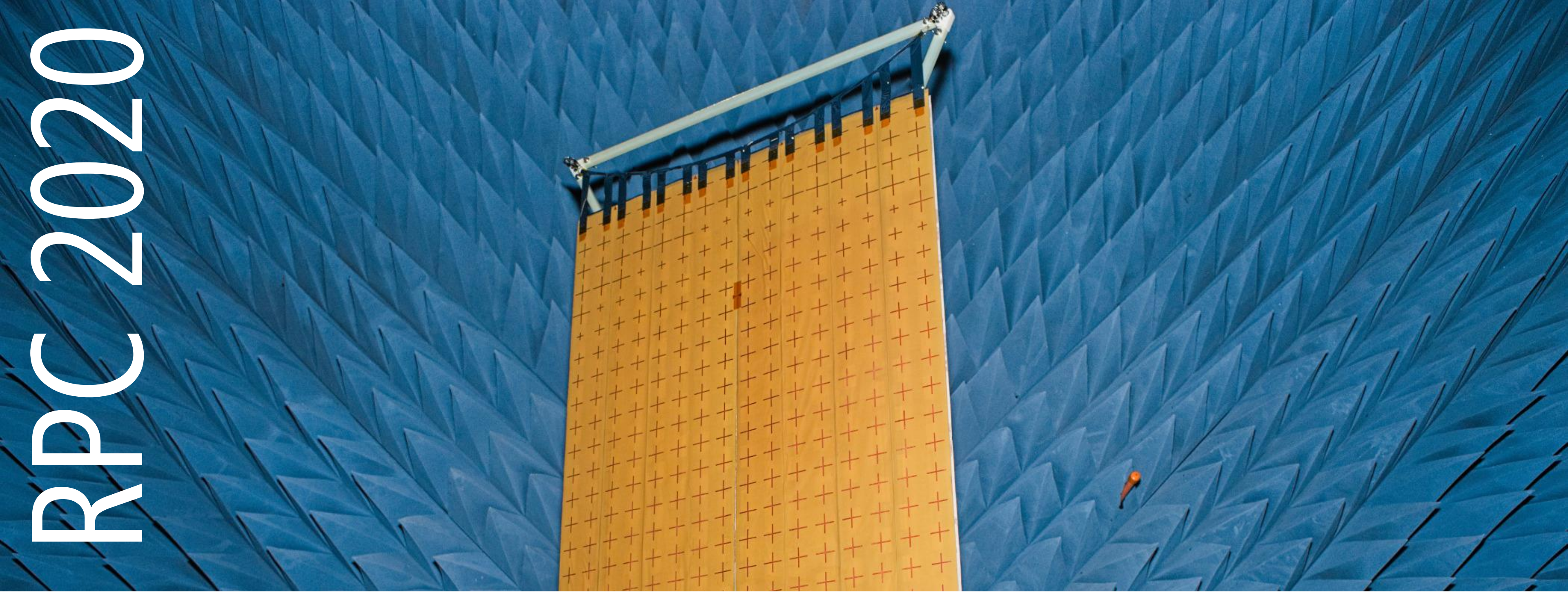

Virtual Research Presentation Conference

Ultra-Lightweight Deployable Composite RF Apertures

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Program: Topics

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Jet Propulsion Laboratory
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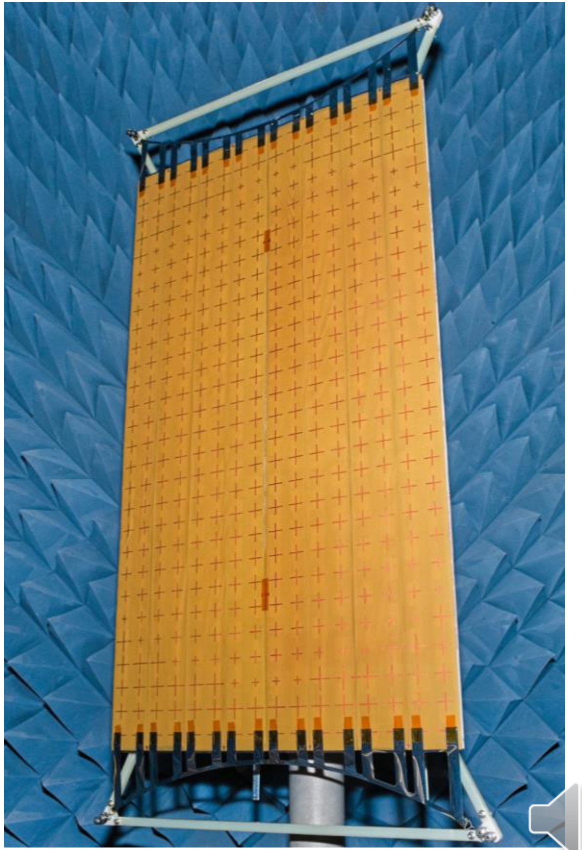
Introduction

Abstract

We have designed and tested an architecture for lightweight deployable radio frequency (RF) reflectors that can be stowed on and deployed from small satellites. These reflectors have about 1/5th the areal density of solid-panel reflectors (such as the ones flown on MarCO), are stiffer and more robust than tensioned membrane reflectors, and are more scalable and more easily fabricated than mesh reflectors (such as the one on the RainCube cubesat). We have targeted a specific form factor that has applications in measuring the deformation and change of the Earth's surface, which is a priority of the 2018 Earth Science Decadal Survey. We built a test article, demonstrated its functionality as an RF reflector and verified that it was ultra-lightweight. These types of reflectors are highly scalable, and their design can be adapted to a large range of aperture sizes and RF frequencies.



Problem Description

Objectives

- Design and test deployable planar radio frequency (RF) reflectarray apertures for small satellites that are ultra-lightweight (<0.8 kg/m^2), highly compactible, structurally stiff, mechanically robust, precise, scalable
- Targeting 1 m x 5 m aperture for an Earth-observing SAR antenna at S band (3.2 GHz)

Comparison with the state of the art

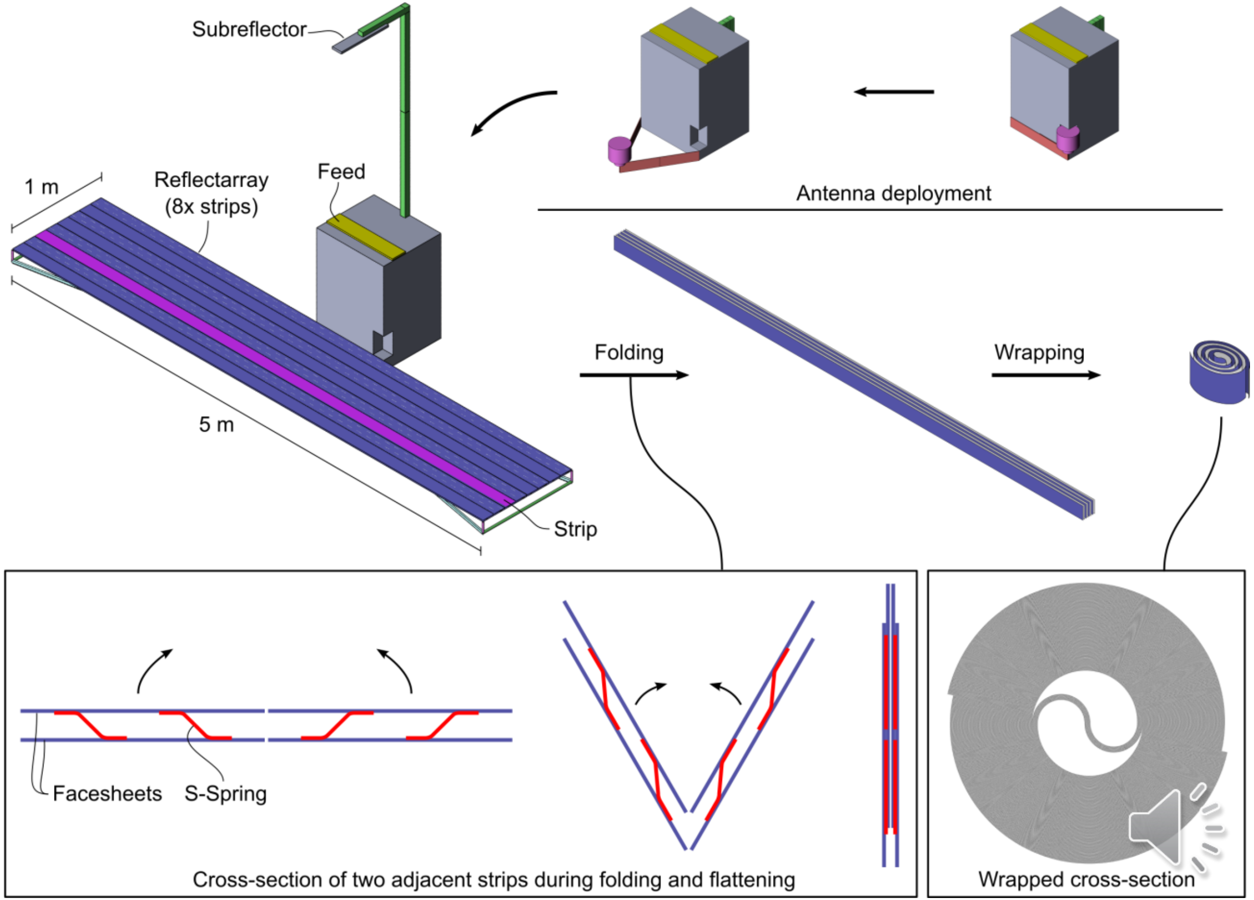
- Lower mass, lower areal density than solid-panel apertures (e.g. MarCO HGA)
- Higher mechanical stiffness, more robust, higher stability than tensioned membranes
  - Fiber-reinforced composite reflectarray structure creates stiffness, stability
- Higher scalability, fewer snag hazards, lower touch labor than mesh reflectors (e.g. RainCube)

Benefits to JPL

- Responsive to 2018 Earth Science Decadal Survey Surface Deformation and Change (SDC) targeted observable
- Enables novel small satellite missions: remote sensing at L, S, and C bands

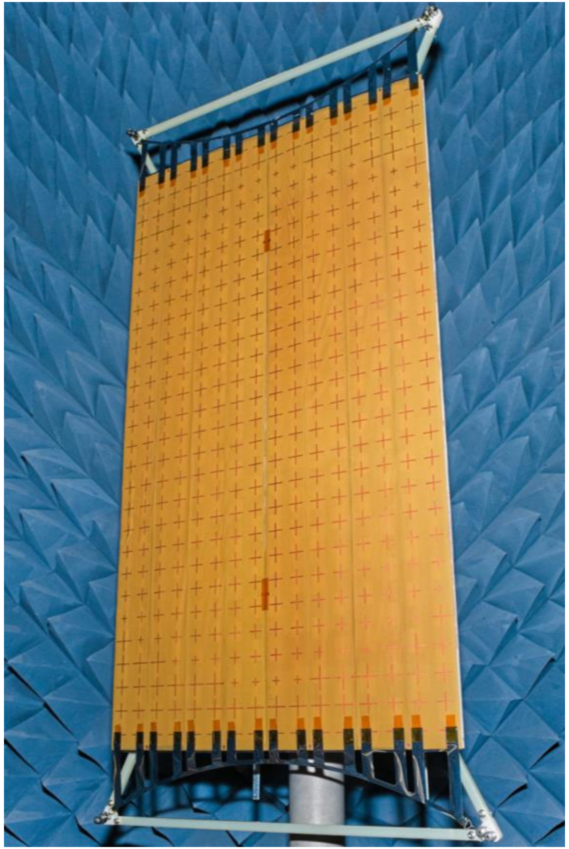
Methodology

- Antenna concept on a standard ESPA-class bus
- Reflectarray consists of 8 composite strips
  - Strip cross-section: 2x facesheets separated by S-springs
  - Top facesheet supports reflectarray element plane
  - Bottom facesheet supports ground plane
  - 12.7 mm separation between facesheets
  - Strips can be simultaneously flattened and folded, and then wrapped into a compact cylindrical form
- Showing antenna in a Cassegrain arrangement with deployable subreflector, but the reflectarray design is agnostic of the exact RF-optical architecture.



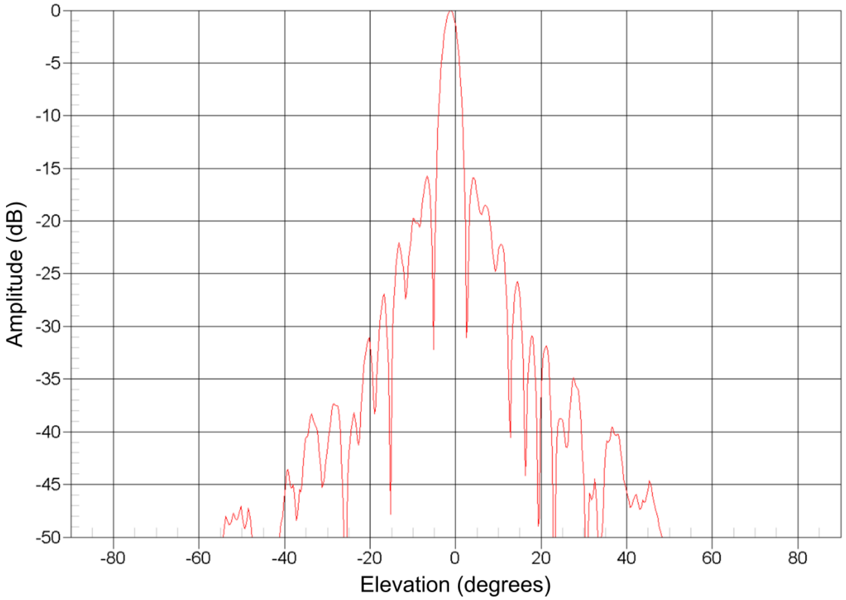
Methodology

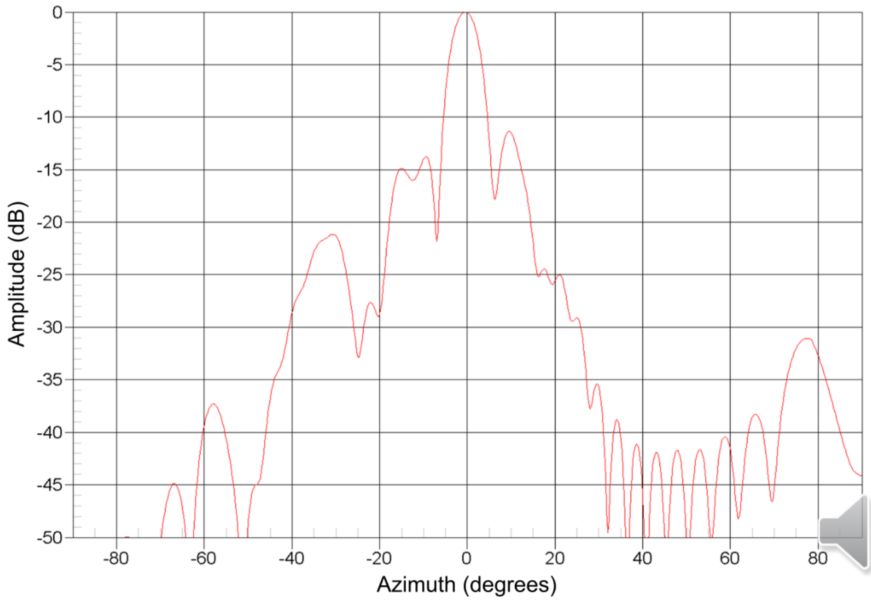
- Constructed a 1 m x 1.67 m test article to demonstrate structural architecture, RF performance
  - 1 m-width is full-scale
  - Truncated center third of 5 m design for 1.67 m length
- Strips made of ultrathin quartz-epoxy material
  - Facesheets and S-springs: [90/0/90] laminate of 3 unidirectional spread-tow plies of Quartzel fiber in TP402 epoxy matrix
  - Single-ply areal density: 52 g/m^2, thickness: 40 um
- Etched copper-on-polyimide film adhered to composite strips for reflectarray surface and ground plane
  - Pyralux (9 um-thick copper on 25 um-thick polyimide) material used
- Non-deployable backing structure applies 10 N tensioning forces at the four corners
  - Thin-film parabolas redirect this tension into 1.1 N vertical tension in each strip



Results

- Measured good antenna RF performance
- Azimuth and elevation cuts through far-field antenna pattern at 3.2 GHz show good beamwidths:



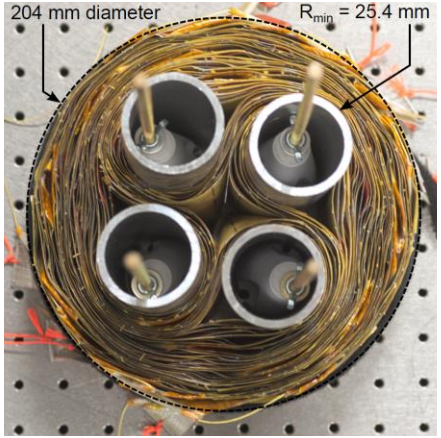


Results

- Measured mass of reflectarray test article (excluding non-deployable backing frame): 1207 g
- Corresponds to reflector areal density of 767 g/m^2, meeting our goal of <800 g/m^2

Results

- Fabrication errors resulted in test article that cannot be fully packaged
- Due to schedule concerns, test article used defective strips that had epoxy "beads" in the sharp corners between the S-springs and facesheets; these defective strips can be flattened but not coiled
- However, we corrected the fabrication error and demonstrated fabrication of flattenable and coilable strips after the test article was assembled
- Have already demonstrated successful stowage of a similar reflector in previous work [3], so low risk of fundamental problems with stowage scheme



Coiled quartz/epoxy 1.5 m x 1.5 m reflectarray from [3]

Next Steps

- Study stiffness and thermo-elastic response of full-scale reflector using finite element modeling
  - Validate model using coupon-level testing on small sections of strips
- Construct improved test article and measure RF performance before and after stow-and-deploy cycles
- Advance the design for deployment and launch restraint mechanisms for reflectarray surface

Publications and References

1. J. M. Fernandez, “Advanced Deployable Shell-Based Composite Booms For Small Satellite Structural Applications Including Solar Sails,” in *Proceedings of the International Symposium on Solar Sailing 2017*, 2017.

2. National Academies of Sciences, Engineering, and Medicine 2018. Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space. Washington, DC: The National Academies Press.

3. M. Arya, J. F. Sauder, R. Hodges, and S. Pellegrino, “Large-Area Deployable Reflectarray Antenna for CubeSats,” presented at the AIAA Scitech 2019 Forum, San Diego, California, Jan. 2019, doi: 10.2514/6.2019-2257.