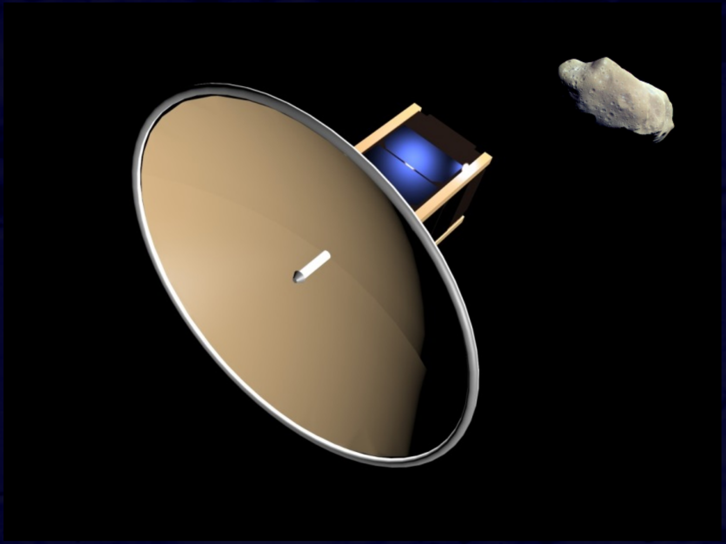
CubeSat Based Inflatable Antennas and Structures for Interplanetary Communication and Tracking



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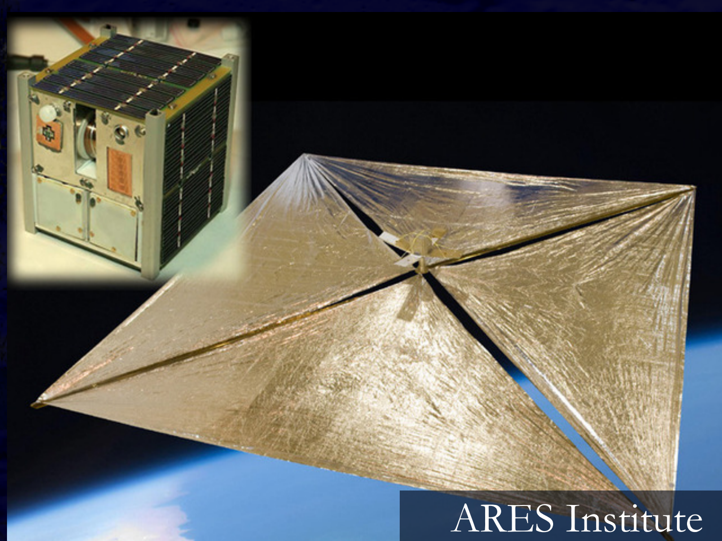
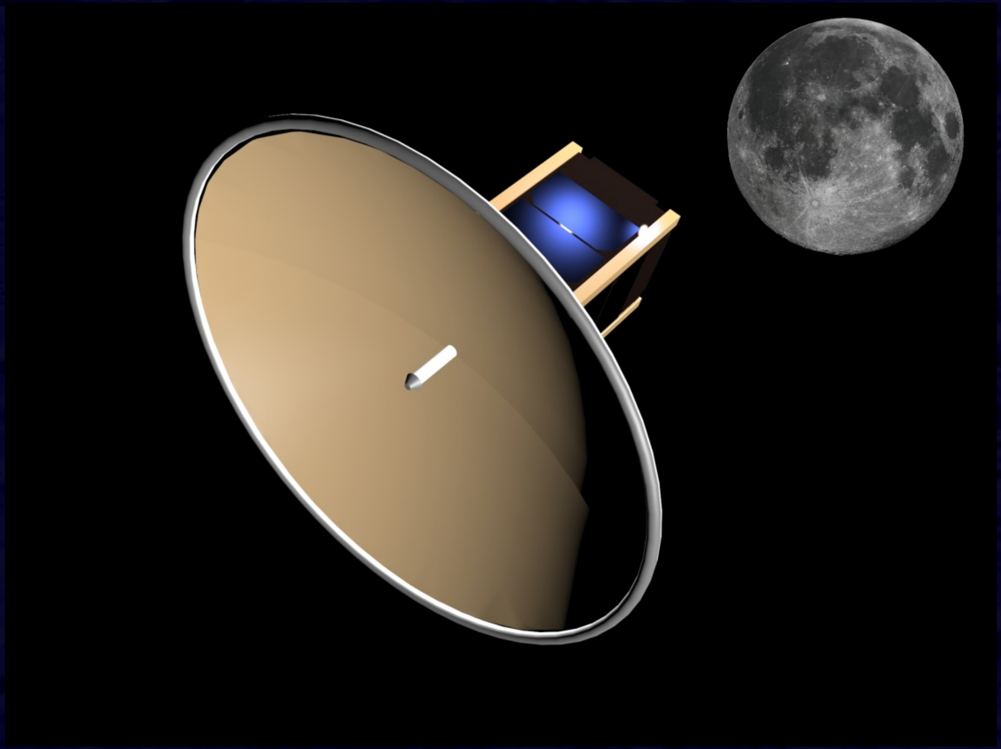
Interplanetary Cubesats



Case Study

- Parabolic antenna (f/d = 0.5)
- Data rate = 128 Kbps
- Frequency = 2.45 Ghz [S-band]
- Lunar Orbit



Deployment Comparison

Parameter	**Non-deployable Antenna**	**Deployed Antenna**
Distance	384,300 km [Moon]	384,300 km [Moon]
Data Rate	128 Kbps	128 Kbps
Frequency	2.45 Ghz [S-band]	2.45 Ghz [S-band]
Ground Station Antenna Diameter	2 m	2 m
Spacecraft Antenna Diameter	0.09 m	2 m
Data Link Margin	**4.27 dB**	**17.9 dB**
Spacecraft Power for Communications	**50~ W**	**2.5 W**

Motivation

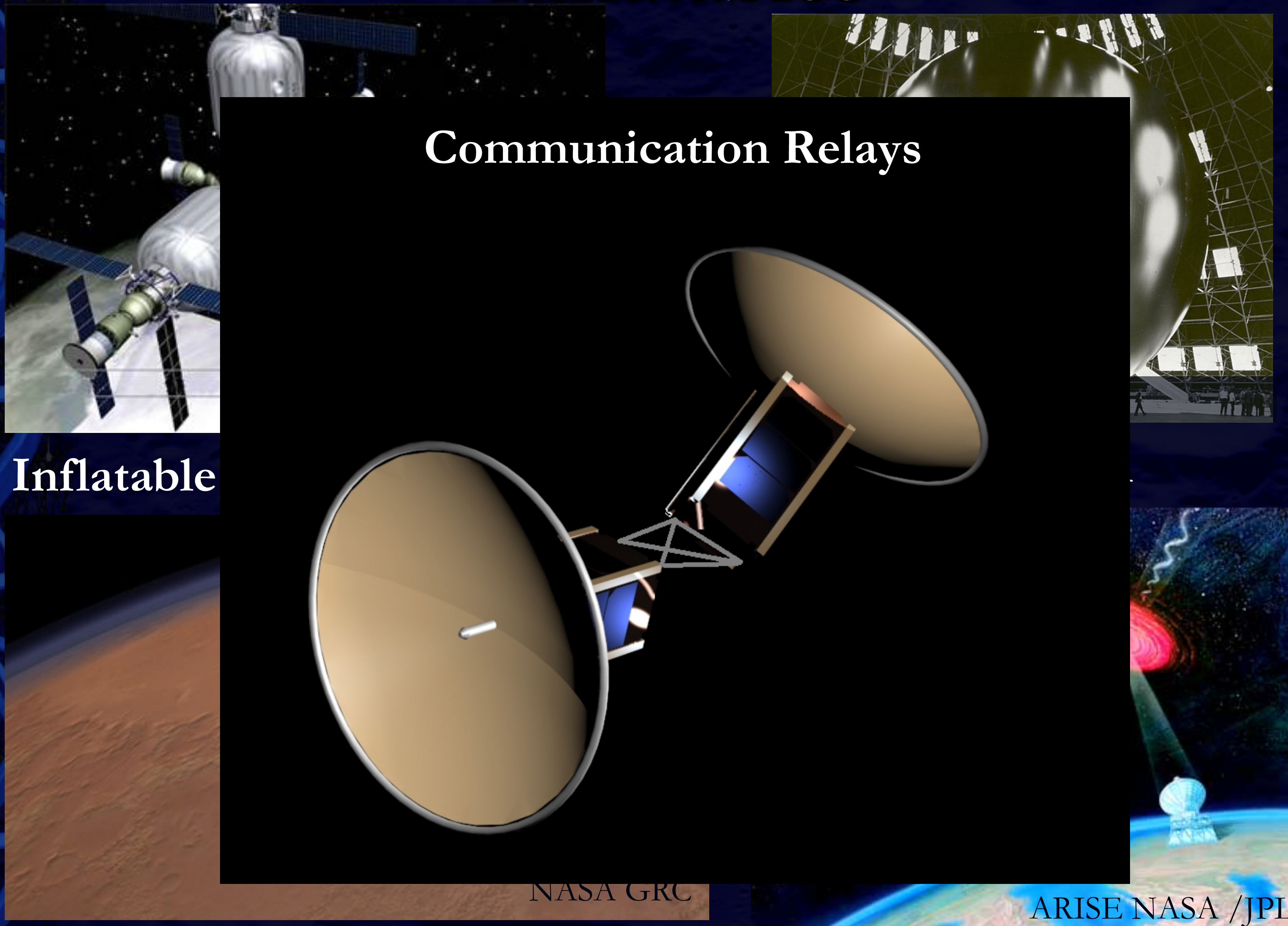
- Inflatable offer a promising technology pathway for interplanetary CubeSat communication and tracking.
  - Very high deployed volume
  - Very low mass
  - High-packing efficiency
  - Quick deployment
  - Relative simplicity

Objectives

Research inflatable technology that maximizes stowed-to-deployed ratio of interplanetary communication antennas and long-distance tracking devices.

- Understand the limits
- Develop validated physical models
- Determine design principles
- Develop open-source rigidizable inflatable design and optimization tools for system engineers.

Inflatables



Inflatable

Hypersonic Decelerator

Radio Telescopes

Related Work

Inflatable Antenna Experiment (1996) [NASA/JPL/LGarde]

[Steiner, Freeland, Veal, 1996]

First large-scale inflatable antenna

14 m diameter, canopy and torus

mylar/kevlar structure, mass: 60 kg

Nitrogen gas for inflation


NASA/JPL/LGarde

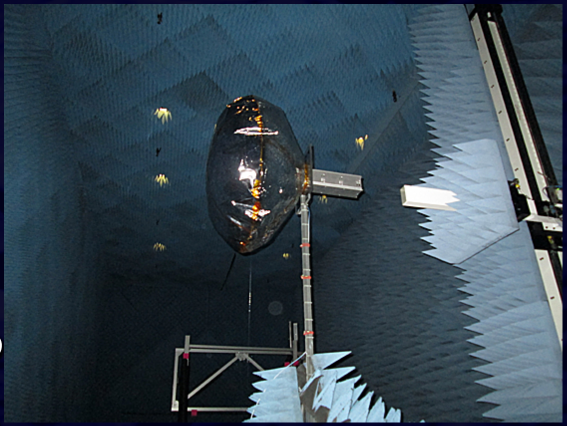
Inflatable antenna for Cubesats

[Babuscia et al., 2013]

First proposed design for cubesat

Sublimating powder maintains inflatio

Target Capability: 100 kbps from GEO


[Babuscia et al., 2013]

Related Work

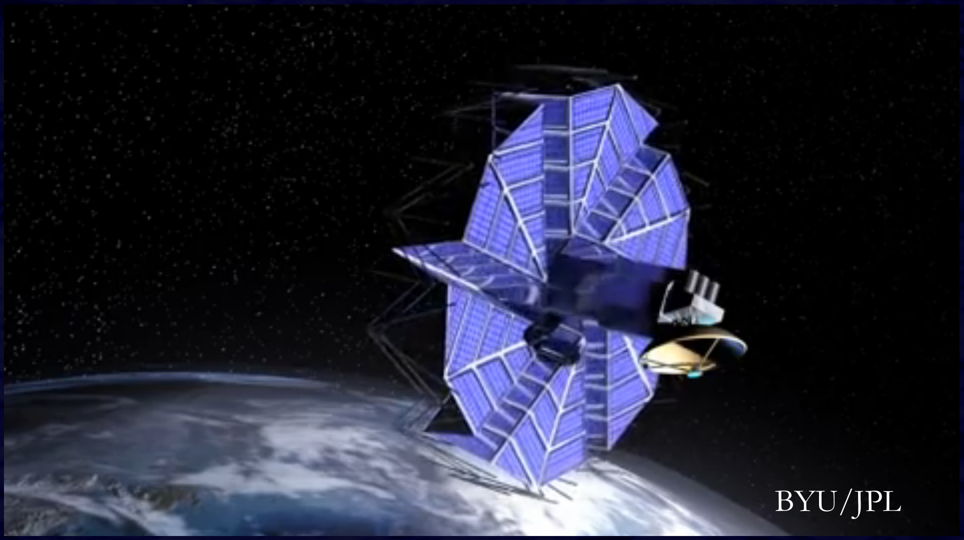
Origami Structures for Space [BYU & JPL, 2013]

[Zirbel et al., 2013]

Rigid structures that can unfold using origami techniques

Solar Panel Deployment

Can these techniques be applied for inflatables ?



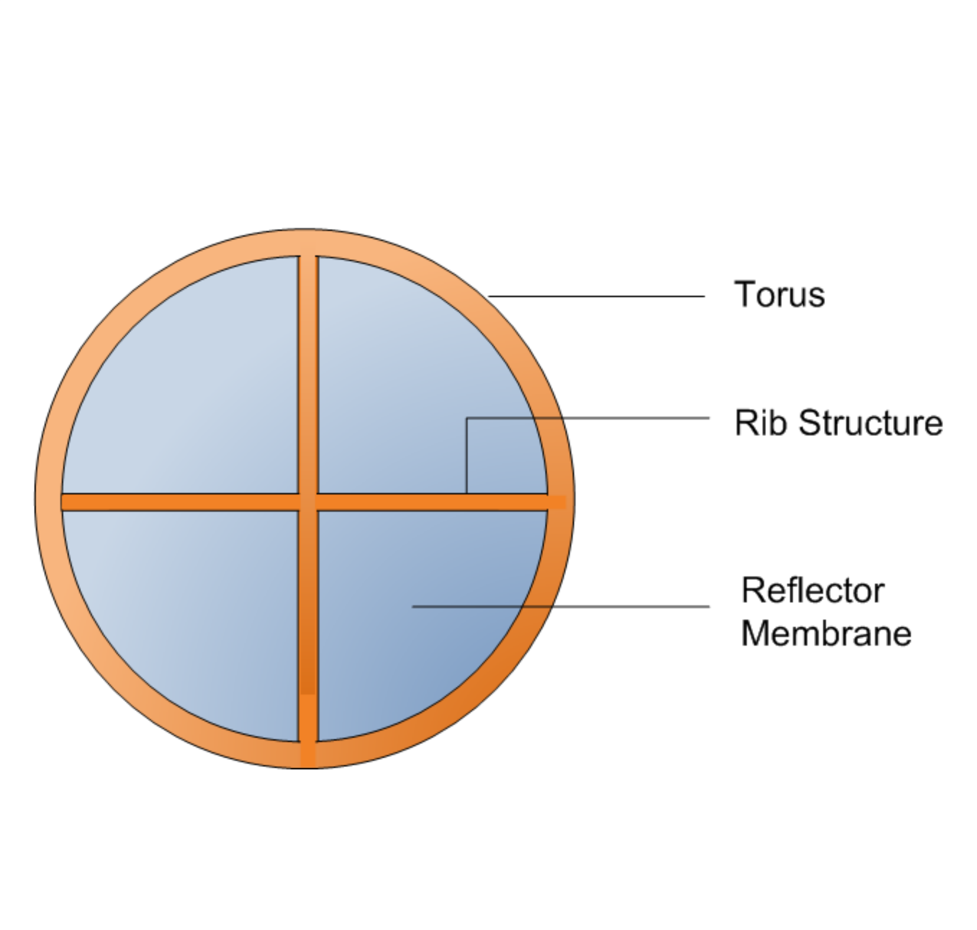
Challenges

- Micro-meteorites
  - Rigidization [Cadogan and Scarborough, 2001]
    - UV, Stretched Aluminum, Passive Cooling
  - Sublimating Powder [Babuscia et al., 2013]
- Fabric Strength [Freeland et el., 1997], [Cadogan and Scarborough, 2001]
  - Laminates, Thermosetting Materials, Vectran
- Packing density and Deployment
  - Simple folding techniques, origami structures for space [Zirbel et al., 2013]
  - Repeatability and Reliability

Inflatable Advantage

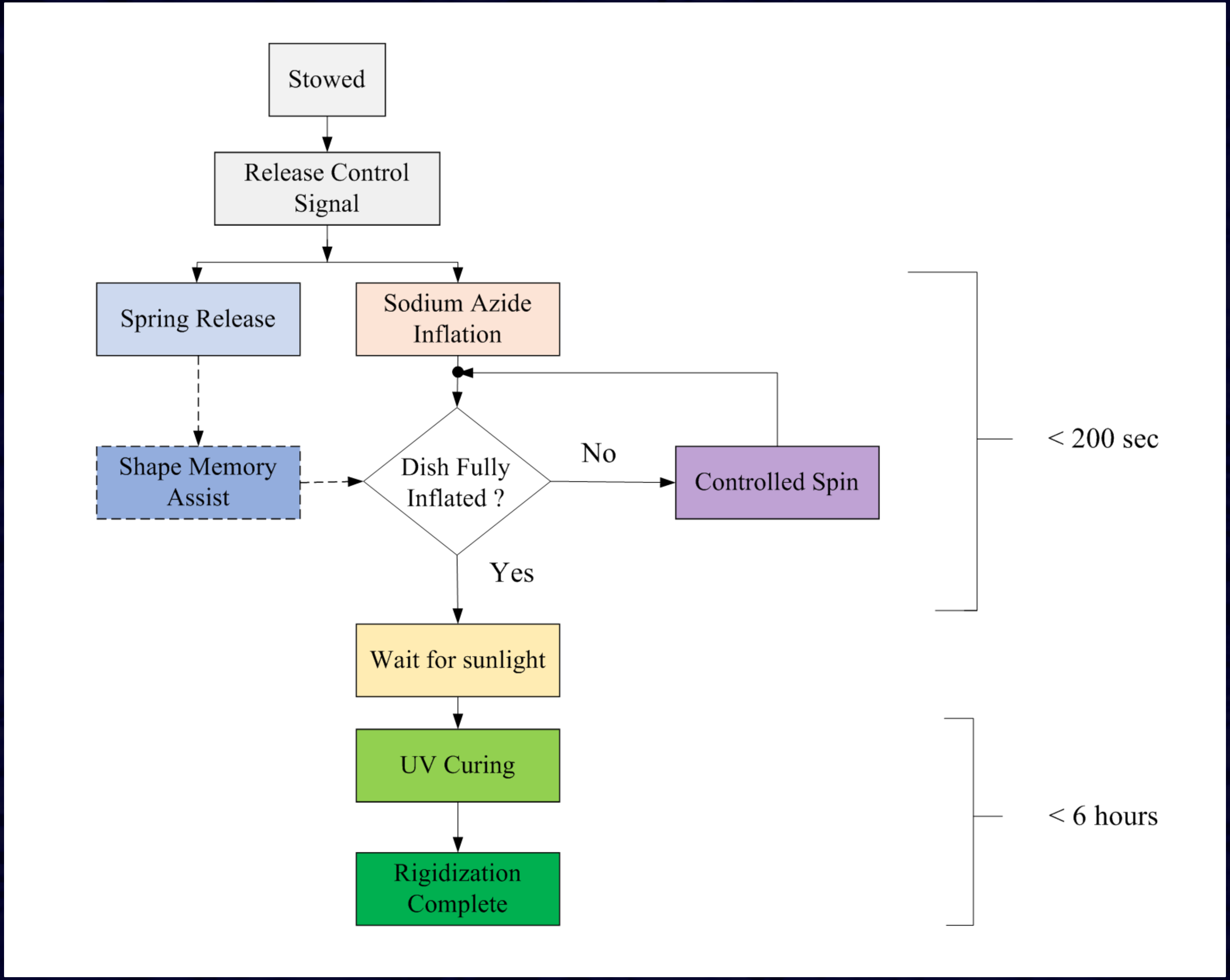
Material	Mass	Proposed System Advantage
Al 6065-T4	34 kg	84x
Ti-6Al-4V	14 kg	35x
Nomex Al Honeycomb	12 kg	31x
Benecor Ti Honeycomb	5 kg	13x
Proposed Kapton UV Cured Inflatable	**0.4 kg**	**-**

Inflatable System Design

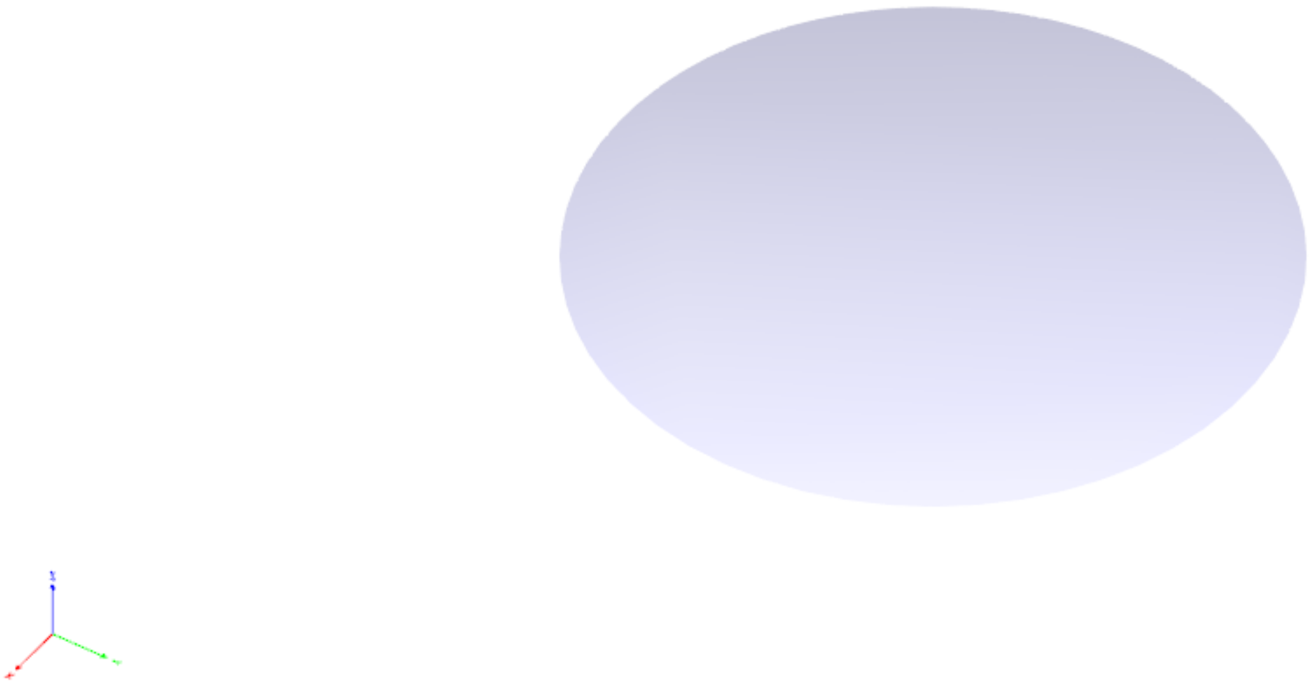


Subsystem Component	Mass
Spark-plug, electronics	50 g
Battery Power Supply	125 g
Sodium Azide Canister	50 g
Sodium Azide	100 g
Rib and Torus Bladder	25 g
Reflector Membrane	50 g
Total	**400 g**

Deployment Steps



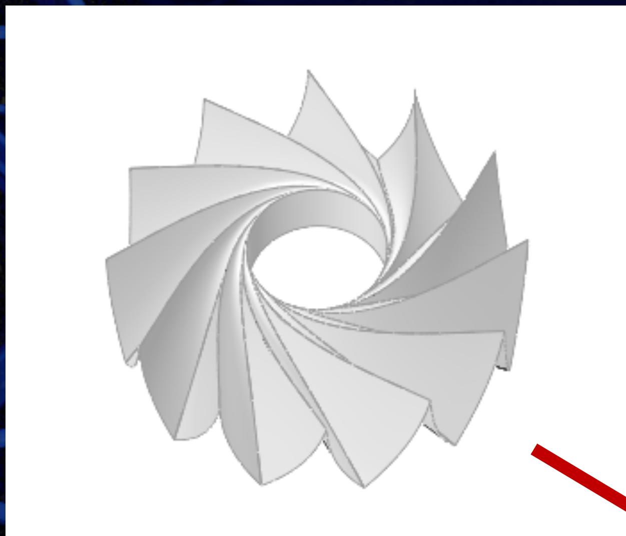
“Accordion” Folds

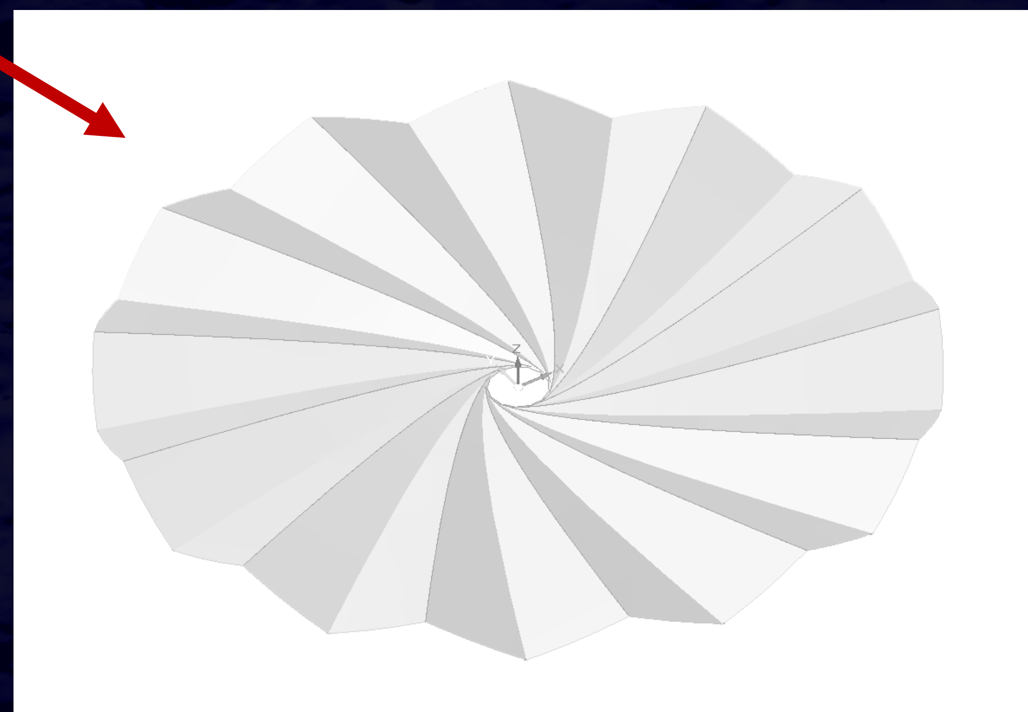


“Radial Accordion” Folds

Unfurl from a spiral roll.

Origami Deployment





Deployment Techniques - Comparison

	Method	Folds	Short Folds	Deployment Time	Stowed Volume	Deployed/ Stowed Volume
1	Exponential - Short Folds	10	10	50 s	0.7 L	110
2	Square - Accordion + Short Folds	31	11	140 s	0.9 L	90
3	**Radial - Accordion + Short Folds + Roll**	**37**	**1**	**160 s**	**0.8 L**	**100**
4	Square - Accordion Folds	40	0	180 s	0.9 L	90
5	Origami - Basic	75	-	170 s	0.5 L	150

- Techniques need to be experimental validated.

Discussion

- Significant potential at least 10 to 30 folds mass advantage over conventional structures
- All the deployment techniques considered are tricky
  - Minimize short-folds
  - Preference for (1) rolling (2) accordion folds
    - Rolling - Spacecraft spin
    - Accordion folds – spring or shape memory
- Feedback control required to guarantee unfolding
  - Rolling - Can be started and stopped, repeated
  - Linear unfolding - shape memory process could be repeated in theory but can get in the way

Future Work

- Details simulation of deployment dynamics
- Identification of preferred deployment technique
- Laboratory demonstration of concept
- A controls approach to increase reliability of deployment system with options for redundancy.
- Flight demonstration – 2015/2016

Thank You!

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