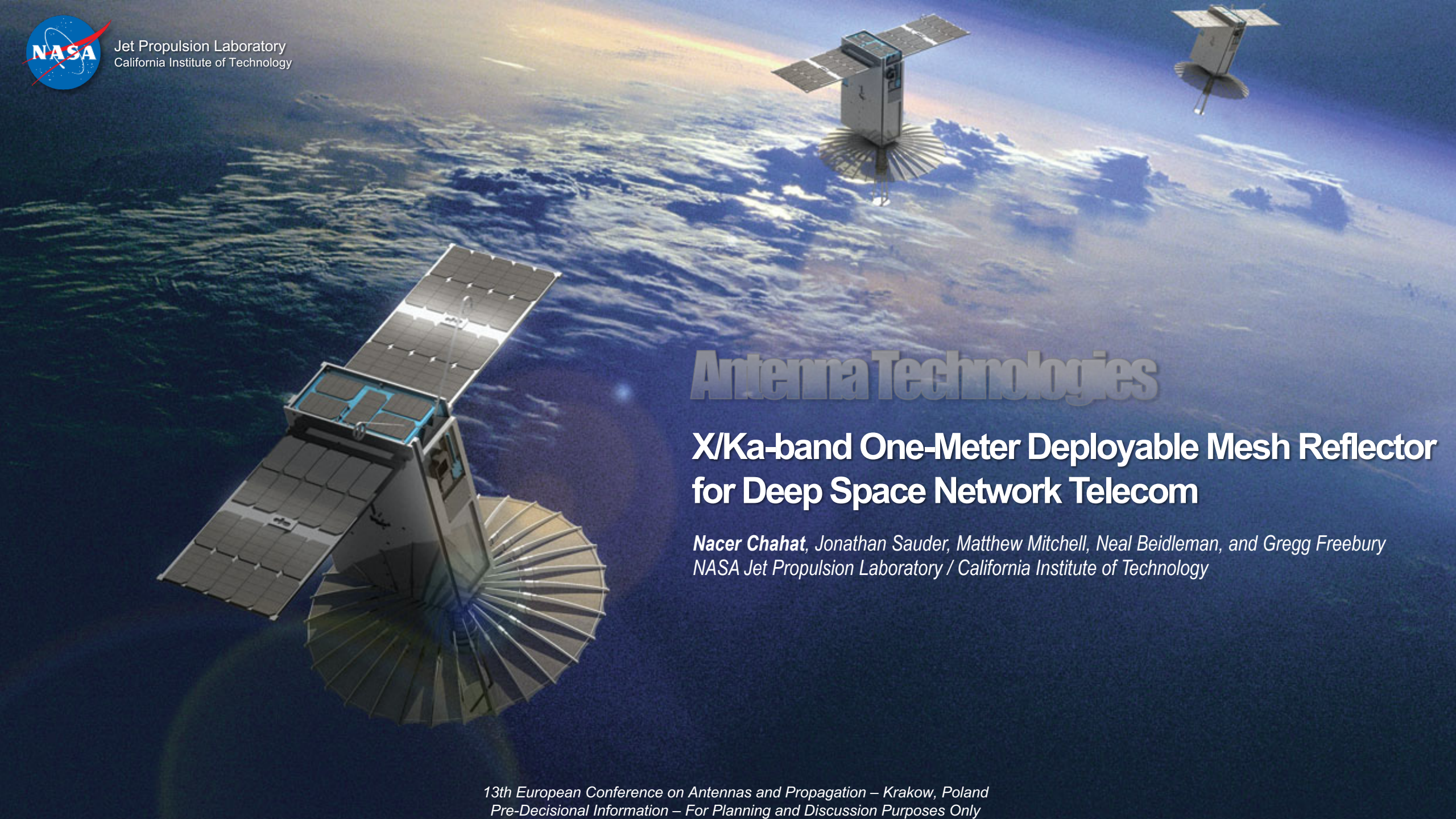


Jet Propulsion Laboratory
California Institute of Technology

Arterra Technologies

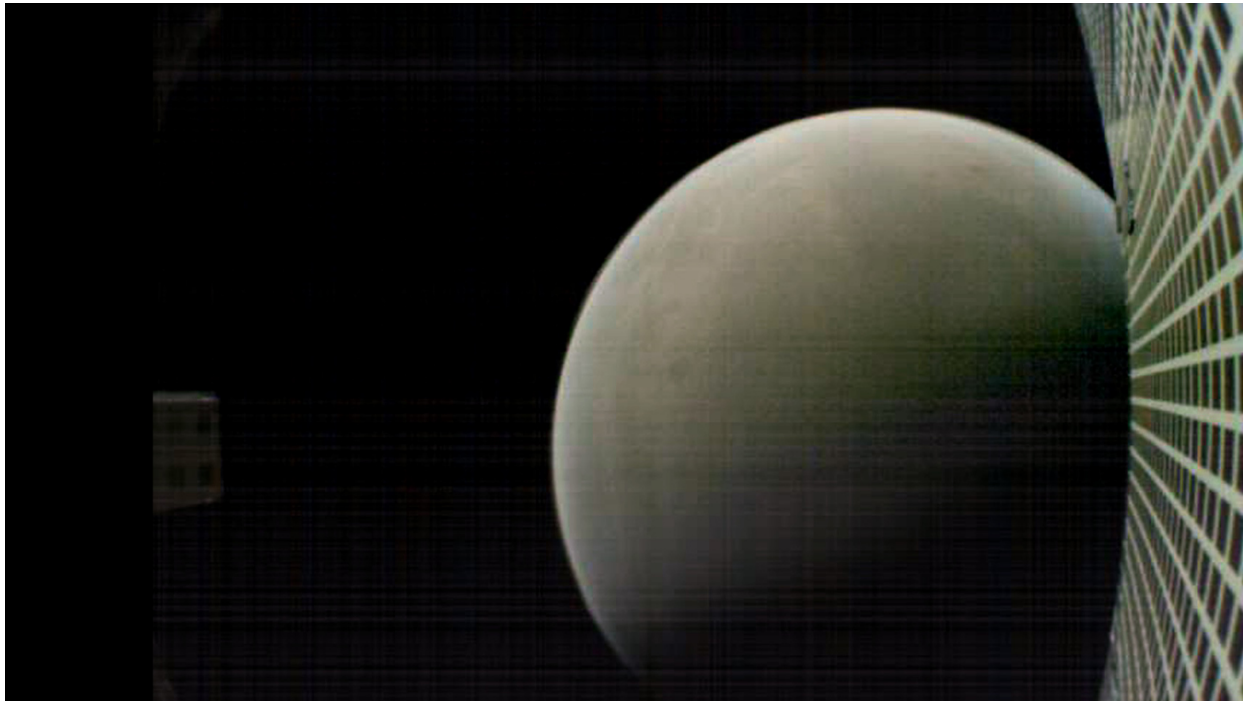
X/Ka-band One-Meter Deployable Mesh Reflector for Deep Space Network Telecom

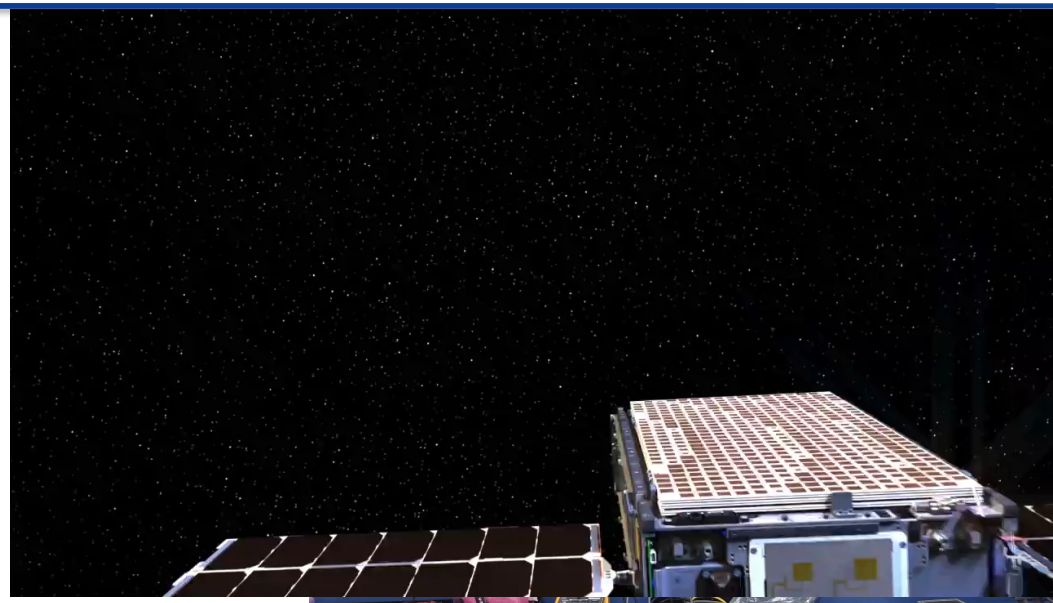
Nacer Chahat, *Jonathan Sauder, Matthew Mitchell, Neal Beidleman, and Gregg Freebury*
NASA Jet Propulsion Laboratory / California Institute of Technology

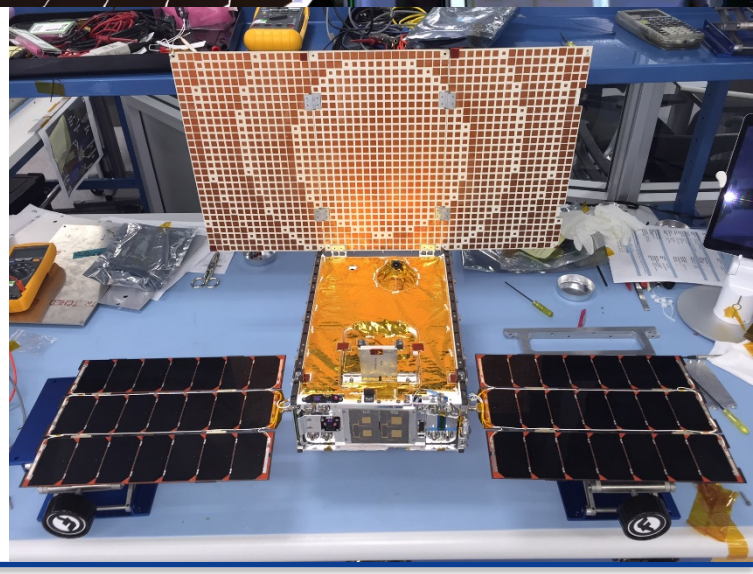
13th European Conference on Antennas and Propagation – Krakow, Poland

Mars Cube One: the first Deep Space CubeSat

- **Demonstrated in Space**:
  - Successful deployment of two antennas in space
  - Gain assessment in flight has shown that the gain is within ±0.4dB.
  - Pattern successfully verified in space
- Achieved 8kbps real-time communication from Mars (~1AU)
- **An historical accomplishment witnessed by a picture**



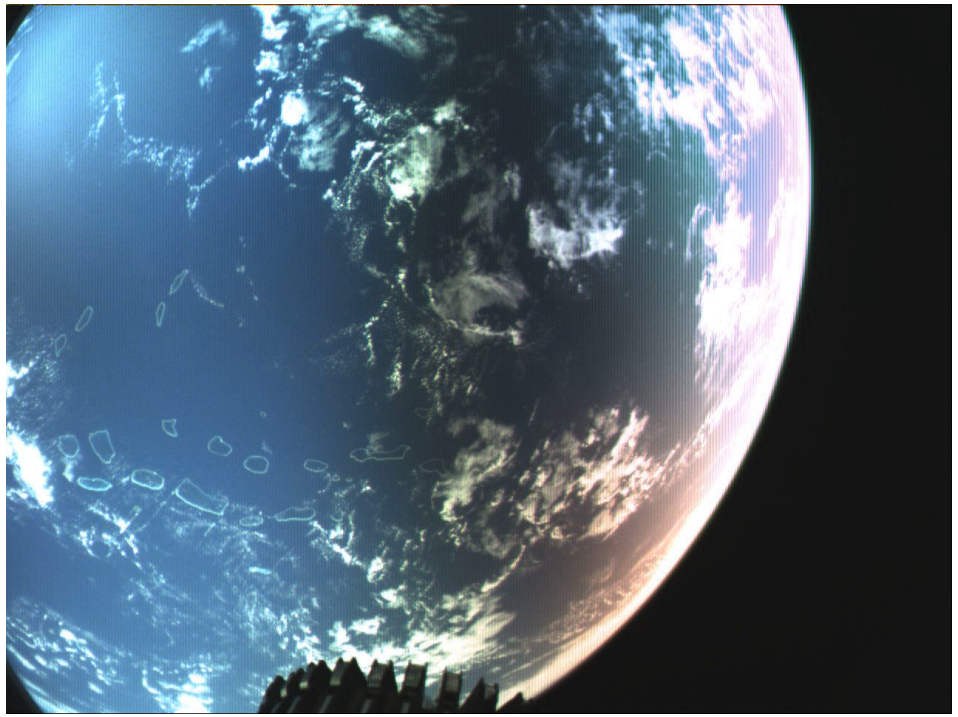


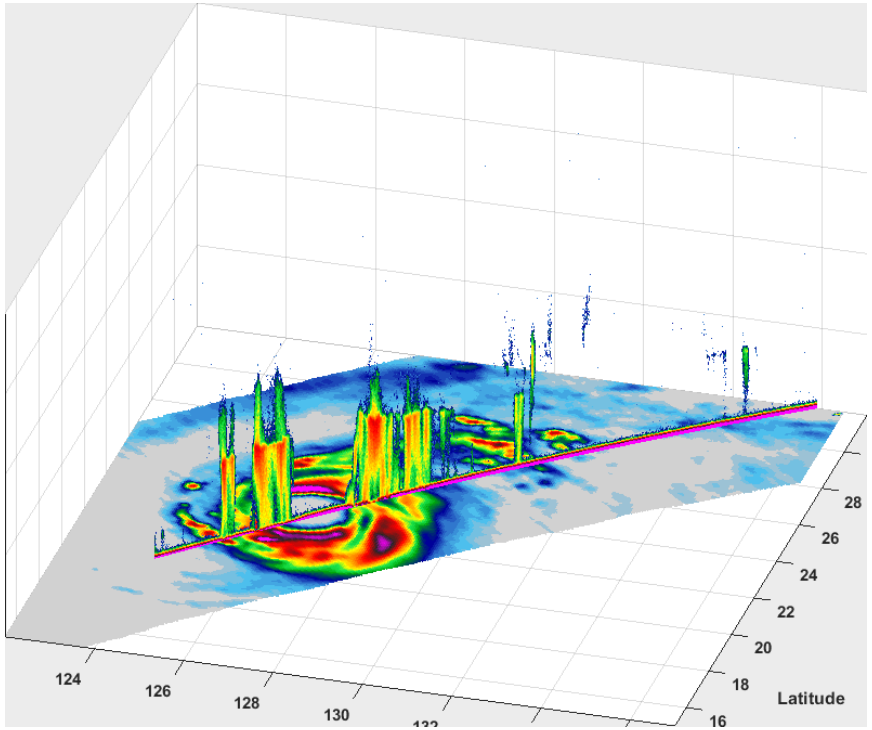


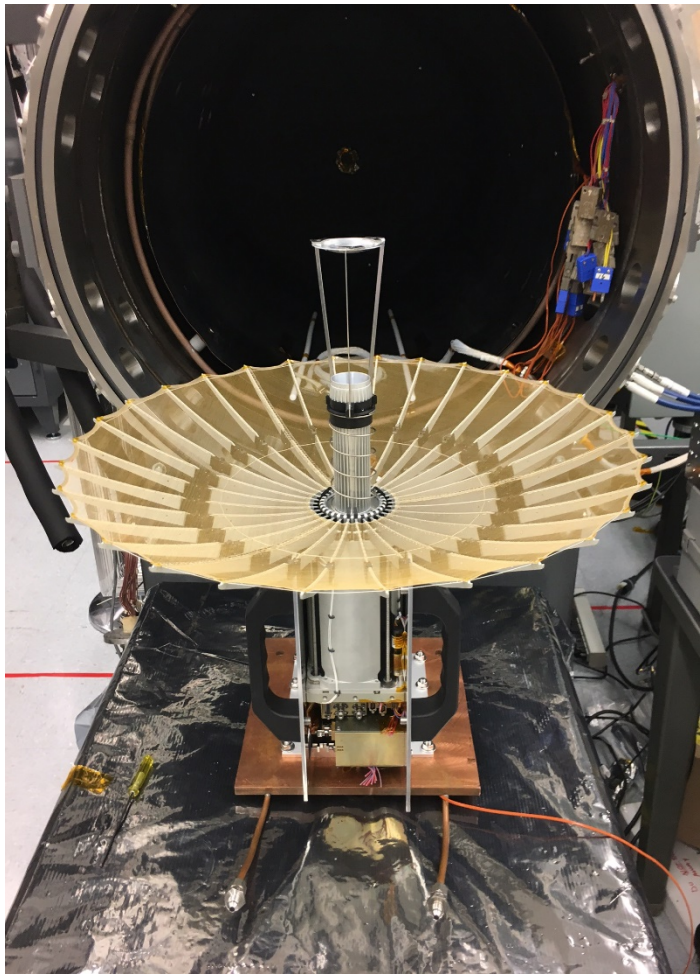
N. Chahat, "A mighty antenna from a tiny CubeSat grows," *IEEE Spectrum*, vol. 55, no. 2, pp. 32-37, Jan. 2018.

RainCube: The first active Radar in a CubeSat

- **Demonstrated in Space**:
  - 0.5m deployable antenna folding into 1.5U (10cm×10cm×15cm)
  - Released from ISS successfully on July 13 2018.
  - Successfully deployment of the 0.5m mesh reflector in space
  - 42.6dBi gain achieved with HPBW of 0.57degree and 56% efficiency
- **Collecting critical science in Low Earth Orbit**



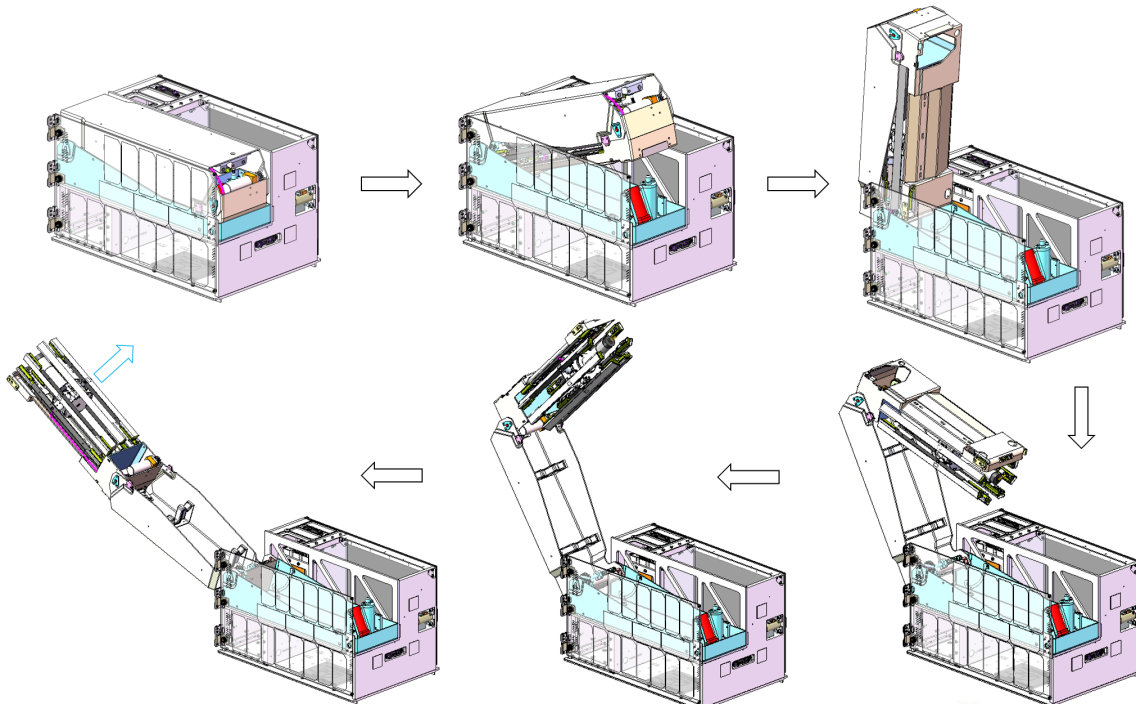


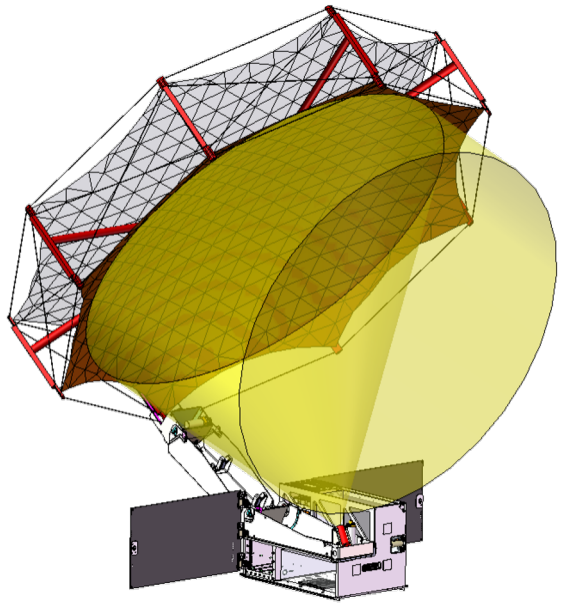


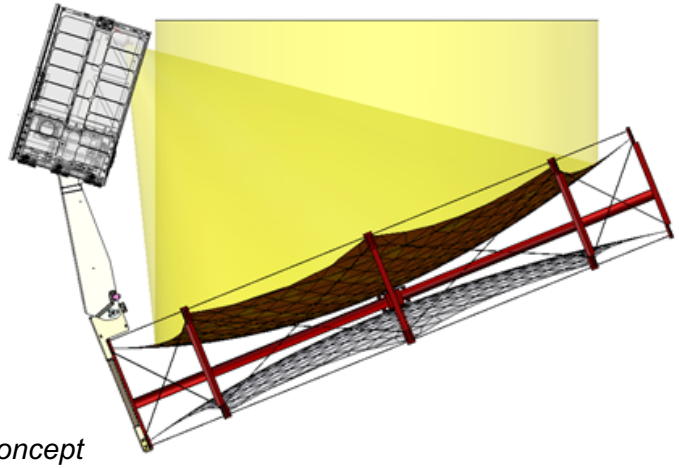
N. Chahat *et al.*, "CubeSat Deployable Ka-band reflector antenna development for Earth Science Mission," *IEEE Trans. Antennas and Propagation*, vol. 64, no. 6, pp. 2083-2093, June 2016.

Toward Larger Aperture for Telecommunication

- **Objective:**
  - Future CubeSats will need higher data-rate at X-band and Ka-band
  - One meter reflector will allow to achieve
    - 64kbps at 1AU at X-band (~×8 increase compared to MarCO)
    - XXXkbps at 1AU at Ka-band
  - Compatible with 12U-class CubeSat and will fit in 3U
- **Antenna description:**



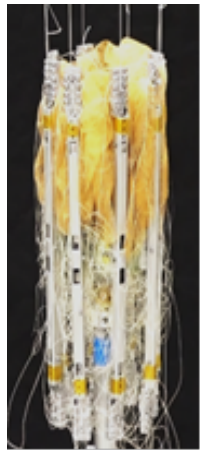
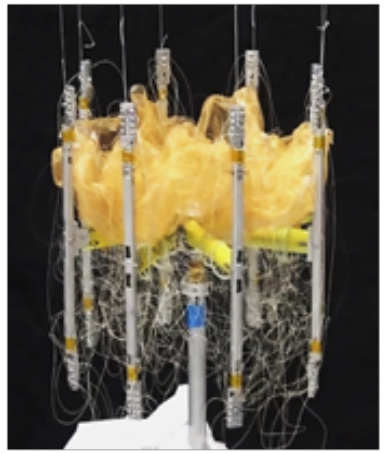
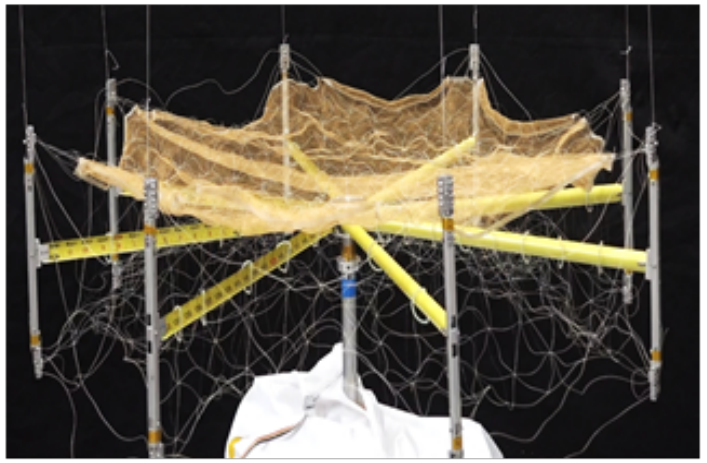
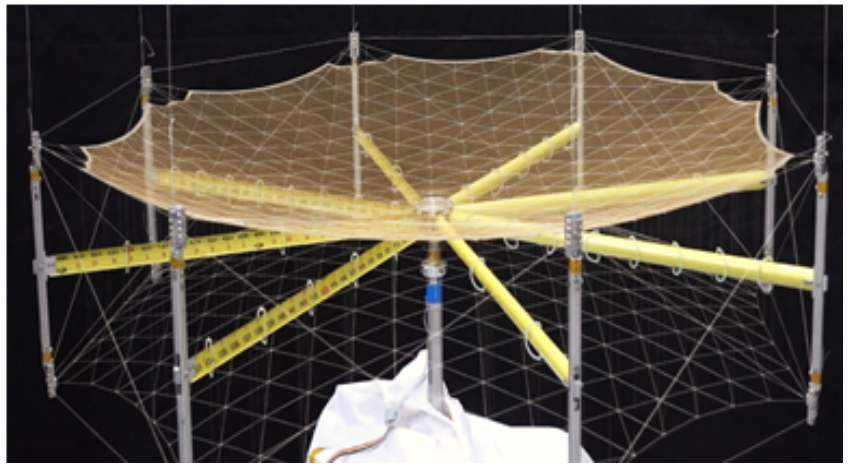




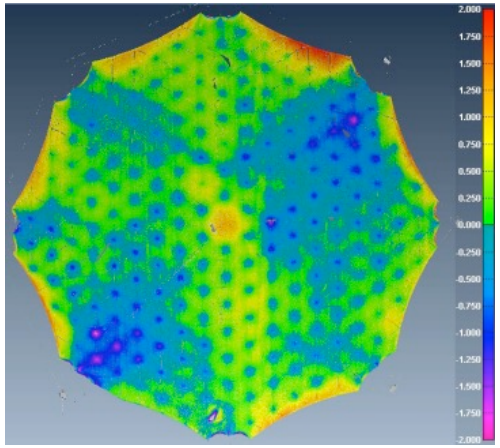
Artist's Concept

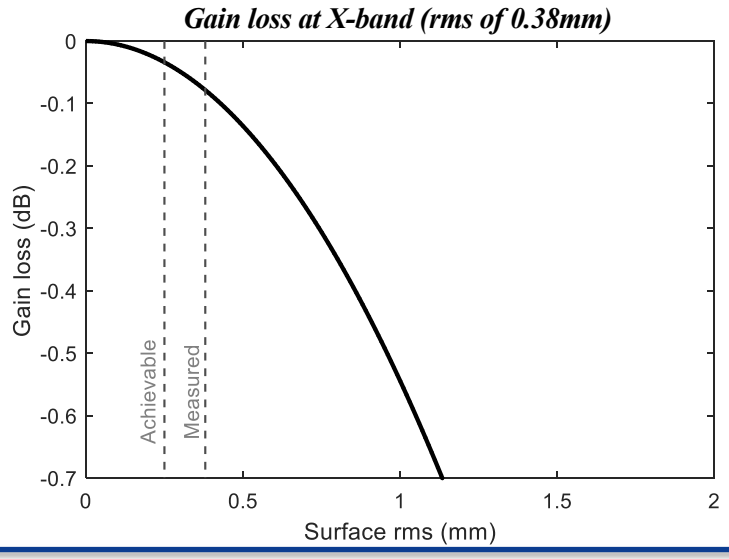
Mesh Reflector

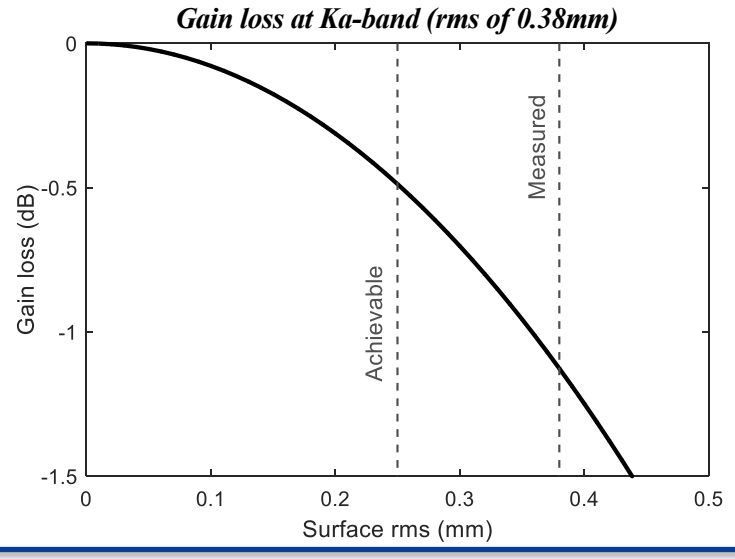
- **Deployment:**

- **Surface accuracy:**

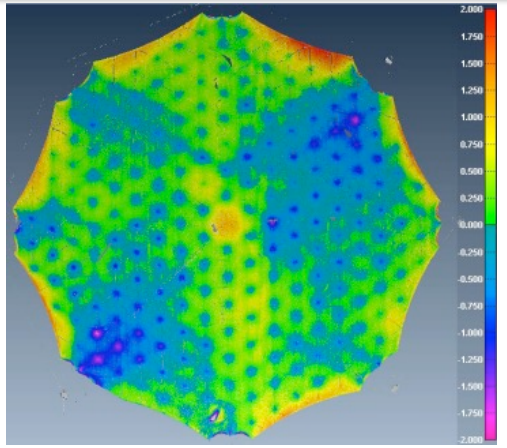




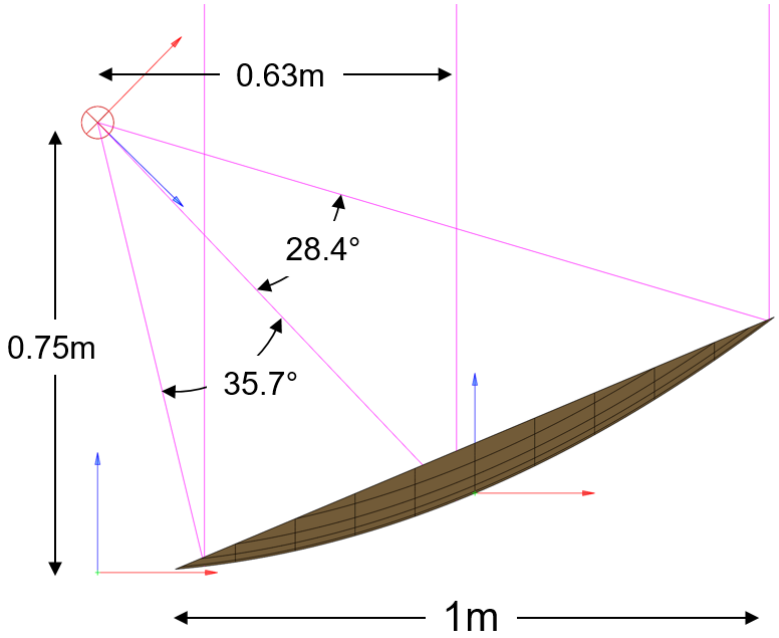


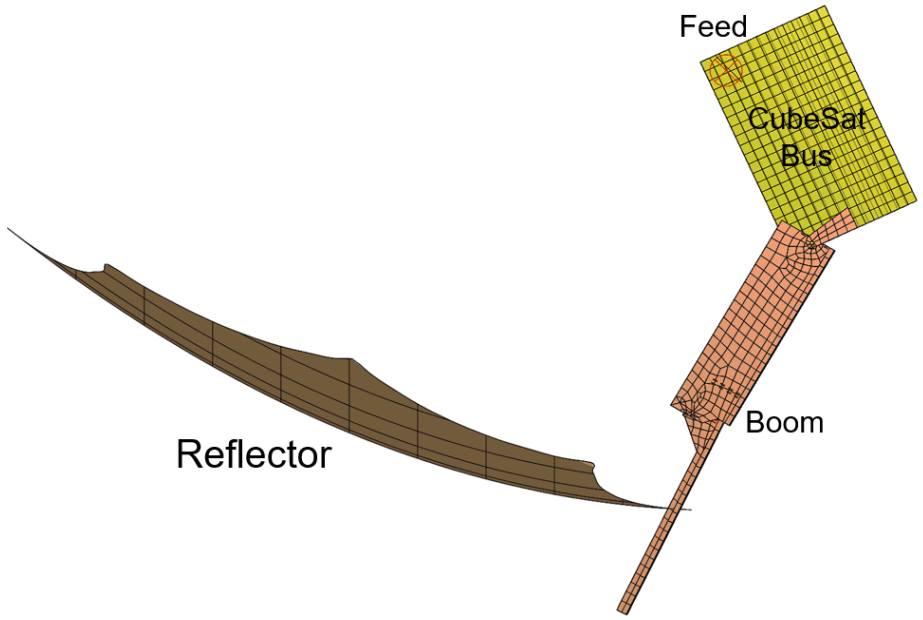
One-Meter Reflector Design

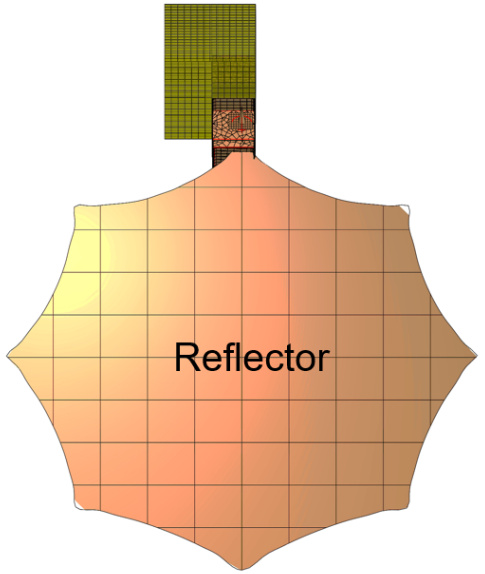
- **Modeling description:**
  - Offset reflector with f/D=0.75
  - Feed performance calculated using full-wave software and imported as a tabulated feed
  - Boom + Bus is represented as MoM object
  - Radiation pattern is calculated using MoM (boom+bus) +PO (reflector)
  - Reflector is represented using:
    - 30 OPI mesh
    - Measured mesh surface using a FERO arm



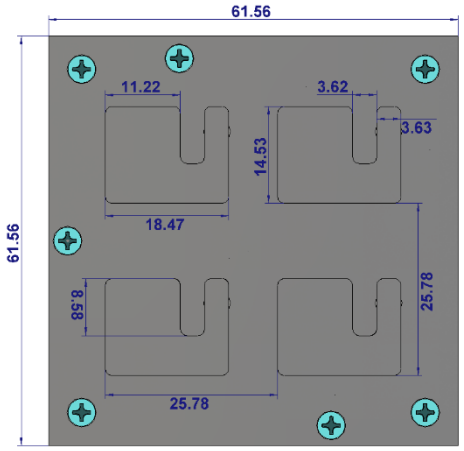
Mesh reflector surface accuracy (rms of 0.38mm)

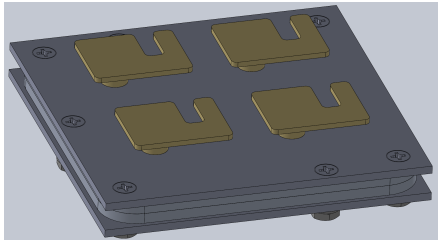




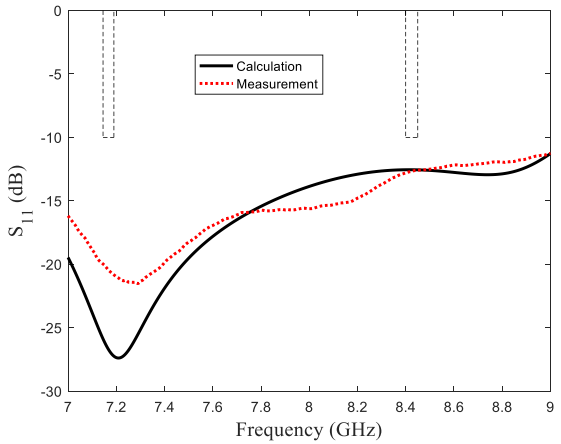


X-band Feed Performance

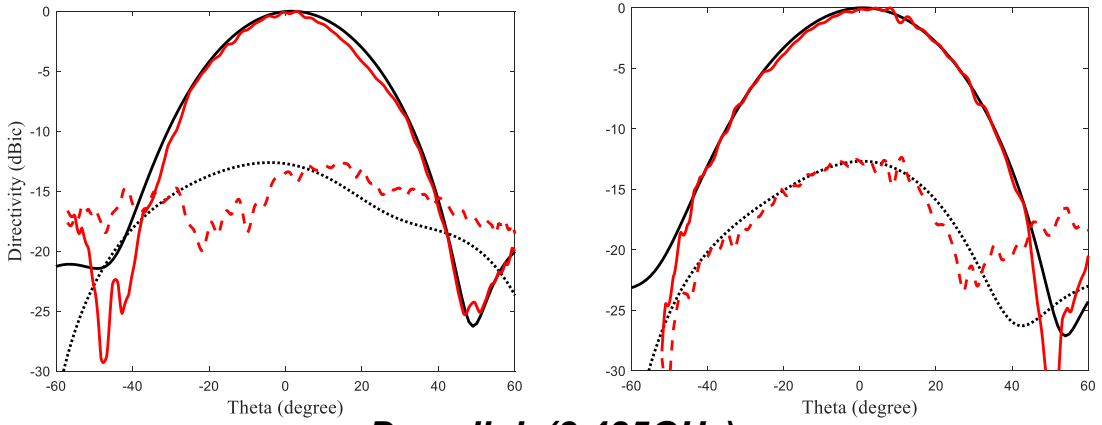




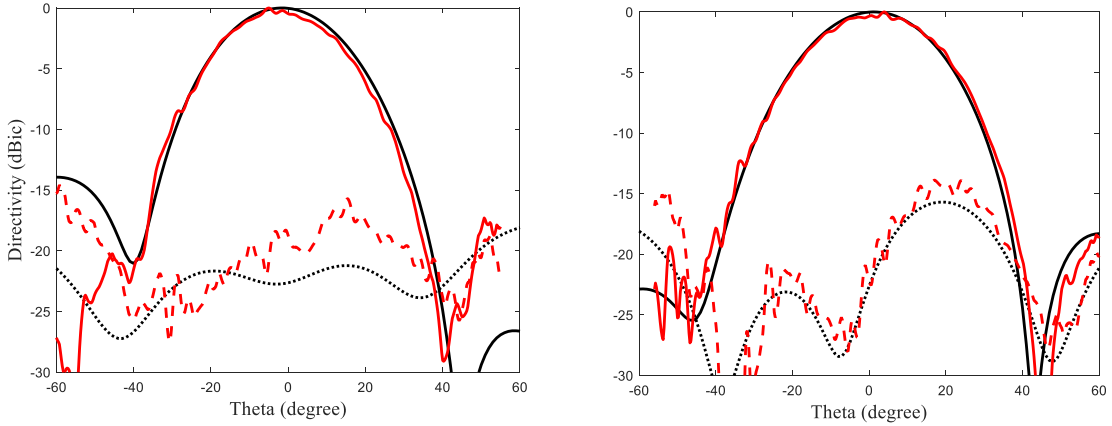
Reflection Coefficient



Uplink (7.19GHz)

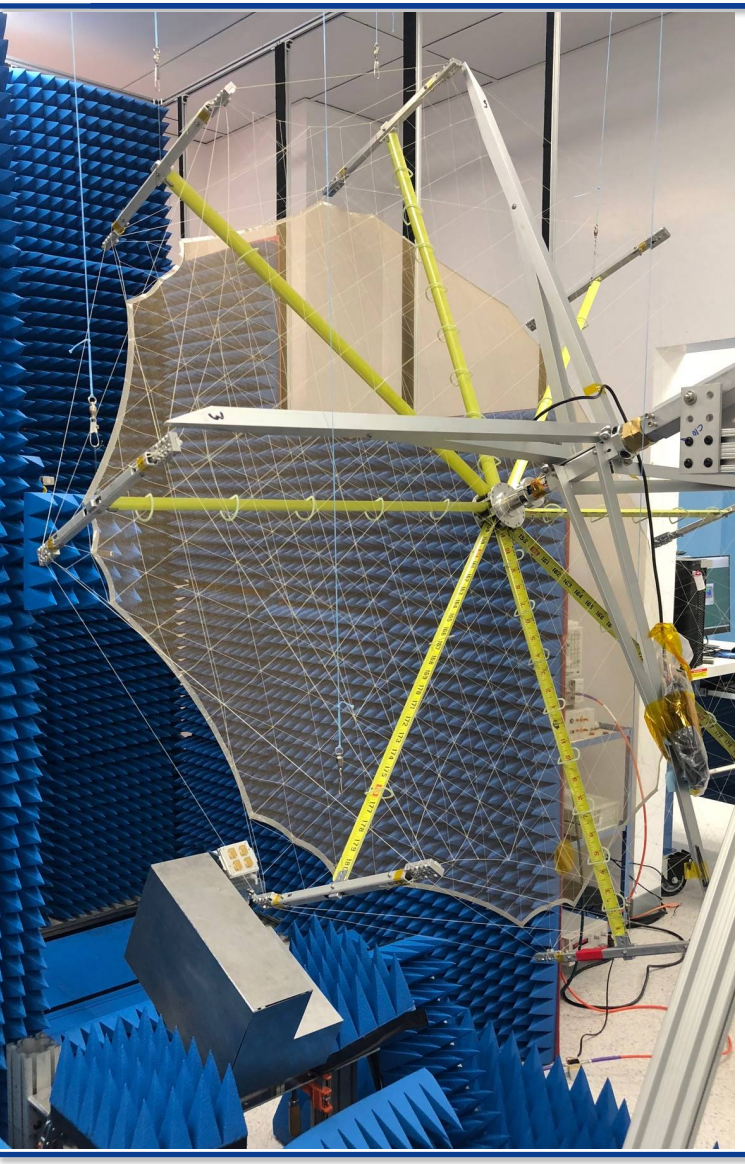


Downlink (8.425GHz)

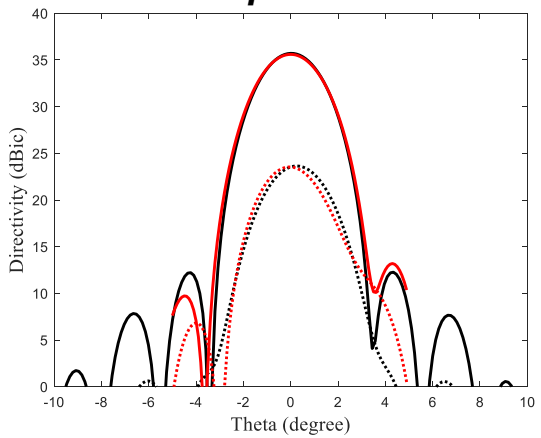


Frequency (GHz)		Directivity (dBi)		Gain (dBic)	
		Calc.	Meas.	Calc.	Meas.
X-band	7.1675	13.5	13.8	13.4	13.1
	8.425	14.3	15.1	14.0	14.0

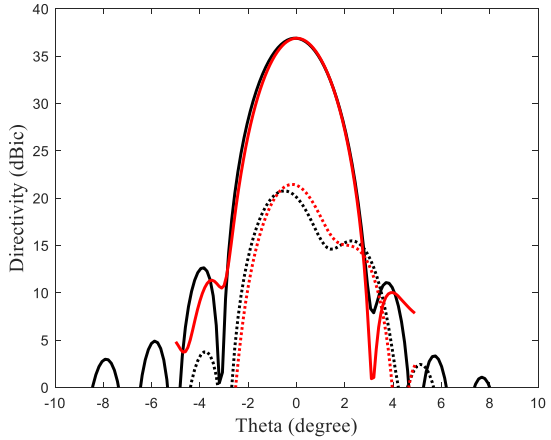
X-band Reflector Performance



Uplink



Downlink



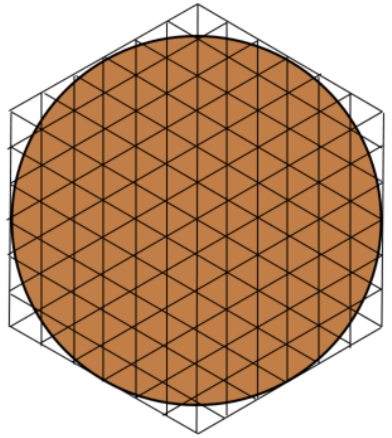
Gain Table at X-band

	Uplink		Downlink	
	Gain (dBic)	Loss (dB)	Gain (dBic)	Loss (dB)
Standard directivity	37.5	-	38.9	-
Taper	37.2	0.3	38.4	0.5
Spillover	36.3	0.9	37.4	1.0
Surface mesh* (30OPI)	36.28	0.02	37.38	0.02
Surface accuracy (±0.38mm)**	36.22	0.06	37.30	0.08
Feed loss	35.92	0.3	37.00	0.3
Feed mismatch (RL=15dB)	35.82	0.1	36.90	0.1
Overall performance	35.82	1.68	36.90	2.00

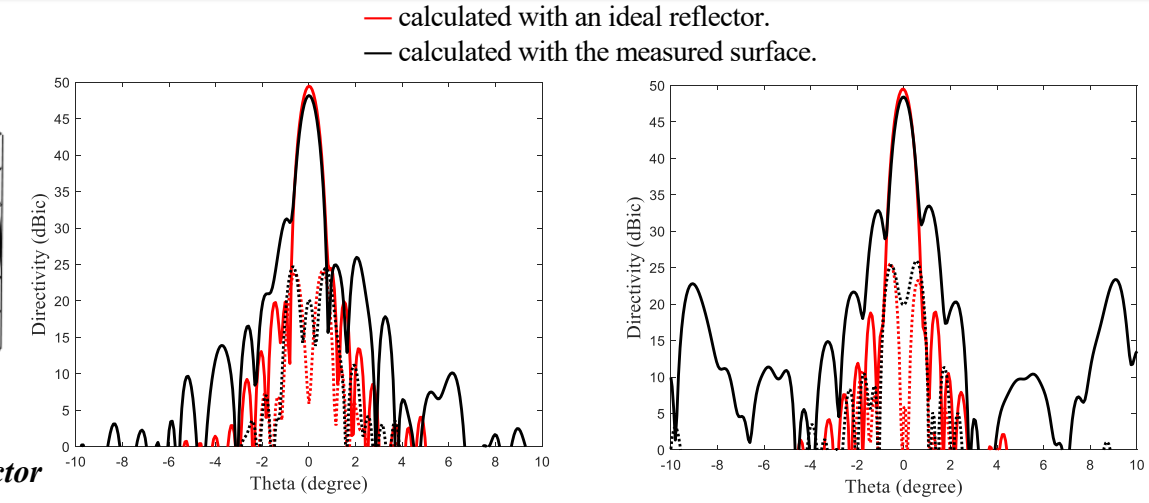
Calculated and measured performance

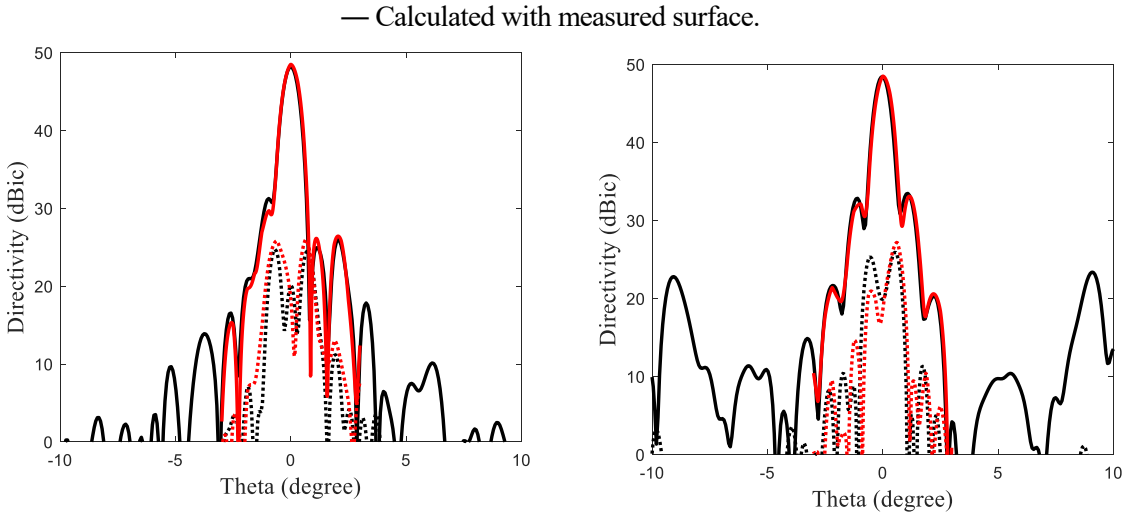
Freq. (GHz)	Directivity (dBi)		Gain (dBic)		Efficiency (%)	
	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.
7.1675	36.3	36.9	35.8	36.1	68	72
8.425	37.4	38.2	36.9	36.8	64	62

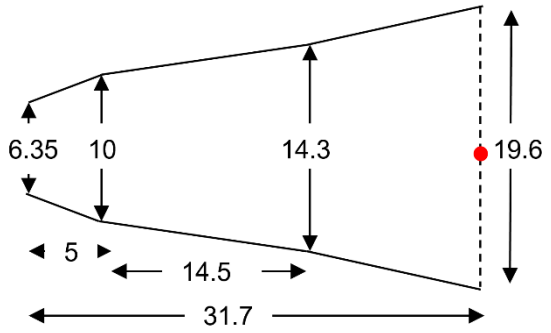
Ka-band Reflector Performance



Uniform hexagonal mesh reflector causing grating lobes







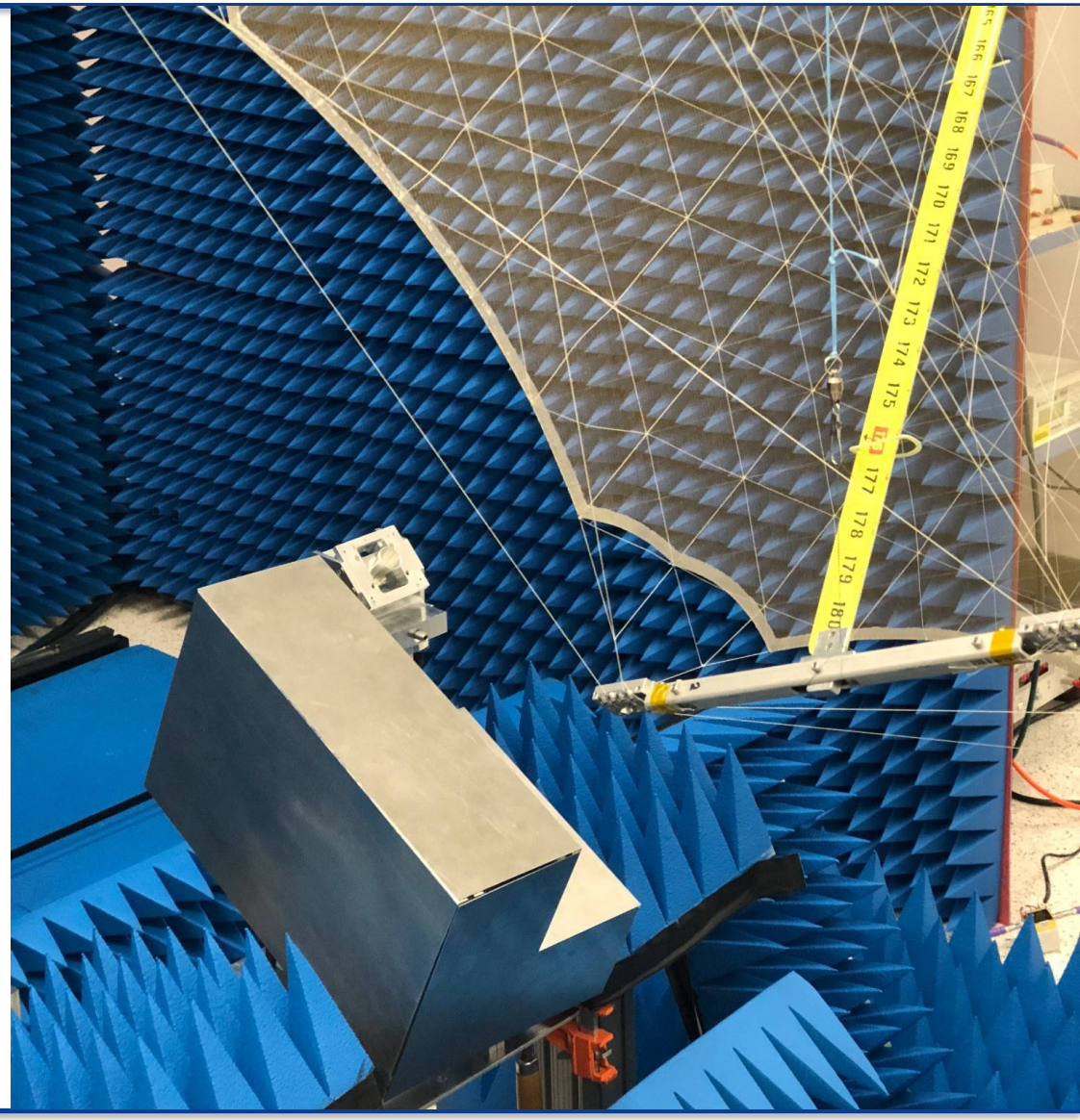
Ka-band Reflector Performance

Gain Table at X-band

	Gain (dBic)	Loss (dB)
Standard directivity	50.5	-
Taper	49.9	0.6
Spillover	49.5	0.4
Surface mesh* (30OPI)	49.25	0.25
Surface accuracy (±0.38mm)**	48.15	1.1
Feed loss	48.10	0.05
Feed mismatch (RL=15dB)	48.05	0.05
Overall performance	48.05	2.45

Calculated and measured performance

	Directivity (dBi)		Gain (dBic)		Efficiency (%)	
Frequency (GHz)	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.
32	48.4	48.8	48.1	48.4	58	62
34.45	48.5	49.0	48.3	48.7	52	57

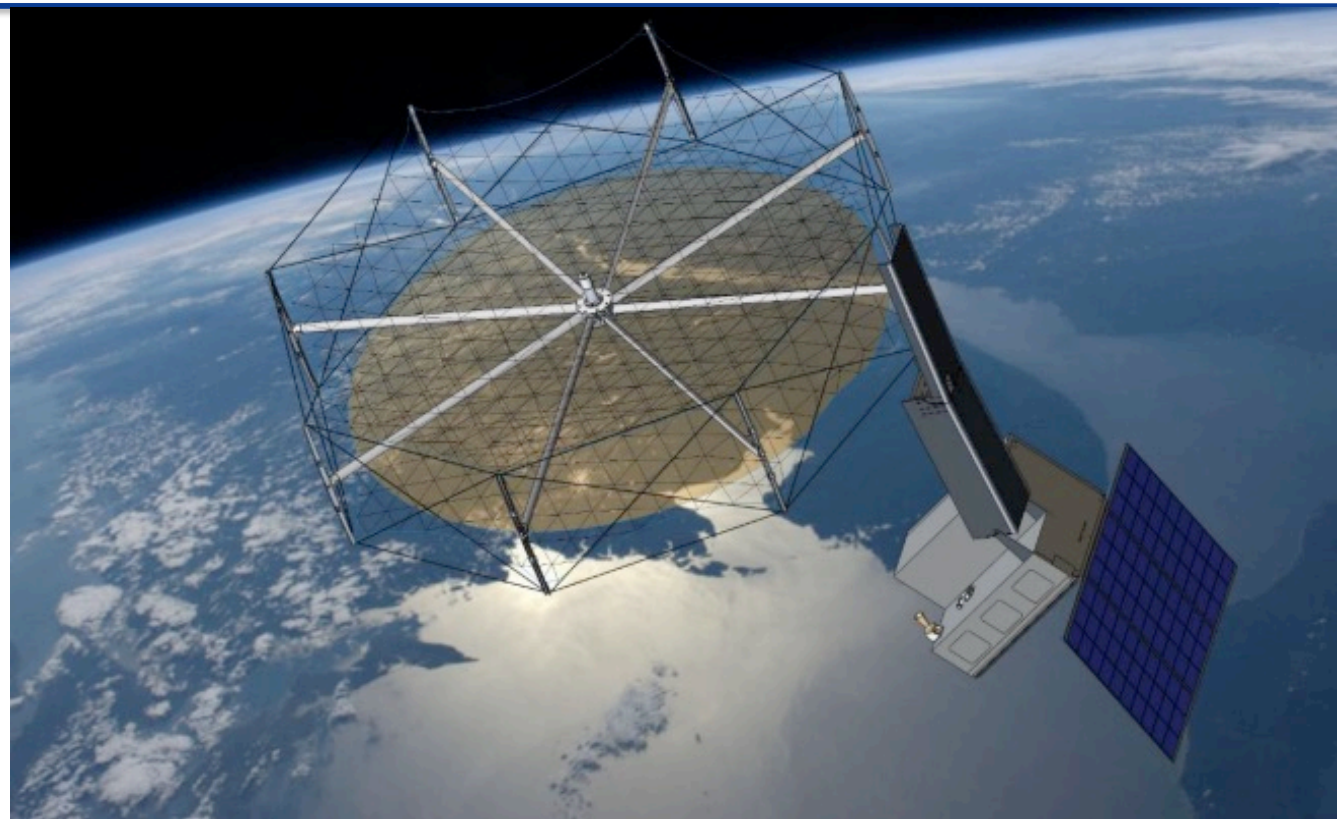


Data rates at X-band using proposed antenna

Downlink X-band Data Rate

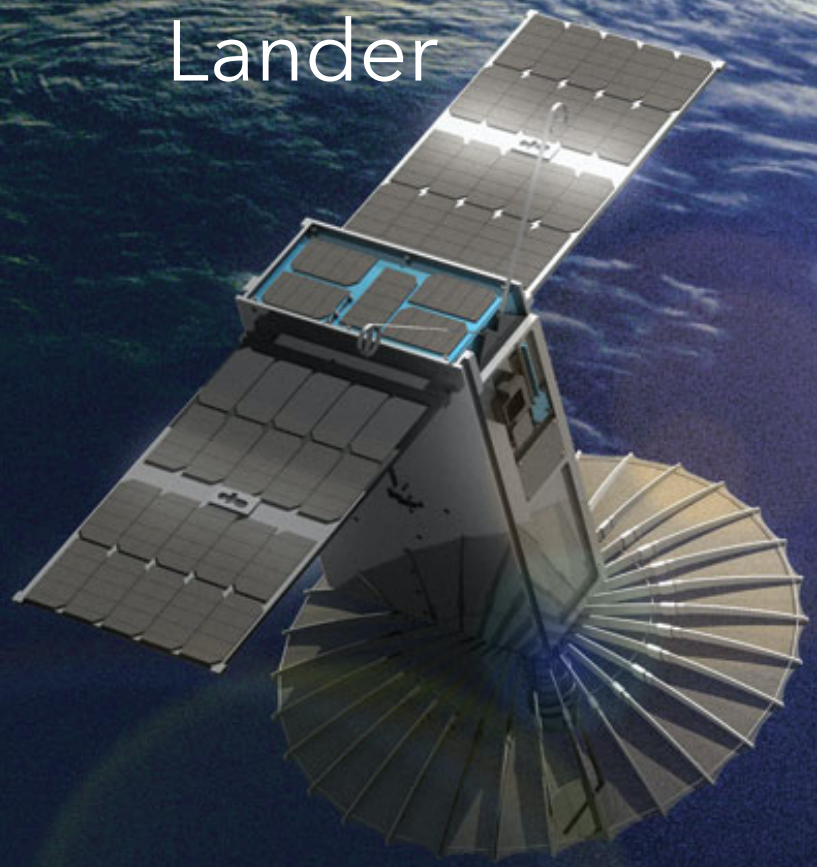
Parameter	Value
Distance	1 AU
Elevation Angle	20 degrees
CubeSat tx antenna gain	36.9dBic
CubeSat tx power	4.4W (EOD)
CubeSat pointing loss	3 dB
Tx circuit/cables loss	1.3 dB
DSN antenna options	70 m
Weather	Year average (95%)
Encoding	Turbo 1/6 (8920 bit frame)
FER	Year average (95%)
Encoding	Uncoded
BER	10^-4
Ranging, DOR tones	Off
X-Band Tx frequency	8.4 GHz
Downlink margin	3 dB
Data rate	**114 kbps**

➔ MarCO achieved 8kbps at 1AU



Artist's Concept

All-metal Dual Frequency RHCP High Gain Antenna for the Extreme Environments of a Potential Europa Lander



Nacer Chahat

April 4, 2019

13th European Conference on Antennas and Propagation – Krakow, Poland