Virtual Research Presentation Conference

Spirally Wrapped Parabolic Solid-Surface RF Reflectors for Small Satellites

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Program: Spontaneous Concept

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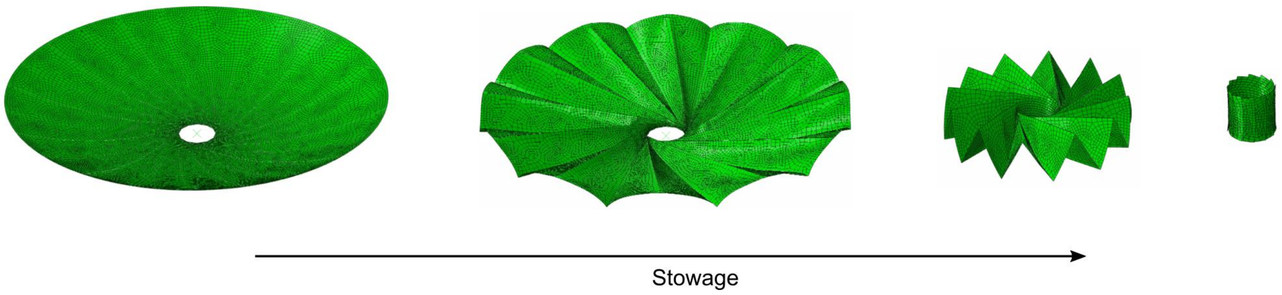
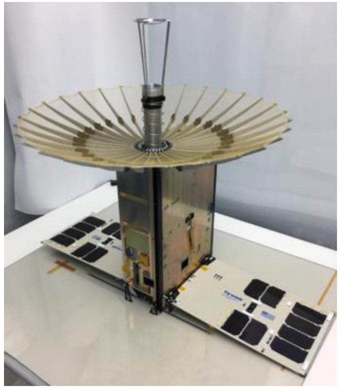
Introduction

- Need to develop low-cost approaches to W-band RADAR antenna systems for small satellites
- However, existing W-band antenna reflectors are large, massive, and non-deployable
- Existing lightweight deployable reflectors for small satellites are mesh-based, and do not scale to W-band
- We have designed and demonstrated a method for stowing compactly solid-surface parabolic reflectors
    - This method is inspired by origami wrapping, and the reflector is wrapped compactly in a cylindrical package
    - Since these reflectors have solid surfaces made of carbon fiber materials, they can operate at W-band
    - We demonstrate, using structural finite element models, the ability of these reflectors to stow, and also that these reflectors are sufficiently stiff when deployed



Problem Description

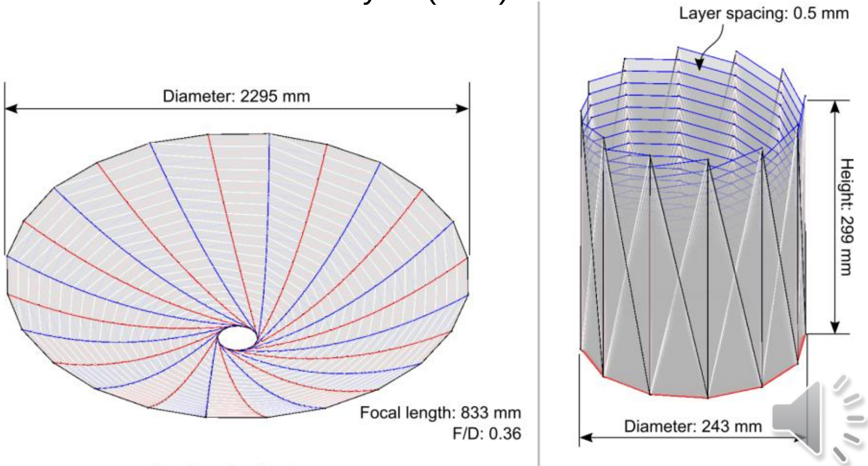
- Need to develop low-cost small satellite W-band (75-110 GHz) RADAR systems to enable Clouds, Convention, and Precipitation (CCP) science per the 2018 Earth Science decadal survey
- Existing W-band RADAR antenna reflectors are large, non-deployable, and massive (e.g. CloudSat)
  - Cannot be scaled down for small satellite use without losing useful aperture size
- Existing deployable reflectors for small satellites (e.g. RainCube) operate at Ka-band (26-40 GHz) and use mesh reflectors
  - Mesh reflectors are transparent to W-band frequencies (because the holes in the mesh are comparable to W-band wavelengths)
- Gap: deployable solid-surface W-band reflectors for small satellites



RainCube Deployable Mesh Reflector, Credit: NASA/JPL-Caltech

Methodology

- Demonstrate the feasibility of a foldable solid-surface radio-frequency parabolic reflector at W-band for small-satellites
  - Origami-inspired spiral-wrapping techniques
  - High-performance carbon-composite shell structures
- Develop algorithms for generating fold patterns for spirally-wrapped parabolic surfaces
- Demonstrate stowage of wrapped parabolic reflectors using structural finite element analysis (FEA)
- Predict the stiffness of a deployed reflector using FEA
- Used novel algorithm to generate candidate fold pattern:
  - 2295 mm deployed diameter, 833 mm focal length
  - Stowed: 243 mm diameter, 299 mm height
  - 0.5 mm layer spacing when wrapped
  - CloudSat-like reflector capable of stowing in an ESPA-class S/C

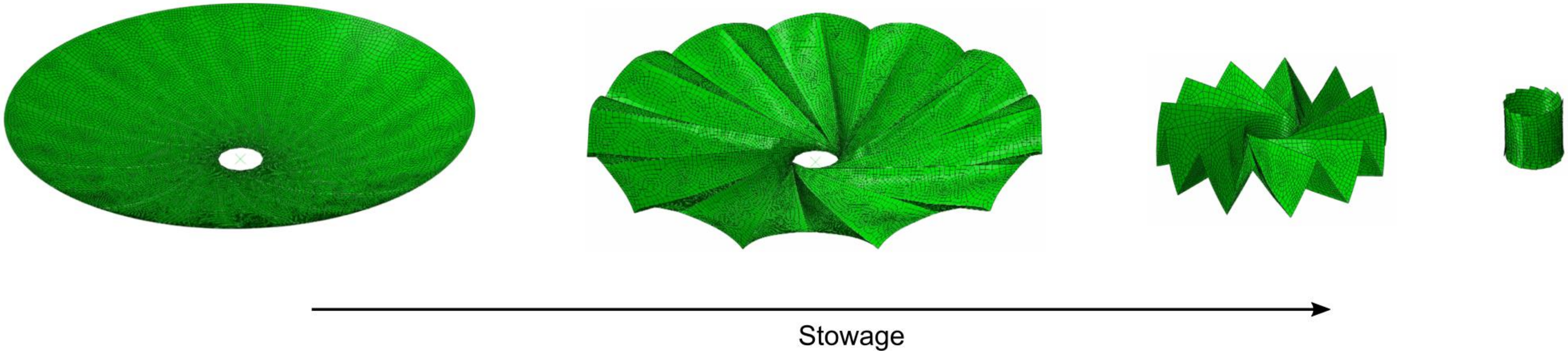


Deployed reflector

Stowed reflector

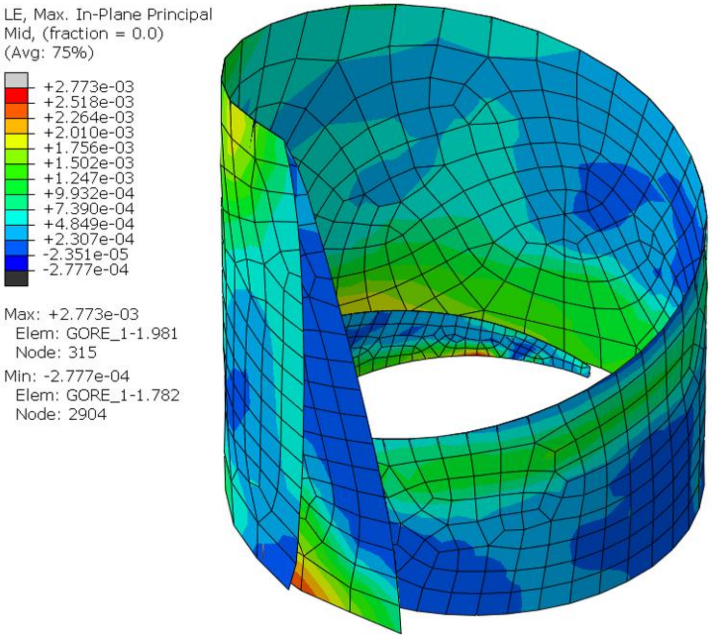
Results

- Demonstrated feasibility of stowage of a doubly-curved paraboloidal surface using Abaqus FEA



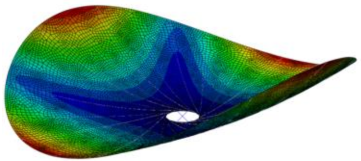
Results

- Demonstrated low-strain stowed state

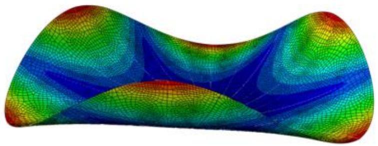


Results

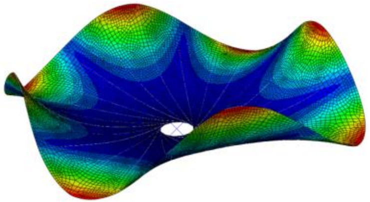
- High stiffness (0.75 Hz first fundamental frequency) of deployed reflector



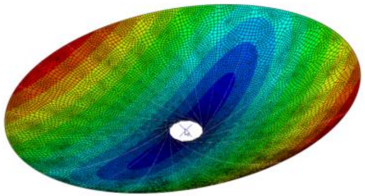
Modes 1 and 2
0.75 Hz



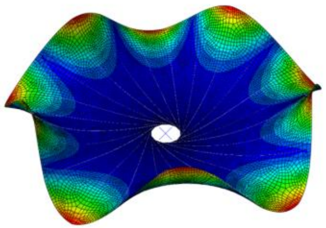
Modes 3 and 4
1.72 Hz



Modes 5 and 6
3.11 Hz



Modes 7 and 8
3.24 Hz



Modes 9 and 10
4.86 Hz

- <100 μm (lambda/30) surface deflection due to 100°C thermal soak
- <30 μm surface deflection due to diametrical 100°C gradient

Publications and References

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2. Zirbel, S. A., Lang, R. J., Thomson, M. W., Sigel, D. A., Walkemeyer, P. E., Trease, B. P., Magleby, S. P., and Howell, L. L., "Accommodating Thickness in Origami-Based Deployable Arrays," Journal of Mechanical Design, Vol. 135, No. 11, Oct. 2013, pp. 111005.
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4. Peral, E., S. Tanelli, S. Statham, S. Joshi, T. Imken, D. Price, J. Sauder, N. Chahat, A. Williams, "RainCube: the first ever radar measurements from a CubeSat in space," J. Appl. Rem. Sens., 13(3) 032504 (2019).