National Aeronautics and Space Administration

High Precision Thermally Stable Flexures for Large Deployable Antennas in SmallSats

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Objectives:

This project explores replacing traditional spring-loaded mechanical hinges in a deployable space structure with high strain composites [1] (HSCs). Eliminating metal hinges, Fig 1 improves the thermal stability of the space structure while reducing the parasitic weight and the part count of hinges. We are assessing the performance of the selected architecture to be used for future space missions. The group at CU Boulder and Stanford University is quite familiar with high curvature bending and failure of composites.

Background:

HSCs for deployable space structures help reduce the weight while making the deployment mechanisms simpler. The thin-walled composites are made into different geometries such as Tubular, TRAC or DLR[2] and can bend with large deformations and strains. Previous work using HSC mainly focus on relatively large structures (500mm-2000mm) with less focus on deployment accuracy. We aim to scale down the flexure dimensions to CubeSat level (100mm – 300mm) while achieving precise deployments. We take One Meter Reflectarray Antenna (OMERA) [3] technology demonstration as a case study and attempt to replace the mechanical hinges with a suitable HSC flexure. This will benefit the reflectarray antenna with a higher thermal stability.

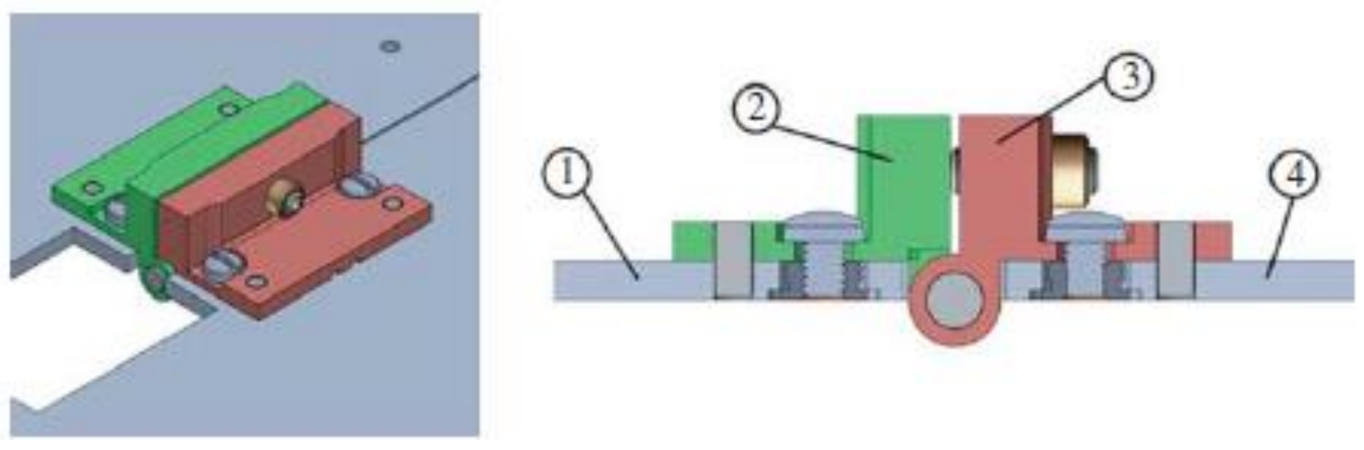

Figure 1. Mechanical hinges with torque springs.

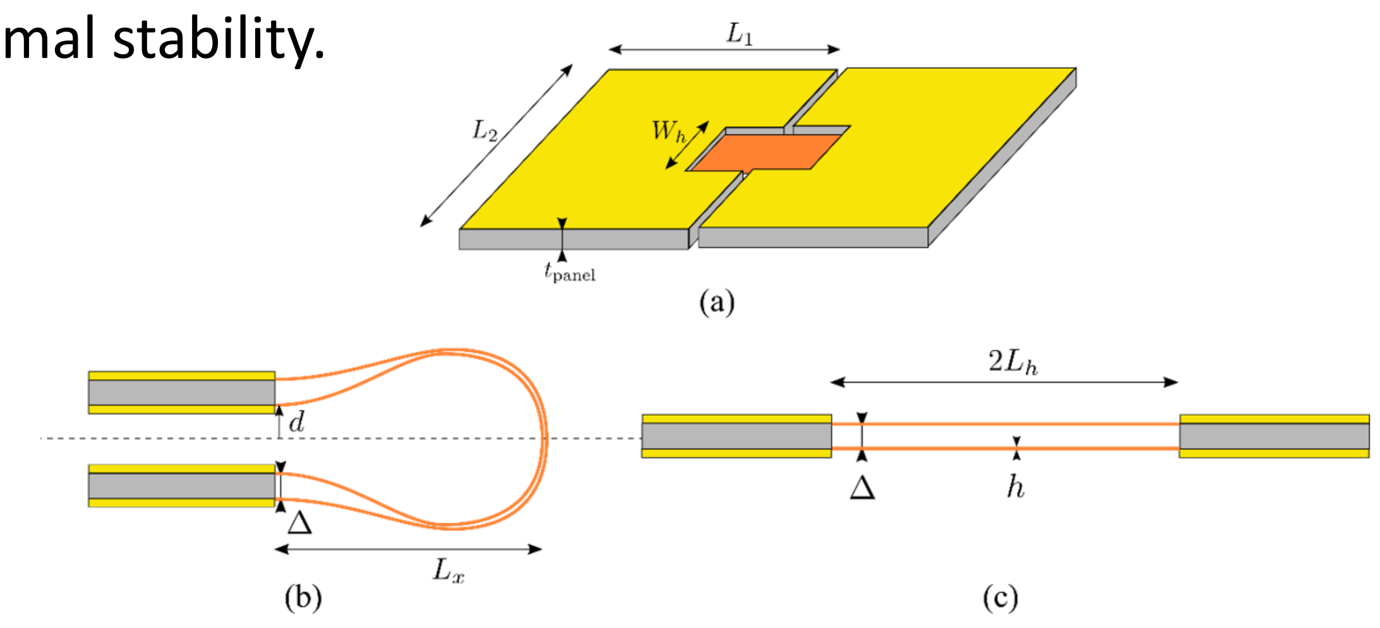

Figure 2. Proposed hinge architecture (a) isometric view with the dimensions (b) hinge when folded and (c) deployed.

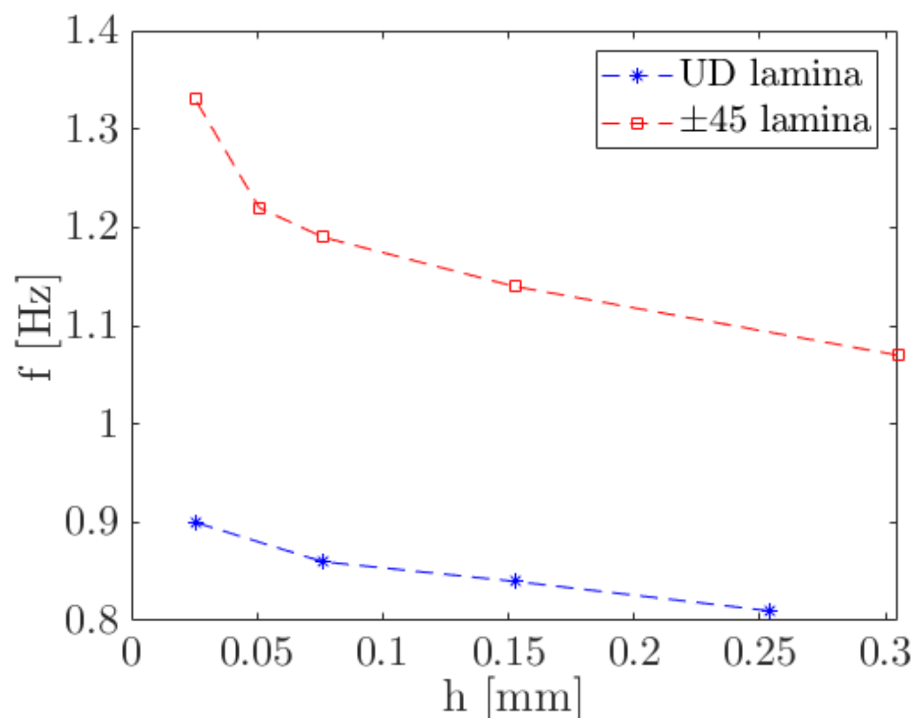

Figure 3. Dependence of natural frequency on the flexure thickness subjected to same maximum strain.

Approach and Results:

The technical requirements were analyzed and came up with a novel flexure architecture. The flexure consists of two flat HSC coupons that can elastically bend when the panel is folded, Fig 2. Having two flexures provides the added bending stiffness in the deployed configuration. Using Euler's Elastica[4], we derived relationships that predict the flexure strain as a function of the geometry (i.e., coupon thickness, core thickness and hinge length). For a given failure strain of the HSC coupons, the length can be approximately halved if the fibers are laid at ±45 as opposed to fibers along the direction of the flexure. However, the stiffness also lowers to one fourth making the natural frequency almost the same over two configurations. Our studies show that there is a slight benefit for the stiffness when the HSC flexures get thinner, Fig 3. We devised a vibration experiment with a shaker table to measure the natural frequencies of the flexure, Fig 4. Our preliminary analysis indicates that the characteristics curve can predict the first two natural frequencies between 4Hz – 20Hz. First prototype was fabricated as a proof of concept, Fig 5, using T300/Ex1515 1k PW 125 GSM with a 10mm thick Al honeycomb core. We fabricated two prototypes with fibers oriented at 0/90 and ±45 where fiber strains were limited at 1%. We carried out a DIC strain measurement on this flexure which confirmed the strain limits [5].

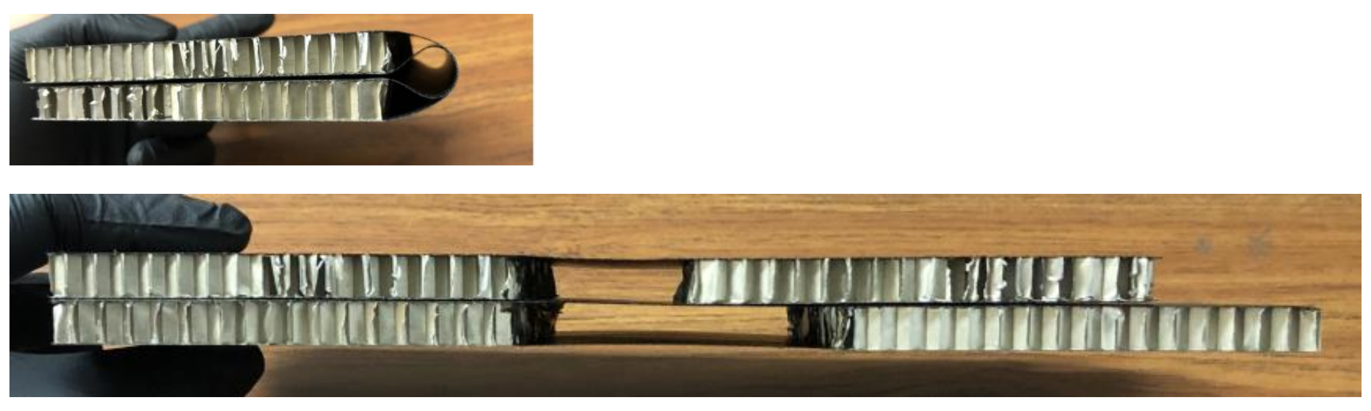

Figure 5. Proof of concept of flexure fabrication.

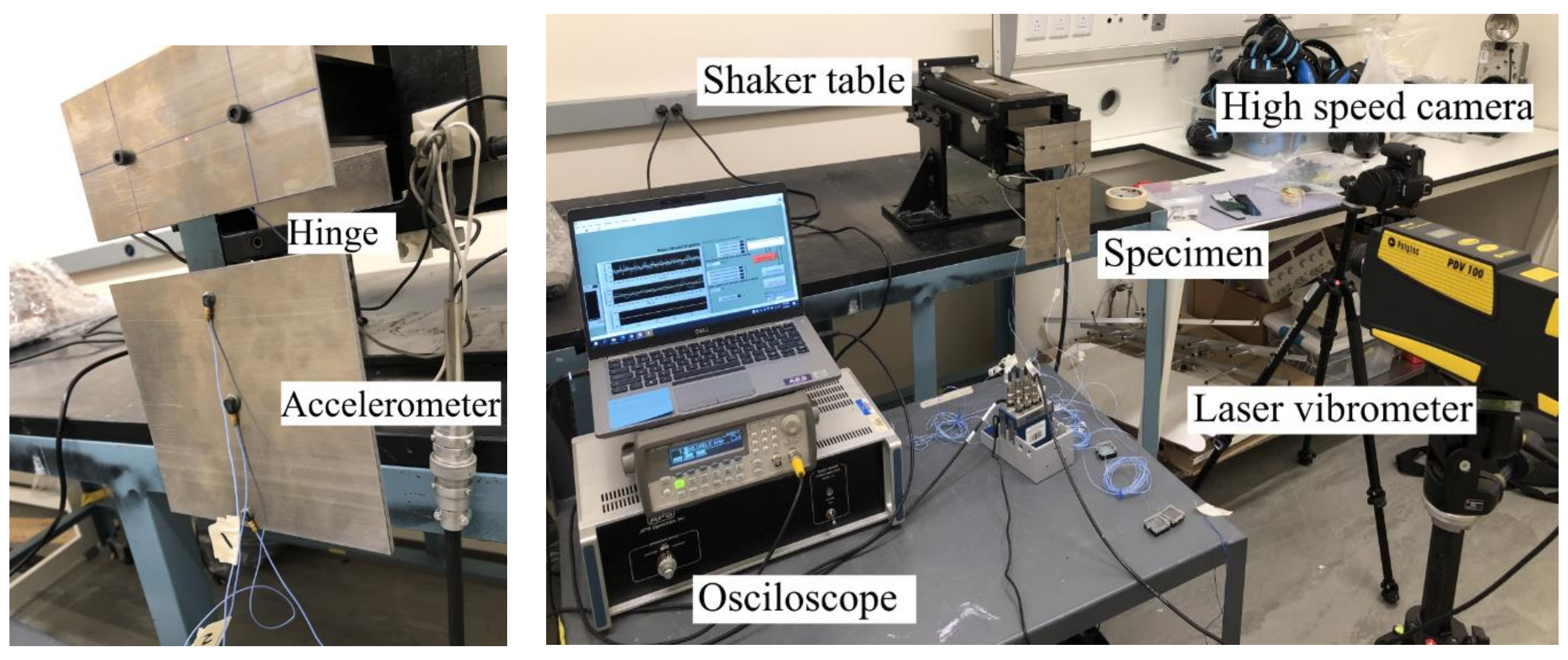

Figure 4. Vibration shaker table experiment setup.

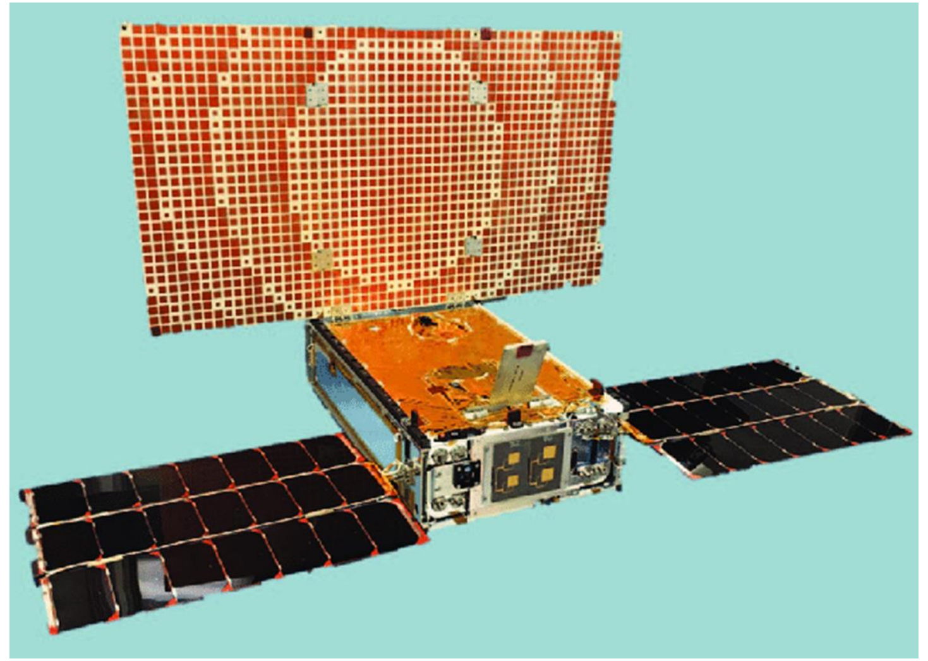

Figure 6. Mars Cube One (MarCO) reffectarray.

Significance/Benefits to JPL and NASA:

Innovations include: (1) unique designs to reduce stress concentrations and improve thermal/mechanical stability, and (2) reduced part count when compared to the torsion spring powered hinges used on the current MarCO (Fig 6) and OMERA antennas. It would also enable antennas like LADeR to self-deploy, eliminating the need for a deployment mechanism. This would further reduce stowed volume and design complexity. The process of developing these flexures will not only to build a useful technology for future JPL SmallSat missions, but will also involve core research on failure, creep, and viscoelasticity of high strain composites.

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Publications:

[1] Murphey, T. W., Francis, W., Davis, B., and Mejia-Ariza, J. M., "High strain composites," 2nd AIAA spacecraft structures conference, 2015, p. 0942.
[2] Roybal, F., Banik, J., & Murphey, T. (2007). Development of an elastically deployable boom for tensioned planar structures. In 48th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (p. 1838).
[3] Sauder, J. F., Arya, M., Chahat, N., Thiel, E., Dunphy, S., Shi, M., Cwik, T. (2019). Deployment mechanisms for high packing efficiency one-meter reflectarray antenna (OMERA). In AIAA Scitech 2019 Forum (p. 0755).
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[5] Dharmadasa, B. Y., Mejia-Ariza, J. M., Arya, M., Sauder, J. F., Focardi, P., Bradford, S. C., & Lopez Jimenez, F. (2022). Design of Flexures for Deployable Reflectarrays using High Strain Composites. In *AIAA SCITECH 2022* Forum (p. 0651).