AIAA SciTech 2020

Distributed System of Passively Mobile Tensegrity Structures

Kelly Wang, Christine Gebara, Adam Duran, Nicholas Saltarelli, Allison Ayad

Jet Propulsion Laboratory, California Institute of Technology

Jet Propulsion Laboratory
California Institute of Technology

High level agenda

- Overview
- Mission Architecture
- Design Approach and Evolution
- Building and Testing

Overview

Mission Architecture

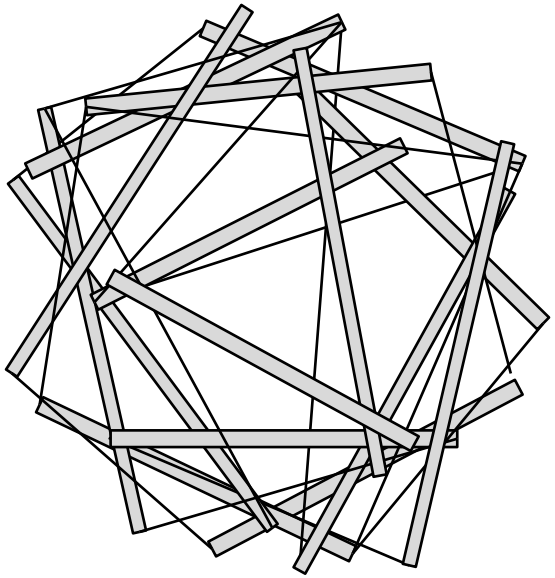
Design Approach and Evolution

Building and Testing

Overview: Tensegrity Background

Tensegrity

- High stiffness-to-mass ratios
- Impact tolerant
- Stow capability



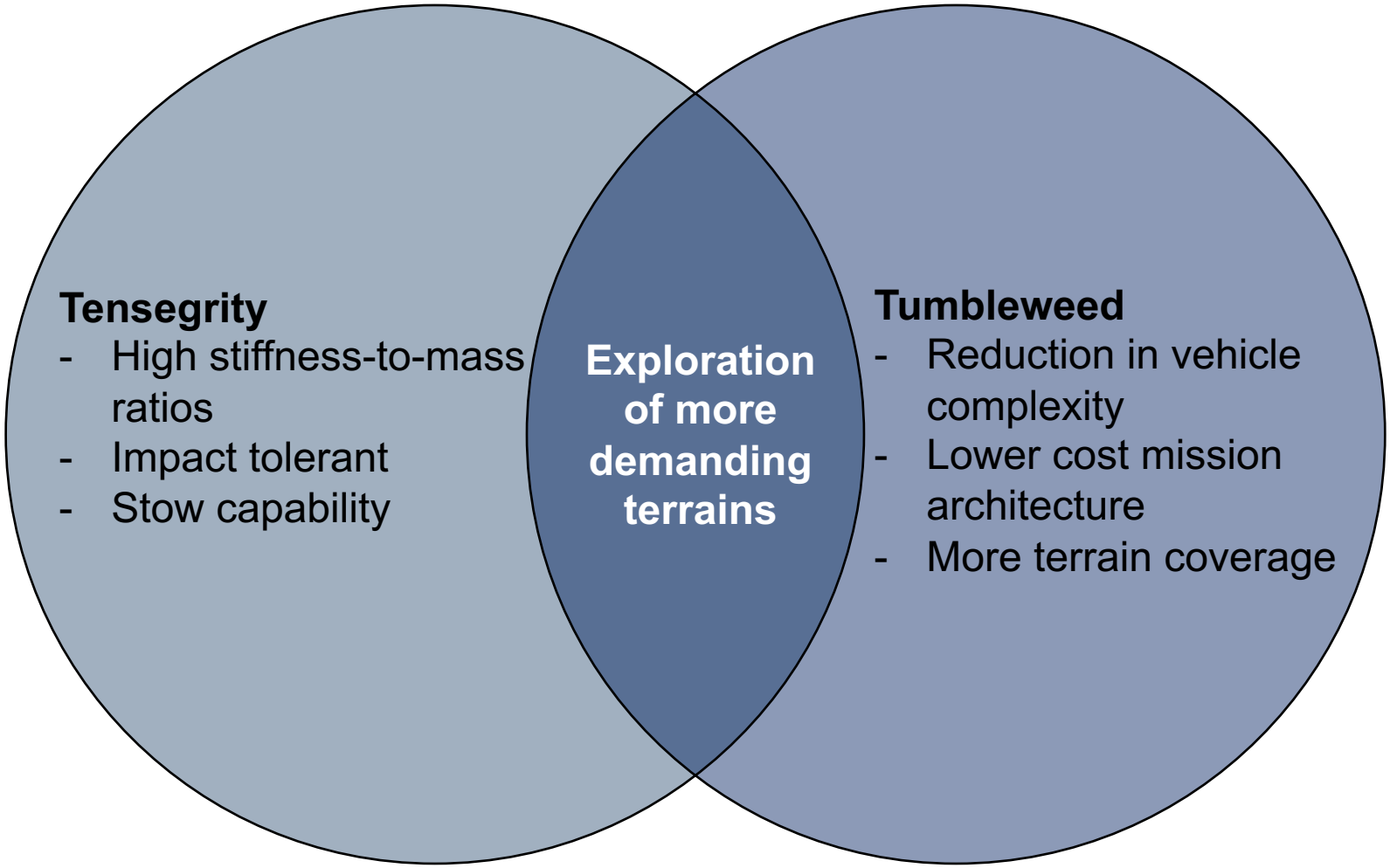
Overview: Tumbleweed Background

Tumbleweed

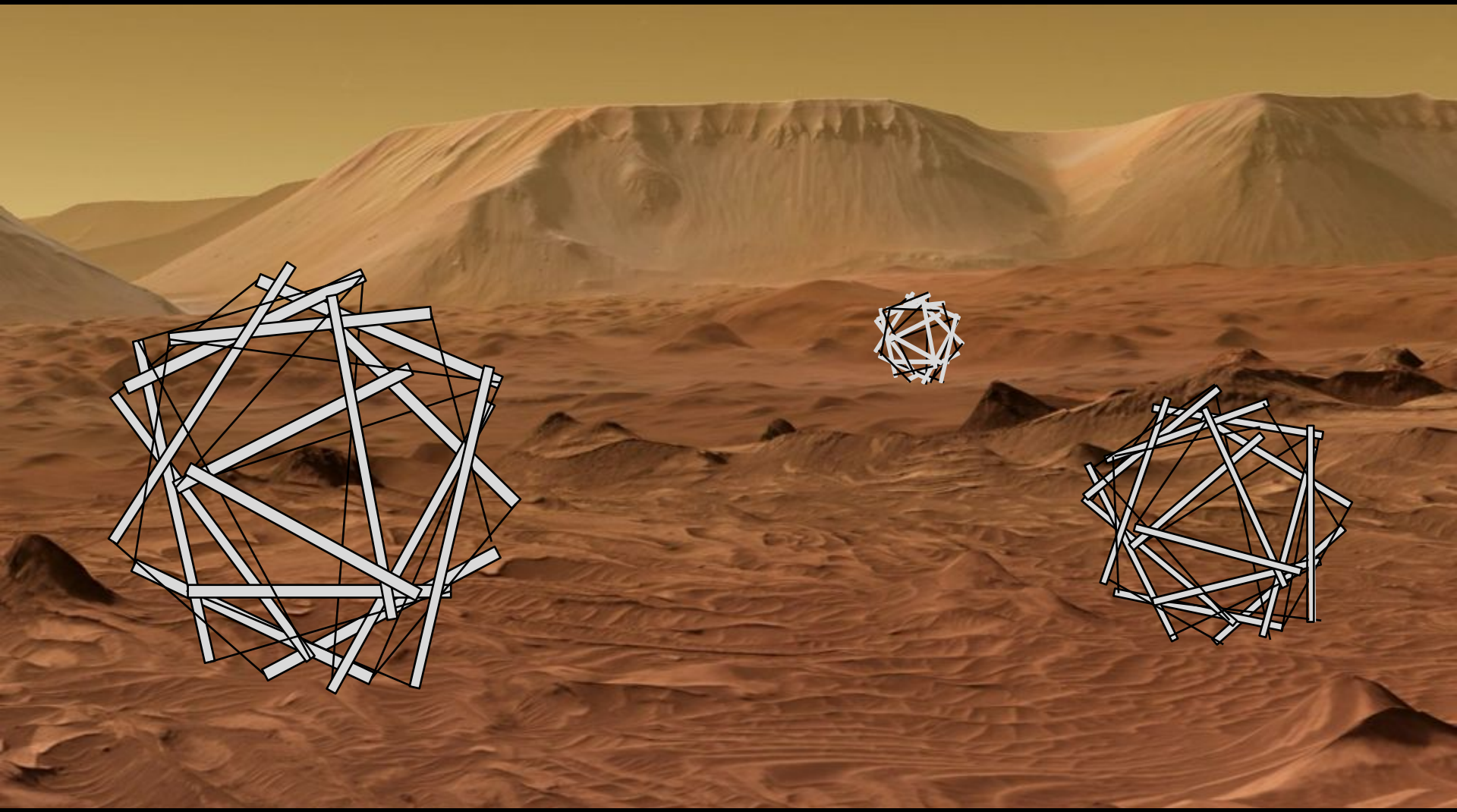
- Reduction in vehicle complexity
- Lower cost mission architecture
- More terrain coverage

Antol, J., Calhoun, P., Flick, J., Hajos, G., Kolacinski, R., Minton, D., Owens, R., and Parker, J., "Low Cost Mars Surface Exploration: The Mars Tumbleweed," NASA TM-2003-212411, August 2003.

Intersection of the two ideas



Mission Architecture



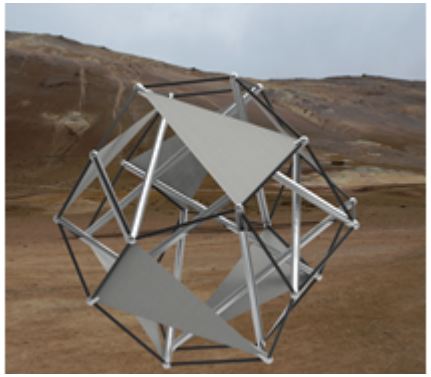
Overview

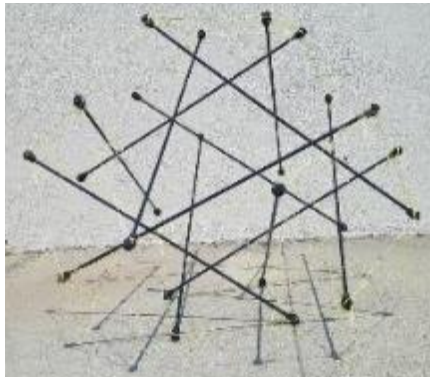
Mission Architecture

Design Approach and Evolution

Building and Testing

Design Concept

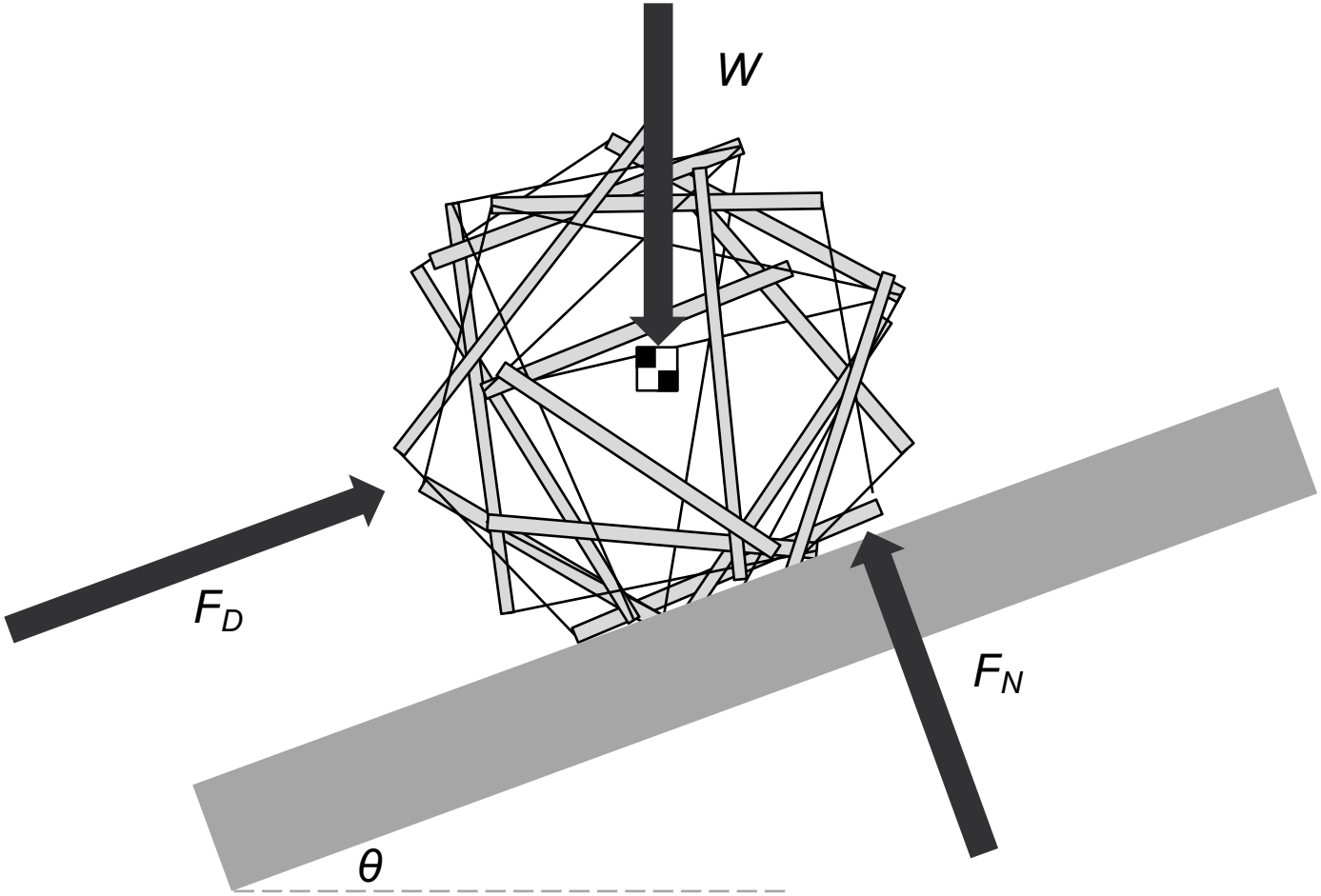




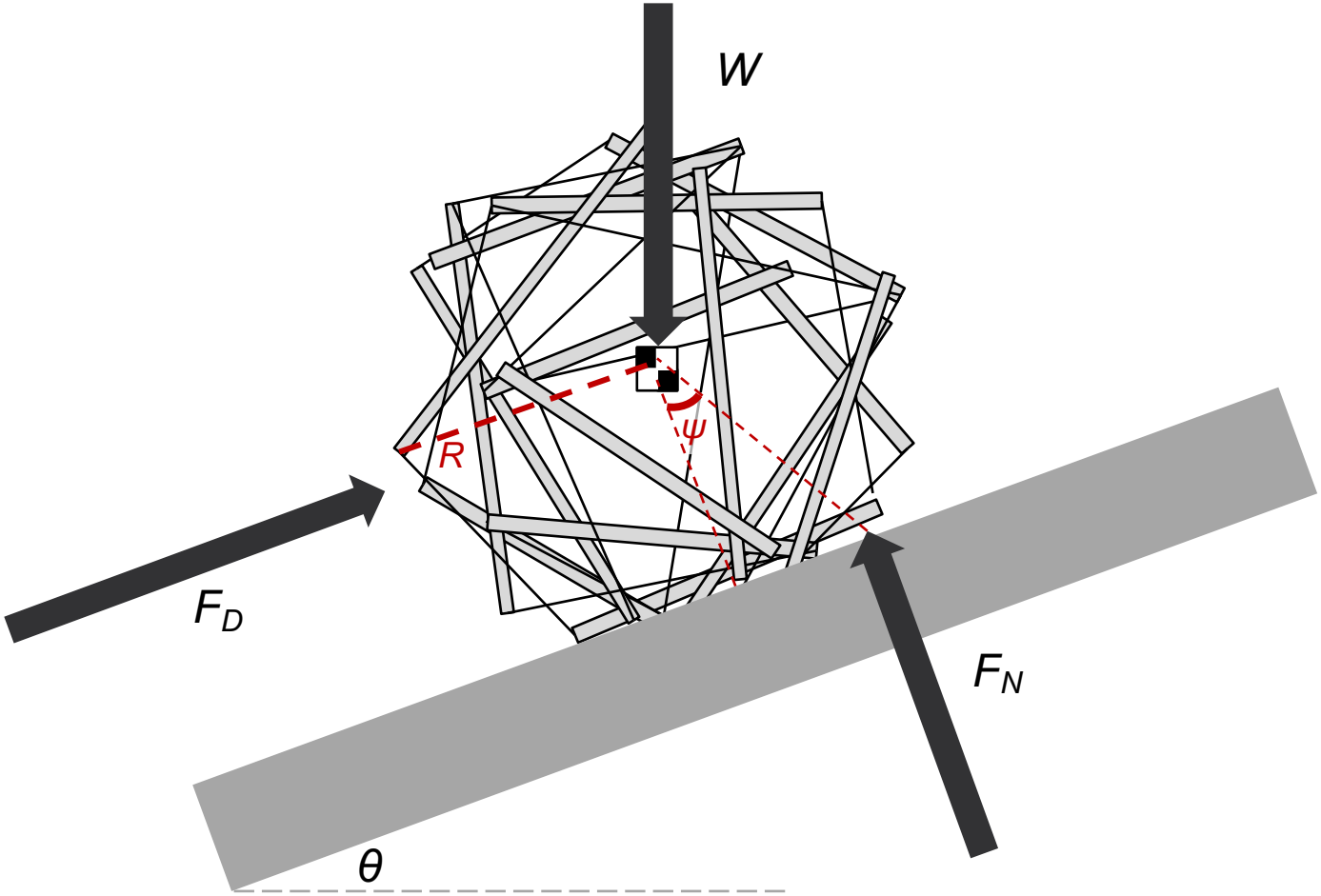
Starting Point: 12 bar spherical tensegrity

Goal: determine necessary size and aerosurface design

Design: Approach

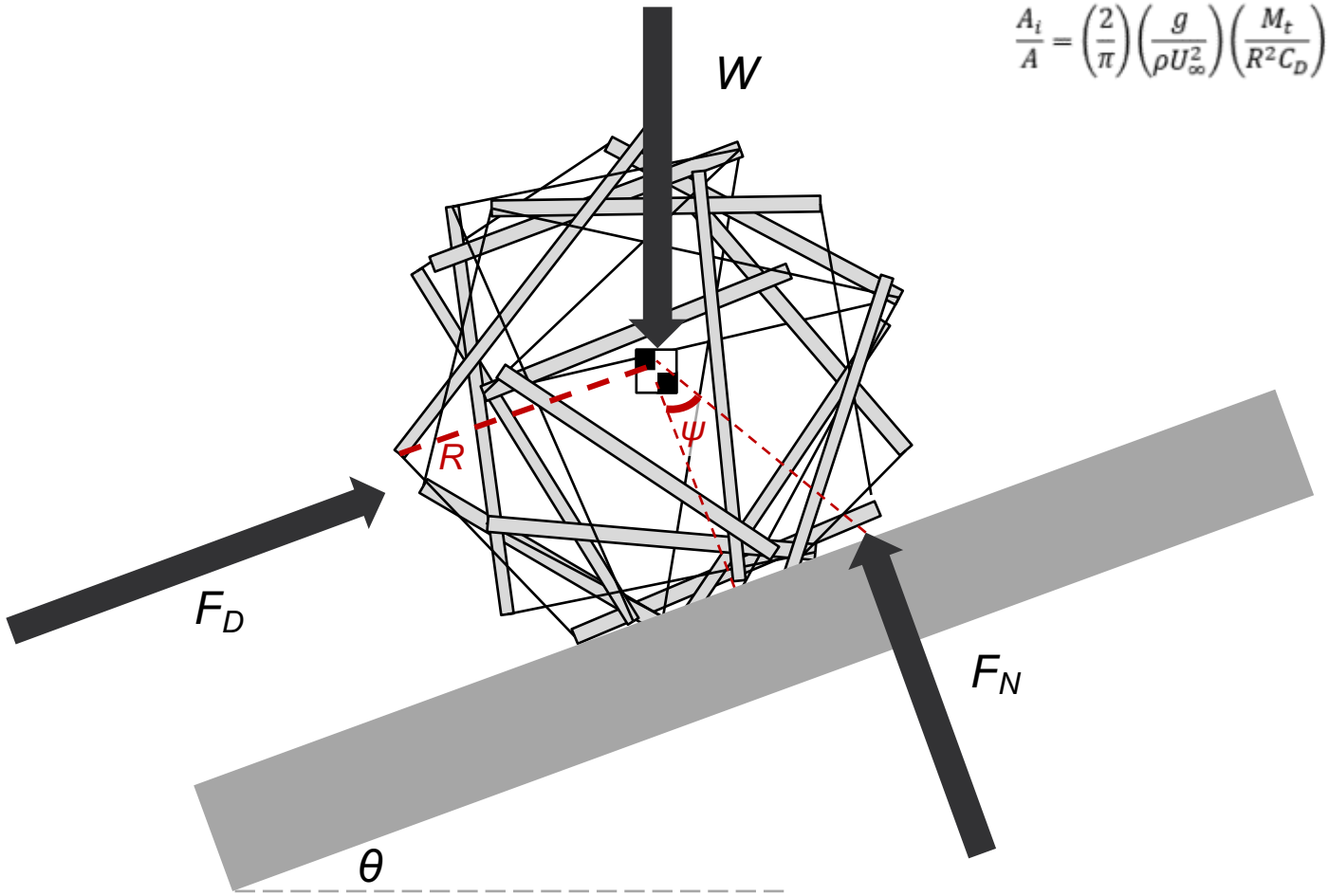


Design: Approach



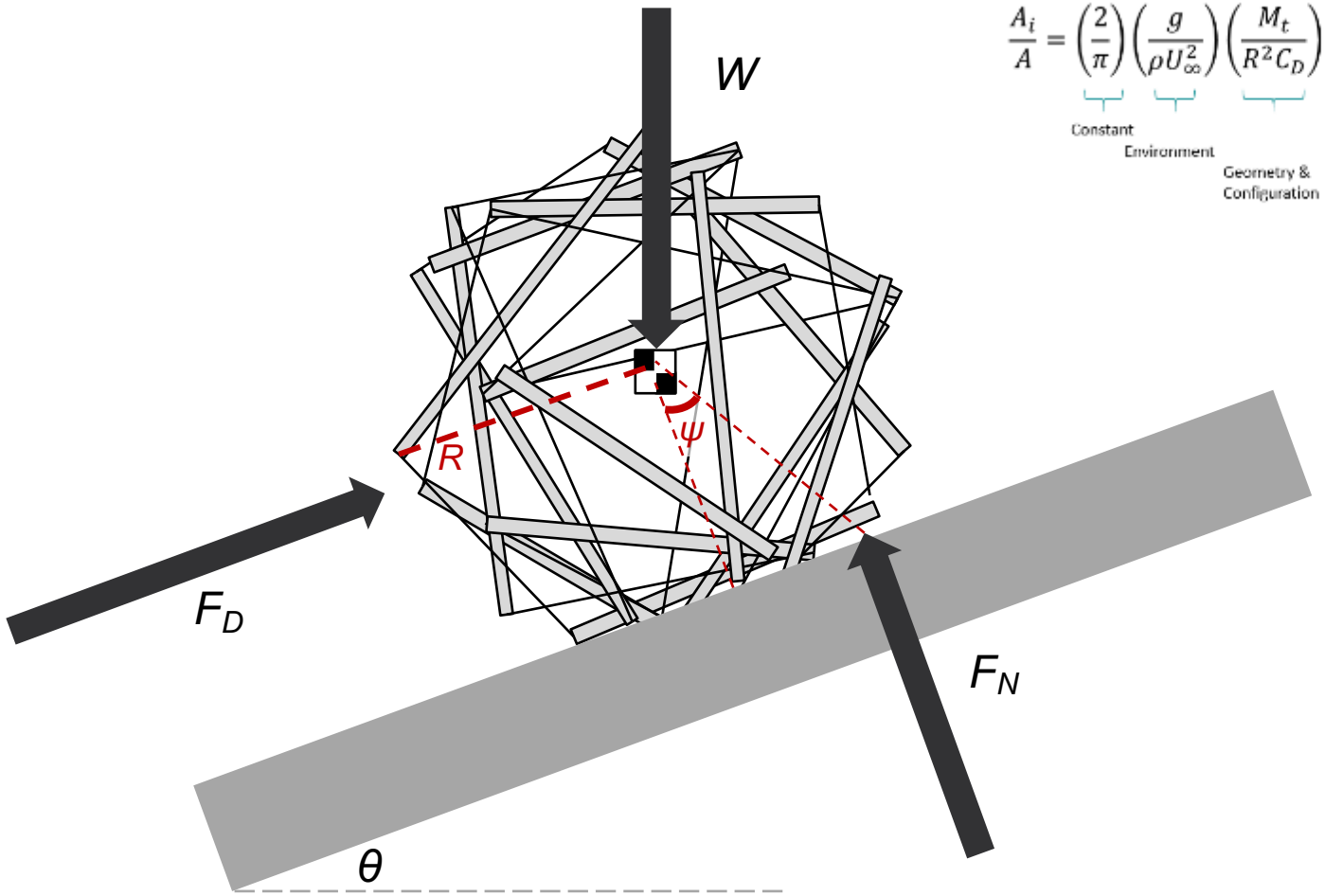
Design: Approach

$$\frac{A_i}{A} = \left(\frac{2}{\pi}\right)\left(\frac{g}{\rho U_\infty^2}\right)\left(\frac{M_t}{R^2 C_D}\right)(tan\theta + cot\psi)$$



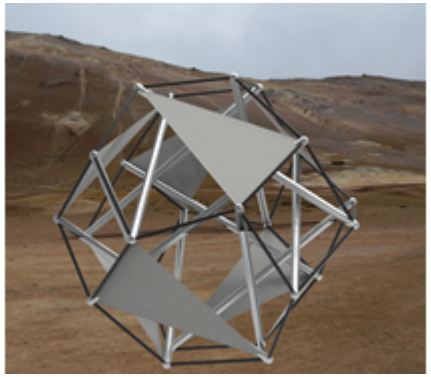
Design: Approach

$$\frac{A_i}{A} = \underbrace{\left(\frac{2}{\pi}\right)}_{\text{Constant}} \underbrace{\left(\frac{g}{\rho U_\infty^2}\right)}_{\text{Environment}} \underbrace{\left(\frac{M_t}{R^2 C_D}\right)}_{\text{Geometry \& Configuration}} \left(\underbrace{tan\theta}_{\text{Environment angle}} + \underbrace{cot\psi}_{\text{Configuration angle}}\right)$$

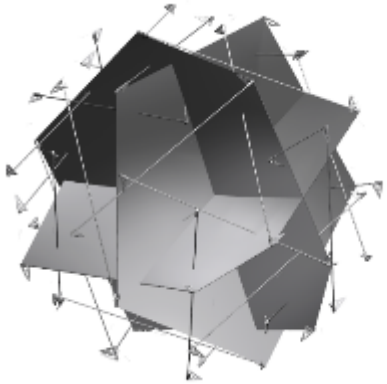


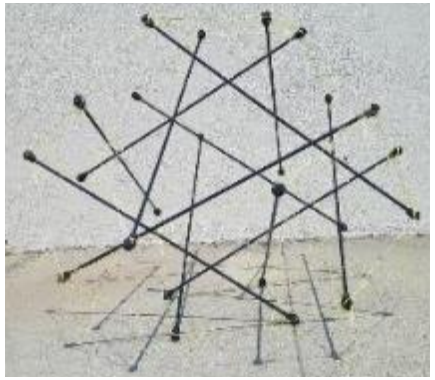
Design Evolution

From Concept to Implementation



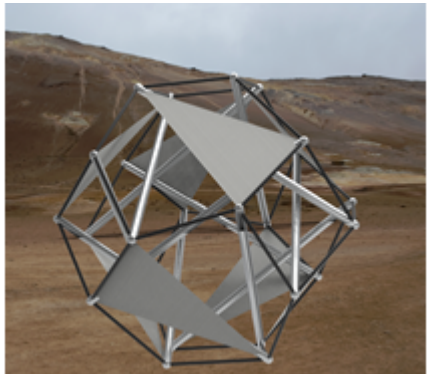
1. Structure Geometry
2. Node Geometry
3. Sail Implementation



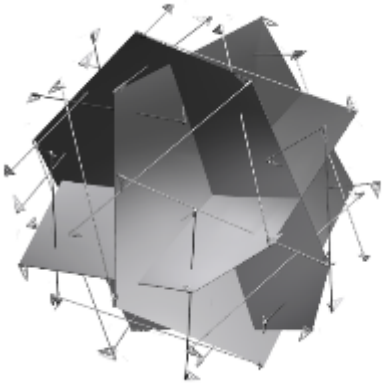


Design Evolution

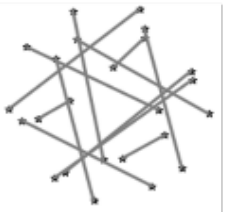
Structure Geometry

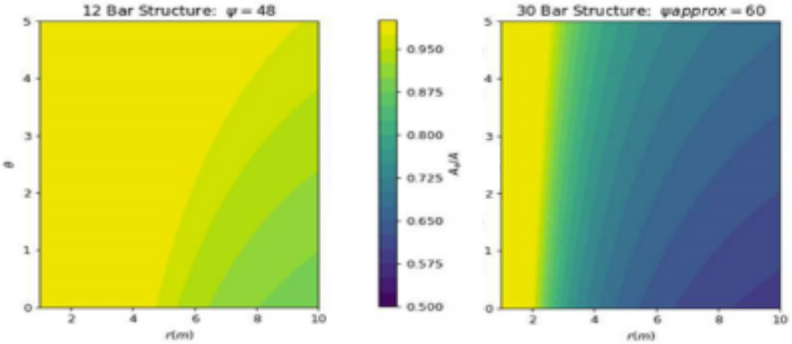


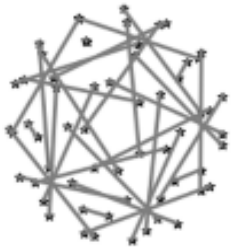
1. **Structure Geometry**
2. Node Geometry
3. Sail Implementation



A_i/A ratio comparison between 12 bar and 30 bar structures.

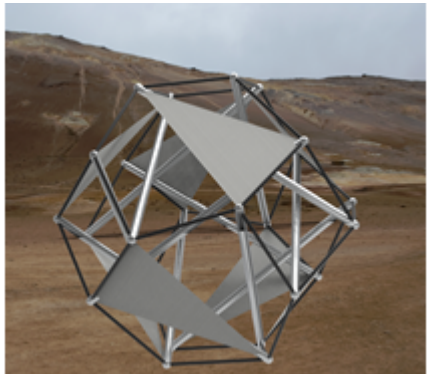




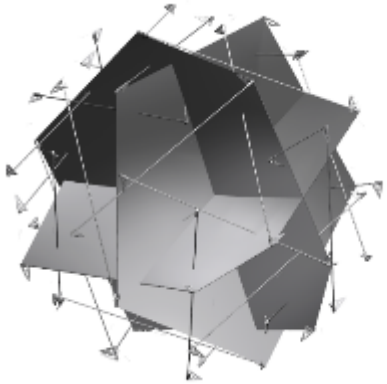


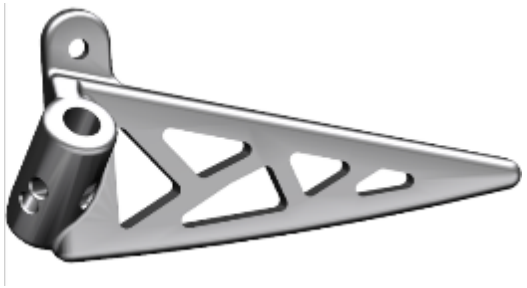
Design Evolution

Node Geometry



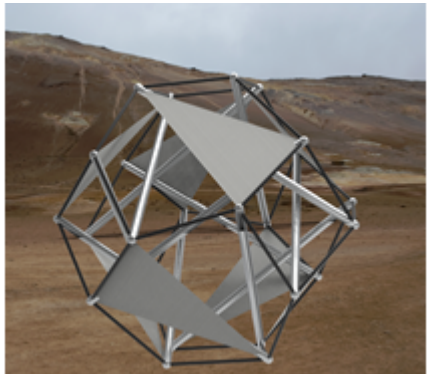
1. Structure Geometry
2. **Node Geometry**
3. Sail Implementation





Design Evolution

Sail Implementation



1. Structure Geometry
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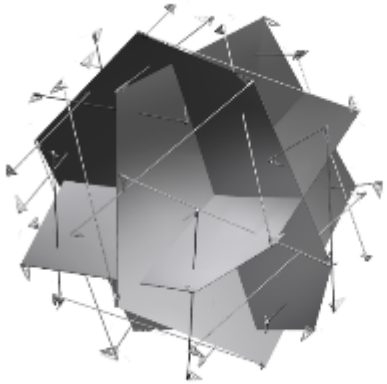
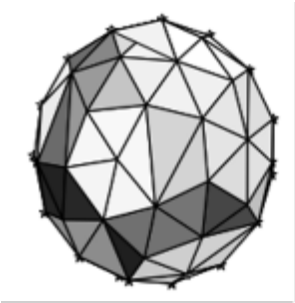
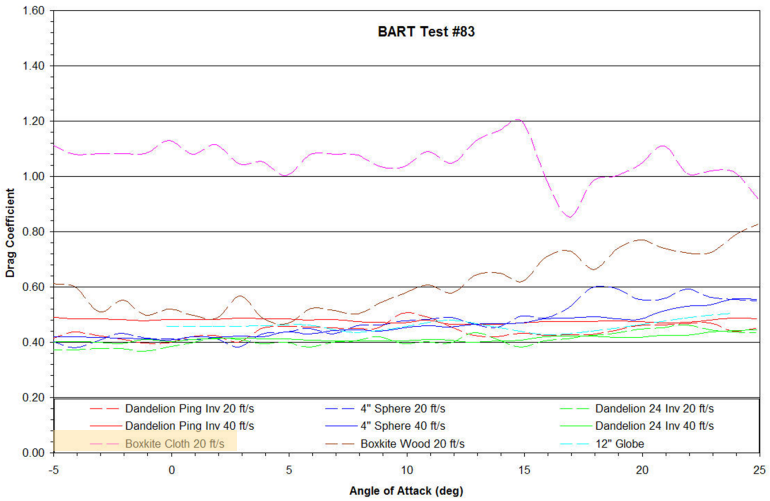
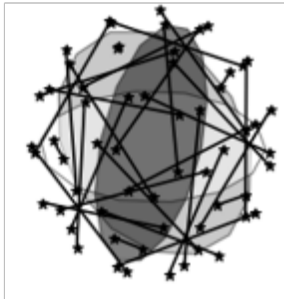
3. **Sail Implementation**









Antol, J., Harris S.B., Hajos G.A., and Strickland, C.V., "Wind Tunnel Tests of Evolved Mars Tumbleweed Concepts," AIAA Paper 2006-0069, January 2006.

Overview

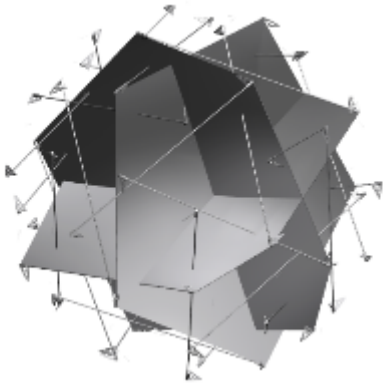
Mission Architecture

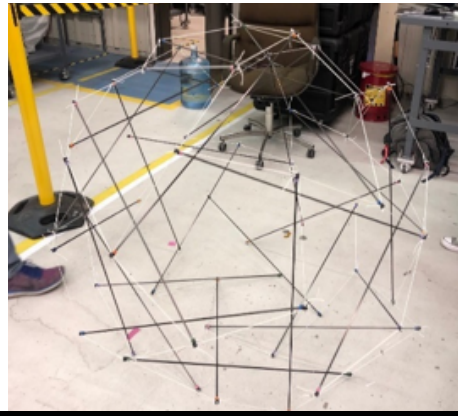
Design Approach and Evolution

Building and Testing

Prototype Build

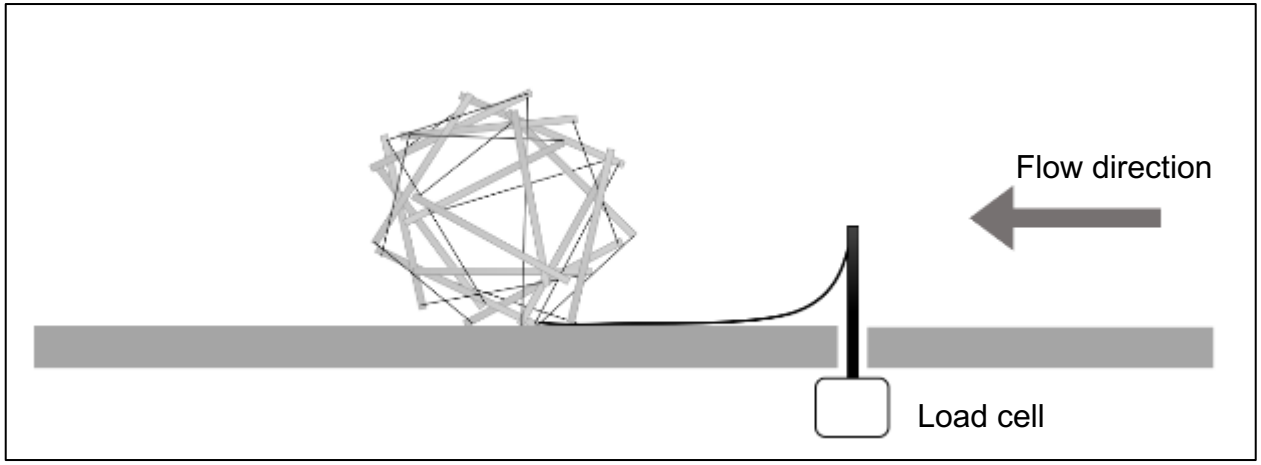
Earth Analog Tensegrity





Wind Tunnel Testing

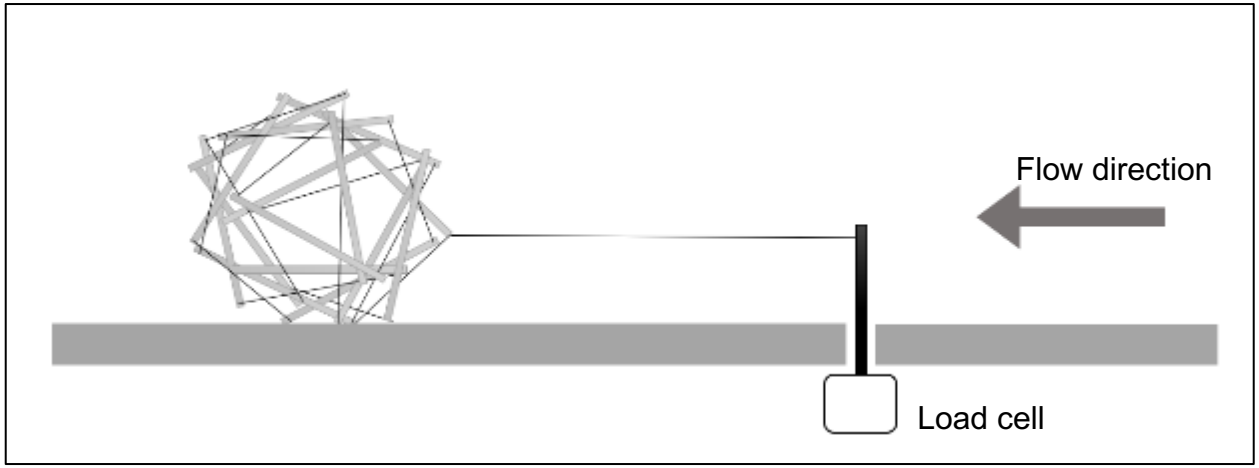
Critical Wind Speeds

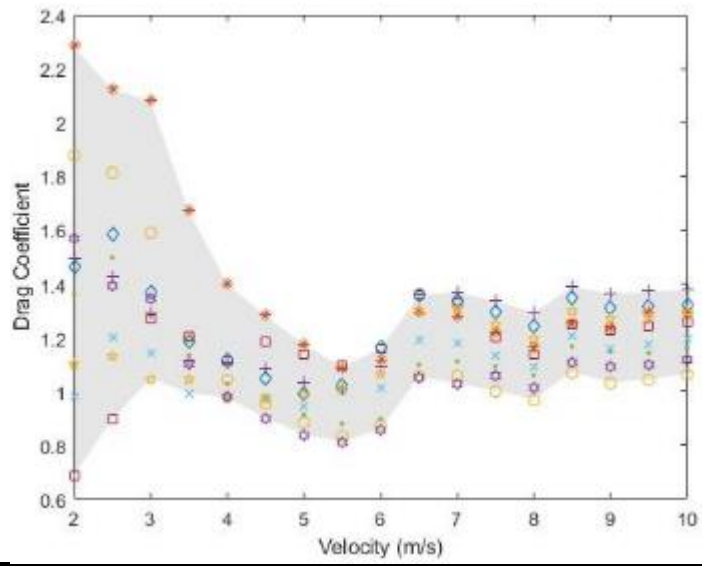


Expected wind speed: 5 m/s
Observed wind speed: 4.55 m/s

Wind Tunnel Testing

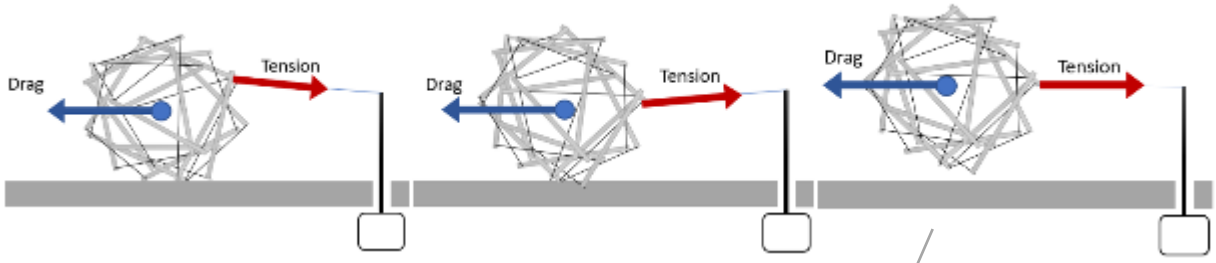
Coefficient of Drag

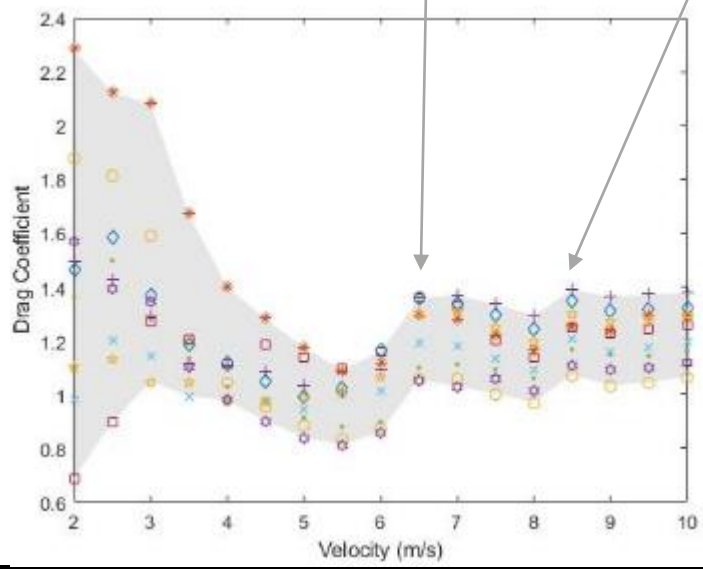




Wind Tunnel Testing

Coefficient of Drag





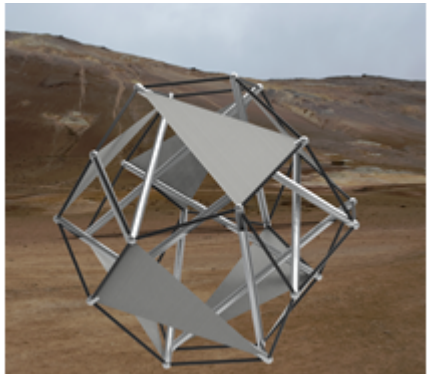
Assumed drag coefficient: 1.1
Observed drag coefficient: 1.05

Field Testing

- Field testing was carried out with 360 video
  - GoPro Fusion camera suspended in structure

Field Testing

Summary



- Sensitivity studies showed that rolling resistance drove the design
  - Addressed by changing the structure and node geometries
- Validation testing showed that the sizing method is conservative

Acknowledgments

- Christine Gebara, JPL
- Dr. Adam Duran, JPL
- Nick Saltarelli, JPL Intern
- Allison Ayad, JPL Intern
- Dr. Samuel Case Bradford, JPL
- David Jeon, CalTech

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