping

- a. Lecture:
  - a.i. The use of conformal mapping as a tool for morphological transformation to space filling geometries.
- b. Workshop:
  - b.i. Stress Analysis studies to investigate the difference between the basic fundamental geometry and the deformed one.
- c. Readings and references:
  - c.i. Thompson D'Arcy. On Growth and Form. Cambridge University Press. Cambridge. UK, 1961
  - c.ii. Giorgini, Vittorio. SPATIOLOGY. The Morphology of the Natural Science In Architecture and Design. L'Arca Edizioni. Italy, 1995.

### 5. Introduction to Solid Work / WORKING MODELS

- a. Lecture. The concept of digital working models.
- b. Workshop:
  - b.i. Lab session 1 to use Solid Works.
  - b.ii. Solid modeling of deployable structure.
- c. Reading:
  - c.i. Servadio, Ilan. "Deployable Regular and Semi-Regular Polyhedral Structures using Hoberman's Technique". In Proceedings Application of Structural Morphology to Architecture. Edit by Ralf Holler, Published by IL, Stuttgart University, Germany 1994.

### 6. Classifications of deployable structures

- a. Lecture:
  - a.i. The different classifications of deployable structures and their limitations.
- b. Workshop
  - b.i. Techniques in building physical deployable structure components.
- c. Reading:

- c.i. Hanaor, Ariel. "Some structural-Morphological aspects of deployable structures for space enclosure." In Bridge between Engineering and architecture. Edited by Joop M. Gerrits. Delft, the Netherlands: Delft University of Technology, 2000.
- c.ii. Alkhayer Mohamad. "Deployable Negative Gaussian Curvature Shell." In Bridge between Engineering and architecture. Edited by Joop M. Gerrits. Delft, the Netherlands: Delft University of Technology, 2000.

## **7. Deployable Structures and Nature**

- a. Lecture:
  - a.i. Deployment in nature.
  - a.ii. Different Joints in Human Anatomy.
- b. Workshop:
  - b.i. Technique workshop to build 3D deployable Structures.
- c. Reading:
  - c.i. Calladine, C. R. "Deployable Structures: What can we learn from biological structures?" In Deployable Structures Theory and Application. Edited by S. Pellegrino and S.D Guest. The Netherlands: Kluwer Academic Publication, 2000.
  - c.ii. Kovács, F., T. Tarnai, S. D. Guest, and P. W. Fowler. "Double-link expandedhedra: a mechanical model for expansion of a virus". In Proceedings: Mathematical, Physical and Engineering Sciences. London: The Royal Society, 2004.

## **8. Midterm Review.**

## **9. Origami and Folded Plates deployable structures**

- a. Lecture:
  - a.i. One dimensional folded plates.
  - a.ii. Interdiction to two and three-dimensional folded plates.
  - a.iii. Plan and space tessellations.
- b. Workshop:
  - b.i. Lab session 2 solid work.
  - b.ii. Project physical working model discussion.
  - b.iii. 3D working model review.
- c. Reading:
  - c.i. Miura, Koryo. "Fold - Its Physical and Mathematical Principles". Origami Science and Art: Proceeding of the Second International Meeting of Origami Science and Scientific Origami.

## **10. Mobile and Rapid Assembly Structures**

- a. Lecture:
  - a.i. Bridges
  - a.ii. Theaters and exhibits
  - a.iii. Scaffoldings
- b. Workshop:
  - b.i. Lab session 3 Solid Work.
  - b.ii. Project Assignment Review and critique
  - b.iii. 3D physical model review.
- c. Reading:
  - c.i. Mohamad Alkhayer "Deployment of Trussed Geometry": Generation of a Deductive Taxonomy of Unfolding Configurations. Unpublished work

## **11. Deployable Structures Applications**

- a. Lecture:
  - a.i. Earth-based deployable structures and deployable structures for space applications Workshop:
- b. Project Assignment Review.
- c. Pre-final Review and detail developments studies
- d. Reading:
  - d.i. Escrig, F., Valcarcel, J.P., Sanchez, J., Deployable Cover on a Swimming Pool in Seville, Journal of the International Association for Shell and Spatial Structures. 1996

## **12. Workshop to finalize 3D deployment simulation.**

- a. Workshop.

## **13. Conclusion.**

Final review panel review and exhibit of material and physical models