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Lessons from Structural Design of a Highly-Flexible Space Structure: the Space-Tow Solar Sail

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(presented by Andrew Lennon)

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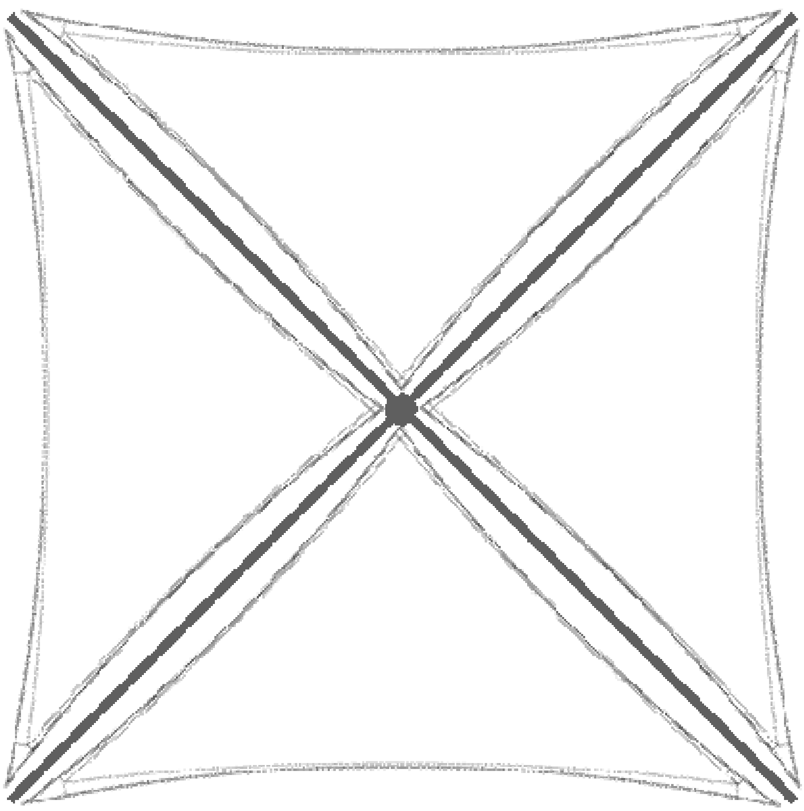
Background

- Hedgepeth in NASA-CR-3484 (1981)
  "*space structures must be designed to deal with phenomena as primary criteria which have been considered as only secondary in the past*"
- Brief presentation of some lessons learned during design of a highly flexible structure
- Presentation based on current work about solar sails (particularly space-tow) by Tibert & Lennon

Typical Square Solar Sail
(image from NASA)



- Square sail
- Triangular sections of film
- Diagonal booms

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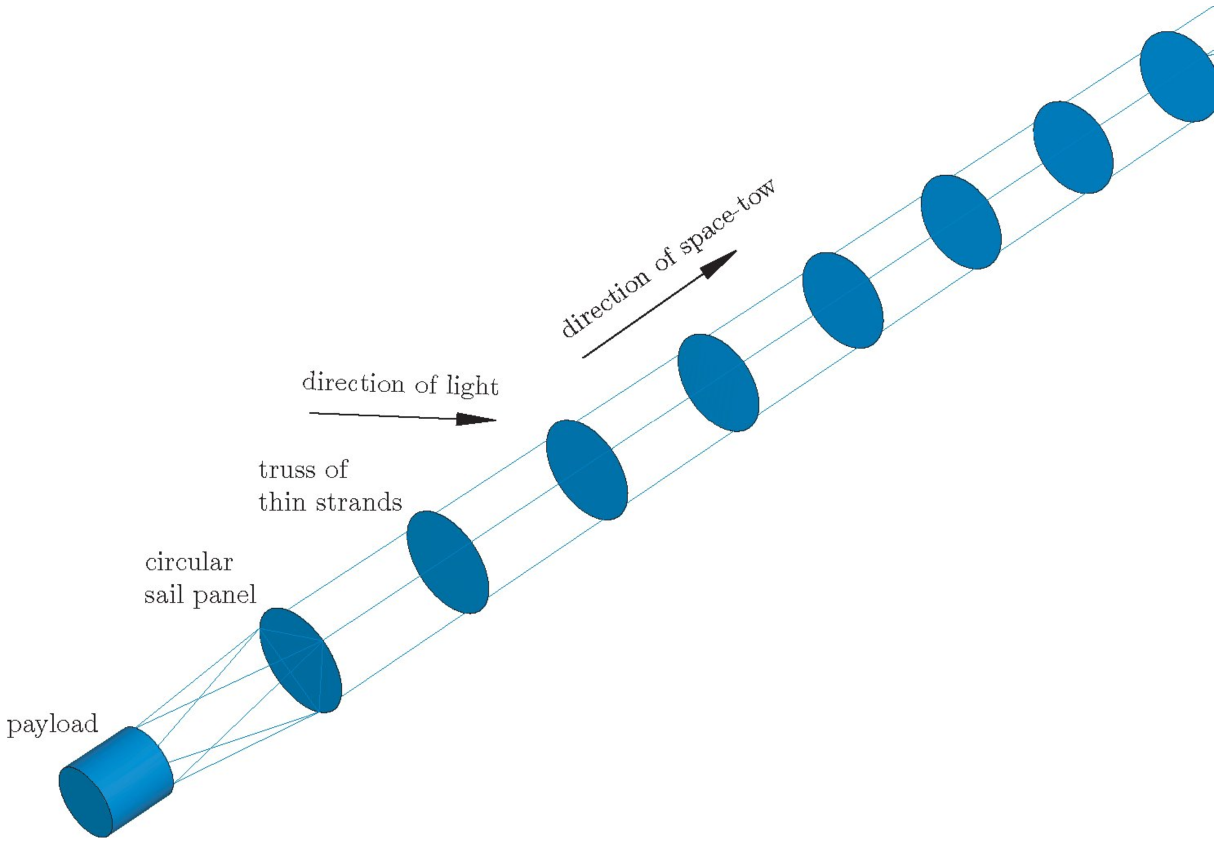
The Space-Tow Concept



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The Space-Tow Concept

- Concept developed by Dr Gyula Greschik (University of Colorado, Boulder)
- Modular design — ease of design, manufacture, testing
- Eliminates need for long booms and large panels of sail film of “typical” square sail configurations

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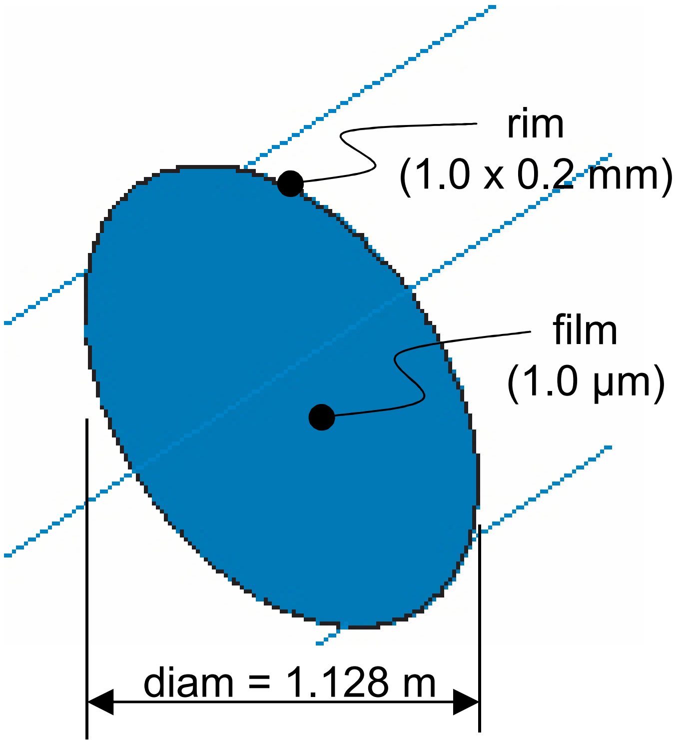
Basic Configuration

- 10 000 m^2
- 10 000 panels (each panel 1 m^2)
- Panel diameter = 1.128 m
- Need 1.954 m between panels for 30° incident light
- Total structure length = 19 544 m

Panel Design

Components

- Panel rim: ring with rectangular cross-section
- Sail film: flat circular membrane
- Adhesive joint for rim-film connection



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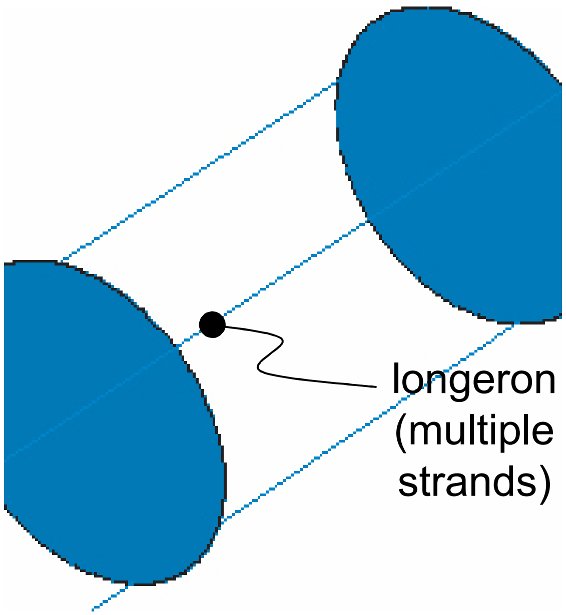
Truss Design

- No diagonals to prevent shear transfer
- "Truss" is actually three longerons
- Longerons composed of a number of strands
- Number of strands decreases with distance from payload



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Stowed Configuration

- Assume longerons coiled inside panel rim
- Dimensions (as per Greschik)
  rim 200 μm
  adhesive 12 μm (as per Greschik)
  gap 50 μm (as per Greschik)
- Stowed structure is 2.62 m high x 1.128 m

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Physical Scales

- Film to rim thickness = 1:200
- Rim width to diameter = 1: 1128
- Stowed to deployed lengths = 1:7460
- Bay length to total length = 1:10 000
- Film thickness to total length ≈ 1: 2×10^{10}

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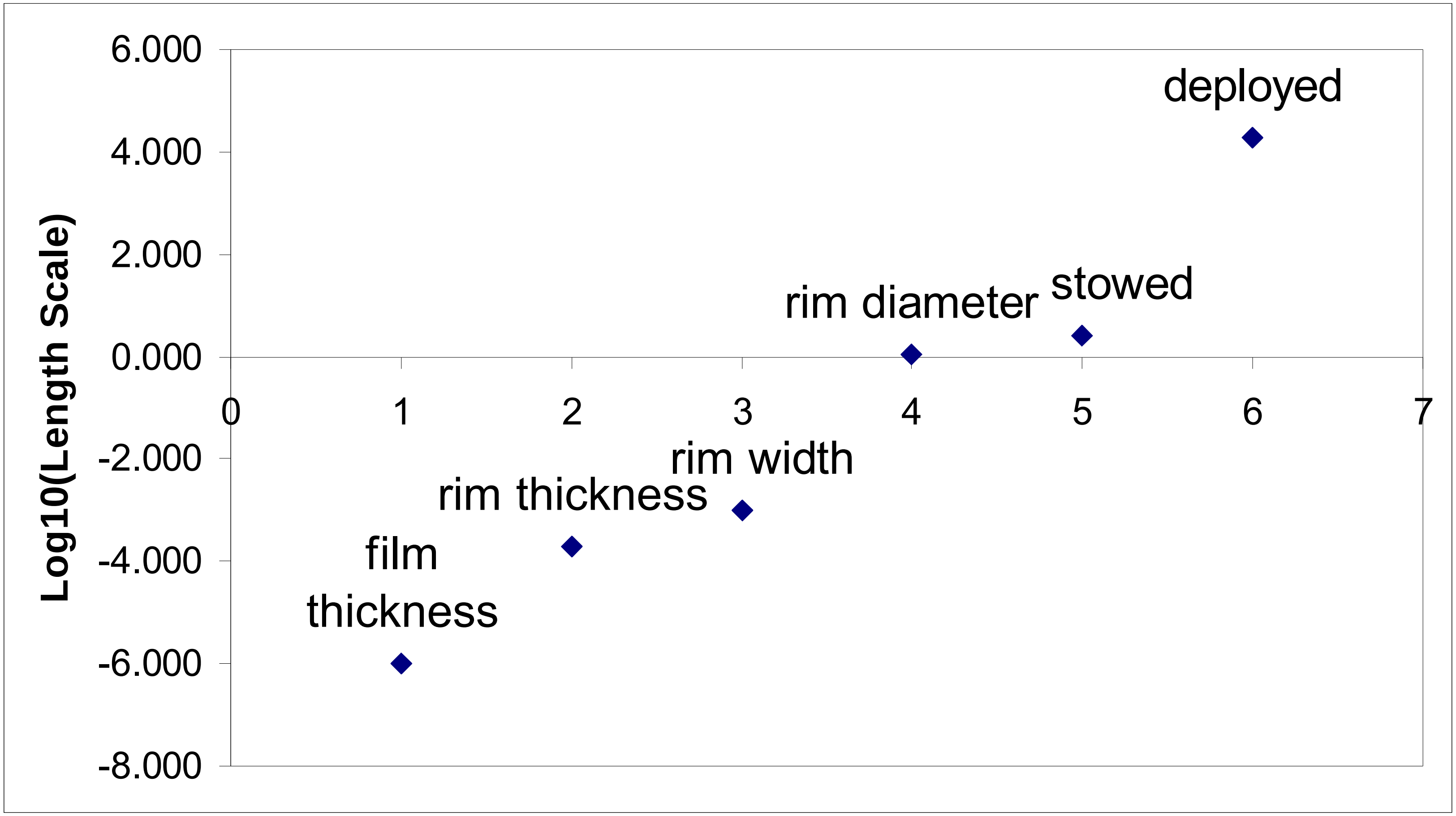
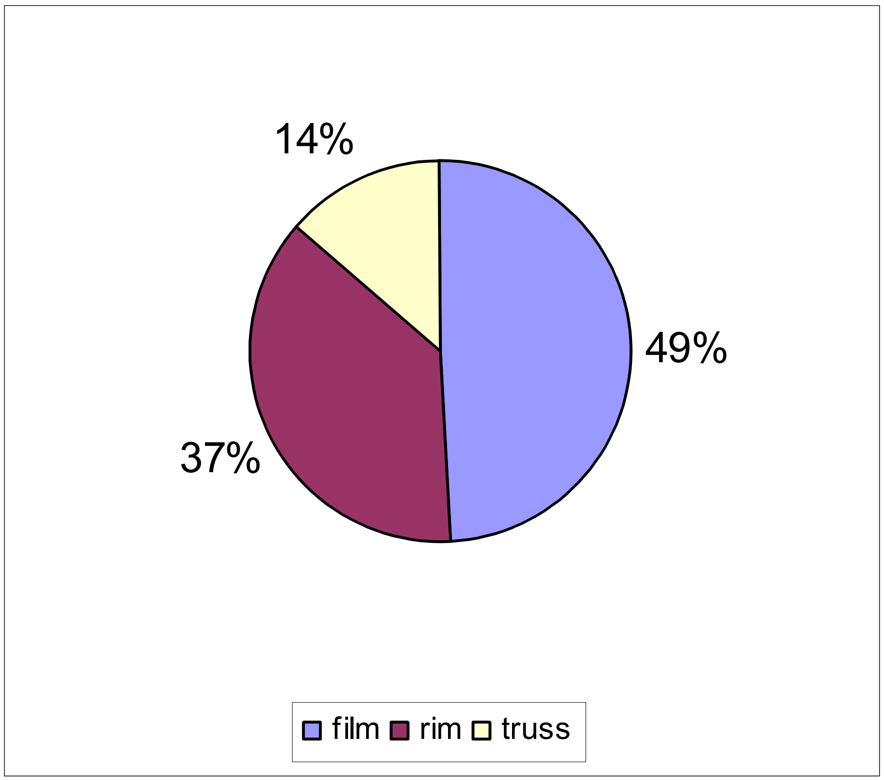
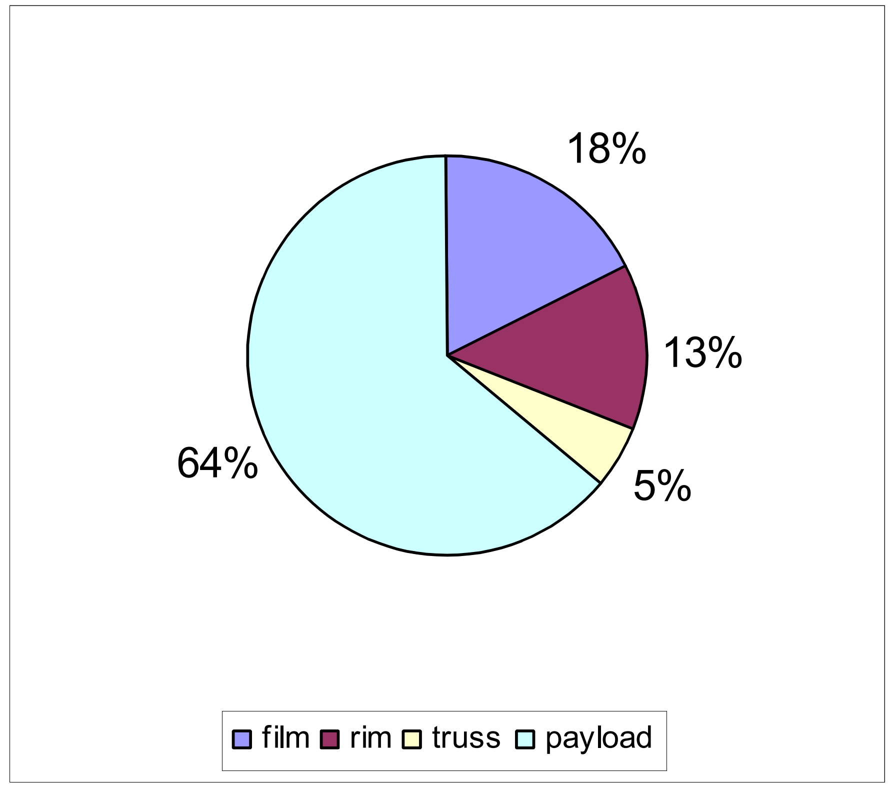
Physical Scales



Mass Distribution





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Performance

- Total mass (structure + payload) = 78.3 kg
  - 28.3 kg structure
  - 50 kg payload
- Acceleration at 1AU = 0.74 mm/s^2
  - 85% reflectivity
  - 30° to incident sunlight

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Conclusion

- Recall Hedgepeth
  "*space structures must be designed to deal with phenomena as primary criteria which have been considered as only secondary in the past*"
- Space-tow has vastly varying scales (μm to km)
- Highly-flexible
- Modular design helps overcome scale problems

Thank you

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