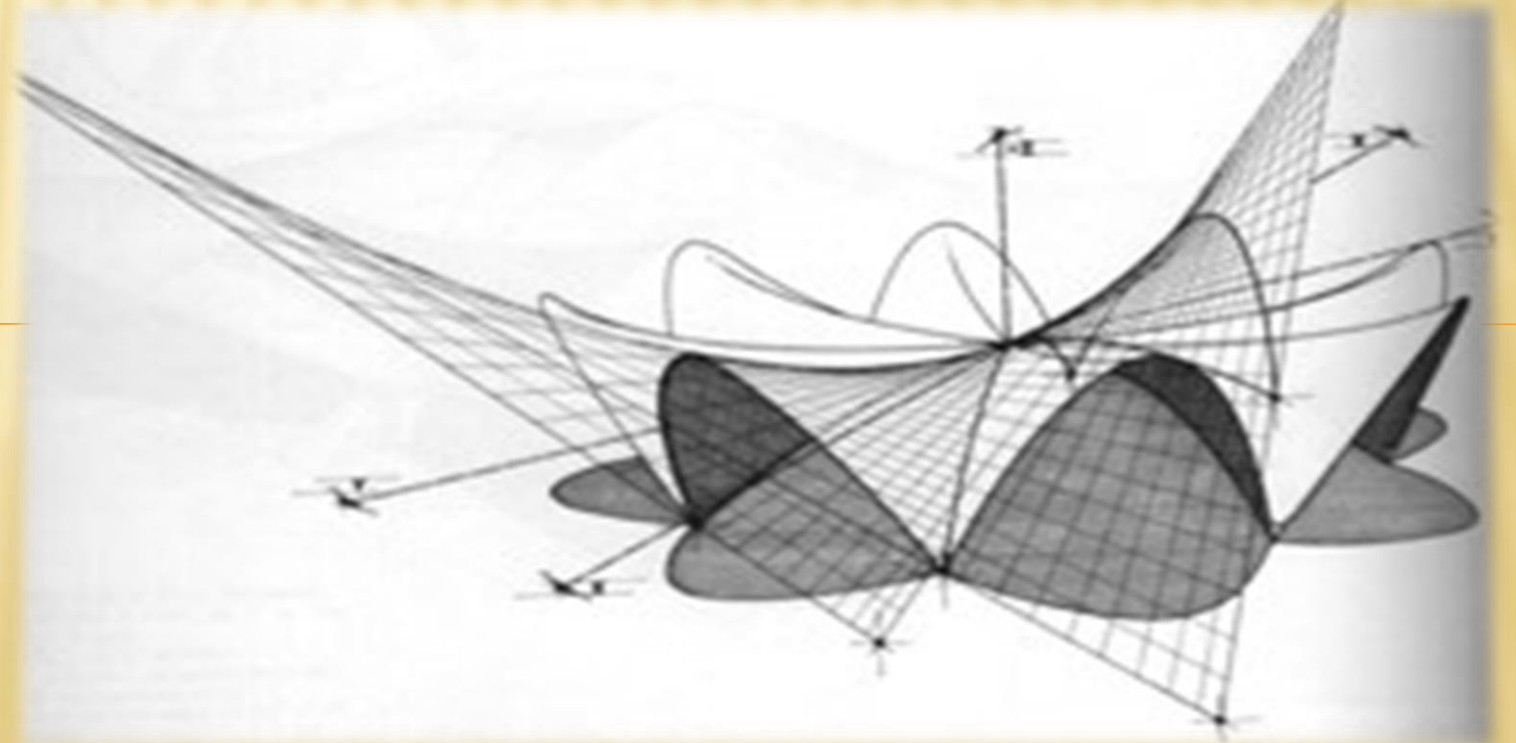


# Thin Shell Structures

Guranter Multari, Christopher Legada, Juliana Pipola





# Washington Dulles International Airport

Location: Dulles, Virginia

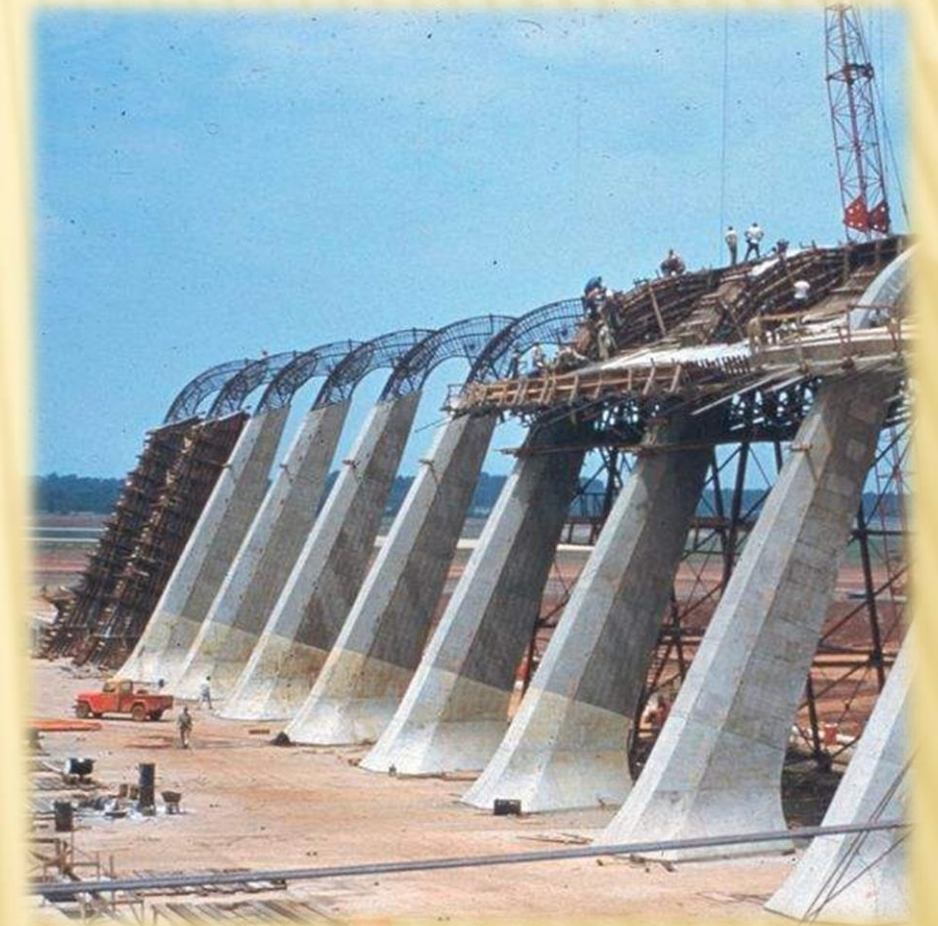
Architect: Eero Saarinen

Date: 1958 to 1962

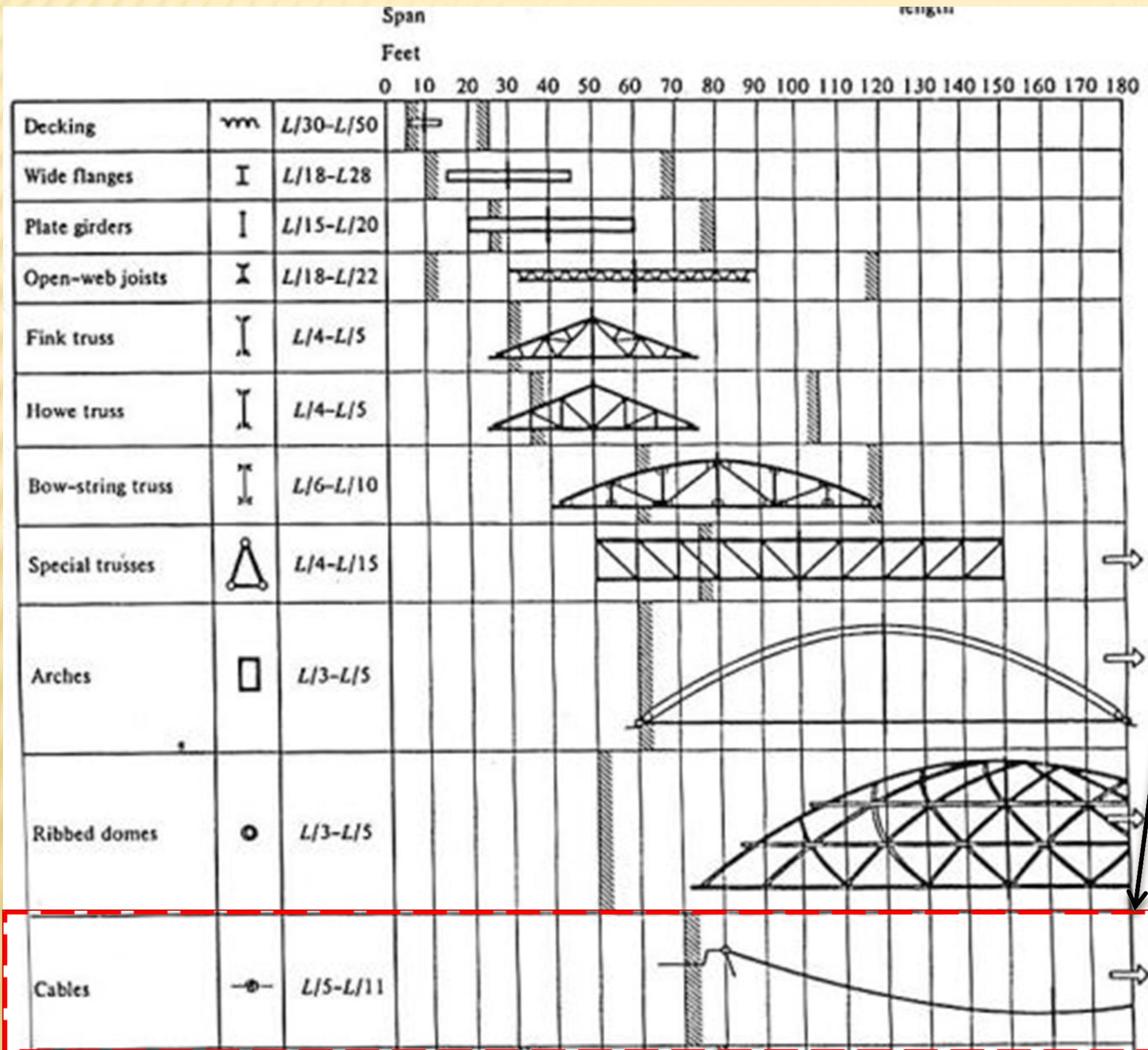
Airport occupies 11,830 acres

# 1. SYSTEM SPAN & EFFECTIVE SPANS

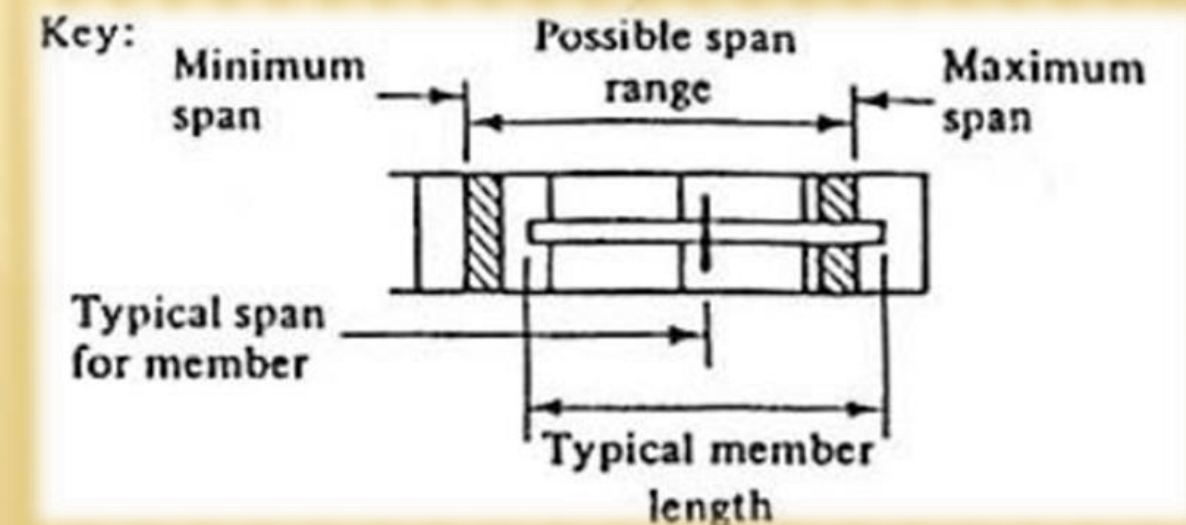
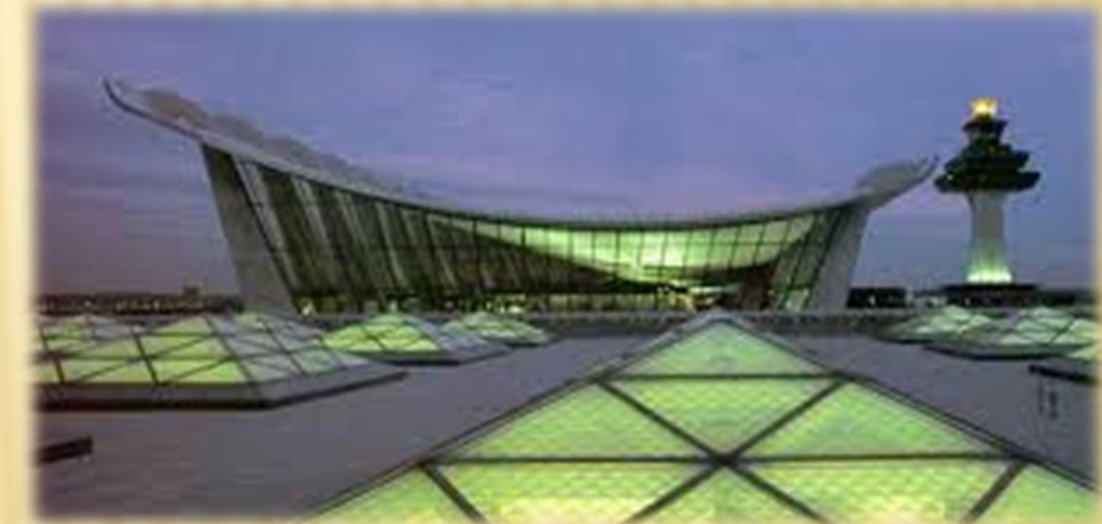
- This structure uses Simply Suspended Cable's
- The cables are light and have high strength to weight ratio small members can be used in very large span. The lightness of the cable provides an expanded impression of space and smoothly curving cables which creates structures with soft outlining.
- The roof cladding is supported by a single layer of non-pre-tensioned cables.
- The steel suspensions cables span across the 164 ft. width and are anchored to slanted reinforced concrete piers, spaced at 10 ft. interval



# 1. SYSTEM SPAN & EFFECTIVE SPANS



Minimum span: 70'-75'  
 Average or typical member: 160  
 Maximum: 180+





# The Sydney Opera House

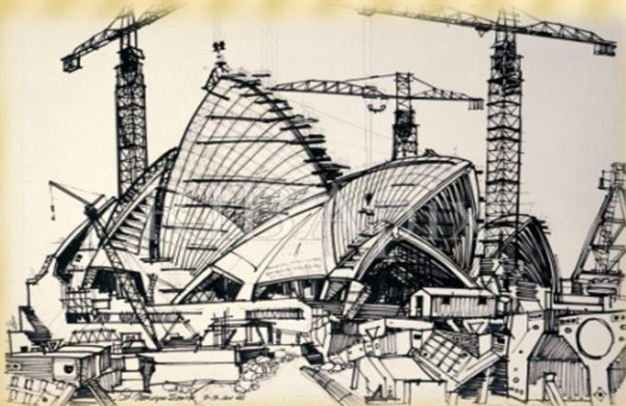
Location: Bennelong Point, Sydney NSW 2000, Australia

Date: October 20, 1973

Architects: Jørn Utzon, Ove Arup (firm Arup)

## 2. CONSTRUCTION TIME & COST

- ✦ Construction time: The Sydney Opera House (Australia) was conceived and largely built by Danish Architect Jørn Utzon, opening in 1973 after a long gestation that began with his competition winning design in 1957. The Fort Macquarie Tram Depot, occupying the site at the time of these plans, was demolished in 1958 and construction began in March 1959. It was built in three stages: stage I (1959–1963) consisted of building the upper podium; stage II (1963–1967) the construction of the outer shells; stage III (1967–1973) interior design and construction.



## 2. CONSTRUCTION TIME & COST

- ✘ Cost; The Opera House was formally completed in 1973, having cost \$102 million.<sup>[34]</sup> H.R. "Sam" Hoare, the Hornibrook director in charge of the project, provided the following approximations in 1973: Stage I: podium Civil & Civic Pty Ltd approximately \$5.5m. Stage II: roof shells M.R. Hornibrook (NSW) Pty Ltd approximately \$12.5m. Stage III: completion The Hornibrook Group \$56.5m. Separate contracts: stage equipment, stage lighting and organ \$9.0m. Fees and other costs: \$16.5m. The original cost estimate in 1957 was £3,500,000 (\$7 million). The original completion date set by the government was 26 January 1963 (Australia Day). Thus, the project was completed ten years late and over-budget by more than fourteen times.





# Washington Dulles International Airport

Location: Dulles, Virginia

Architect: Eero Saarinen

Date: 1958 to 1962

Airport occupies 11,830 acres



# 3. FLEXIBILITY OF THE SYSTEM DIVERSITY OF FORMS AVAILABLE

Types of structure with significant tension members

- Linear structures

Suspension bridges

Draped cables

Cable-stayed beams or trusses

Cable trusses

Straight tensioned cables

- Three-dimensional structures

Bicycle wheel

3D cable trusses

Tensegrity structures

Tensairity structures

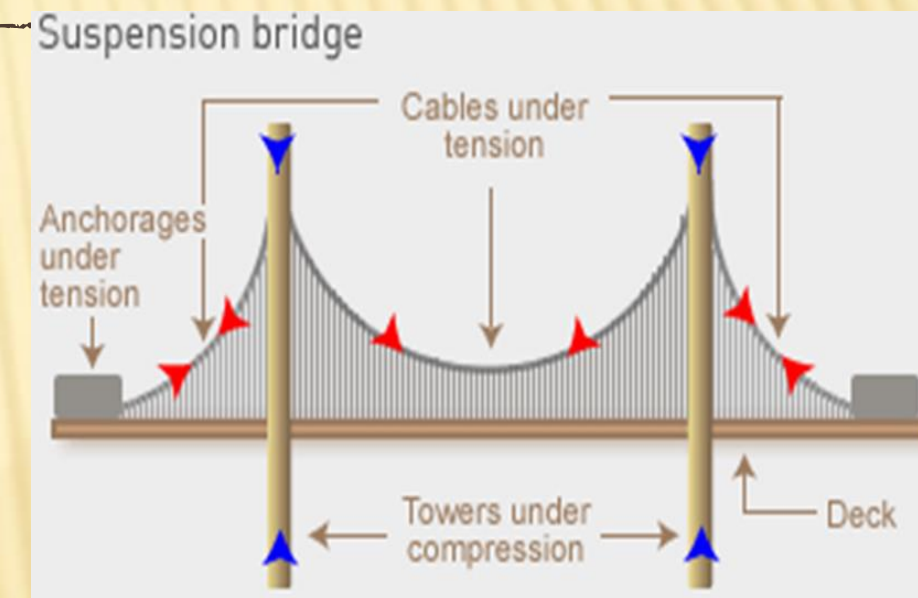
Surface-stressed structures

Pre-stressed membranes

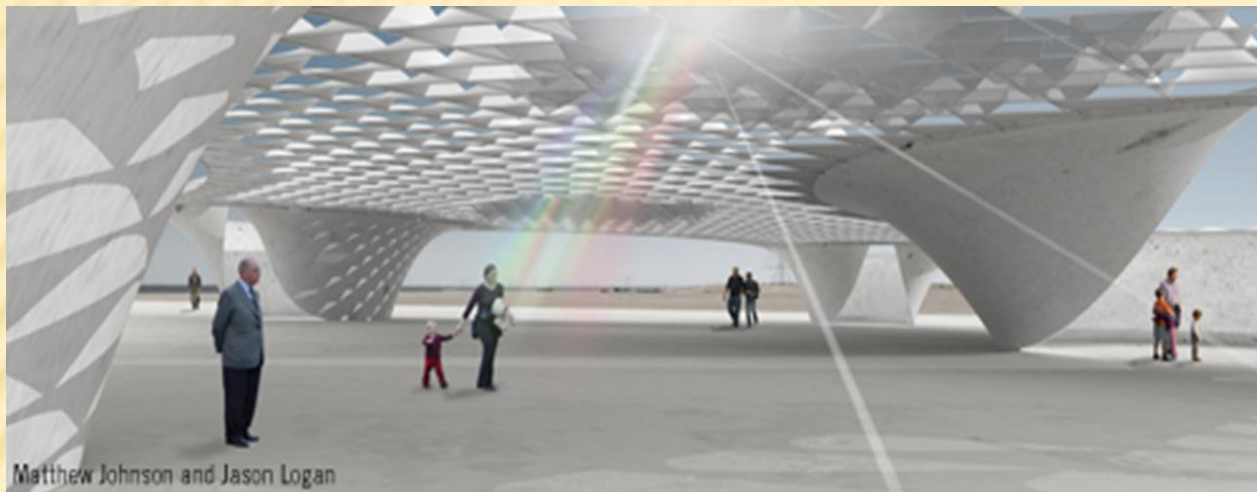
Pneumatically stressed membranes

Grid shell

fabric structure



# 3. Flexibility of the system diversity of forms available

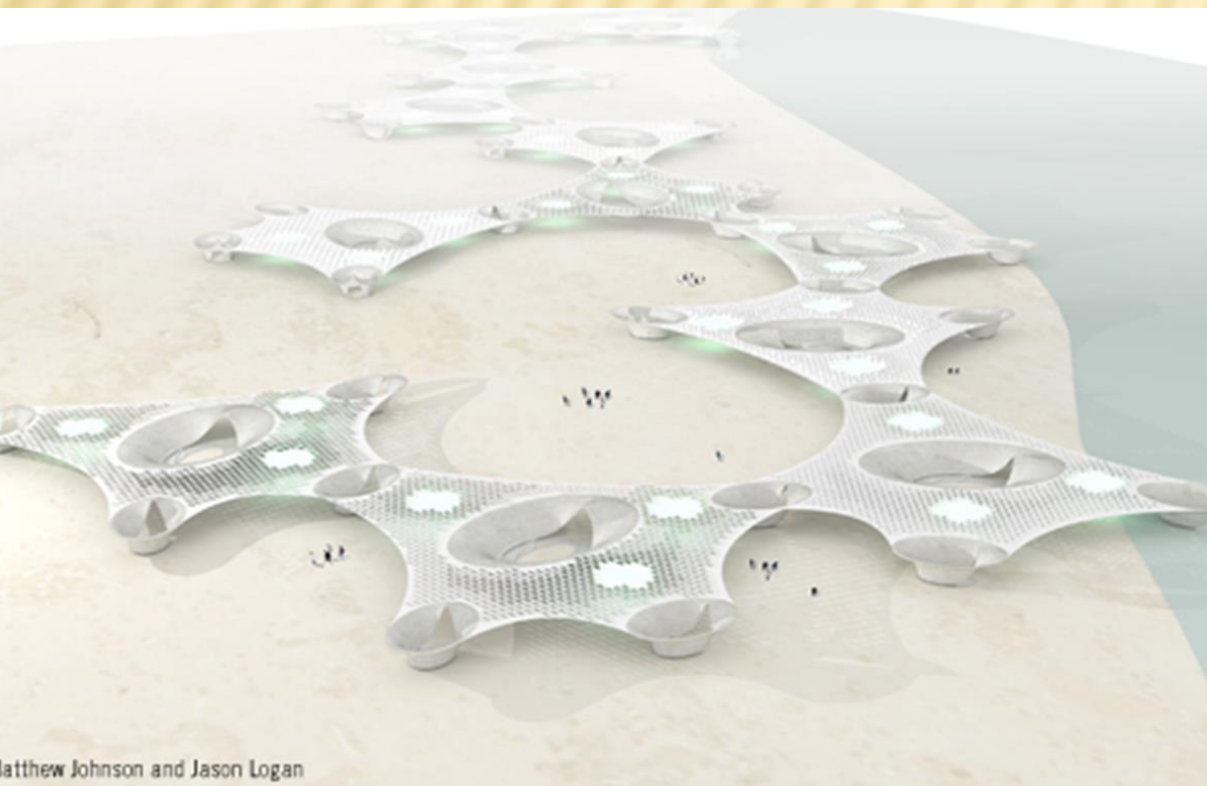


Matthew Johnson and Jason Logan

(Design Submission for the 2010 Land Art Generator Initiative Design Competition)

“The Prism Cloud is minimally invasive to its environment and the surrounding desert ecology, since the only point at which it touches the ground is at the concrete piers, which can be spaced far apart. The primary structure is a cable net that never touches the ground.”

Grid shell



Matthew Johnson and Jason Logan



The State University of New York- New Paltz



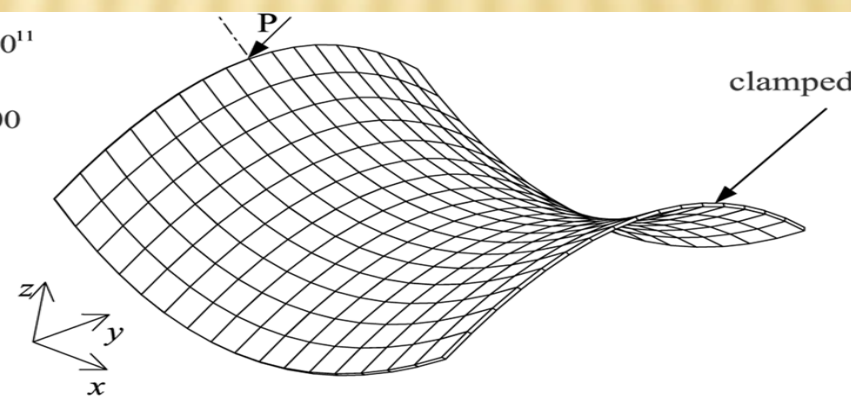
Pneumatically stressed membranes



$$E = 2 \times 10^{11}$$

$$\nu = 0.3$$

$$\rho = 8,000$$





# John F. Kennedy International Airport (The TWA Flight Center or Trans World Flight Center)

Architect: Eero Saarinen

Area: 17.6 acres

Location: Queens, New York

Time: 1959 - 1962

# 4. ARCHITECTURAL FINISHES AVAILABLE

- Most common finishes include: leveling, floating, troweling, stamping, stenciling, brooming, rock salting, sealing and hardening.
- In the TWA terminal the type of concrete finishes include: high tolerance, heavy duty, colored, exposed aggregate.
- Colored Concrete Finishing
- Colored concrete finishing is achieved by adding dyes and pigments used to alter and control the color of concrete. Colored concrete finishes are often combine with stamped concrete finishing and exposed aggregate concrete finishing.







# The Sydney Opera House

Location: Bennelong Point, Sydney NSW 2000, Australia

Date: October 20, 1973

Architects: Jørn Utzon, Ove Arup (firm Arup)

# 6. SYSTEM STRENGTH & WEAKNESSES

- ✦ Systems strengths:
- ✦ The Sydney Opera House in Australia. These and other structures are more than just architectural masterpieces. They're works of engineering genius that highlight one of the field's most important elements: a thin shell. Made from just about any material (but mostly concrete since the 1920s), thin shells emphasize the majesty of a structure while offering a wealth of support that seems inconsistent with their thin nature. In thin-shell structures, aesthetic beauty and structural strength derive from exactly the same source: the curved shape of the shell. And it's this perfect form of marriage and structure that makes seeing and understanding thin-shell structures so uniquely satisfying.



# 6. SYSTEM STRENGTH & WEAKNESSES

- ✘ System weakness:
- ✘ Since concrete is a porous material, concrete domes often have issues with sealing. If not treated, rainwater can seep through the roof and leak into the interior of the building. On the other hand, the seamless construction of concrete domes prevents air from escaping, and can lead to buildup of condensation on the inside of the shell. Shingling or sealants are common solutions to the problem of exterior moisture, and dehumidifiers or ventilation can address condensation.





## Resources:

[http://en.wikipedia.org/wiki/F%C3%A9lix\\_Candela](http://en.wikipedia.org/wiki/F%C3%A9lix_Candela)

[spacesymmetrystructure.wordpress.com](http://spacesymmetrystructure.wordpress.com)

<http://cobagonzo.blogspot.com/2011/10/temporary-pavilion-structures-1.html>

[http://www.greatbuildings.com/buildings/Dulles\\_Airport.html](http://www.greatbuildings.com/buildings/Dulles_Airport.html)

<http://landartgenerator.org/blagi/archives/date/2010/09/page/2>

<http://www.jaunted.com/story/2011/10/16/22910/552/travel/Inside+the+Historic+TWA+Flight+Center+at+New+York's+JFK+Airport>

[http://www.neighborhoodpreservationcenter.org/db/bb\\_files/Trans-World-Airlines-Flight-Center--Ground-Level-Interior.pdf](http://www.neighborhoodpreservationcenter.org/db/bb_files/Trans-World-Airlines-Flight-Center--Ground-Level-Interior.pdf)