Origami-based Composite Space Structures

Rebecca Hall

Jin Ho Kang, Keith L Gordon, Sheila Thibeault, and Jeff Hinkley

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Personal Introduction

- ❖Rebecca Hall
- ❖Grew up in Houston, TX
- ❖UCF Mechanical Engineering Student
- ❖Work with Langley Research Center in the Advanced Materials and Processing Branch
- ❖Active member of Students for the Exploration and Development of Space
- ❖Interested in the development of payloads and habitable structures in space as a long-term career

Challenge

❖ Mars and Moon missions need deployable structure for surface habitats and payload transferring systems

❖ Existing approaches have limitations

- Thin-walled tubular composite booms cannot support large loads
- Inflatables need continuous gas supplement
- Gas and cutting mechanisms can fail

❖ Challenge is to create robust, foldable structure

Objective

❖ Proof of concept of new technology for load-bearing space structures

- Compact for stowage and launch
- Reliably deployed in space
- Rigidizes to maintain structural integrity

Approach

❖Use origami, composite materials, UV curing resins, and shape memory polymers.

❖Project phases:

- Literature survey
- Conceptual design
- Materials selection and proposed manufacturing method
- Substructure element tests
- Design refinement

❖Ultimate product: detailed research proposal.

History of Deployable Structures

- ❖There has been a major gap in the development of deployable space structures
- ❖In the 60s there were early demonstrations like the ECHO Satellite, but little development since
- ❖Most rely on inflatable deployment
- ❖Only major tests in space have been BEAM and the Russian Volga Airlock on Vokshod 2

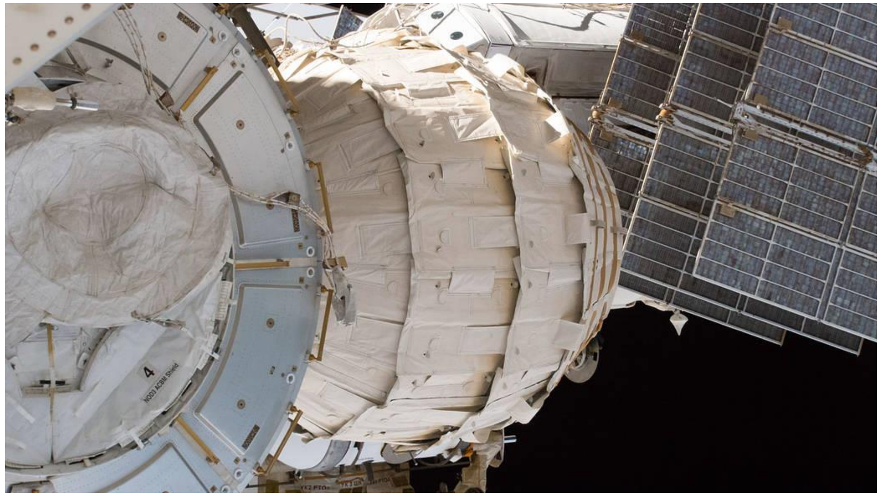

Image credit: NASA

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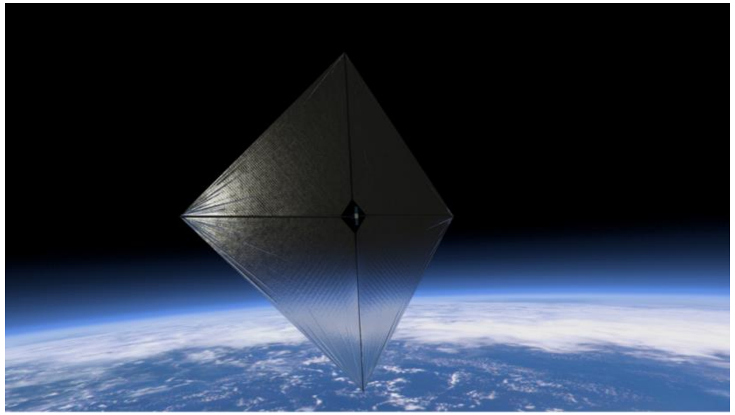
History of Deployable Structures

- Solar Sails
  - IKAROS JAXA Solar Sail launched in 2010
  - ACS3 Advanced Composite Solar Sail System developed by Langley



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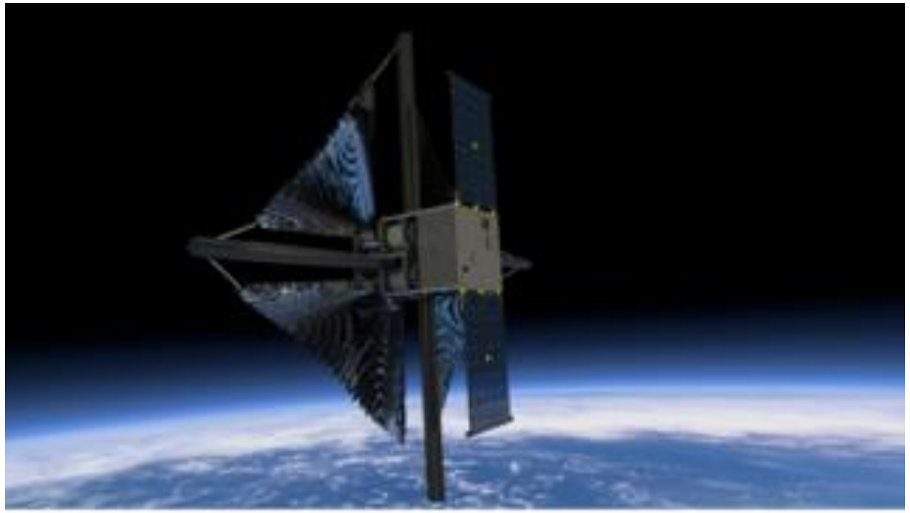

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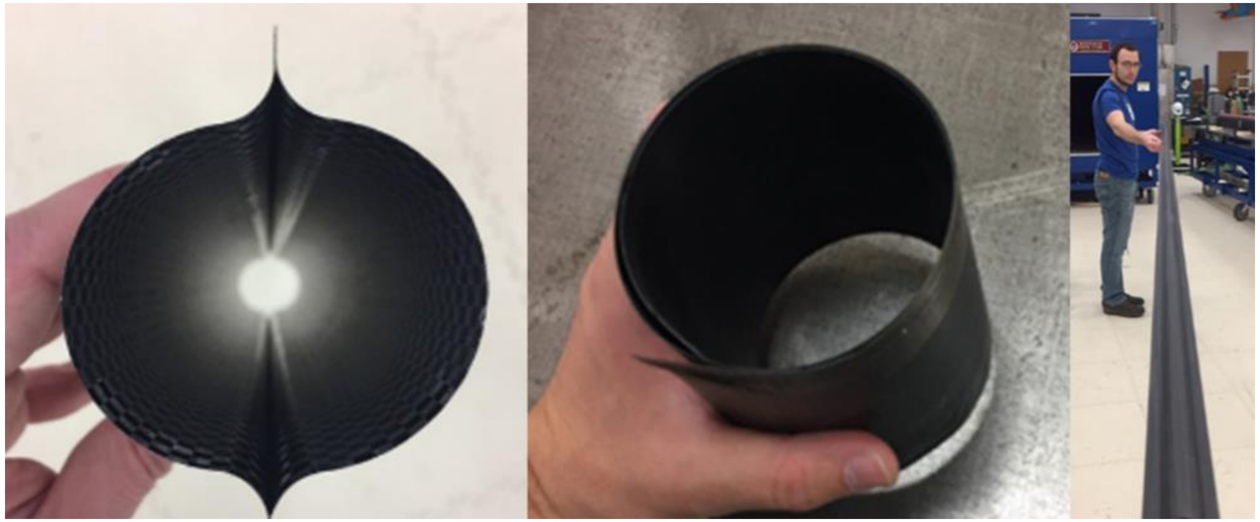
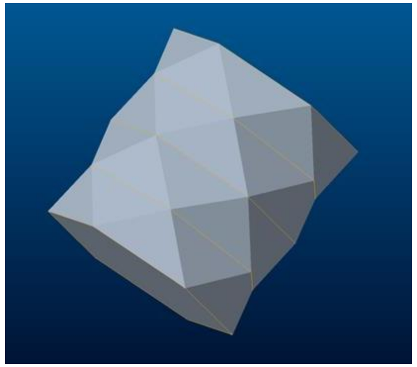


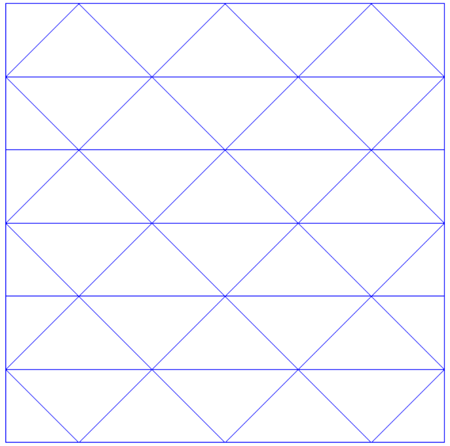
Image credit: NASA

Structural Choice

- Origami inspiration
  - Yoshimura structure
- Hinge development
  - Membrane hinges
- Taking into account thickness
- Other considerations
  - Miaru Ori fold
  - Shape morphing architected sheets
  - Microlattices and compliant arrays

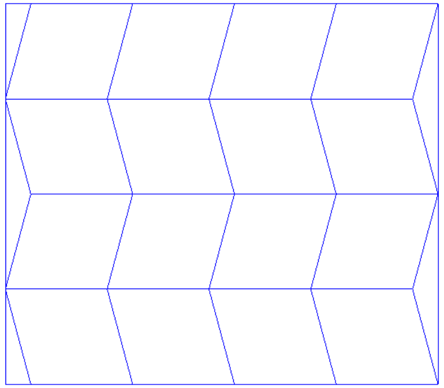


Yoshimura Structure



Yoshimura Flat Layout

Miura Ori Structure



Miura Ori Flat Layout

Image credit: NASA

Materials Selection

- ❖UV Curing Resins
- ❖Shape Memory Polymers
- ❖Other Considerations
  - ❖CHEM foam
  - ❖Thermally Cured Thermoset Composites
  - ❖Aluminum and Film Laminates
  - ❖Second Order Transition Change Composites
  - ❖Foam Rigidization

Materials Selection

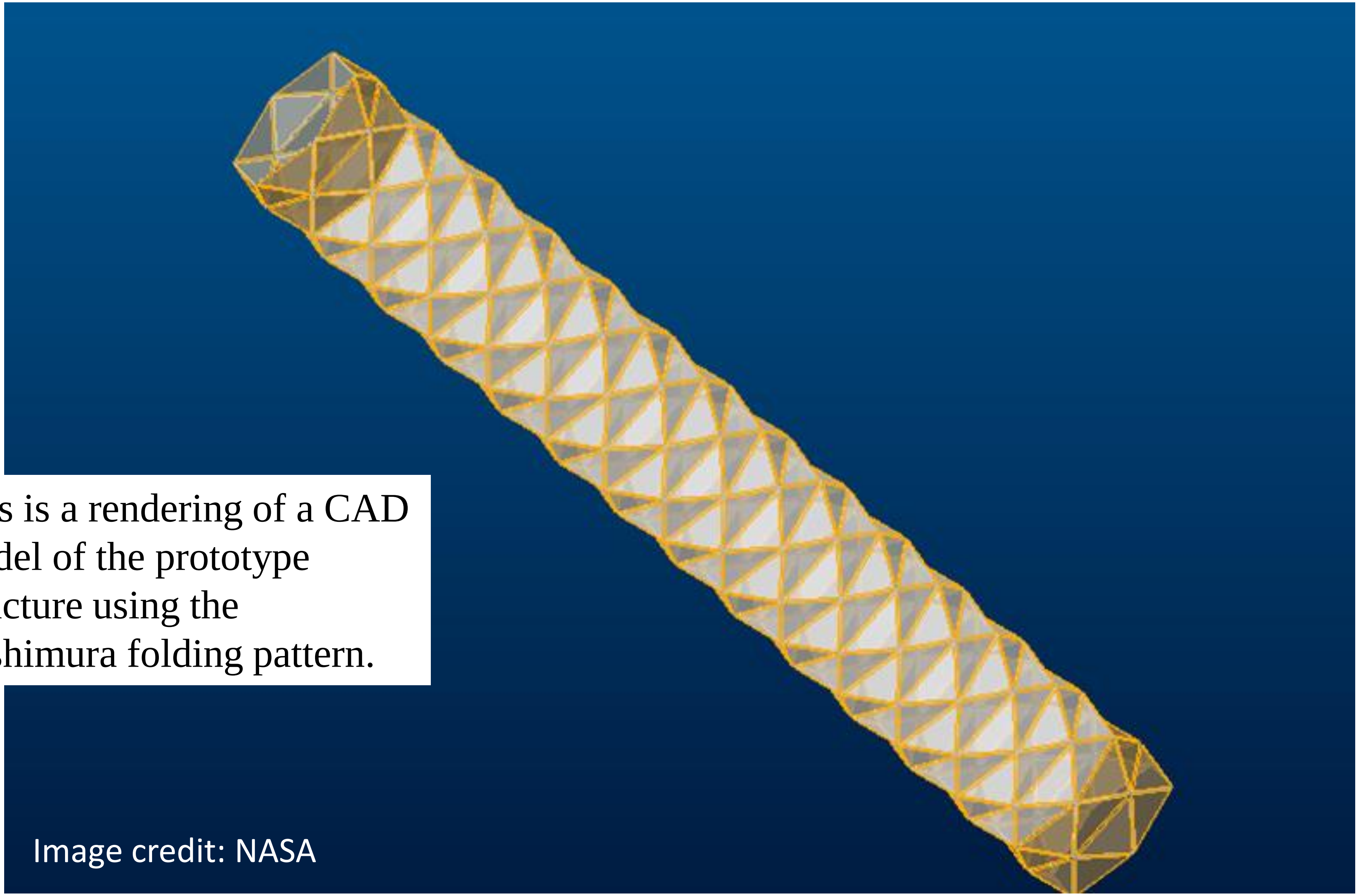
UV Curing Resin and Additive Candidates

Material	Supplier	• Properties
ATI-ROC-P600-2	Adherent Tech	• Can cure at low temperatures • Can polymerize at 10°C • Low outgassing • Can be cured with only sunlight • Rigid On Command system already tested in isogrid booms
EPV 3408CO	Polymer-G	• One component low viscosity • 100% reactive liquid that can be cured by exposure to UV lamp at 395nm wavelengths • High stability in outdoor environment • High temperature and hydrolytic stability.
SpeedCure 2-ITX	Sartomer	• 2-Isopropylthioxanthone • Absorption maxima at 259 and 383nm • Specialized for composite and depth curing • Several other options

Results

- Our current results from the literature survey stage
  - Structure
    - Yoshimura Hexagon based tube structure
  - Materials
    - UV curing polymer, film, glass fiber composite
  - Potential Manufacturing methods
    - Mandrel or flat projection
  - Potential Testing Methods
    - Resin curing determination, materials coupon testing, load bearing tests

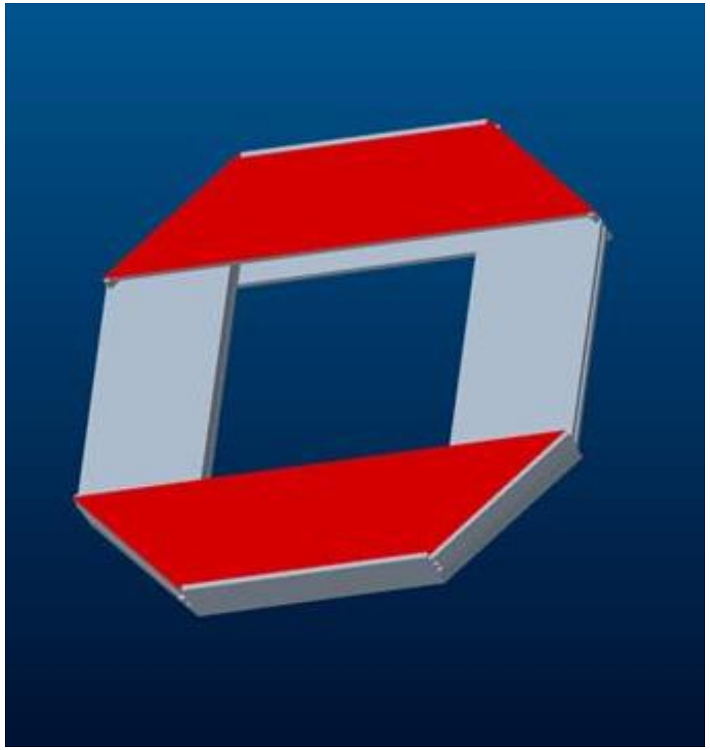
Prototype Model for Proof of Concept and Testing

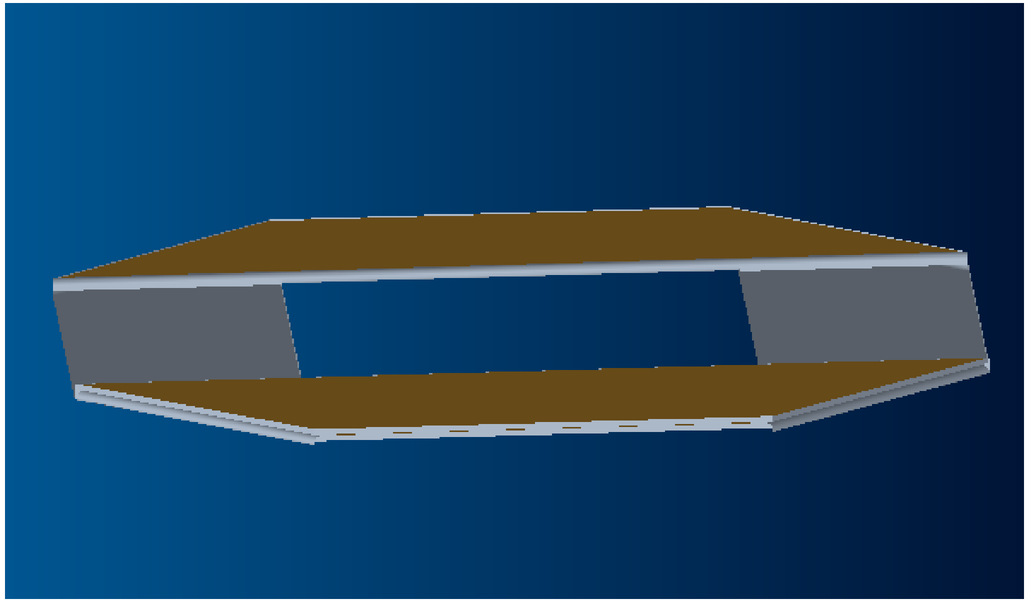


This is a rendering of a CAD model of the prototype structure using the Yoshimura folding pattern.

Image credit: NASA

Compacted Position of Structure

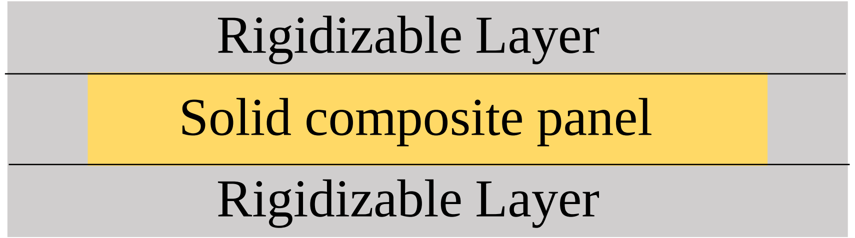




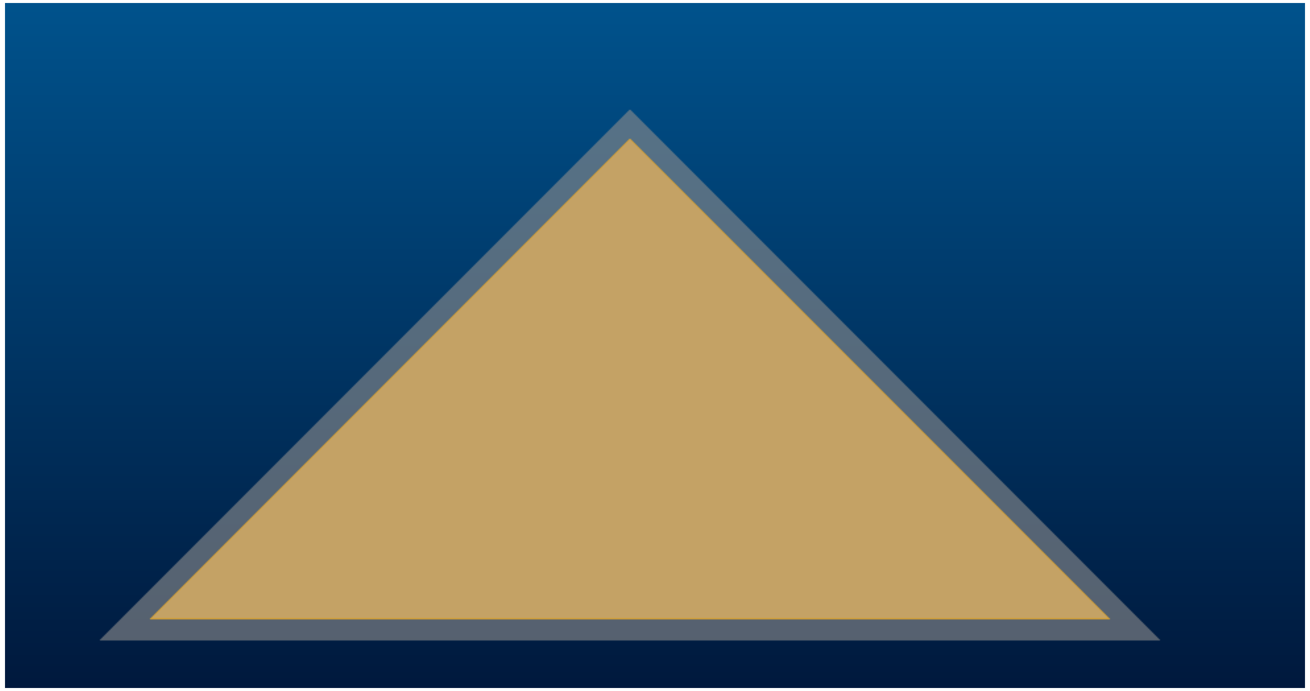
A rendering of a CAD model of the compact variation of the structure for pre-deployment stowage.

Image credit: NASA

Individual Composite Layered Unit Cell Panel



A cross section of the unit cell



A rendering of a CAD model of a single triangular unit cell of the composite panels.

Image credit: NASA

Prototype Deployment Geometry Demonstration

Image credit: NASA

Analysis/Summary

- ❖We have determined that there is a gap in the technology and we have the potential to develop a new deployment option in the burgeoning field of deployable space structures as NASA aims to develop LEO habitable stations, return to the Moon, and head to Mars
- ❖To fill this gap, we have decided to design a composite deployable Yoshimasa structure that uses UV curing or shape memory polymer resins in membrane hinges to rigidize

Next Steps/Outlook/Future Work

- ❖The next stage is to determine manufacturing method and do testing on the prototype and materials.
- ❖Long term, the goal is to scale up the design, testing, and increase the TRL of rigidizable deployable space structure using UV curing resins or shape memory polymers.
- ❖The end goal would be to see this technology used in Lunar and Martian missions, especially in regard to infrastructure development.

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