Deployable Antennas for Small Satellites

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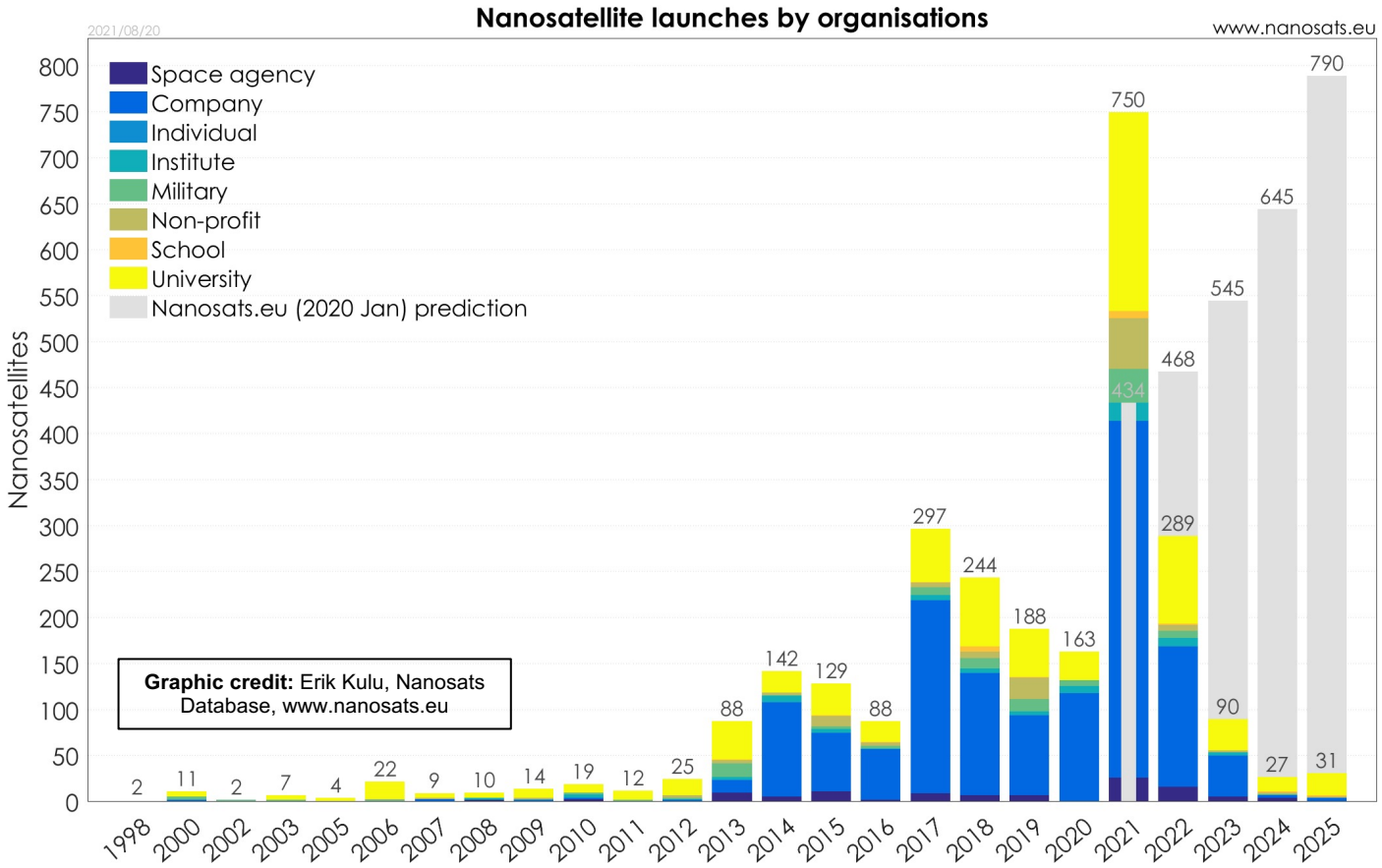
Rise of Micro/Nano-satellites

Micro/nano-satellites[1] have had disruptive impact on space access



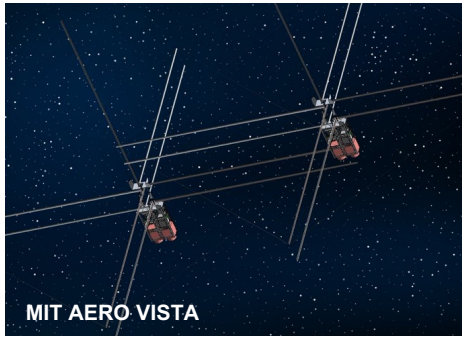
[1] 1-100 kg mass

SmallSat RF Applications

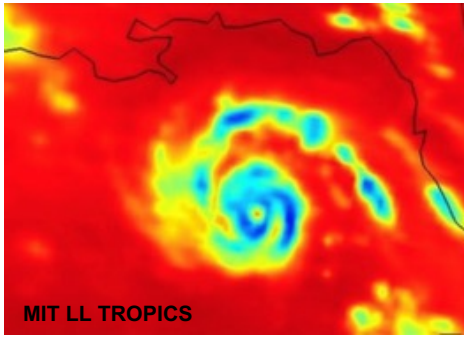
Highly complex RF systems now realizable on small platforms

Imaging Radar

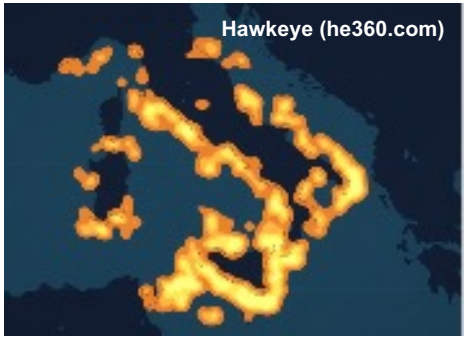
Scientific Sensing



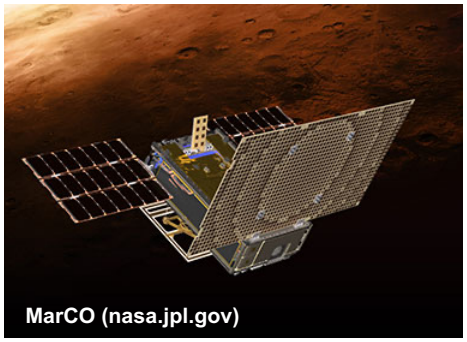
Weather Monitoring



Spectral Monitoring



Communications



SmallSat RF Applications

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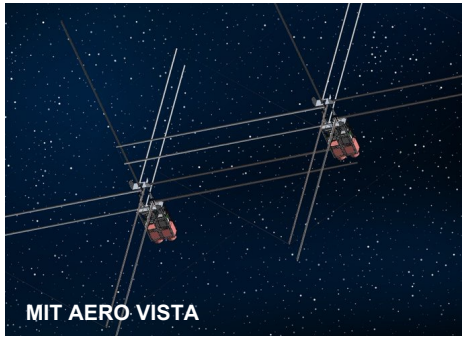

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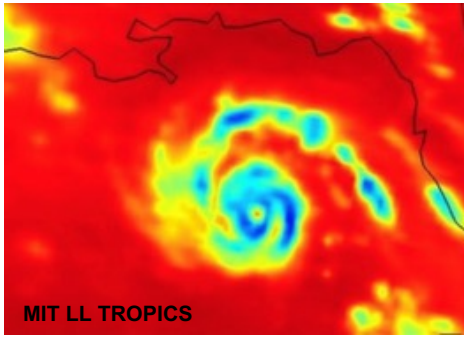

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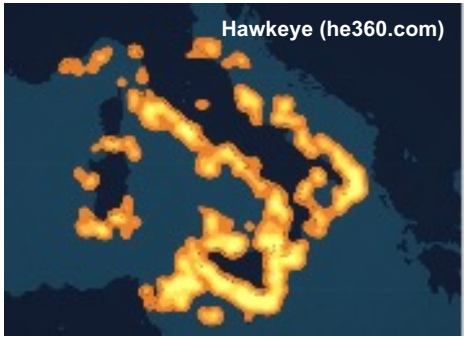

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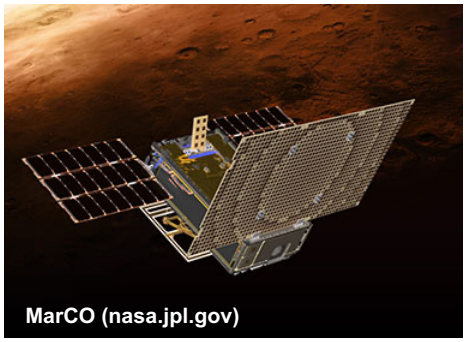
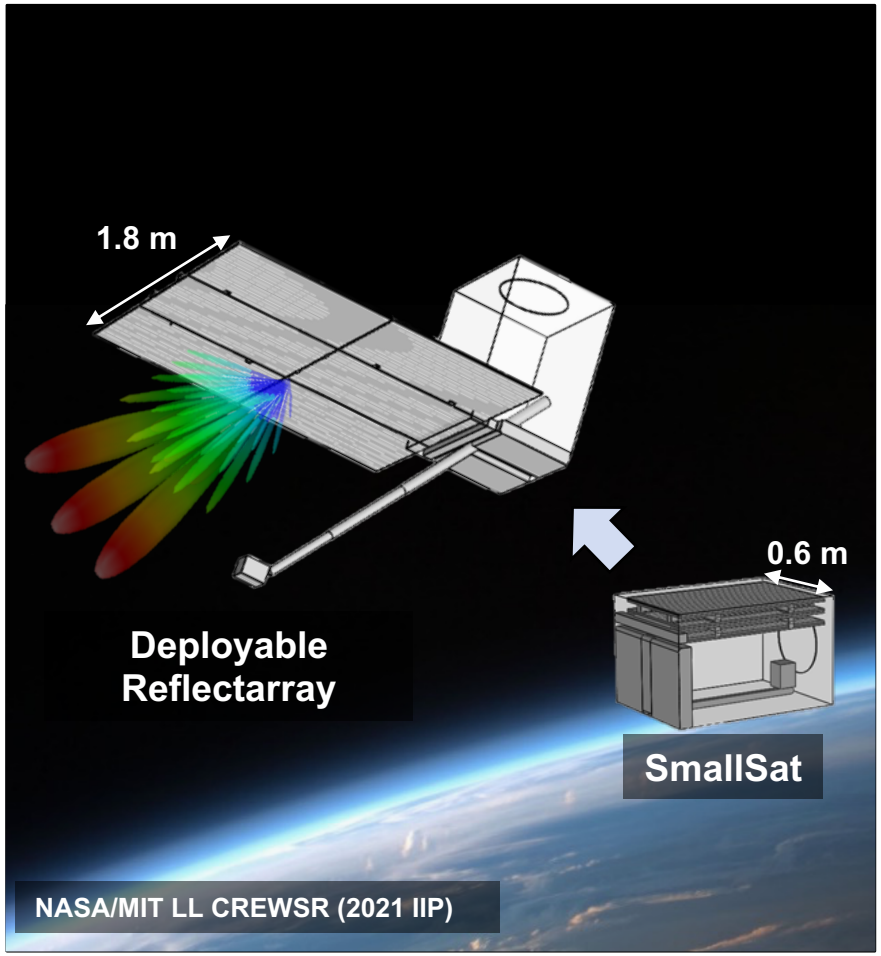


…but large antennas are still needed!

Deployable Antenna Challenges

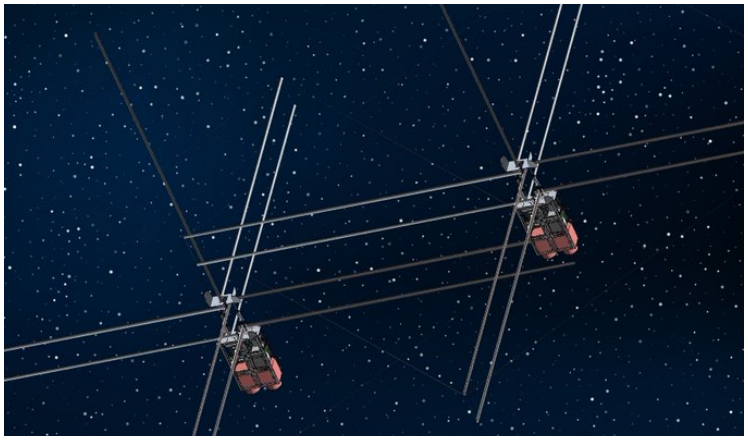
Deployable antenna example



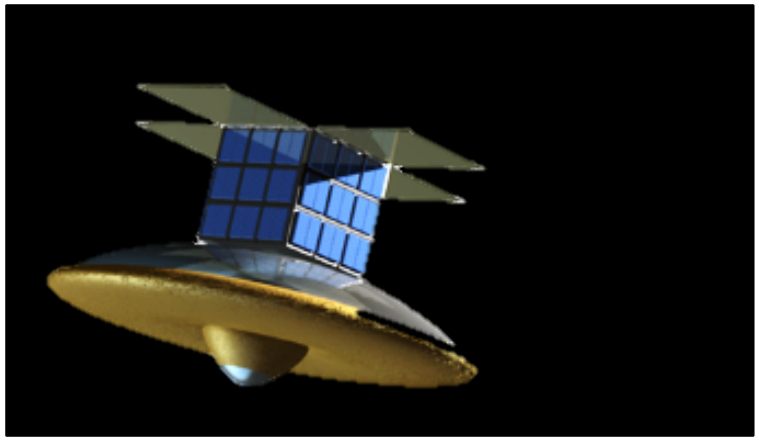
- **Compact stow/deploy**
- **Low mass**
- **Rigidity**
- **Low power consumption**
- **Thermal stability**

Types of Large Antennas for SmallSats

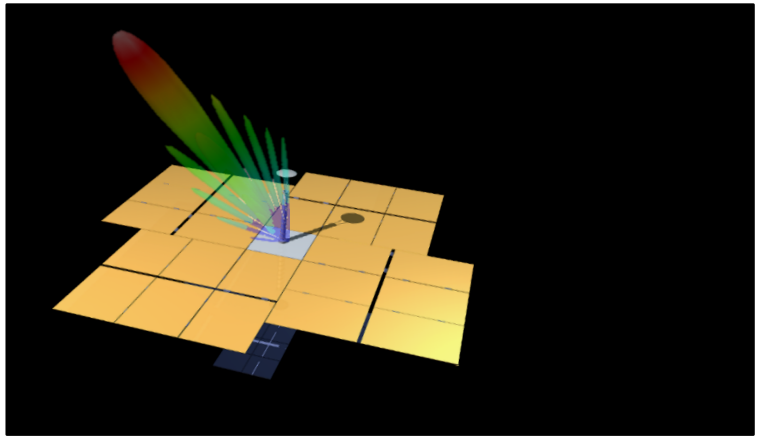
Antennas for low frequencies



Highly-directive fixed-beam antennas



Highly-directive scanning antennas



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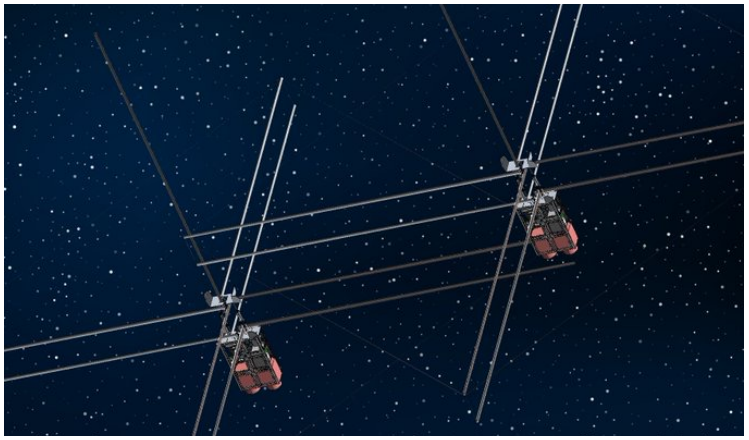
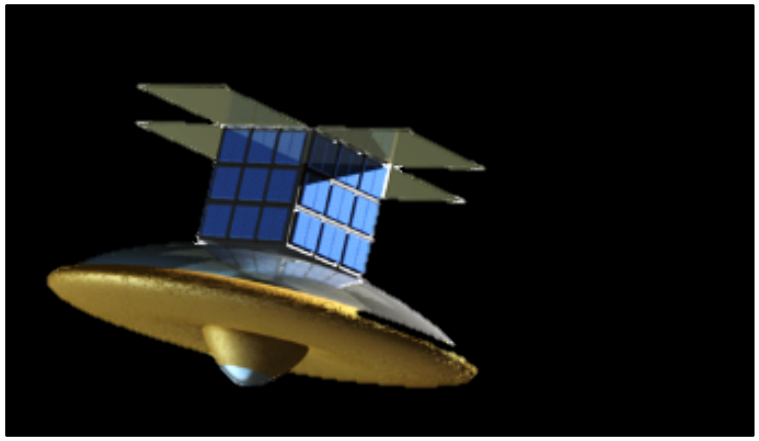
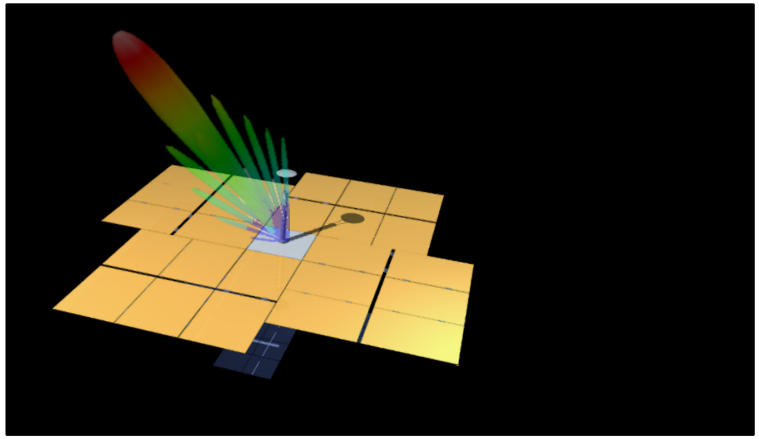
Antennas for low frequencies



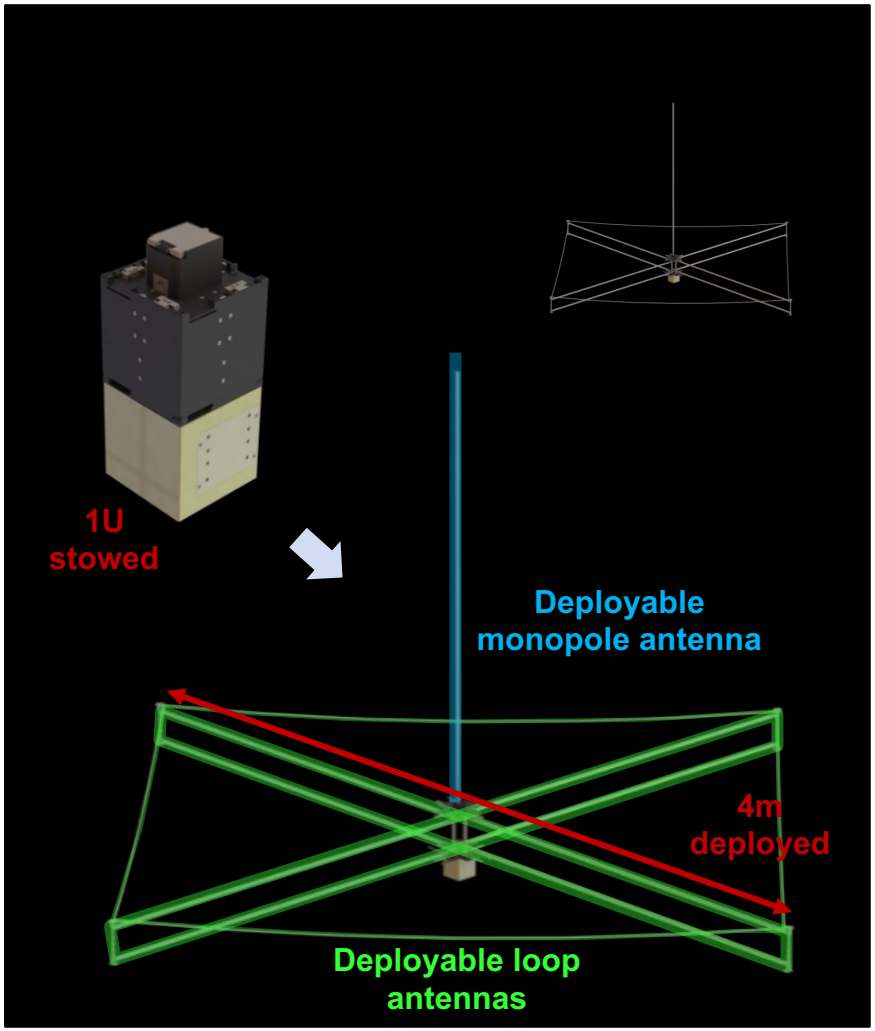
Highly-directive fixed-beam antennas



Highly-directive scanning antennas



Deployable Vector Sensor Antenna

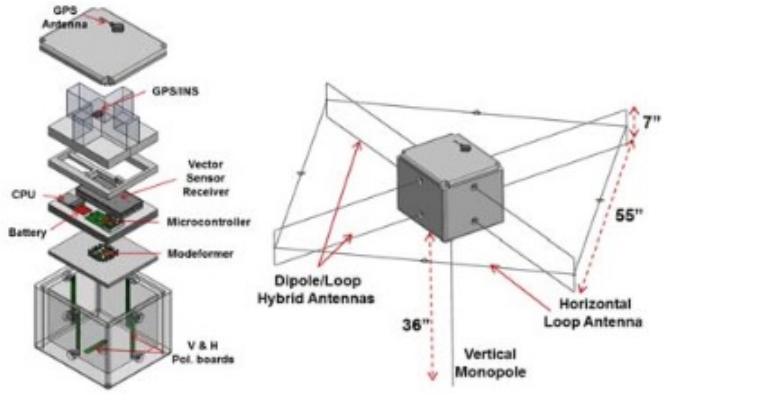


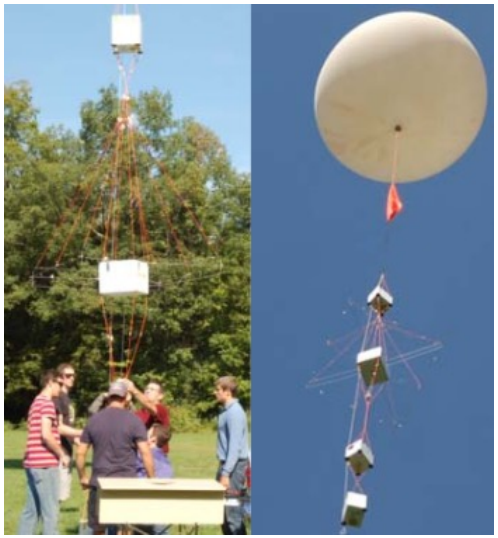
- **MIT AERO, VISTA satellites will sense aurora radio emissions**
- **Deployable antennas sense 0.1 – 15MHz**
- **Multi-antenna configuration localizes radio emissions**

F. D. Lind, et. al., "AERO & VISTA: Demonstrating HF Radio Interferometry with Vector Sensors," *SmallSat Conference 2019*

Vector Sensor Prototype

Balloon-Mounted Prototype



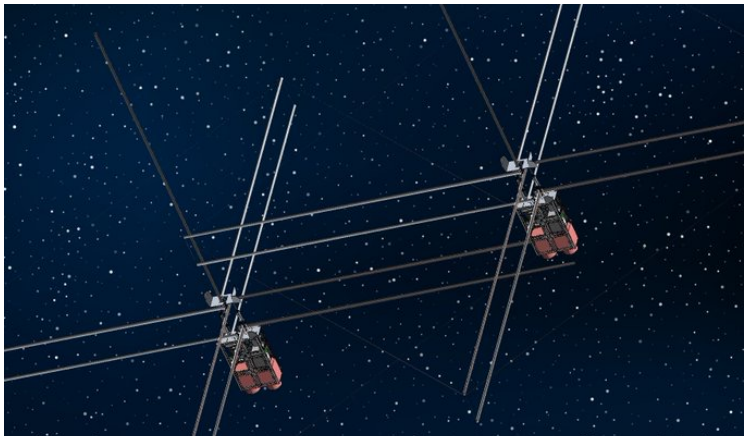


- **Antenna concept validated w/ balloon-mounted prototype**
- **Localization of signals in target band demonstrated**
- **AERO/VISTA cubesat launch targeted in 2022**

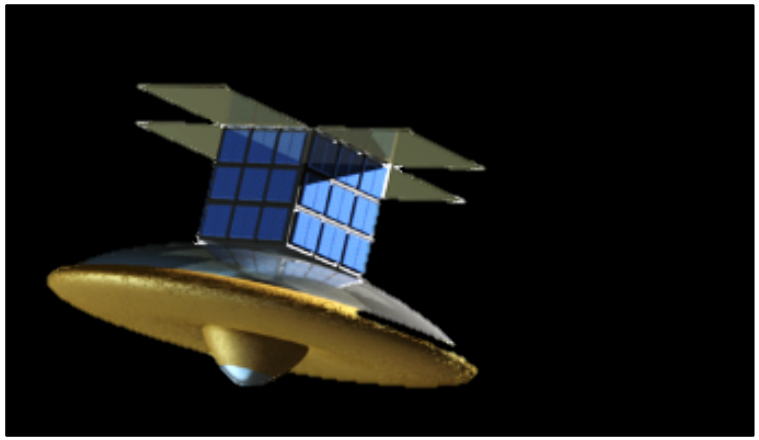
F. C. Robey, et. al., “High Frequency (HF) Radio Astronomy from a Small Satellite”

Types of Large Antennas for SmallSats

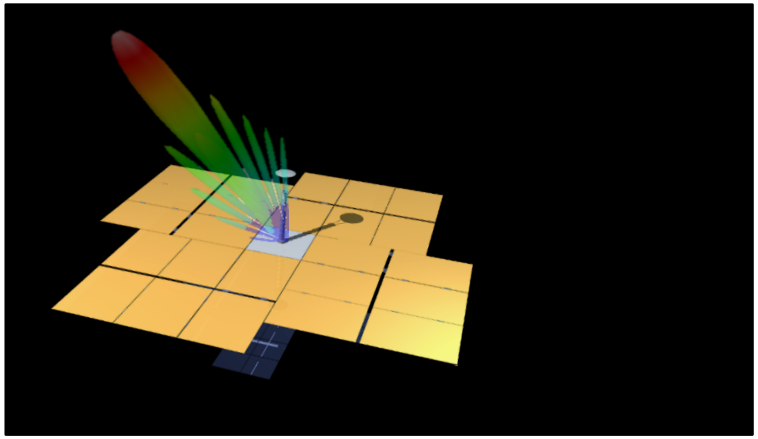
Antennas for low frequencies



Highly-directive fixed-beam antennas

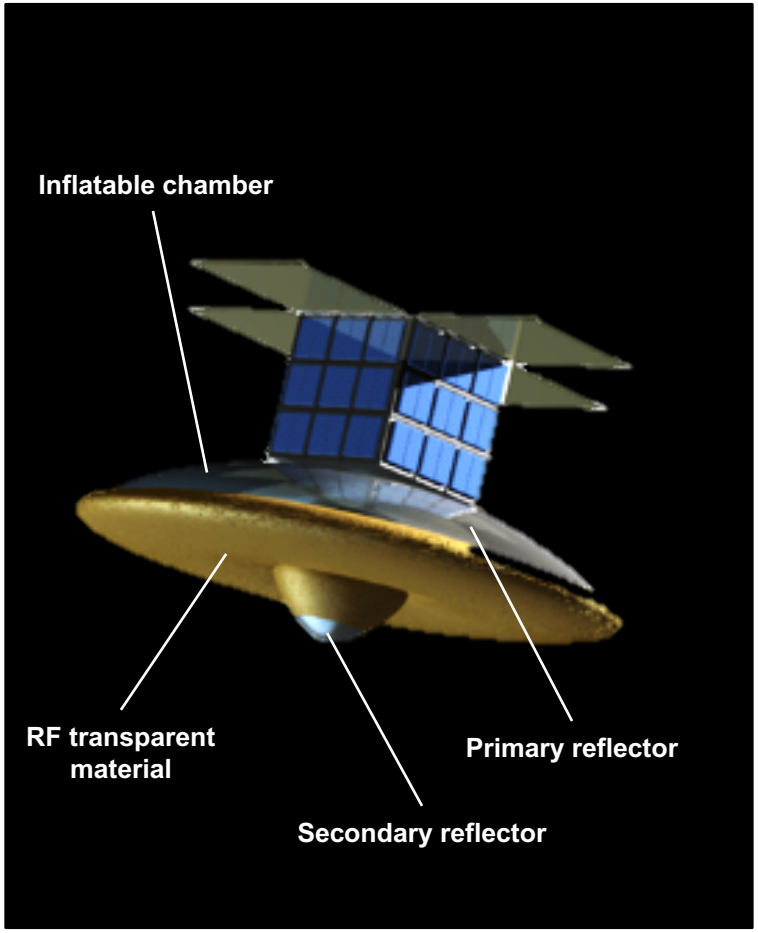


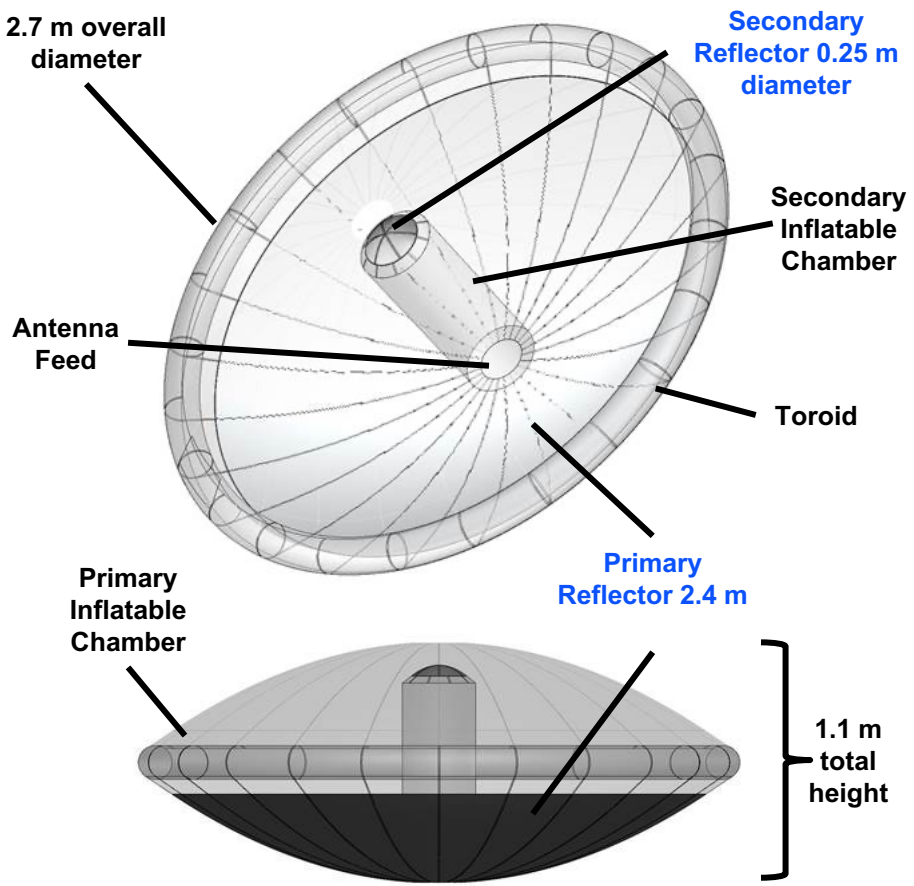
Highly-directive scanning antennas



Inflatable Reflector Antenna

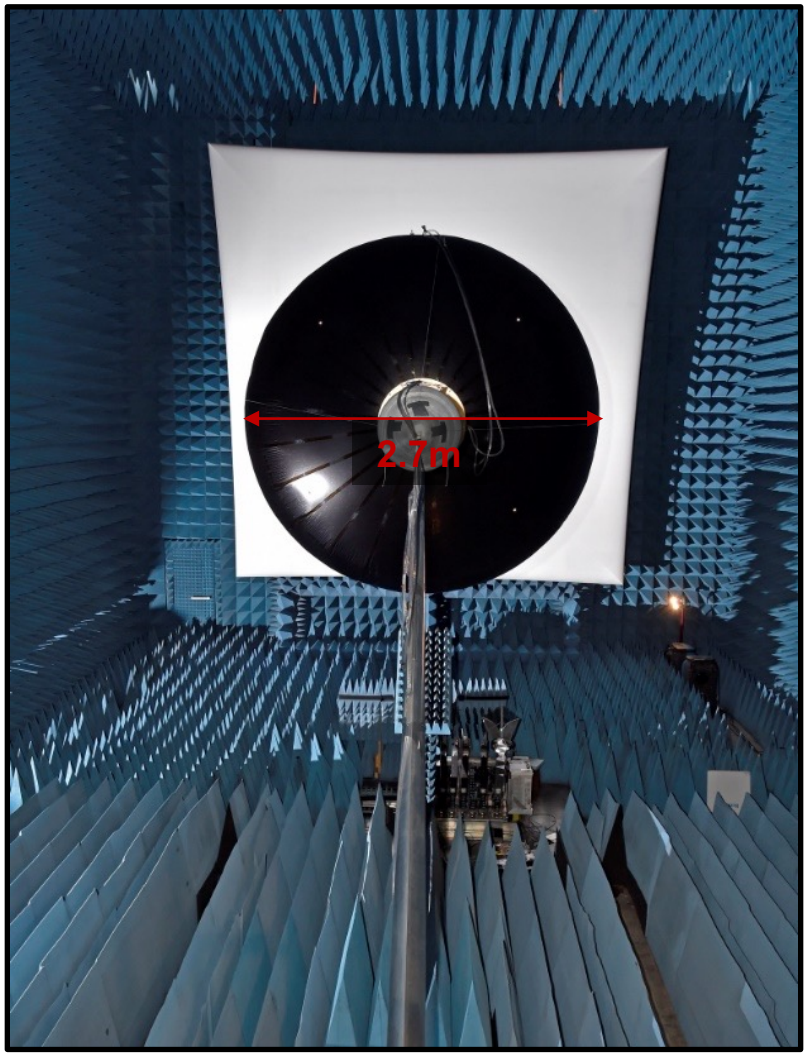
Enables large, ultra-light dish antennas deployed from small volume





A. J. Fenn, et. al., "Axisymmetric Gregorian Reflector System for a Space-Deployed Inflatable Antenna: Simulations and Measurements," *2019 IEEE International Symposium on Phased Array System & Technology (PAST)*

Prototype Reflector



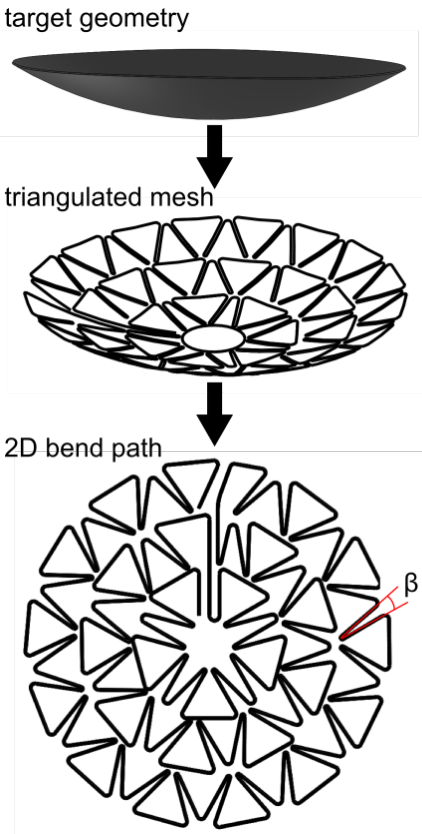
- Design validated through measurement
- Measured RMS surface error ~2.7mm
- Deflated volume of outer torus ~1.25U

A. J. Fenn, et. al., "Axisymmetric Gregorian Reflector System for a Space-Deployed Inflatable Antenna: Simulations and Measurements," *2019 IEEE International Symposium on Phased Array System & Technology (PAST)*

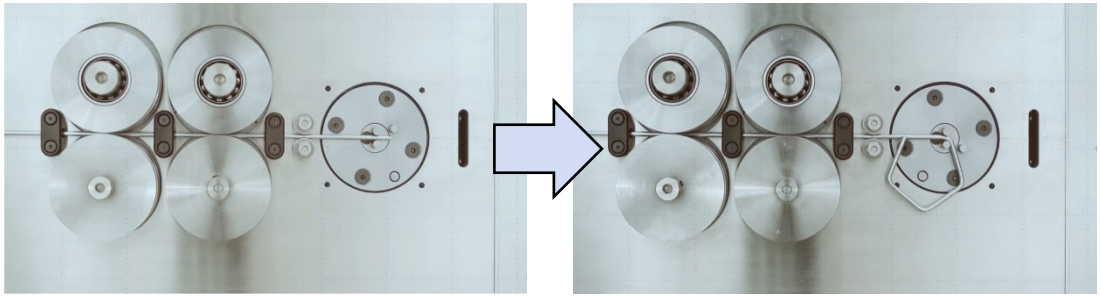
Wire Bending for Large Reflectors

Lead: Prof. Zachary Cordero, MIT

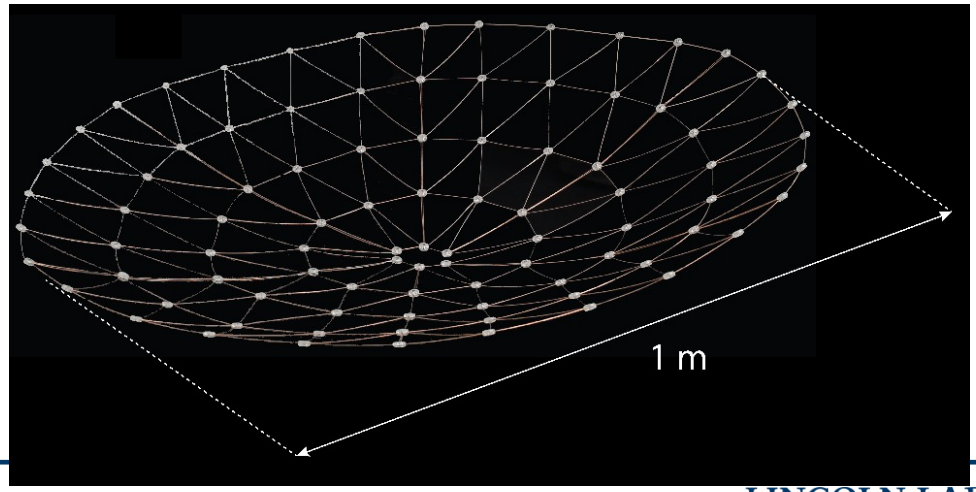
CNC wire bending can enable in-space manufacturing of large reflectors



CNC Wire Bender



Bend-Formed parabolic dish



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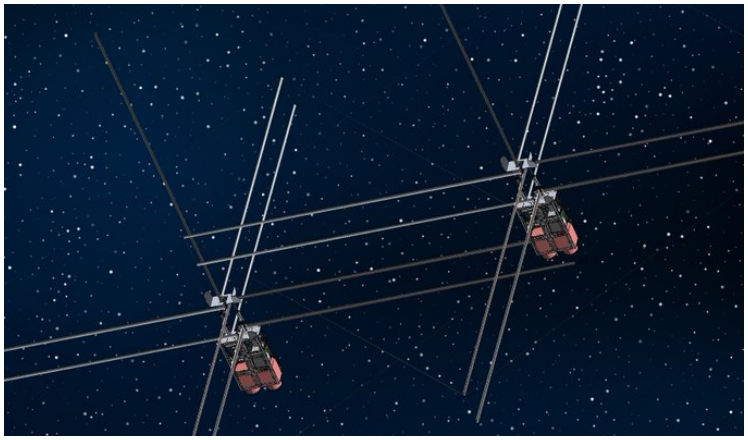

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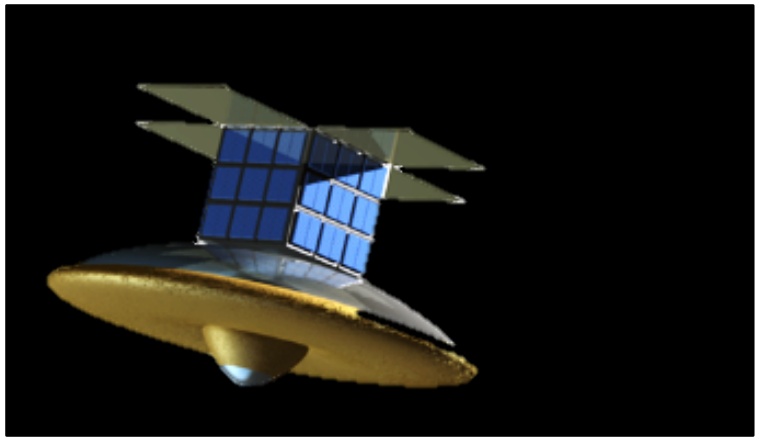
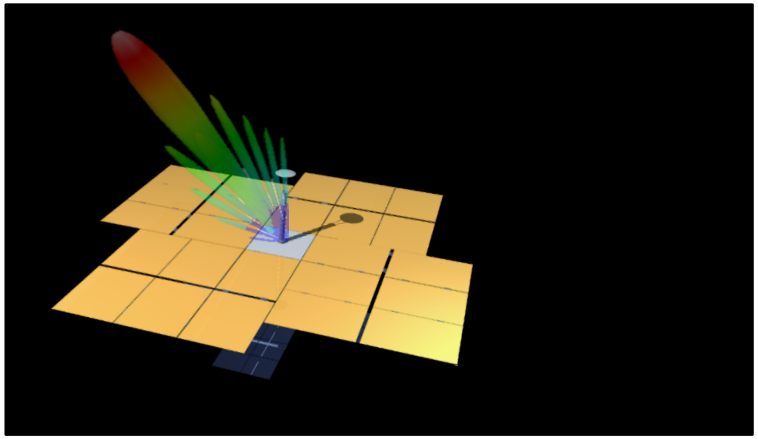
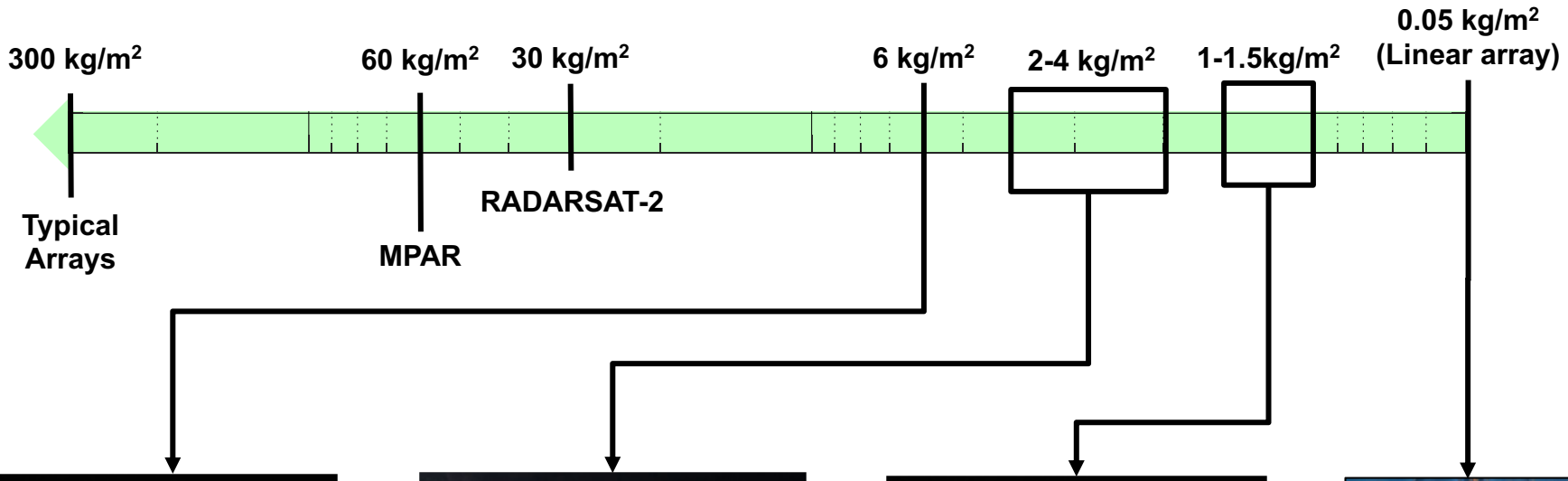
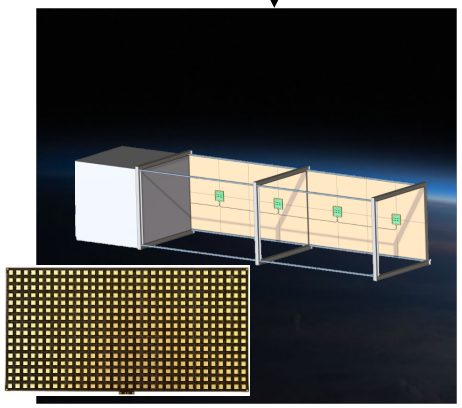


Highly-directive scanning antennas

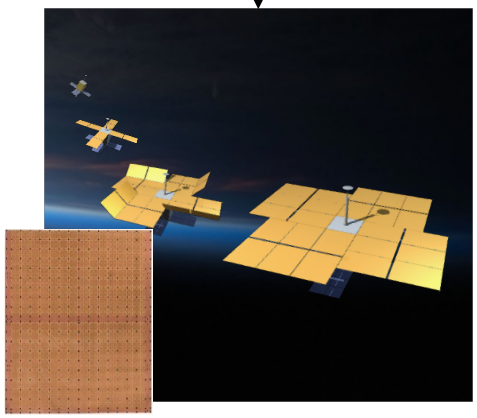


Lightweight Scanning Array Technology

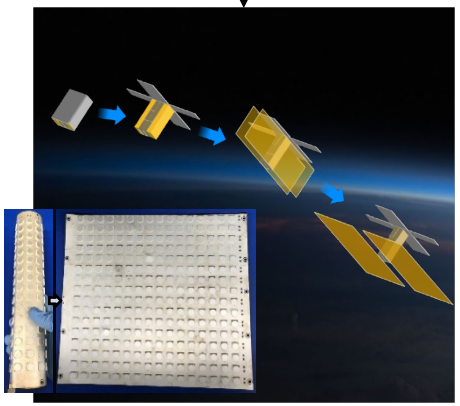




LWAESA: Lightweight Active Electronically-Scanning Array



DESRa: Deployable Electronically-Scanning Reflectarray



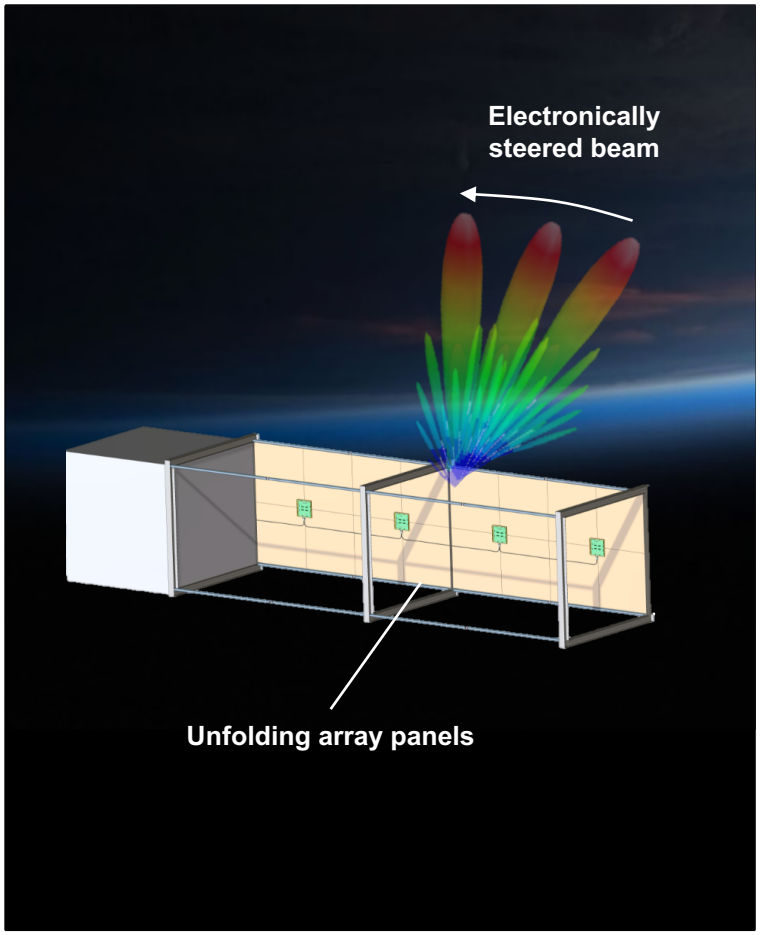
RFAA: Rigid-Flex Antenna Array

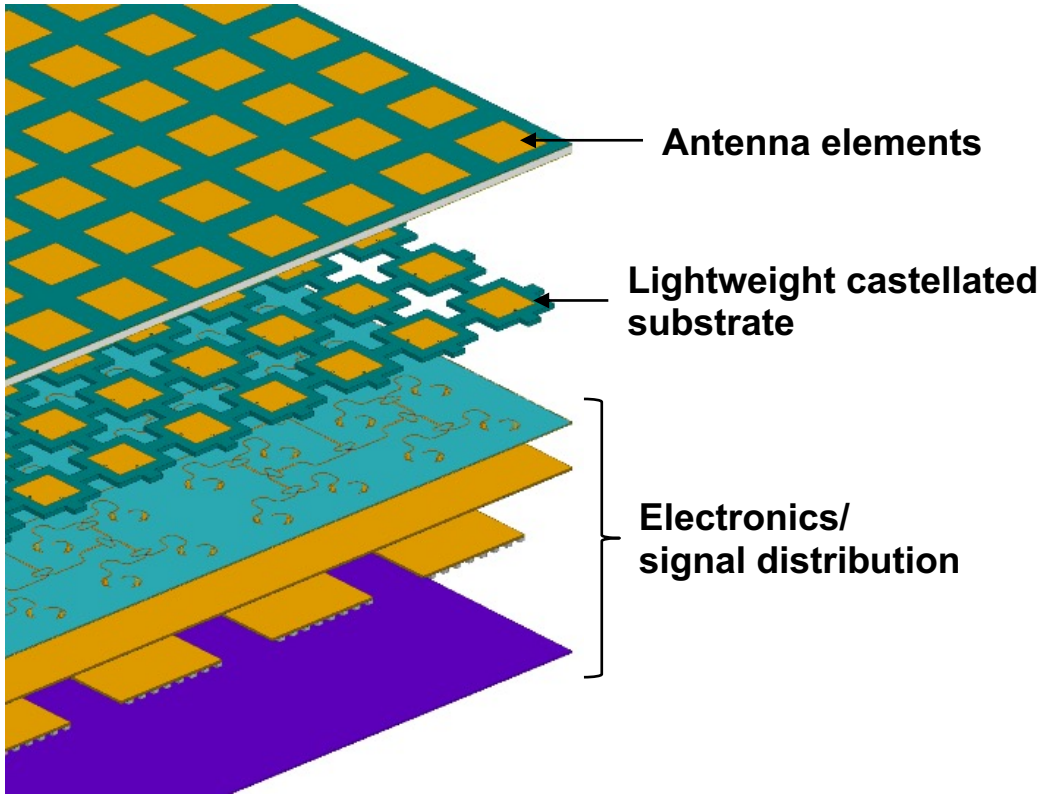
RF Fiber Array

LWAESA

Lightweight Active Electronically-Scanning Array

Novel low-mass antenna array enables use on small platforms

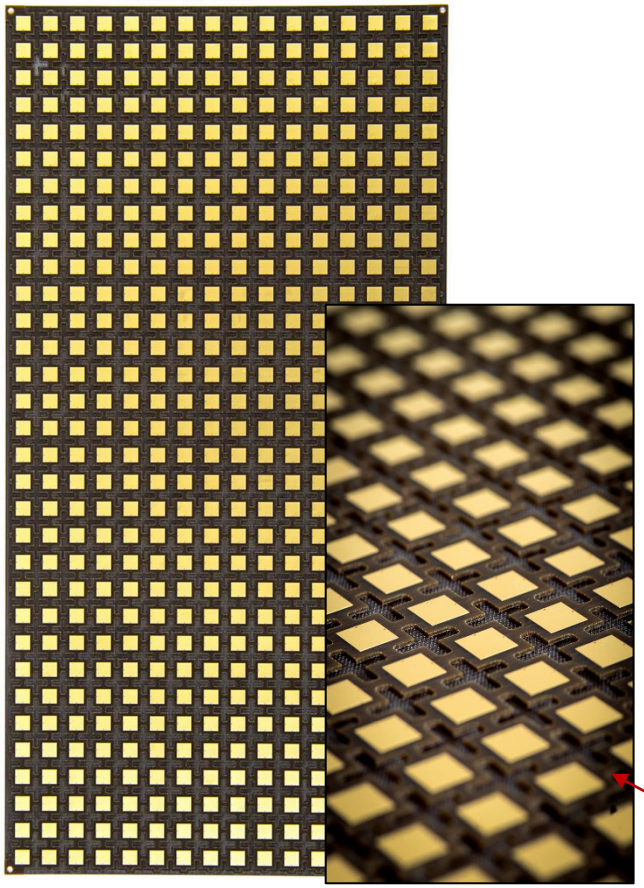




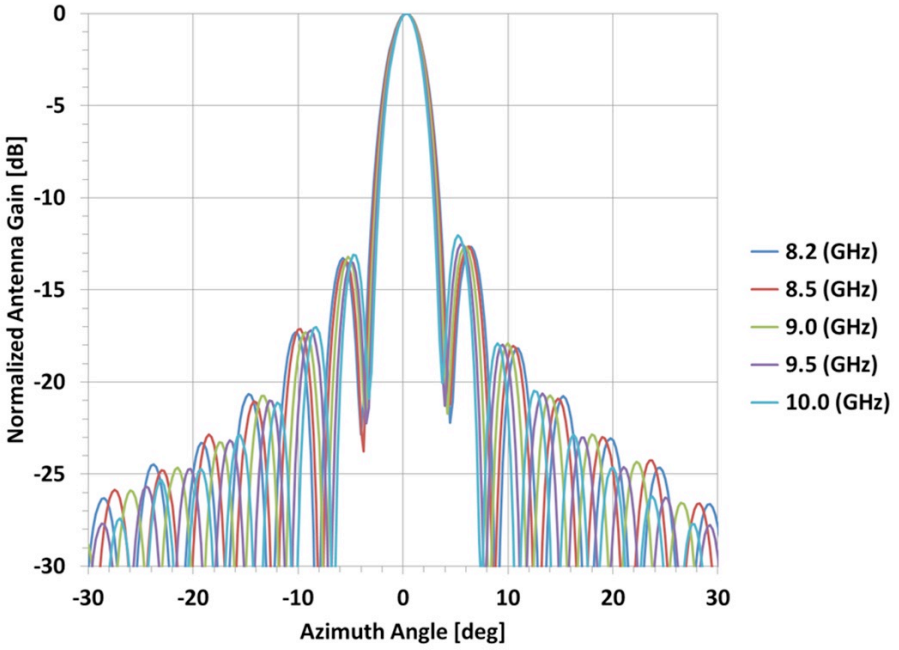
P. Dufilie, et. al., "Lightweight Arrays for Space Applications," *2017 Antenna Applications Symposium*

LWAESA Prototype

Prototype with castellated substrate validated with measurements



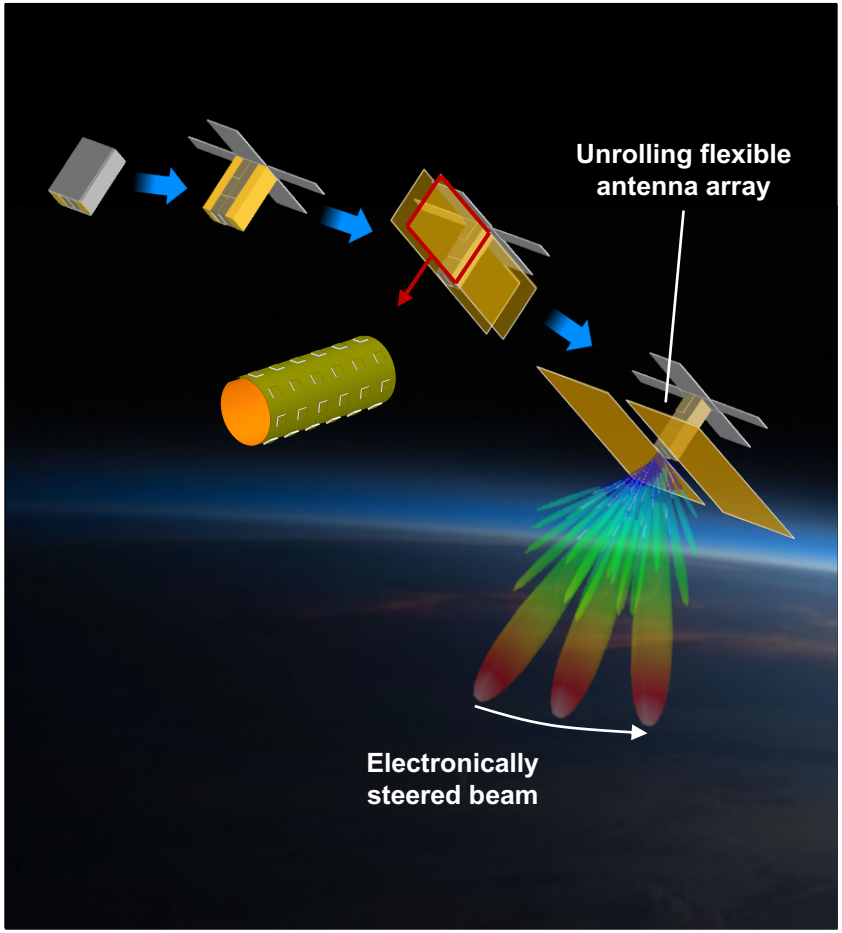
Novel castellated substrate

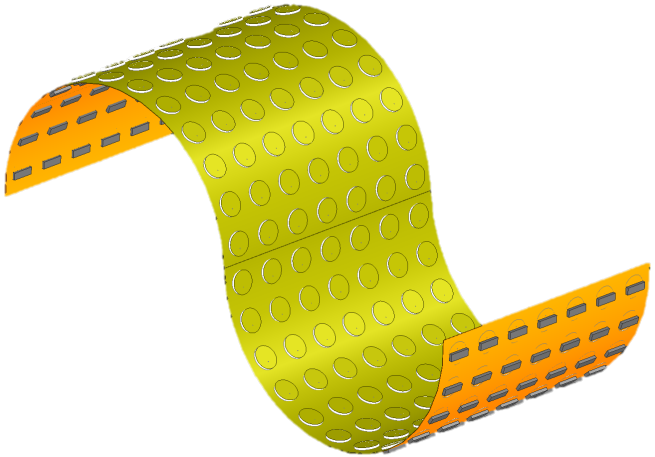


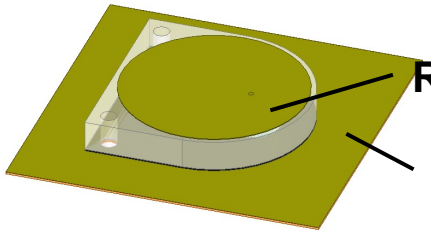
P. Dufilie, et. al., "Lightweight Arrays for Space Applications," *2017 Antenna Applications Symposium*

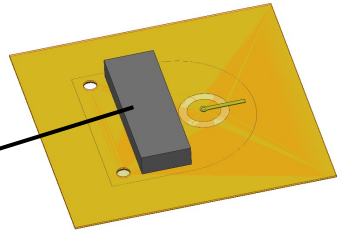
RFAA
Rigid-Flex Antenna Array

Flexible, ultra-light array can be rolled and unrolled for deployment



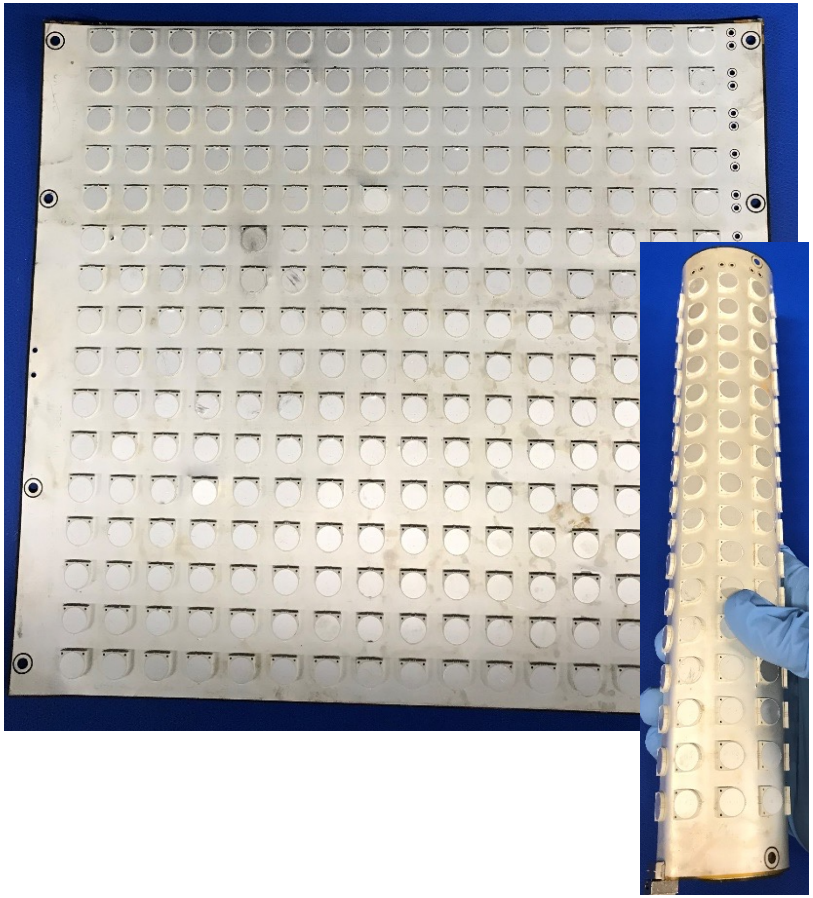


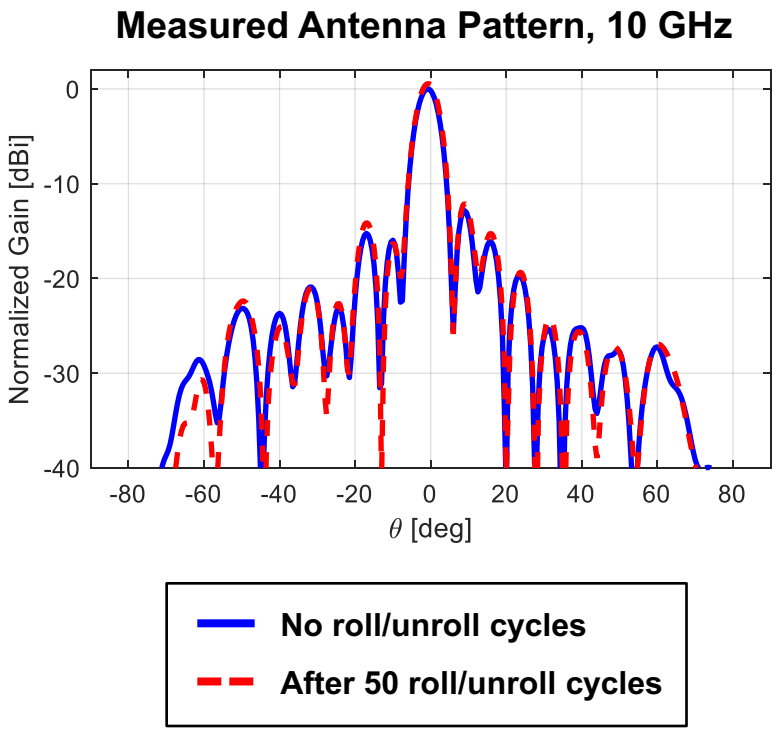




RFAA Prototype

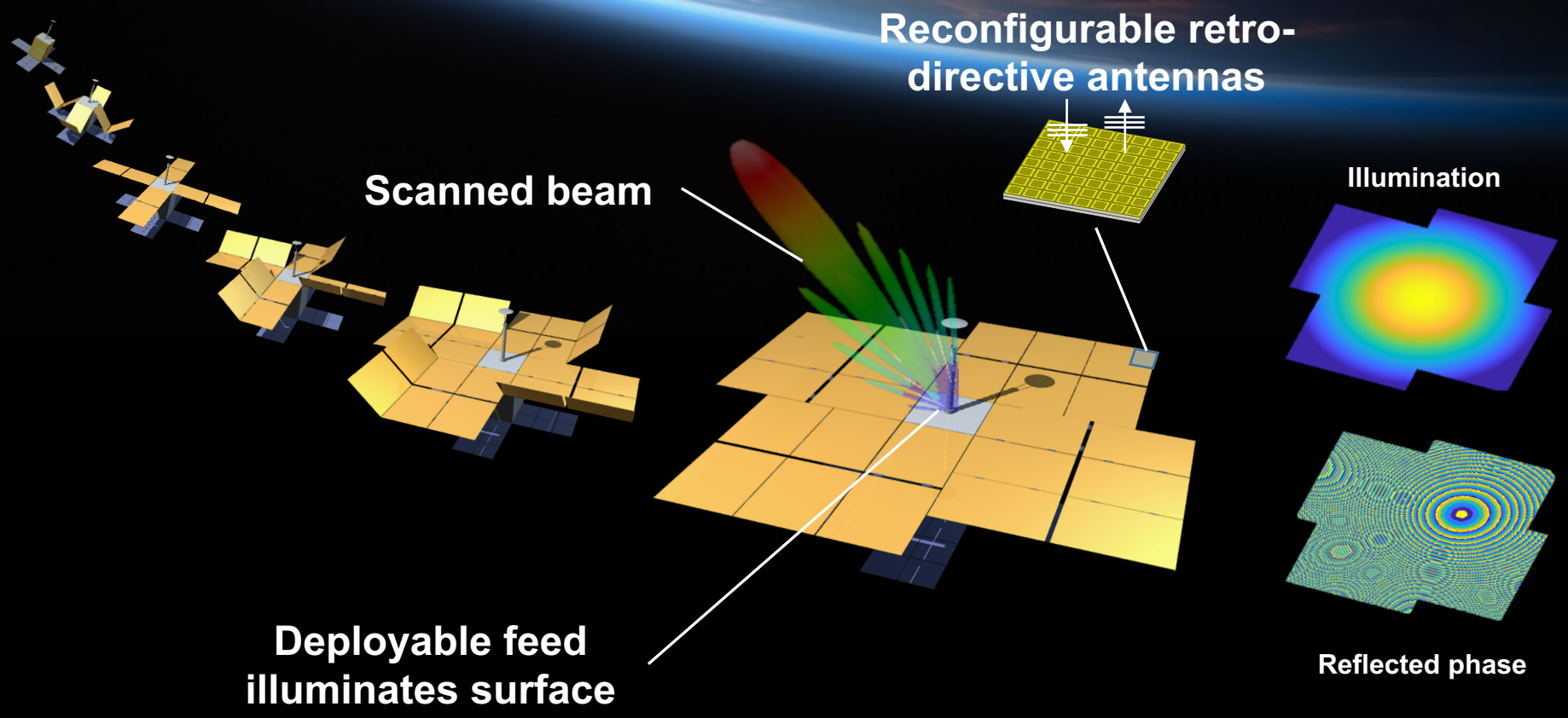
Concept validated experimentally after numerous roll cycles



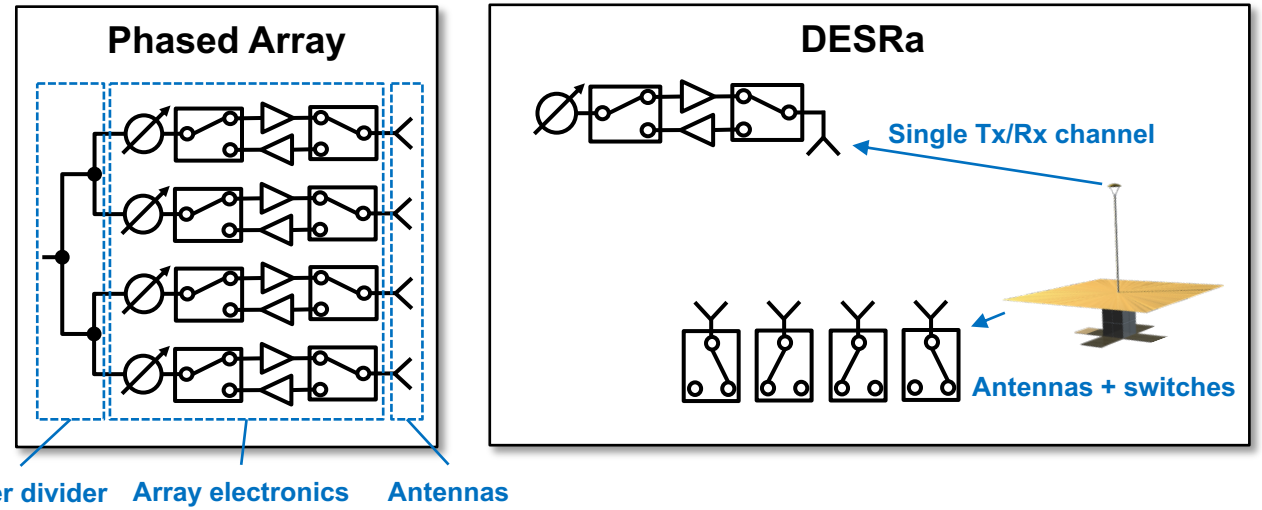


DESRa
Deployable Electronically Scanning Reflectarray

DESRa scans beam by illuminating reconfigurable reflective surface



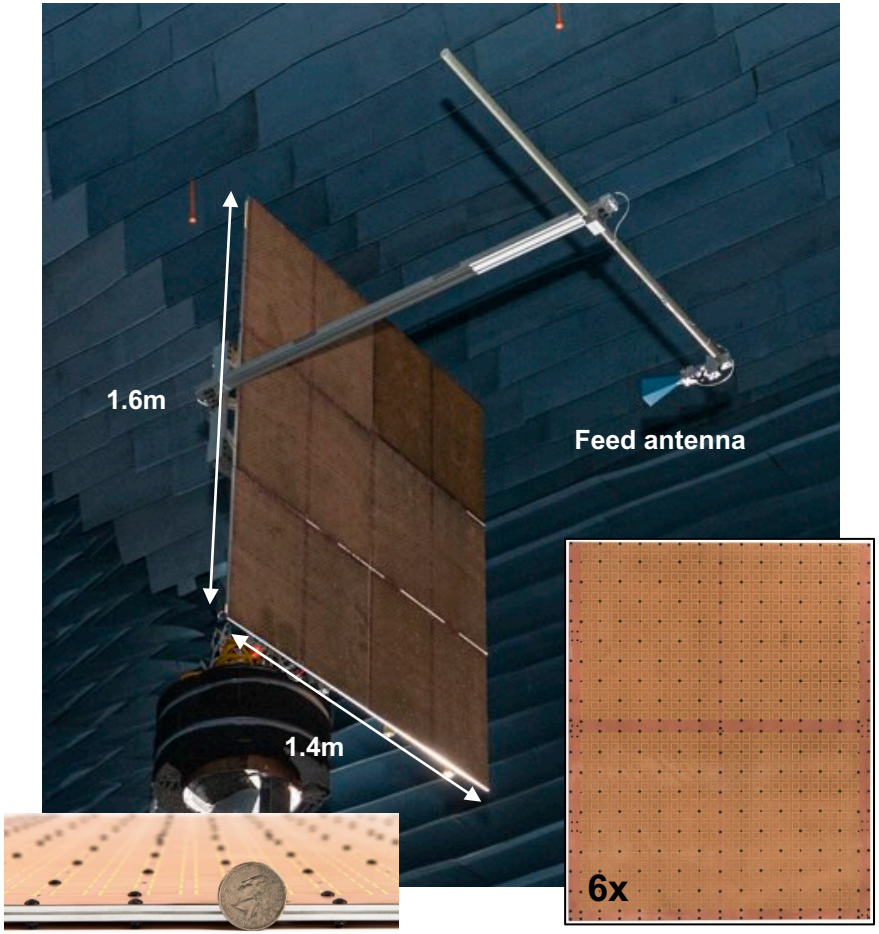
Large Scanning Apertures



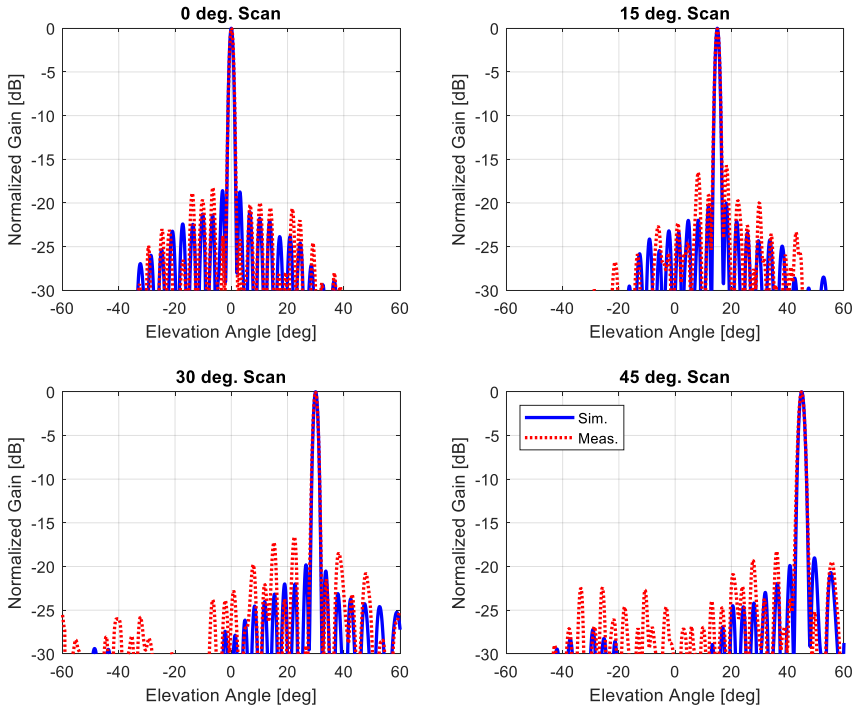
	Phased Array	DESRa
Power consumption	High	Low
Thermal management	Complex	Simple
Scanning range	Wide	Wide
Cost	High	Low

DESRa Prototype

2.2 m² prototype demonstrated highly directive scanned beam



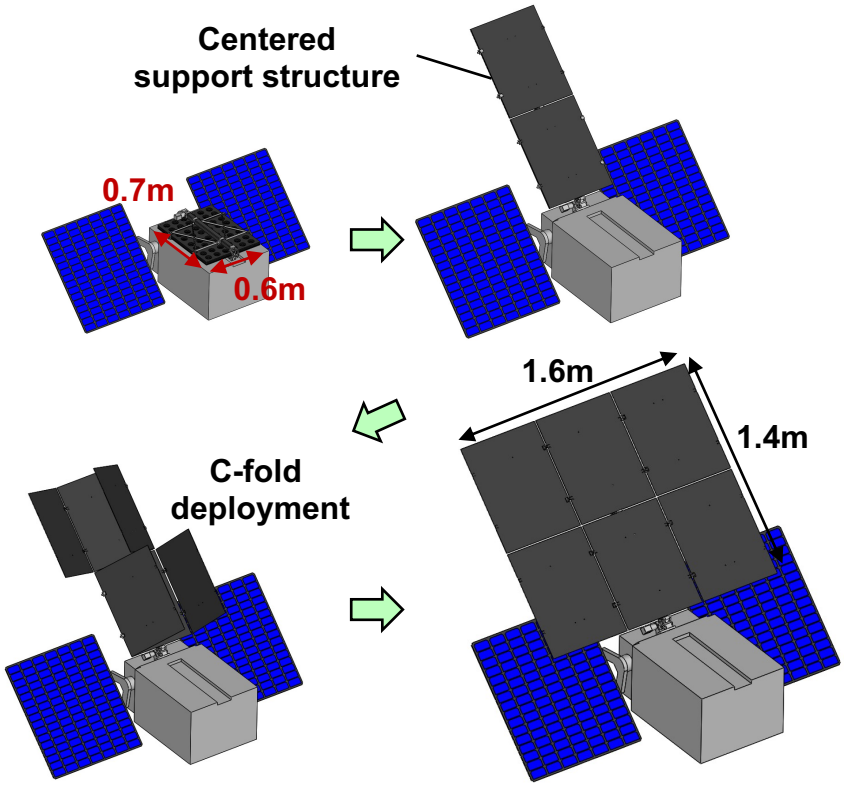
Electronically scanned patterns, 9 GHz



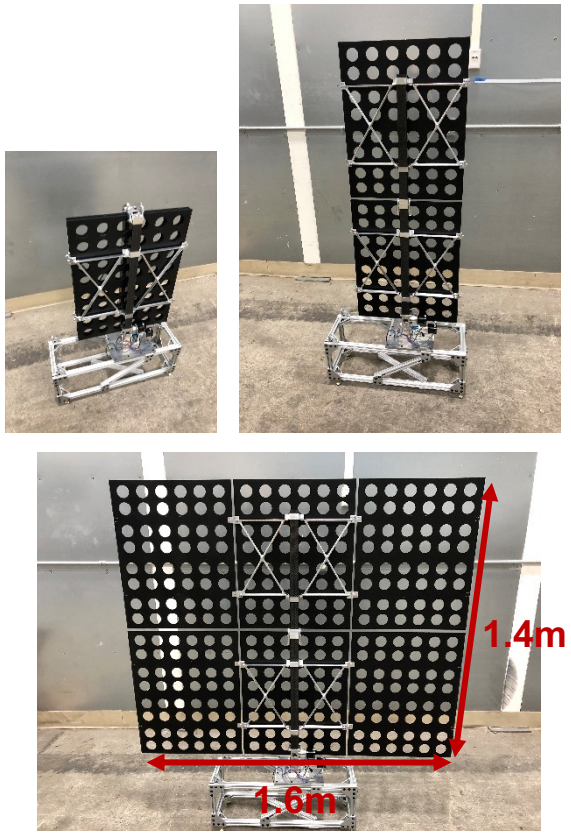
Deployment System

Simple deployment scheme provides 2.2m^2 aperture from 0.4m^2

Deployment Scheme

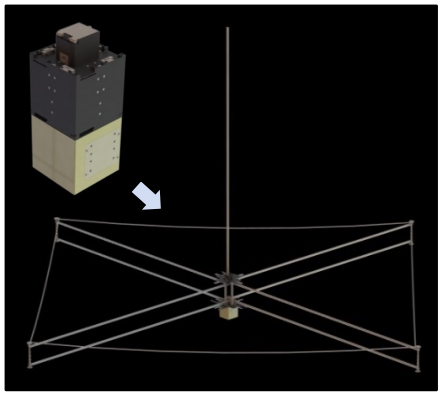


Deployment EDU

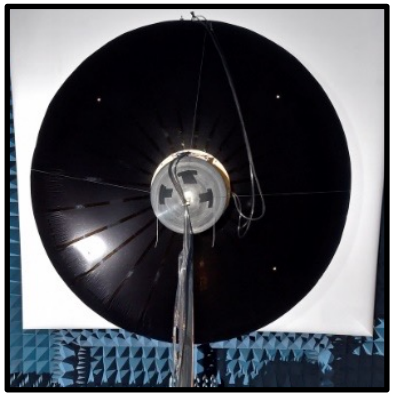


Summary

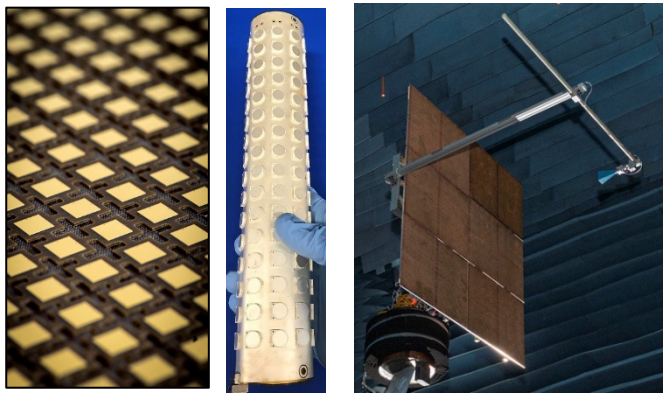
- SmallSats enable new RF capabilities, pursued by more entities
- Deployable antennas critical for realization of large apertures
- MIT LL has demonstrated innovative deployable antennas for:
  - Low frequency systems
  - Highly-directive fixed-beam antennas
  - Highly-directive scanning antennas



HF Vector Sensor



Inflatable Reflector



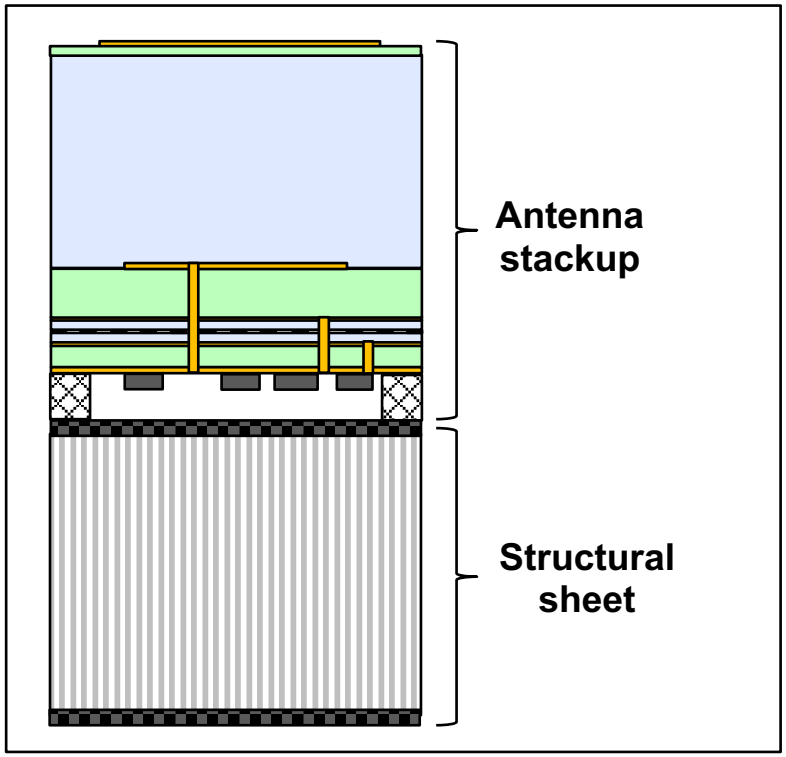
Lightweight Scanning Arrays

BACKUP

Panel Construction

Structural grids integrated within antenna for thin, symmetrical design

Antenna w/ structural sheet



DESRa