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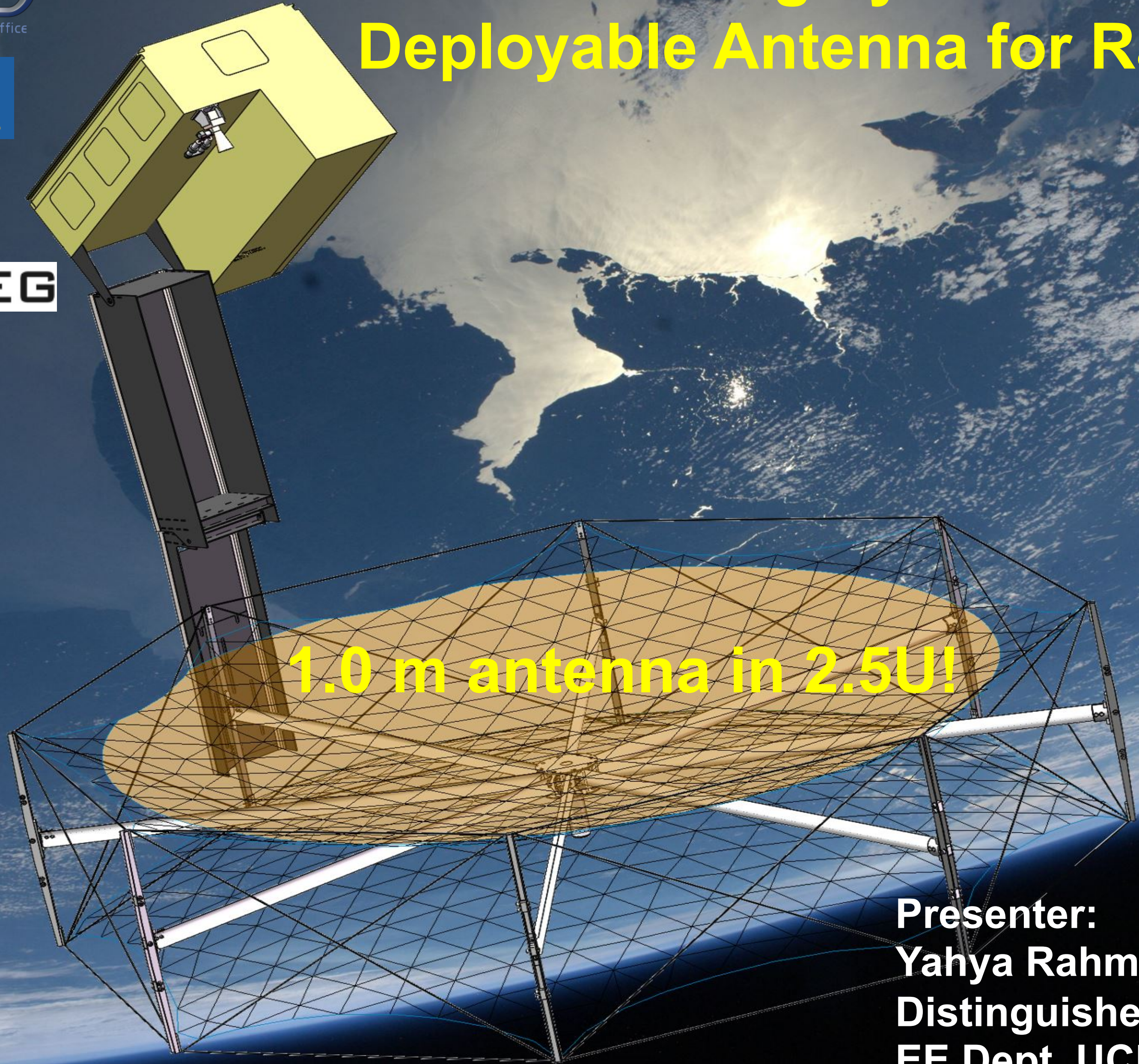
Ka Band Highly Constrained Deployable Antenna for RaInCube



Presenter:
Yahya Rahmat-Samii
Distinguished Professor
EE Dept. UCLA

Key Contributors

Yahya Rahmat-Samii: UCLA PI responsible for overall program management, development of the algorithms for parametric characterization of mesh reflector antenna and the feed horn

Eva Peral: JPL PI responsible for vendor interfaces, integrations and measurements

JPL Co-Is: Richard Hodges, Simone Tanelli, Jonathan Sauder

UCLA Student/Postdoc: Vignesh Manohar, Joshua M. Kovitz

Gregg Freebury: Tendeg LLC, responsible for the antenna development and prototyping

A Recent Review Paper on CubeSats

IEEE Antennas and Propagation Magazine, April 2017

For Satellites, Think Small, Dream Big

A review of recent antenna developments for CubeSats.

Yahya Rahmat-Samii, Vignesh Manohar, and Joshua M. Kovitz

Advances in modern technology have aided the development of a class of miniaturized satellites called *SmallSats* that typically weigh less than 500 kg. Key members of this family are CubeSats. CubeSats can weigh as little as 1.33 kg, with a typical volume of $10 \times 10 \times 10$ cm^3. Their potential has motivated the scientific community to revisit existing spacecraft technologies to make them suitable for CubeSats.

This work particularly focuses on CubeSat antenna development. An extensive literature study is presented to survey the current state of the art in CubeSat antenna systems. We summarize several recent CubeSat missions and describe antennas that have been used in past CubeSat launches. We also discuss recent antenna research that can enable many exciting missions in the future.

THE RISE OF CUBESATS

For many years, smaller was not an option for the satellite industry. The stringent radio-frequency (RF) requirements for high-performance satellites to deliver the desired quality of service demands very heavy payloads. The typical timeframe for such large, conventional satellites is more than five years from proposal to launch, with a cost ranging from US$100 million to US$2 billion

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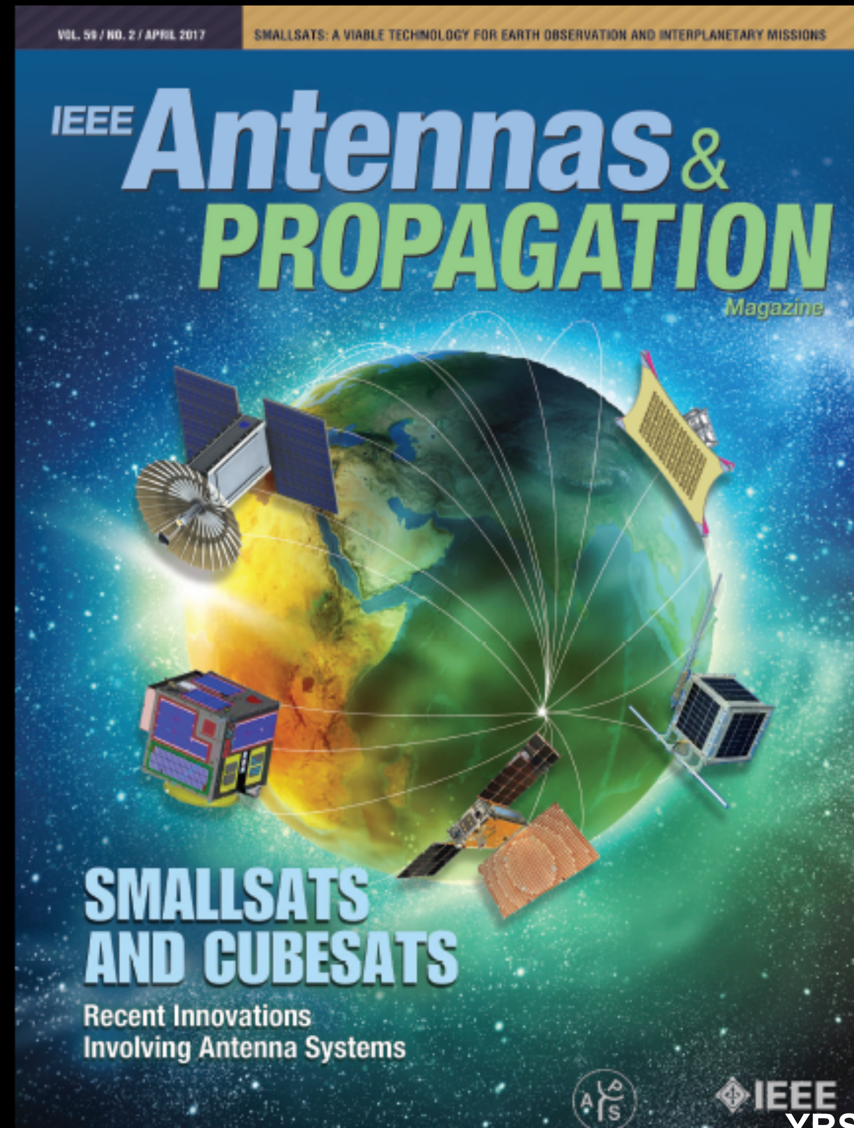

Guest Editor: Yahya Rahmat-Samii

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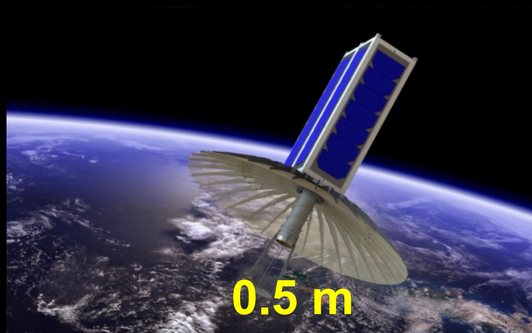
The Big Picture: Needing larger antennas

Achieving the future challenging science requirements for remote sensing

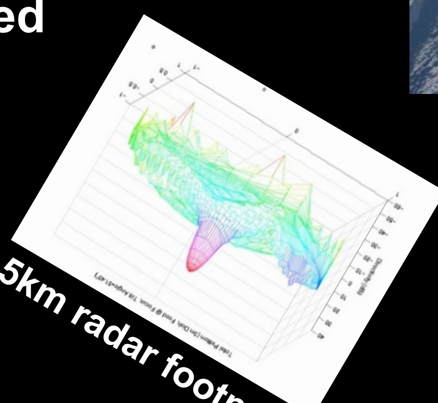
Freq. = 35.75 GHz



Current 0.5m design:

Too small for future science needs. This symmetric design could not be extended beyond 0.5 m.

Bringing the TRL of the 1.0 m antenna design from 3 to 5.



5km radar footprint

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CubeSats: Genie in the bottle!

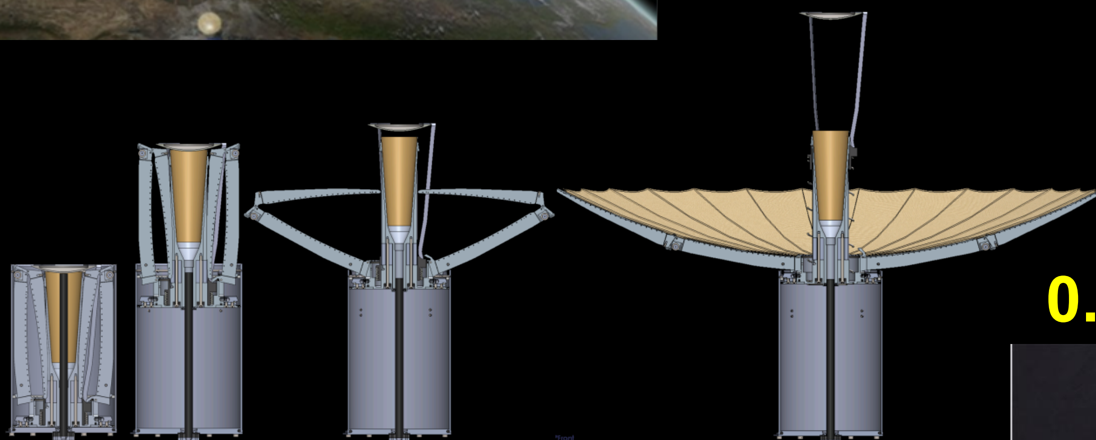
Future of low cost missions 1.5U and 2.5U

Requires extremely chalenging antenna designs for high gain applications!

Ka-Band Deployable Antenna for CubeSats: Recent Collaborative Design with JPL

Frequency = 35.75 GHz

1.5 U



0.5 m diameter

Unfortunately this rib packaging design could not be extended to 1.0 m.

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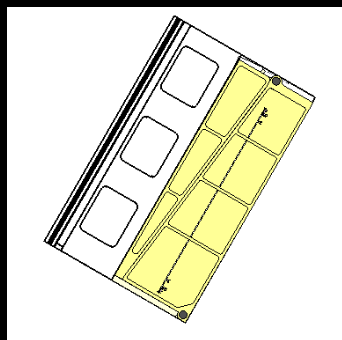
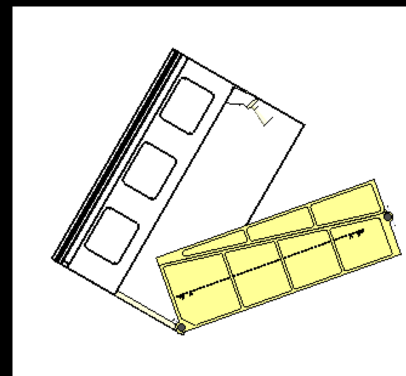
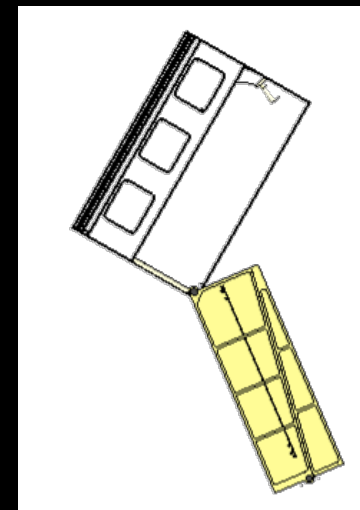
A Novel Offset Mesh Deployable Reflector Configuration allowing for Larger Reflectors

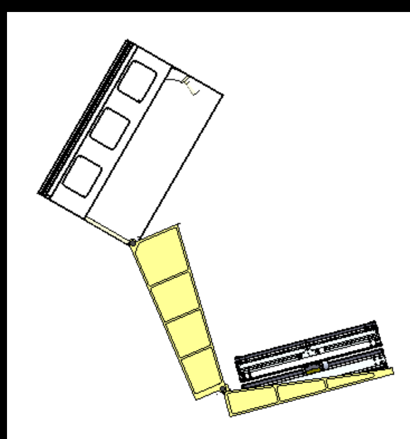
Stowed formation

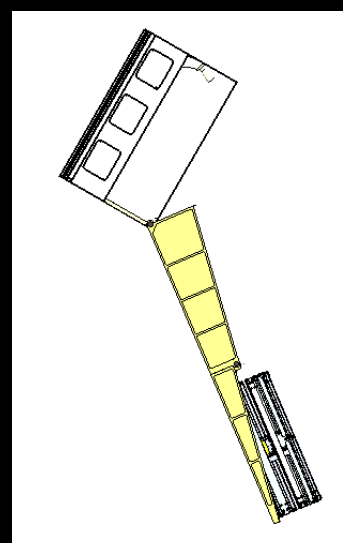


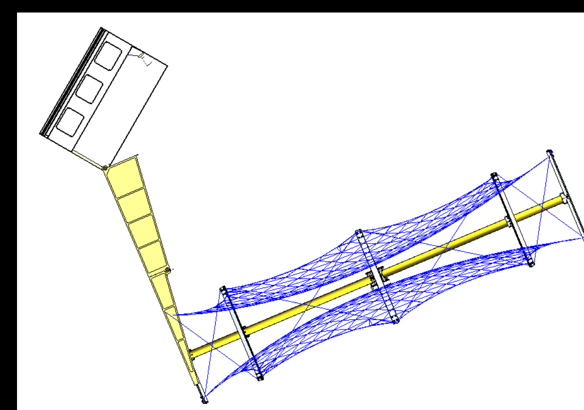




About 2.5 U







Science community desires 1.0 m antennas

1.0 m projected aperture after deployment.

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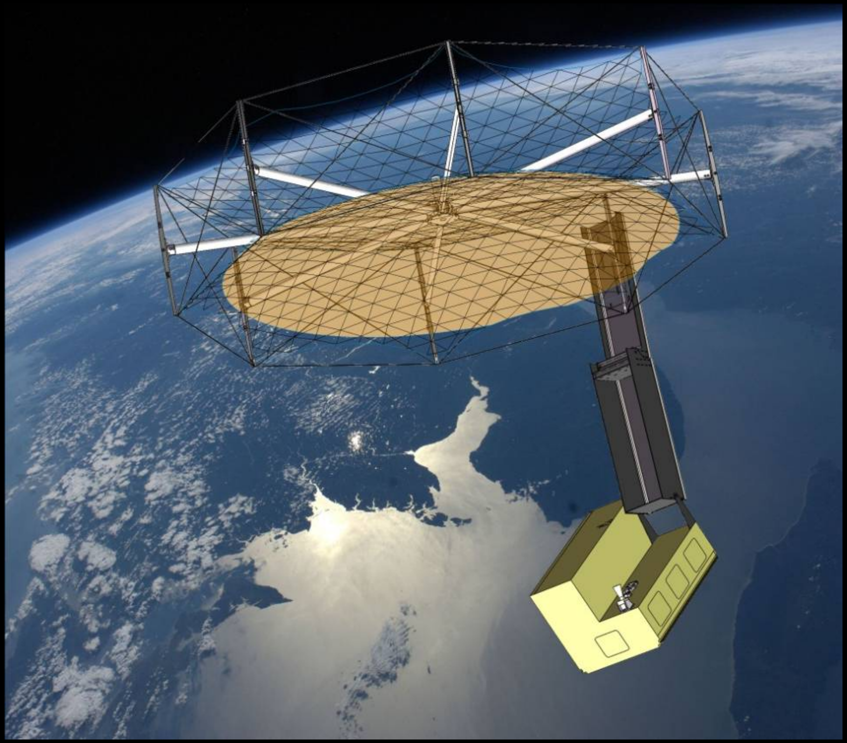
In the process of RF design of a mesh deployable reflector antenna many questions need to be answered

Effects of the mesh

Surface rms

Optimal focal point



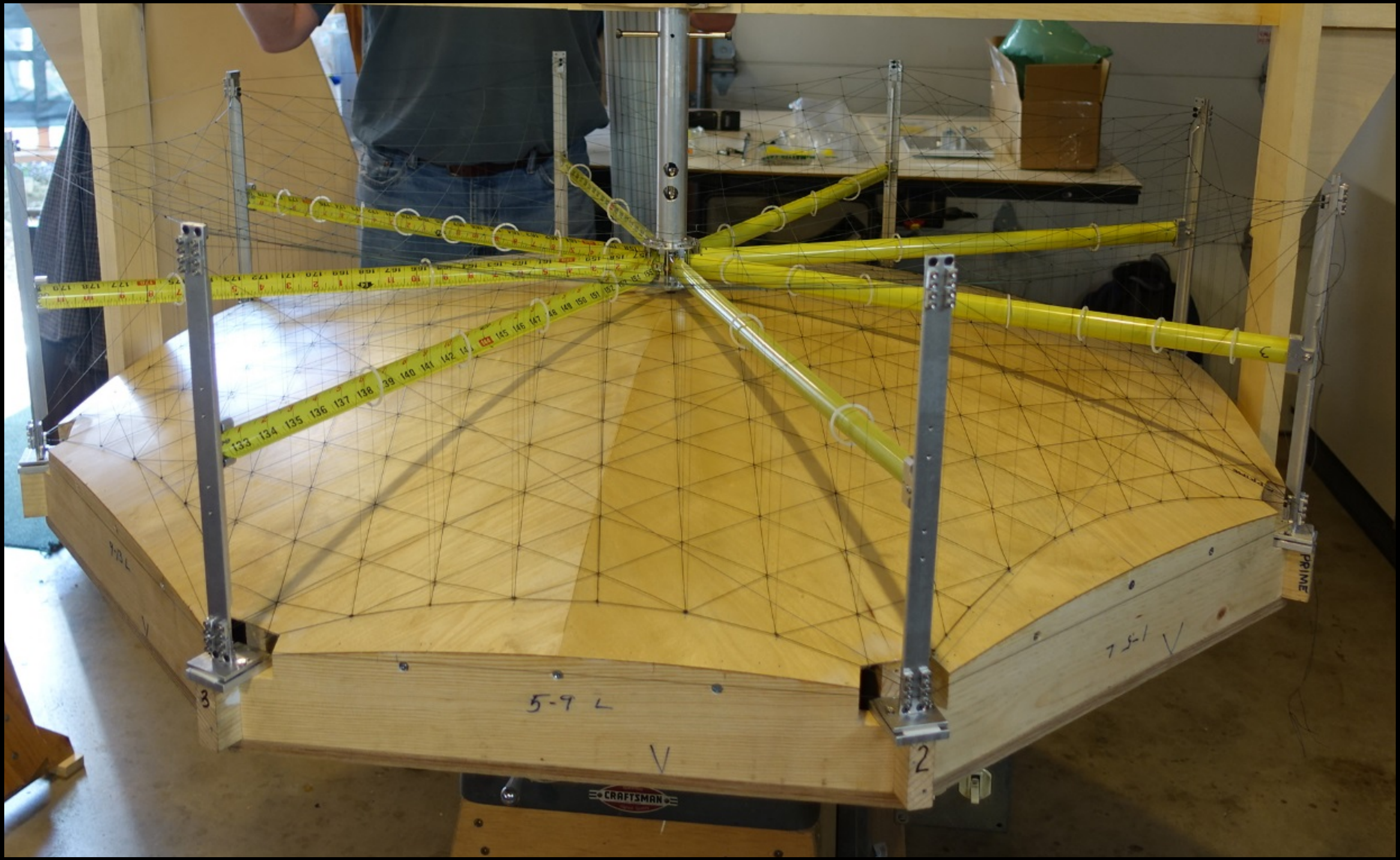
Effects of boundary truncation

Number of ribs

This is best represented by various efficiency components:

$$\eta = e\,\eta_t\,\eta_s\,\eta_b\,\eta_p\,\eta_{sq}\,\eta_{rms}\,\eta_g\,\eta_{tr}\,\eta_m\,\eta_{sc}\,\eta_{vswr}\,\eta_{st}\,\eta_{bl}\,\eta_{um}$$

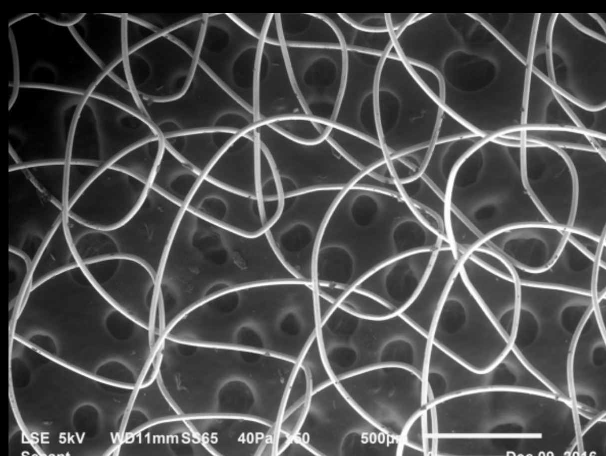
Breadboard of 1.0 m Offset Mesh Antenna



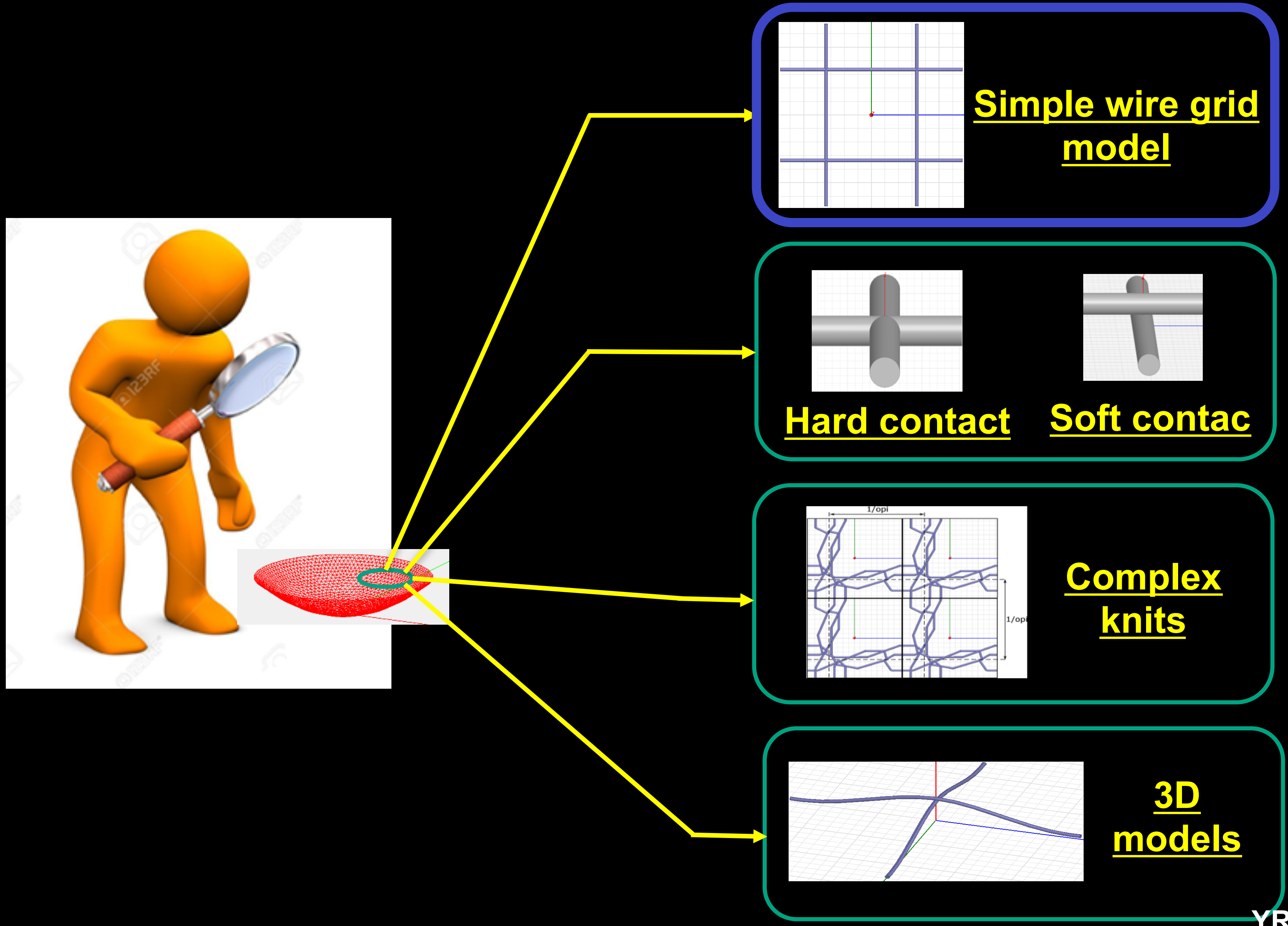
Tendeg LLC’ s tensegrity design utilizing spiral wrapped ribs as the compression members and tensioned offset dual nets.

A Potential Mesh Surface Under Development

30 OPI gold plated wires



Detailed Analysis of Complex Mesh Surfaces



Equivalent Wire Grid model for complex knits

Full wave analysis

Complex mesh

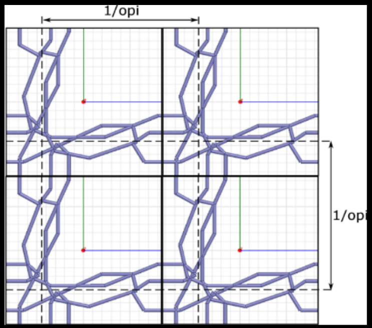
↓

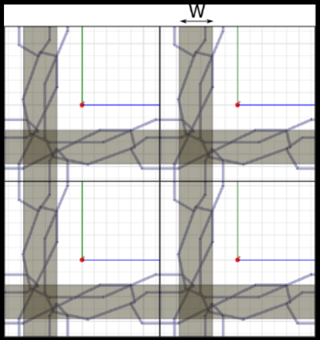
Build an equivalent strip model

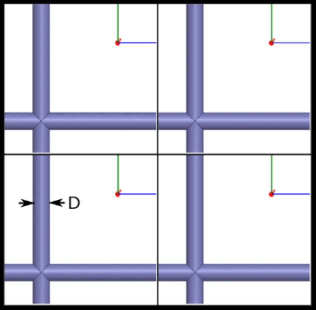
↓

Build the equivalent wire-grid model using strip-wire equivalence (D=W/2)

Analytical formulation







Strip Wire Equivalence:

$$Diameter\ of\ wire(D) = \frac{Strip\ Width\ (W)}{2}$$

OPI	ΔG (dB)		
	Tricot knit mesh	Wire grid model	
		D=0.0008"	D=W/2
20	-0.56	-2.53	-0.42
30	-0.19	-1.01	-0.19
40	-0.09	-0.47	-0.10
	Reference	Bad	Good

Good match is seen between the complex knit surface and the EQUIVALENT wire grid model for normal incidence

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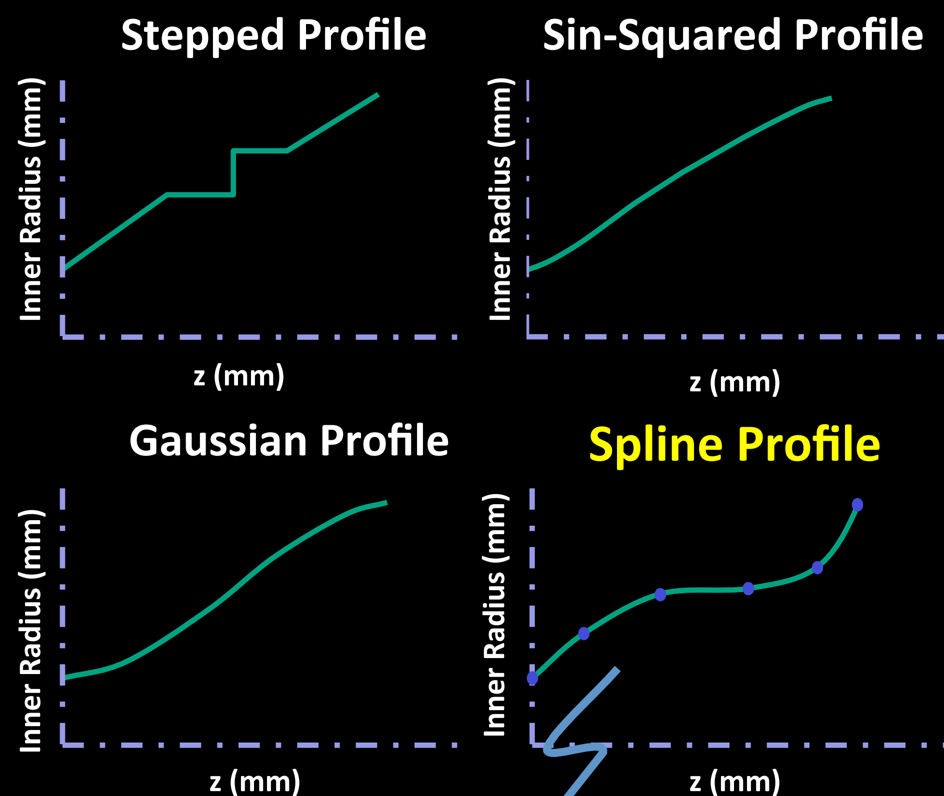
Novel Optimized Profiled Feed Horn Design

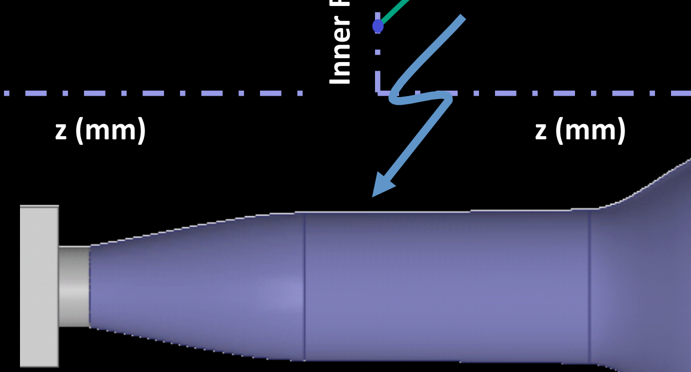
Standard horn designs could become large and not satisfying the desired performance requirements.

Many other options are available to horn designers, but not all designs fit the requirements

The spline profile allows to generalize the profile and apply optimization to meet the requirements

Splines can also be defined to satisfy certain analytical conditions such as monotonicity, etc to ease fabrication





Example of Spline-Profile

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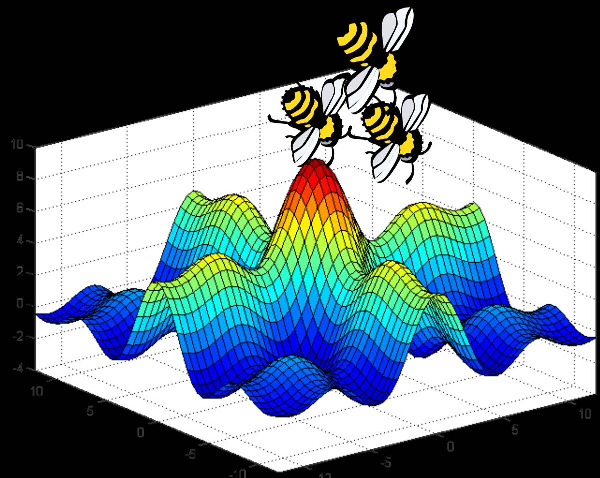
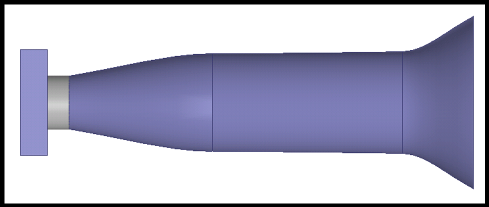
Particle Swarm Optimization (PSO):
Optimized miniaturized profiled feed horn

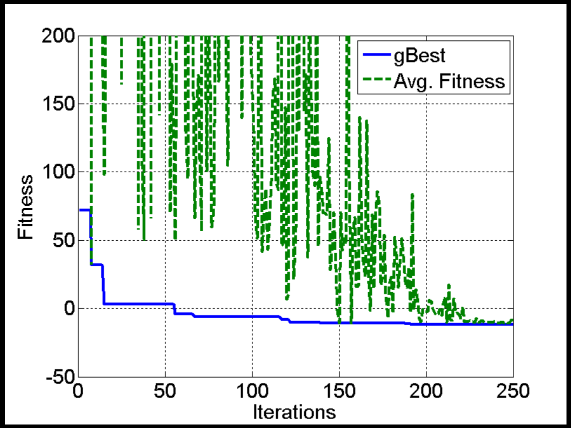


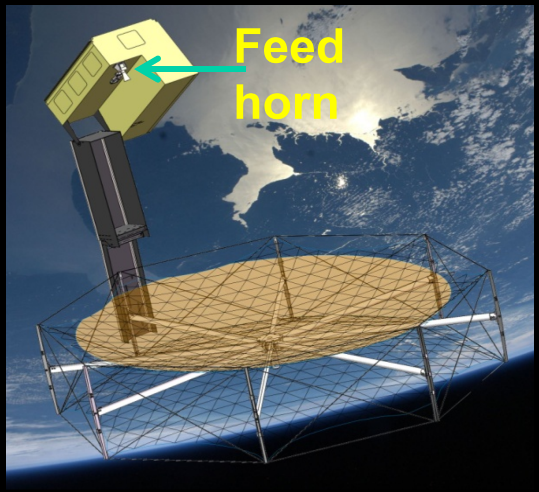
L = 4.6 cm

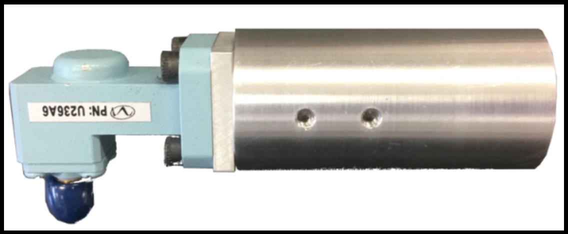


D = 2.0 cm

Convergence







Inside is profiled

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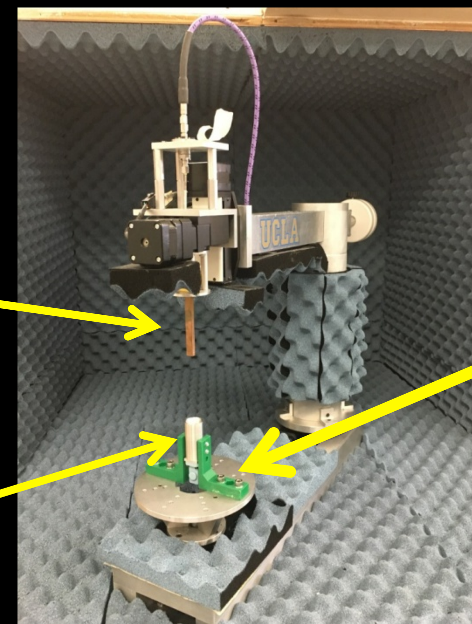
Horn Measurement at UCLA mm-wave Bi-polar Planar Near-Field Facility

A table-top mm-wave chamber at UCLA

Probe

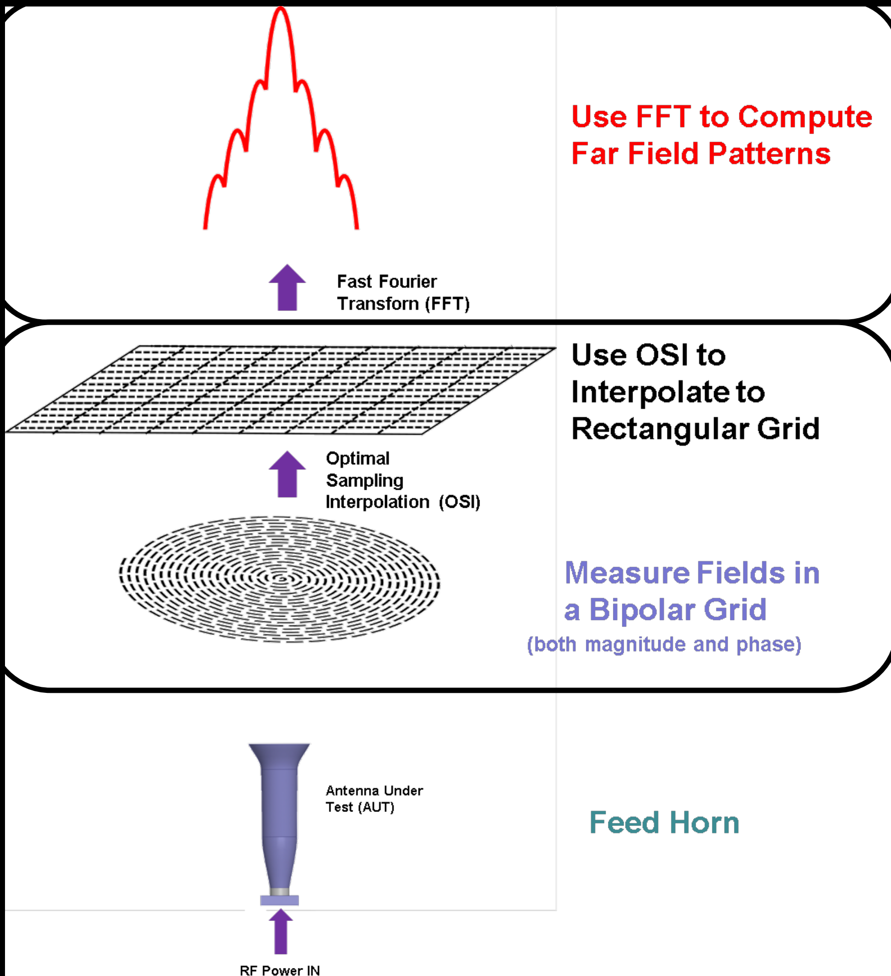
Optimized Feed Horn

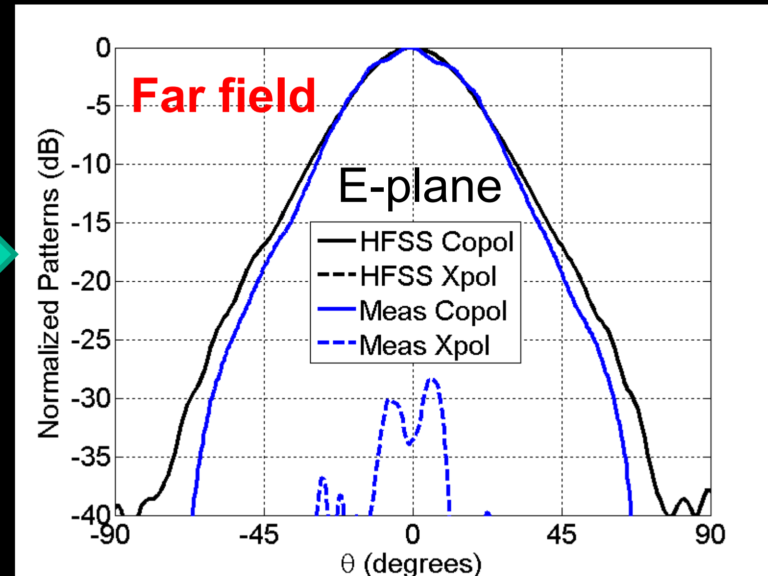


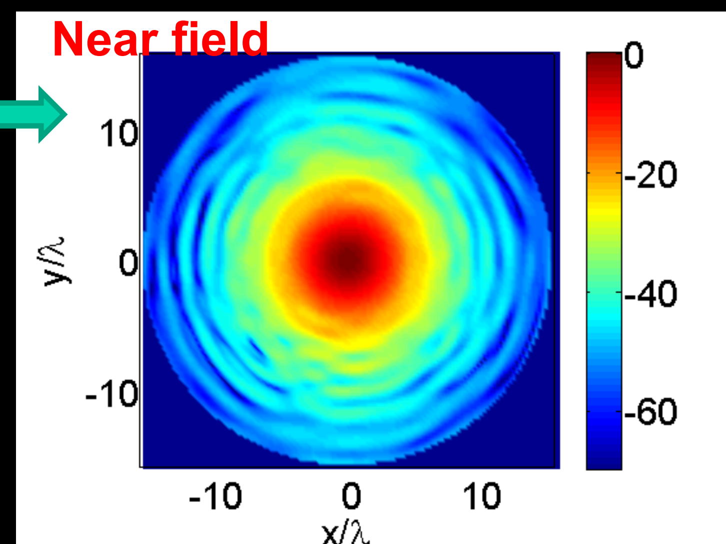
3D Printed brackets

Configure Vector Network Analyzer (VNA) & Motor Controller from a Master Computer Controller

Feed Far Field Patterns from Measured Near Field







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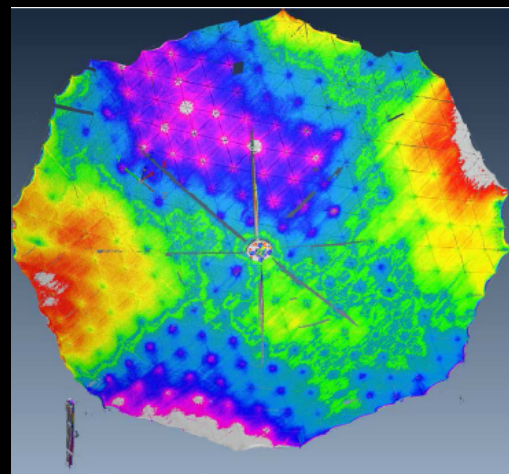
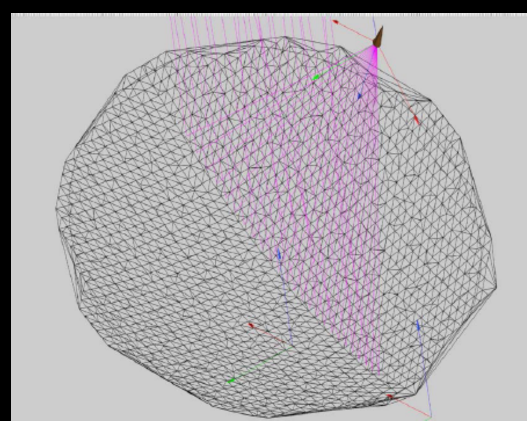
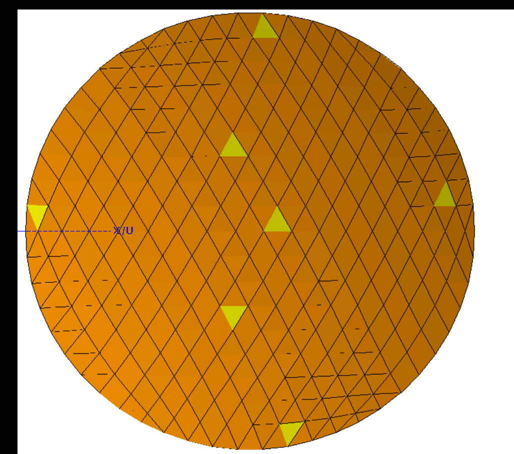
Tendeg's Initial Surface Measurements and Representative Antenna Profile

Reflector surface measurements





Surface profile based on measurements



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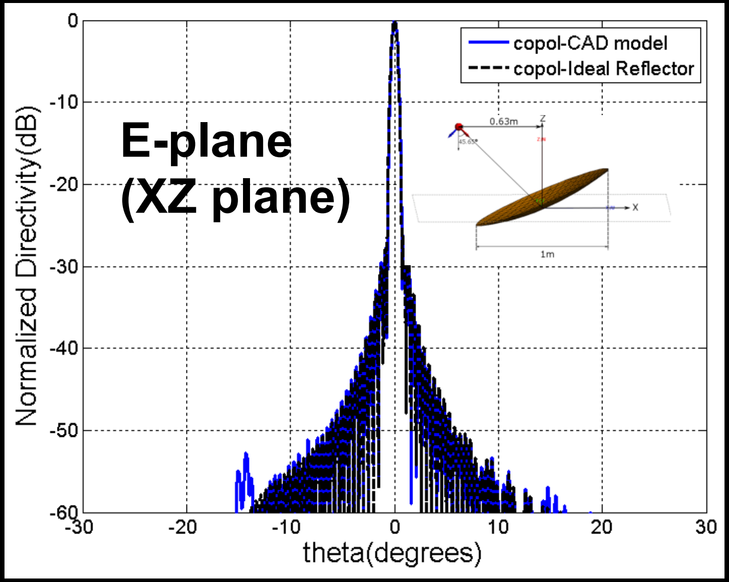
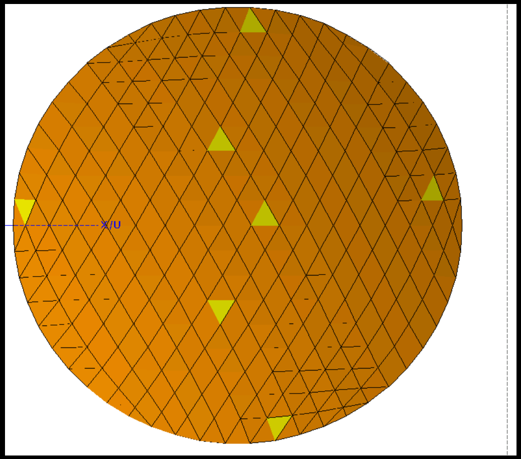
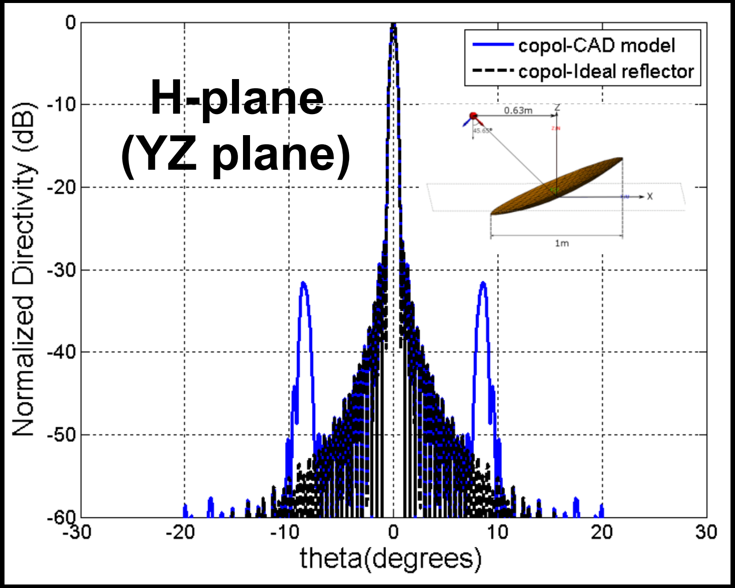
Ideal vs. Non-ideal Simulated Reflector Patterns at 35.75 GHz





Non-ideal Surface profile based on measurements



Directivity and Beamwidth Table

	CAD model	Ideal Reflector
Directivity at boresight	50.06 dB	50.15 dB
HPBW (E-plane)	0.56°	0.56°
HPBW (D-plane)	0.56°	0.56°
HPBW (H-Plane)	0.57°	0.56°

Note: Actual gain, yet to be measured, will be lower than directivity.

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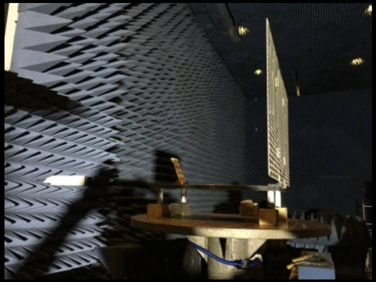
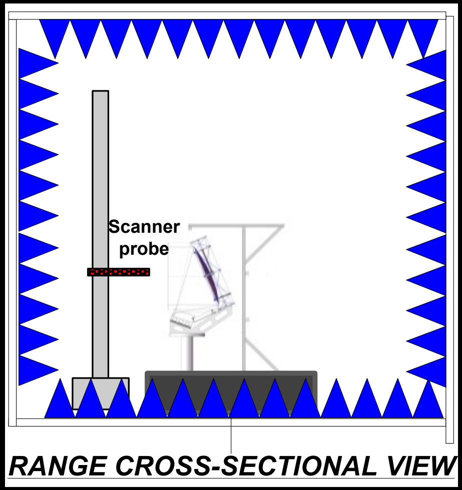
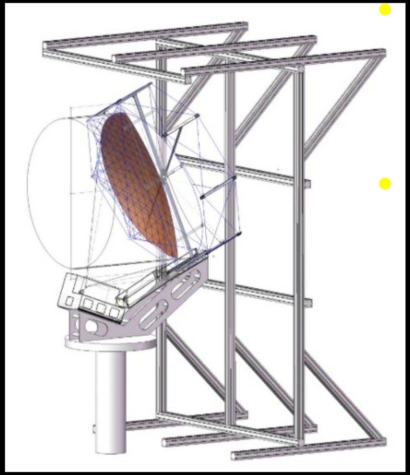
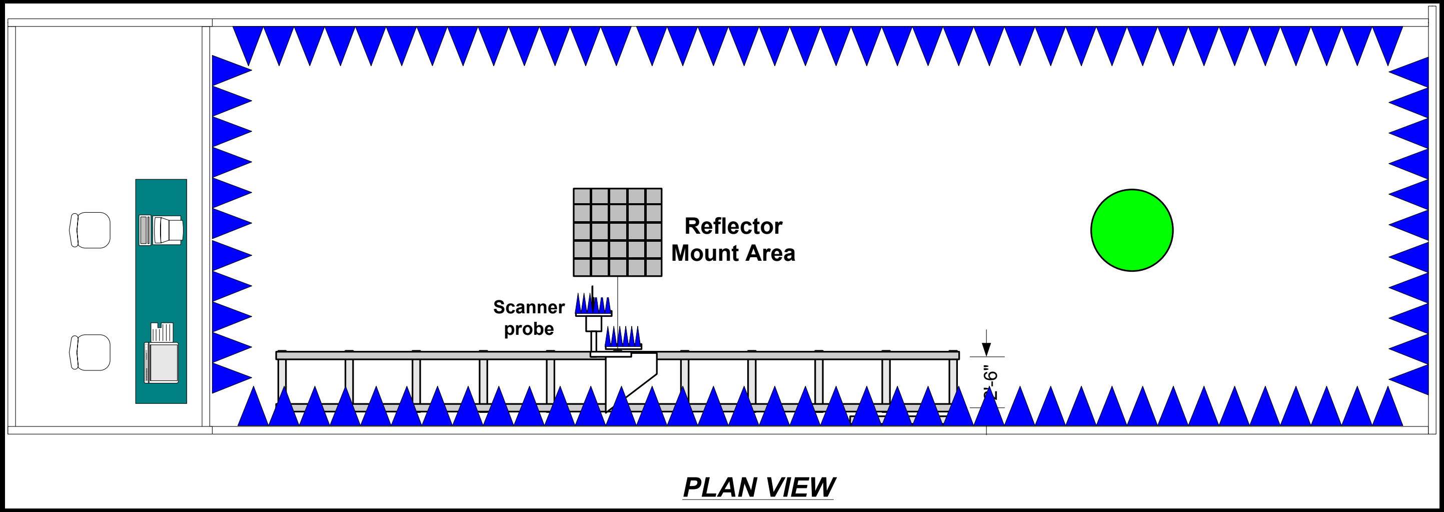


Measurement Campaign at JPL Antenna Near Field Range before the End of 2017





- **GSE Support Structure**
  - Provide gravity offload
  - Simulate RF scattering of typical s/c
- **JPL Planar Nearfield Scanner**
  - Proven Ka-band test facility
  - AUT is stationary – simplifies gravity offload
  - Indoor measurement – no thermal, wind load or weather issues
  - Compatible with metrology equipment



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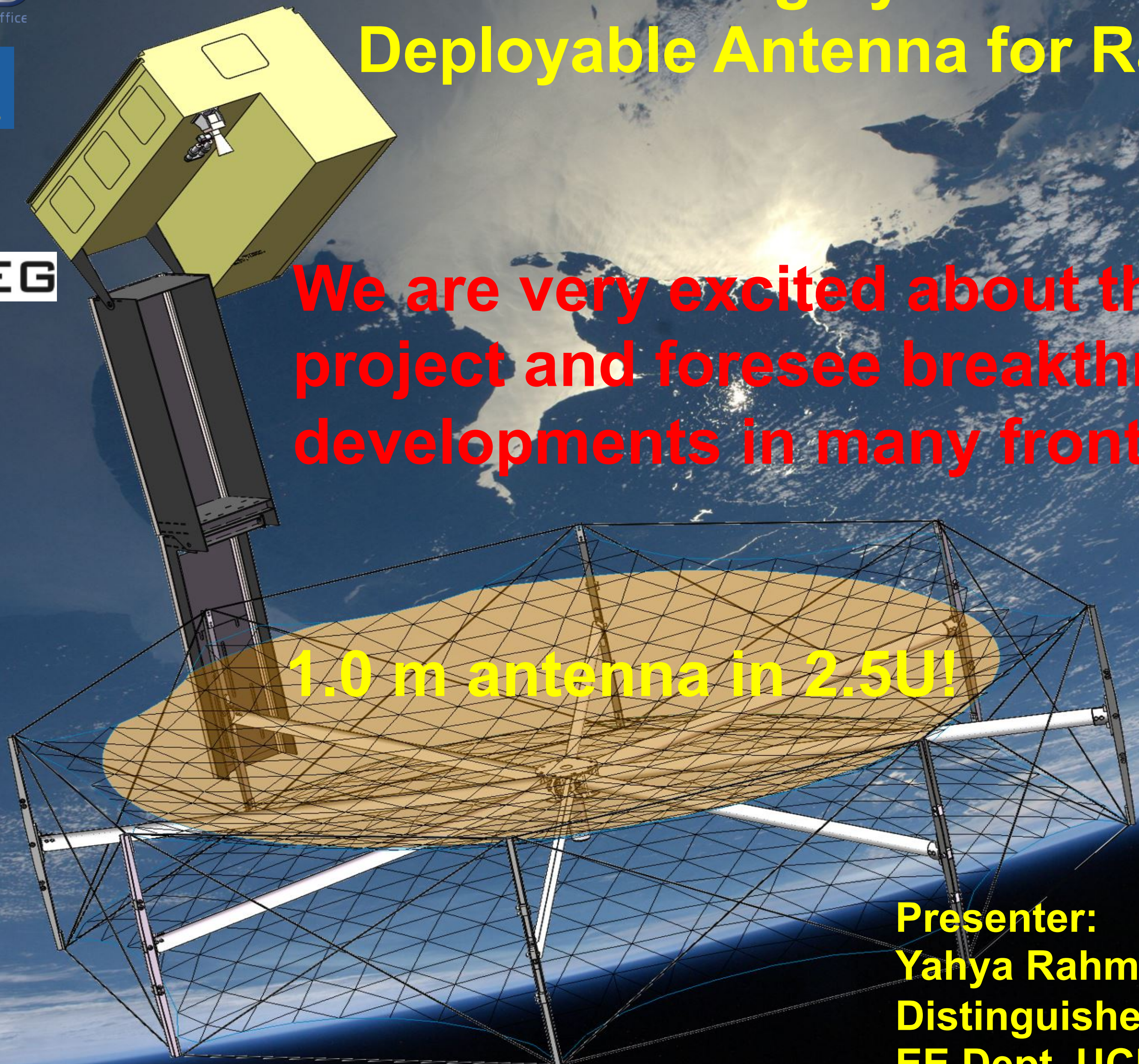
We are very excited about this project and foresee breakthrough developments in many fronts.



1.0 m antenna in 2.5U!

Presenter:
Yahya Rahmat-Samii
Distinguished Professor
EE Dept. UCLA

Thank you

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