Smart Tensegrity Wings

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A Systems Approach to Wing Design

The 20th century wing design isolates these functions the 21st century design integrates them

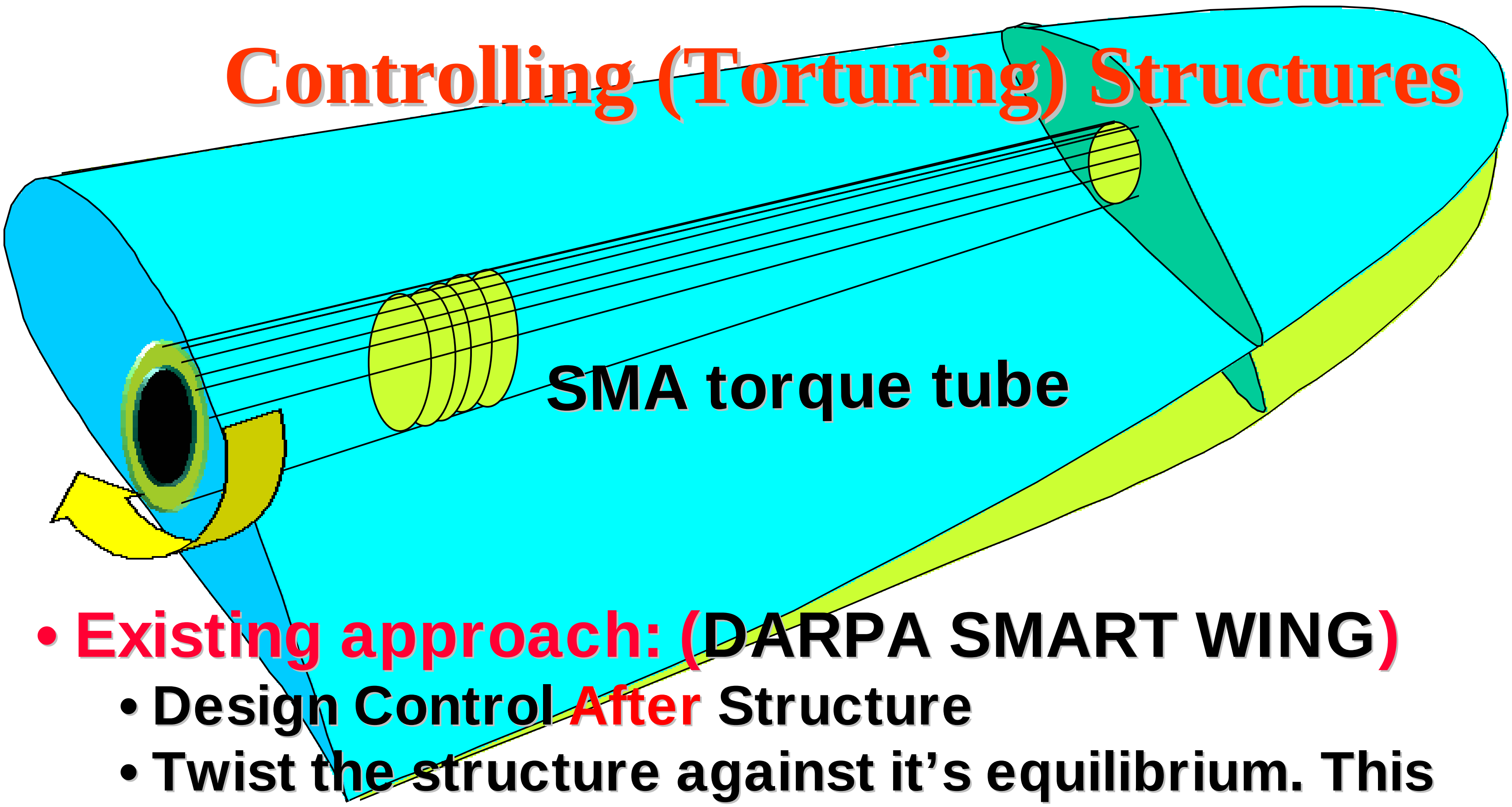
Functions:

fuel container
structural stability
structural strength
flow control
power generation
antenna
thermal management
sensing
actuating
shape control
health monitoring
communication

Resources:

materials
material architecture
sensing architecture
actuating architecture
signal flow paths
control algorithm
signal processing
manufacturing

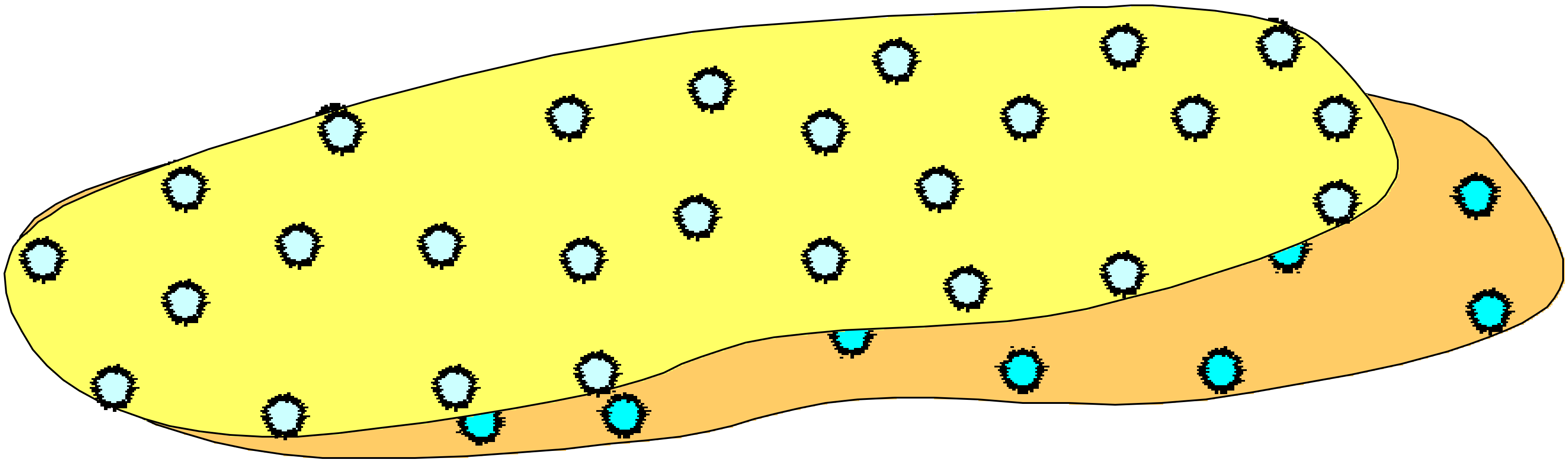
Controlling (Torturing) Structures



- Existing approach: (DARPA SMART WING)
  - Design Control After Structure
  - Twist the structure against it's equilibrium. This requires work (7 deg limit, 20 deg desired)

- New Paradigm: Unify at more fundamental level
  - Change shape by changing the equilibrium

Tensegrity Paradigm for Structural Control



•Changing the Shape With Less Control Energy

- •Construct a Tensegrity Geometry with a specified stiffness
- •Actuate the tendons (rest lengths) to avoid straining the structure
- •Modify the equilibrium to accommodate damage, high winds
- •Hold the shape (stiffness) while changing the stiffness (shape)

Tensegrity Geometry

$$(h, a, d) = \text{Stable equilibrium}$$

$$F(h, a, d)t = 0, \quad , \quad t > 0$$

$$\left| F^T F \right| = 0$$

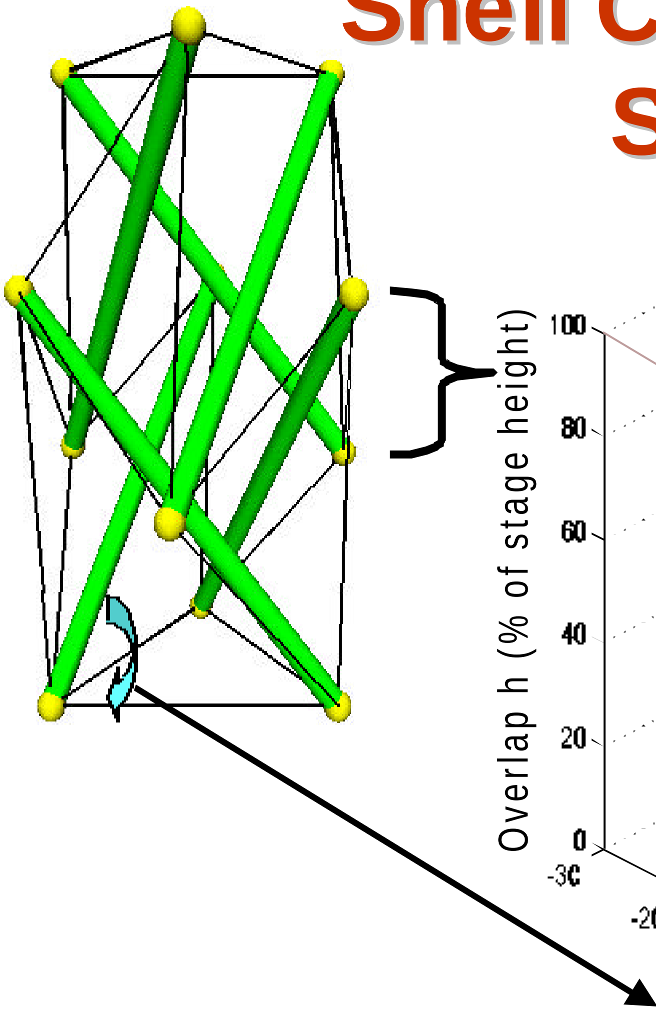
Tensegrity Geometry

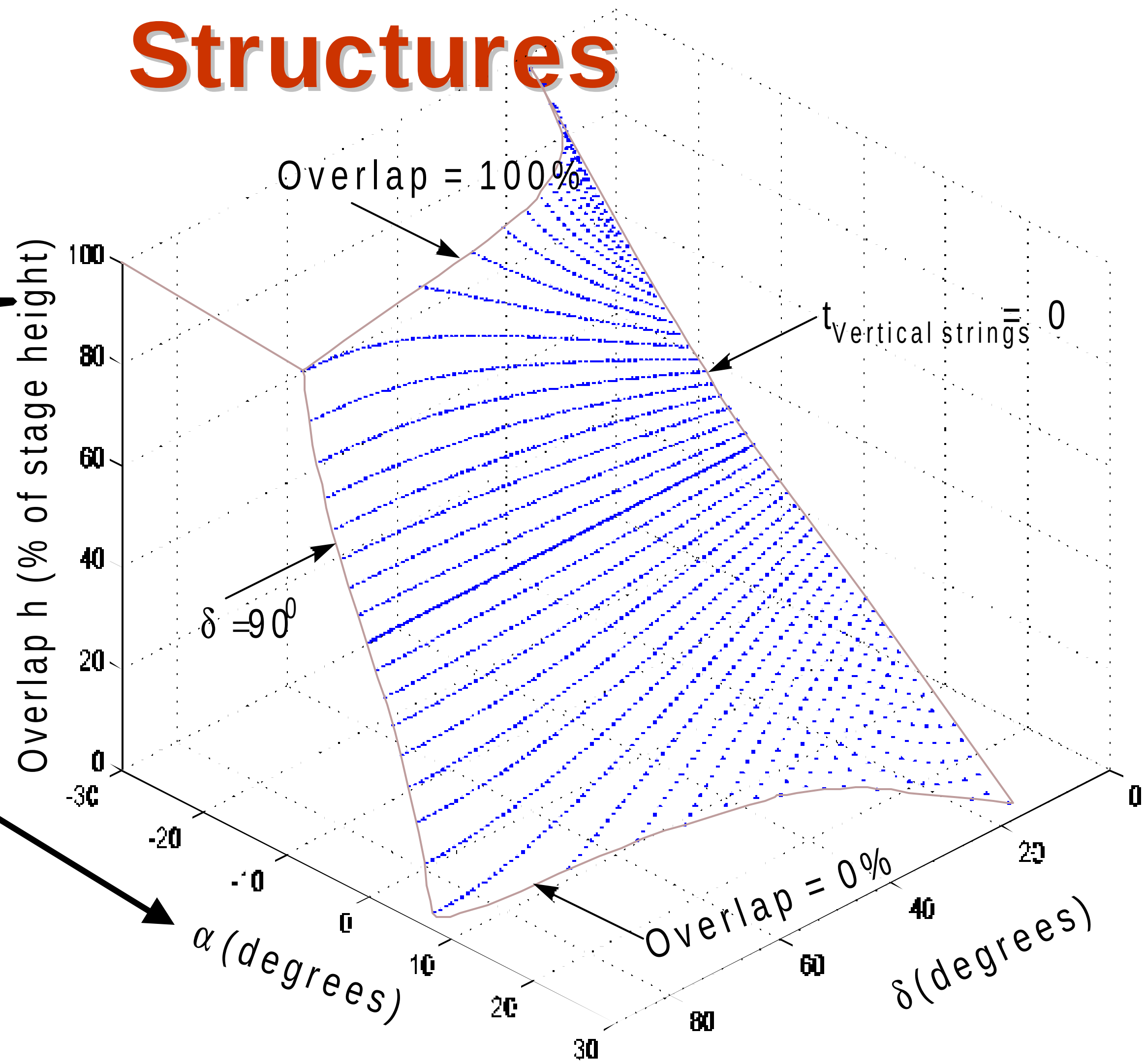
[Skelton, Helton, Adhikari, 1998], [Sultan/Skelton, 1998]

$$h = \frac{1}{2 \tan d \cos\left(a + \frac{p}{6}\right)} \left(-\frac{L_t}{\sqrt{3}} + L \sin d \cos\left(a + \frac{p}{6}\right) + \sqrt{\frac{L_t^2}{3} - 3L^2 \sin^2 d \cos^2\left(a + \frac{p}{6}\right)} \right)$$

- Pugh, 1976
- Pelligrino, Calladine, 1986
- Motro, 1986
- Furuya, 1992
- Coughlin, Stamenovic, 1997
- Skelton, 1993 - 1999
- Sultan, 1996,1997, 1998, 1999
- Oppenheim, 1998
- Williamson, Skelton, 1999

Shell Class Tensegrity Structures





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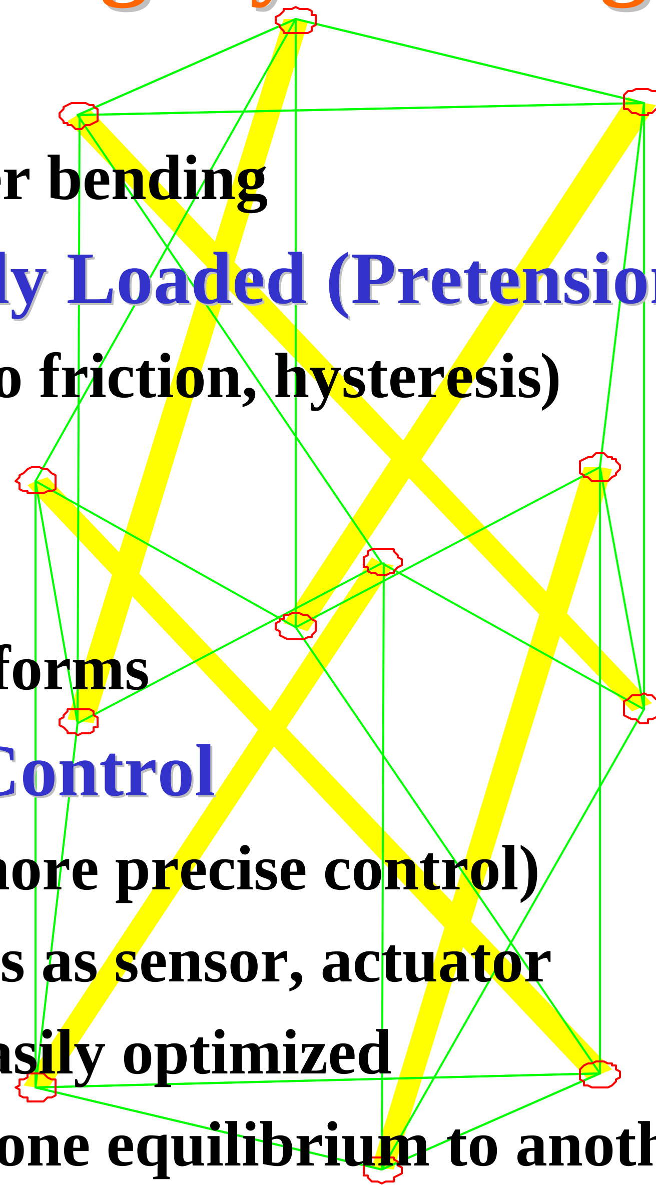
Advantages of The Tensegrity Paradigm



- **All Members Axially Loaded**
  - **Global bending without member bending**
- **All Members Uni-Directionally Loaded (Pretension)**
  - **No reversal of load direction (no friction, hysteresis)**
- **Structural Efficiency**
  - **Strength to mass very high**
  - **Inspired by Art and Biological forms**
- **Easy to Integrate Structure/Control**
  - **More accurate models (hence more precise control)**
  - **A structural member also serves as sensor, actuator**
  - **Actuator/Sensor architecture easily optimized**
  - **Change shape with little work (one equilibrium to another)**