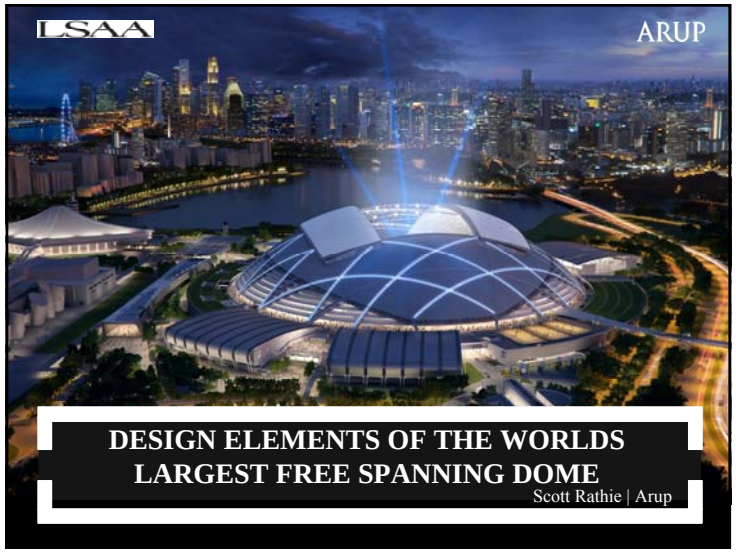
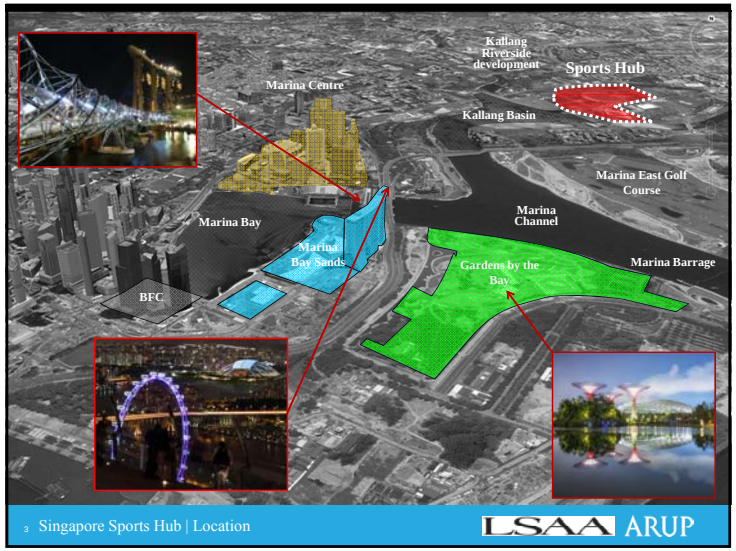


The key parties in the design and construction include:

Lead Architect - Sports Venue Design	Arup Sports Venue Design
Structural Engineer	Arup
Main Contractor	Dragages Singapore
Architect (Non-Sports Buildings & Masterplan)	DPArchitects
NST roof Steel Contractor	Yongnam
Louvre Cladding	YJ International
Movable Roof Cladding	Vector Foiltec
Fixed Roof Cladding	Craft

2 Singapore Sports Hub | The Team LSAA ARUP

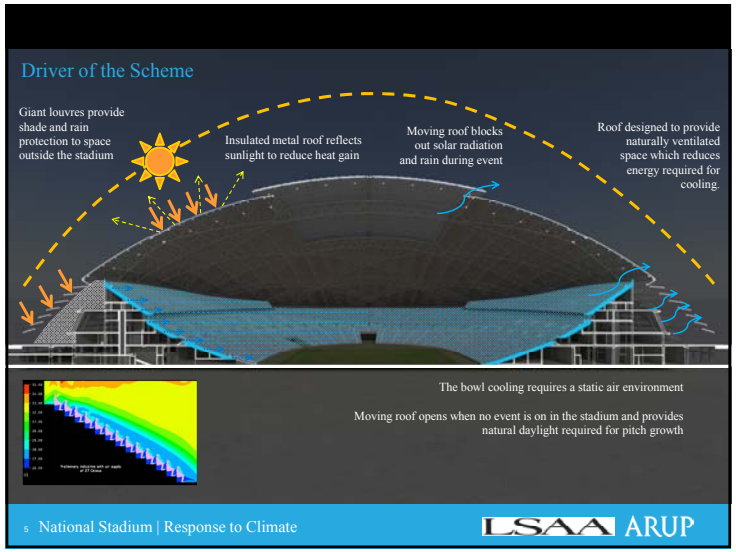


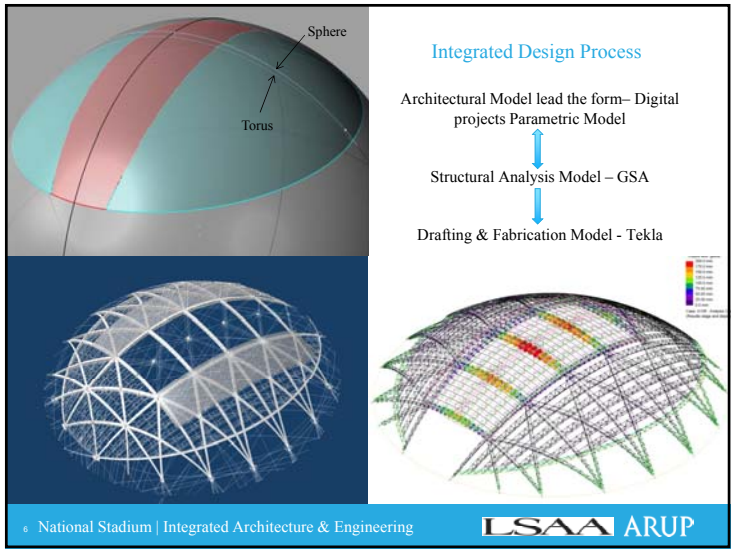
3 Singapore Sports Hub | Location LSAA ARUP

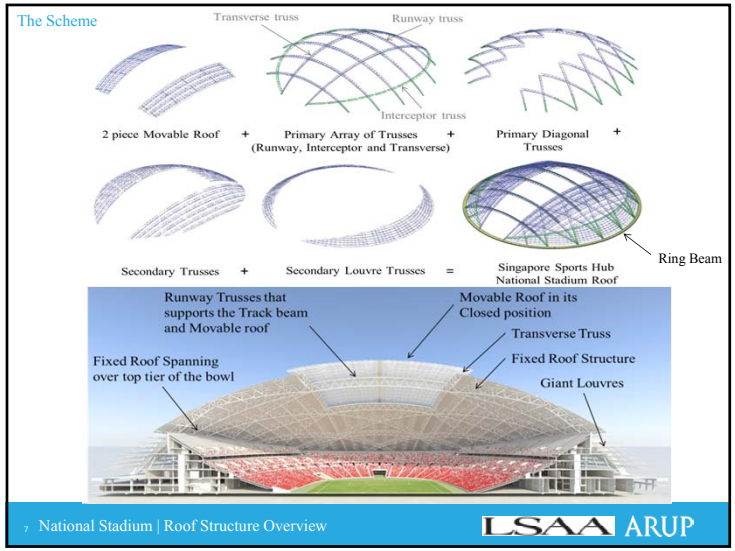
The Original National Stadium

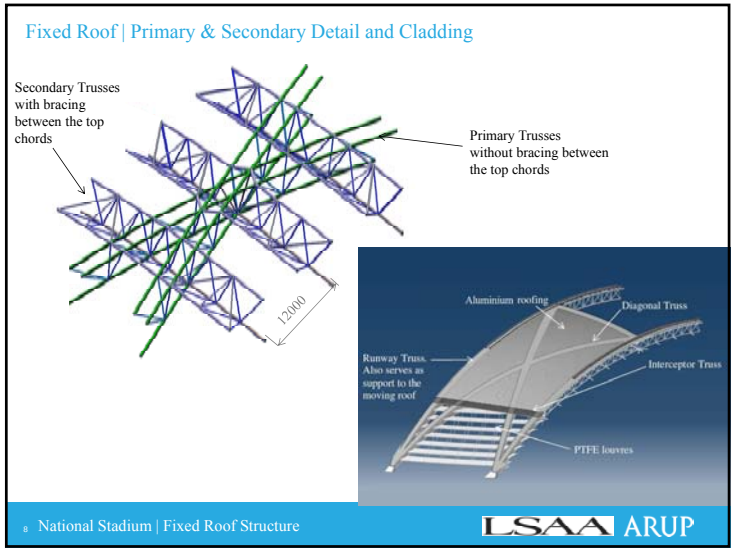
- Opened 1973
- Closed in 2007 to make way for the Sports Hub Development
- Site office
- Demolition delayed to Sept 2010
- Was the home of the Kallang Roar
- Did not address the local tropical climate

4 Singapore Sports Hub | The Old Stadium LSAA ARUP

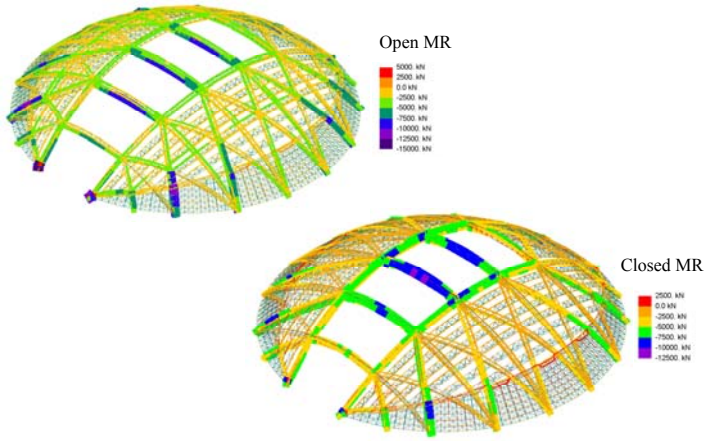

Driver of the Scheme
Giant louvres provide shade and rain protection to space outside the stadium
Insulated metal roof reflects sunlight to reduce heat gain
Moving roof blocks out solar radiation and rain during event
Roof designed to provide naturally ventilated space which reduces energy required for cooling.
The bowl cooling requires a static air environment
Moving roof opens when no event is on in the stadium and provides natural daylight required for pitch growth
5 National Stadium | Response to Climate
LSAA ARUP


Sphere
Torus
Integrated Design Process
Architectural Model lead the form– Digital projects Parametric Model
Structural Analysis Model – GSA
Drafting & Fabrication Model - Tekla
6 National Stadium | Integrated Architecture & Engineering
LSAA ARUP


The Scheme
Transverse truss
Runway truss
Interceptor truss
2 piece Movable Roof + Primary Array of Trusses (Runway, Interceptor and Transverse) + Primary Diagonal Trusses +
Secondary Trusses + Secondary Louvre Trusses = Singapore Sports Hub National Stadium Roof
Ring Beam
Runway Trusses that supports the Track beam and Movable roof
Movable Roof in its Closed position
Transverse Truss
Fixed Roof Structure
Giant Louvres
Fixed Roof Spanning over top tier of the bowl
7 National Stadium | Roof Structure Overview
LSAA ARUP

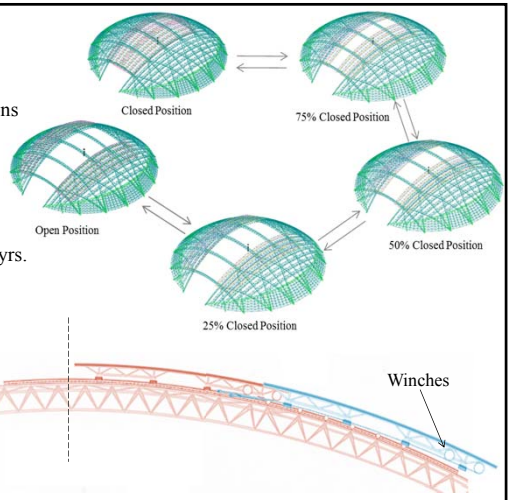

Fixed Roof | Primary & Secondary Detail and Cladding
Secondary Trusses with bracing between the top chords
Primary Trusses without bracing between the top chords
12000
Aluminium roofing
Diagonal Truss
Runway Truss. Also serves as support to the moving roof
Interceptor Truss
PTFE louvres
8 National Stadium | Fixed Roof Structure
LSAA ARUP

Fixed Roof | Predominantly a 3d axial load system



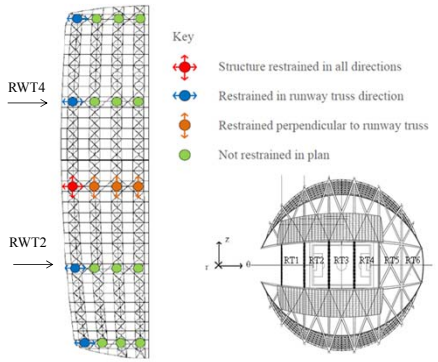
The Movable Roof Configurations

- FR Load Considerations
- Open vs. closed
- Parked vs. moving
- Fatigue Sensitive
- 10400 cycles over 50 yrs.
- Push vs. Pull Solution

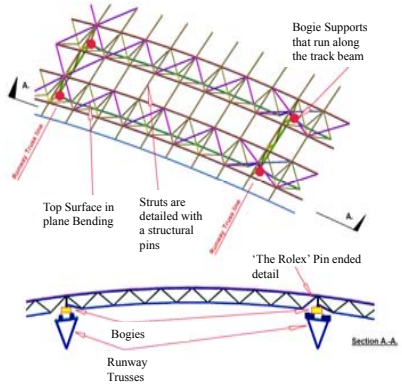


The Movable Roof Design Philosophy

- Relative flexibility so it won't lock up
- Weight > friction in closed position
- 2 point push solution
- When moving spans between RWT2&4
- Slow process 20 mins
- Except in the case of an emergency stop, whilst the roof is moving the maximum acceleration or deceleration shall be limited to 0.5 m/s^2
- Fixed roof designed for a permanent cable force of 1800kN



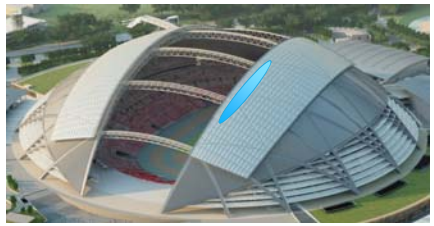
Movable Roof | Movable Roof Framing w.r.t the Design Philosophy

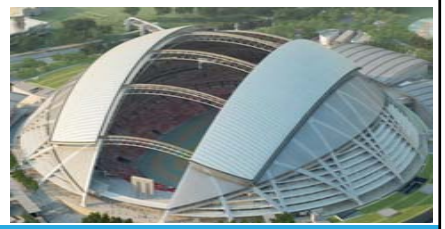


Movable roof truss Elevation

Movable Roof – Multiple Layer ETFE pillows

- Chosen cladding – flexible, lighting opportunities
- Warping, skew, differenerntial movement described to VF
- Initial scheme had ponding issues
- 20,000 m^2 led screen





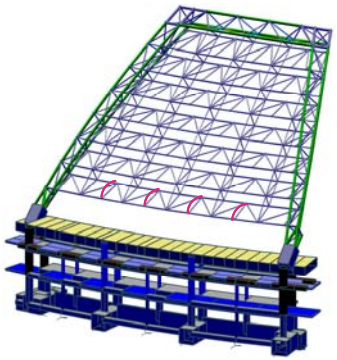
13 LSAA ARUP

14 National Stadium | Integrated Architecture & Engineering LSAA ARUP

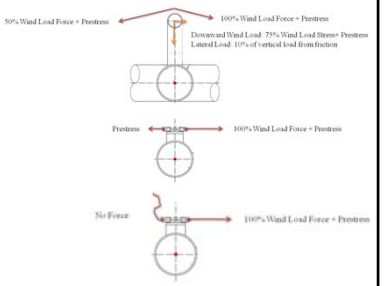
The Giant Louvre' and their Complex Geometry

15 National Stadium | Integrated Architecture & Engineering LSAA ARUP

The Giant Louvres | Framing and loading

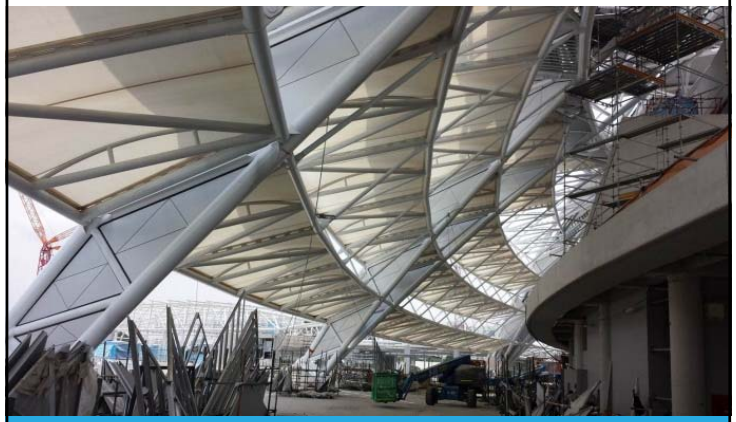


- Louvre's approximately span 5-7m
- Architectural intent were flat PTFE louvres



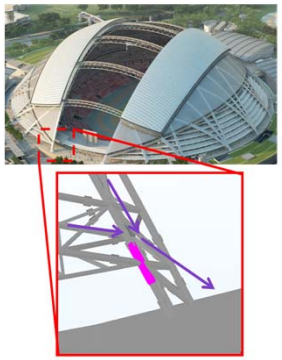
16 ARUP

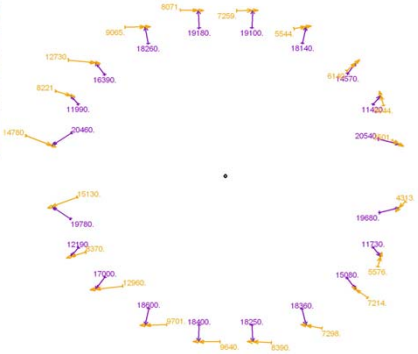
The Giant Louvres | As-built



17 ARUP

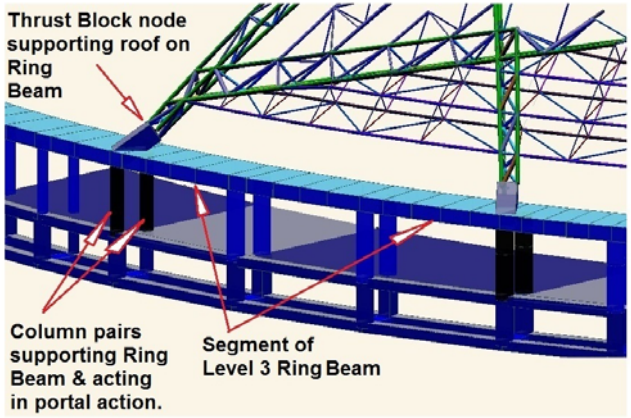
Thrust Block | Design Philosophy





18 National Stadium | Ring Beam Structure LSAA ARUP

Support Structure

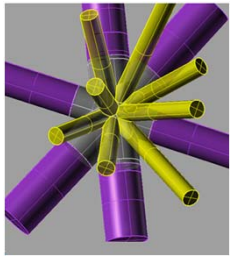


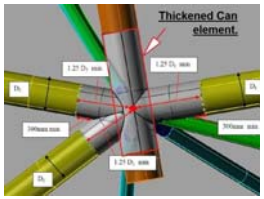
19 National Stadium | Ring Beam Structure LSAA ARUP

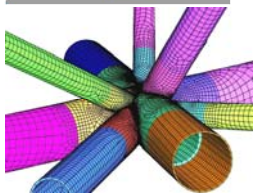
Complex multi-CHS node connections

Designed Using
- Cidect
- AWS
- Finite Element Analysis

There were a significant number of connections the





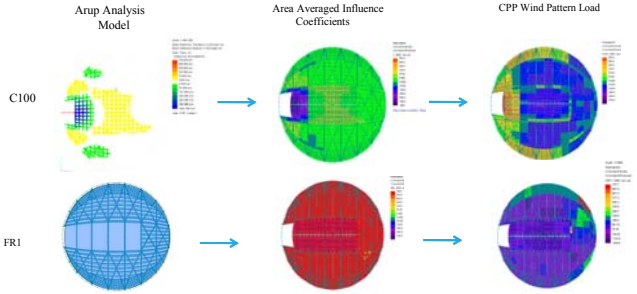


20 National Stadium | Fixed Roof Structure LSAA ARUP

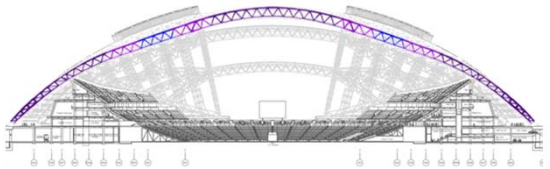
Wind Analysis | 'Influence Surface' time history approach to optimising design

- Mode shapes under 1Hz
- 39 engineering informed
- 388 element response

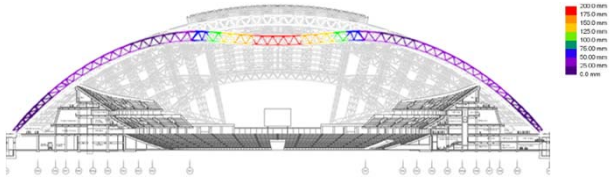
CPP Wind Pattern Load



Analysis | Deflected Shape of 'Runway Truss' in 'Open' configuration and 'Closed' Configuration

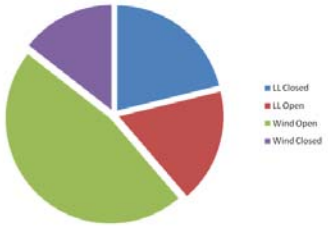


RWT3 in Open Configuration

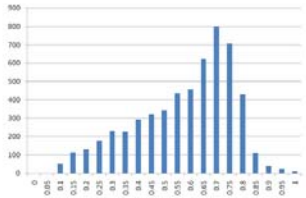


RWT3 in Closed Configuration ~ 200mm MR + 100mm FR

Analysis | Governing load cases and member utilisation

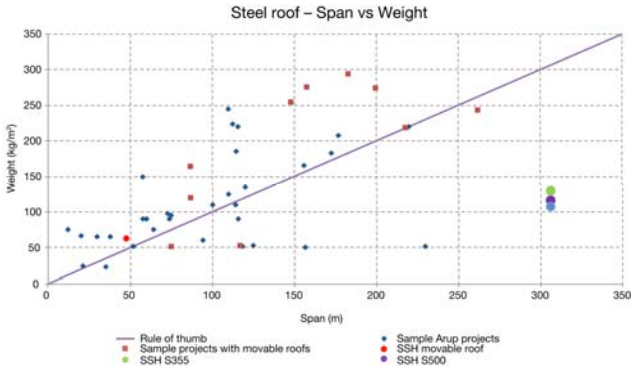


Critical Load Case Summary

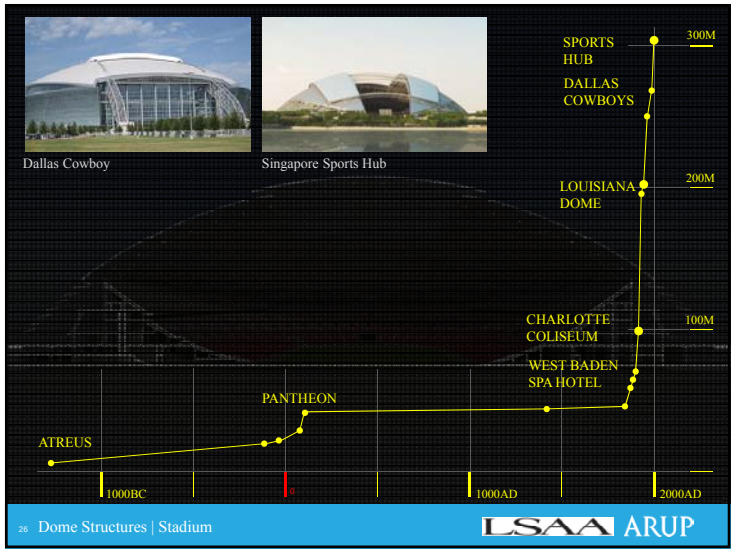


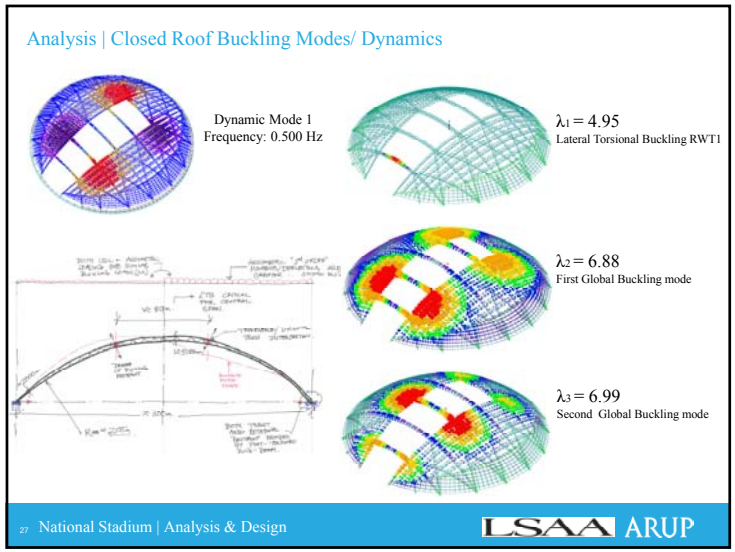
Summary of Utilization of Member Capacity

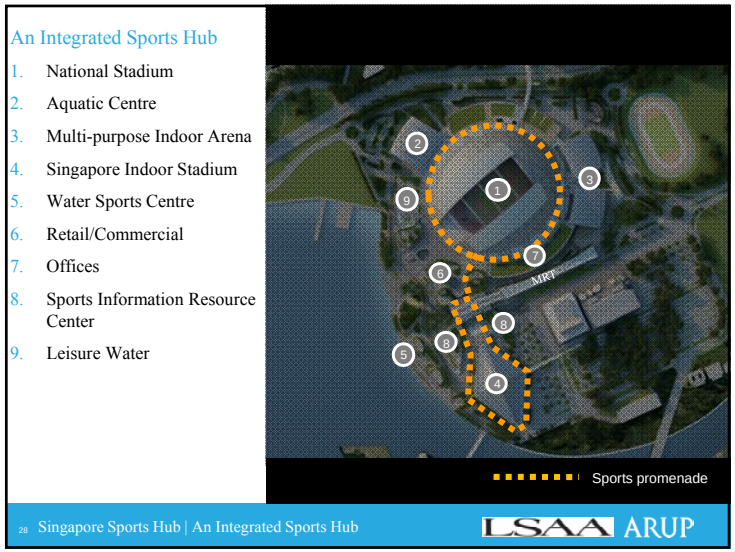
Roof Efficiency




Design Elements the World's Largest Free Spanning Dome
ARUP
25
by Scott Rathie | Arup | 14th November 2013
ARUP

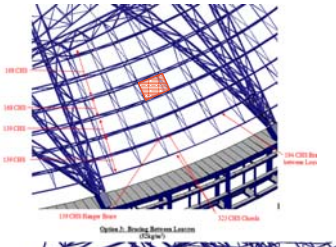

Dallas Cowboy
Singapore Sports Hub
SPORTS HUB
DALLAS COWBOYS
300M
LOUISIANA DOME
200M
CHARLOTTE COLISEUM
100M
WEST BADEN SPA HOTEL
PANTHEON
ATREUS
1000BC
0
1000AD
2000AD
26 Dome Structures | Stadium
LSAA ARUP

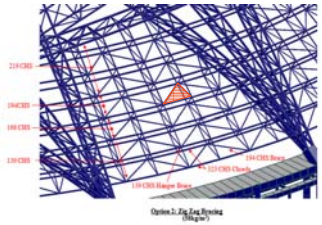

Analysis | Closed Roof Buckling Modes/ Dynamics
Dynamic Mode 1
Frequency: 0.500 Hz
λ1 = 4.95
Lateral Torsional Buckling RWT1
λ2 = 6.88
First Global Buckling mode
λ3 = 6.99
Second Global Buckling mode
27 National Stadium | Analysis & Design
LSAA ARUP

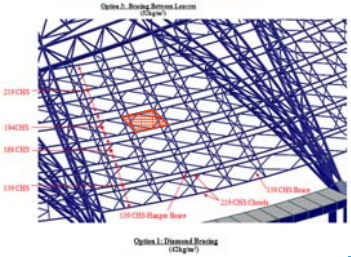

An Integrated Sports Hub
1. National Stadium
2. Aquatic Centre
3. Multi-purpose Indoor Arena
4. Singapore Indoor Stadium
5. Water Sports Centre
6. Retail/Commercial
7. Offices
8. Sports Information Resource Center
9. Leisure Water
MRT
Sports promenade
28 Singapore Sports Hub | An Integrated Sports Hub
LSAA ARUP

The Giant Louvres | Framing

- Louvre's approximately span 5-7m
- Architectural intent were flat PTFE louvres
- Pros and cons







29

ARUP