AirMOSS P-band SAR Calibration

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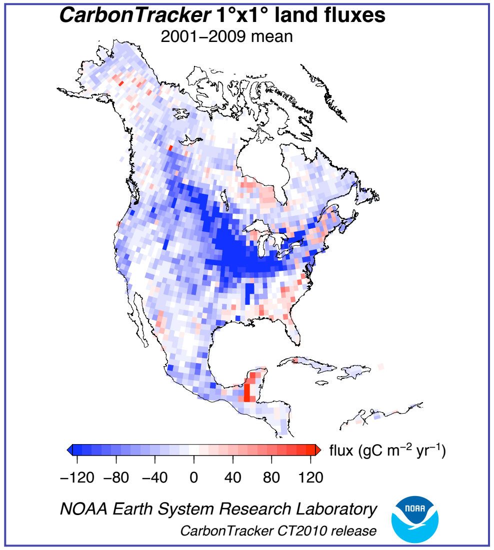
2011 CEOS SAR Calibration and Validation Workshop
Fairbanks, Alaska
Nov 7-9, 2011

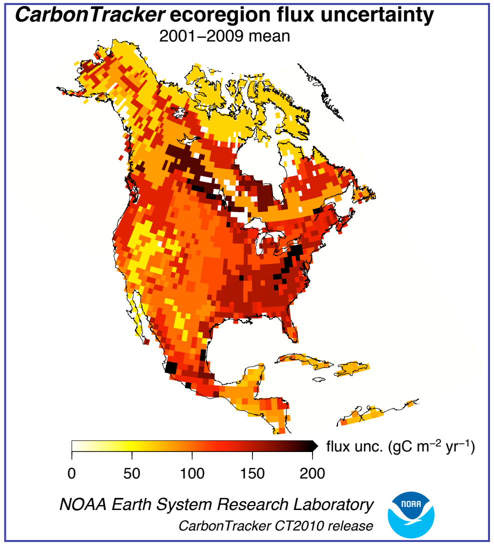
Outline

- Introduction to AirMOSS
- AirMOSS P-band SAR
- Calibration strategy
- Hardware calibration paths
- 4.8 m corner reflector
- Future plans

Introduction to AirMOSS

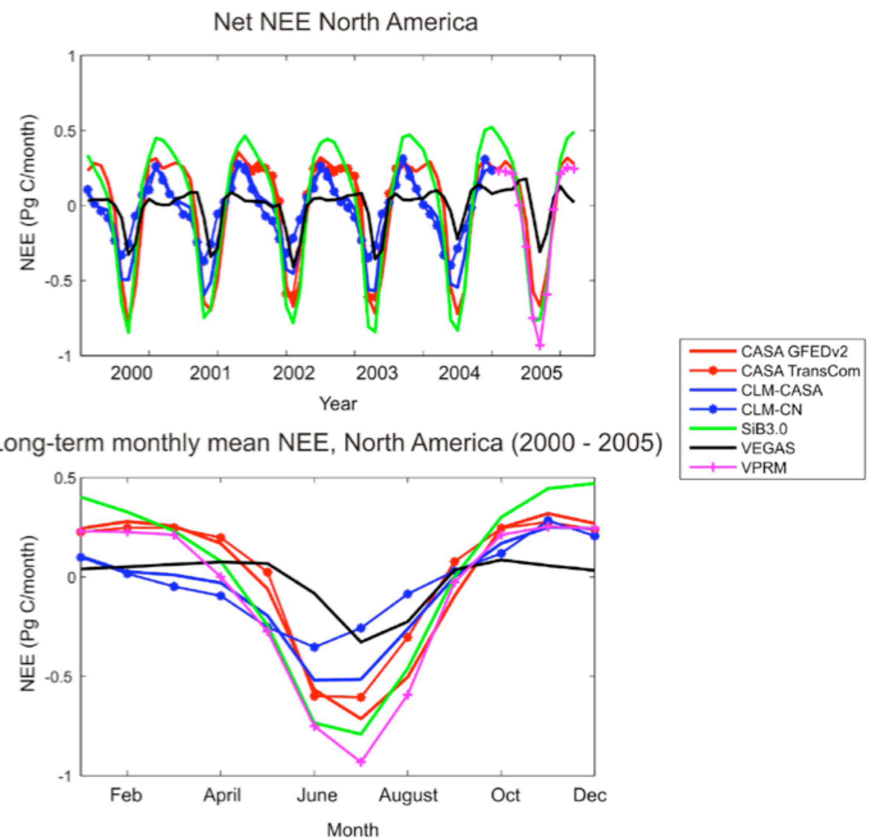
- Airborne Microwave Observatory of Subcanopy and Subsurface
- NASA Earth Venture (EV-1) program
- AirMOSS will provide a new net ecosystem exchange (NEE) estimate for North America with a reduced uncertainty by:
  - Providing high-resolution observations of root zone soil moisture (RZSM) over regions representative of the major North American biomes
  - Quantifying the impact of RZSM on the estimation of regional carbon fluxes
  - Upscaling the reduced-uncertainty estimates of regional carbon fluxes to the continental scale of North America





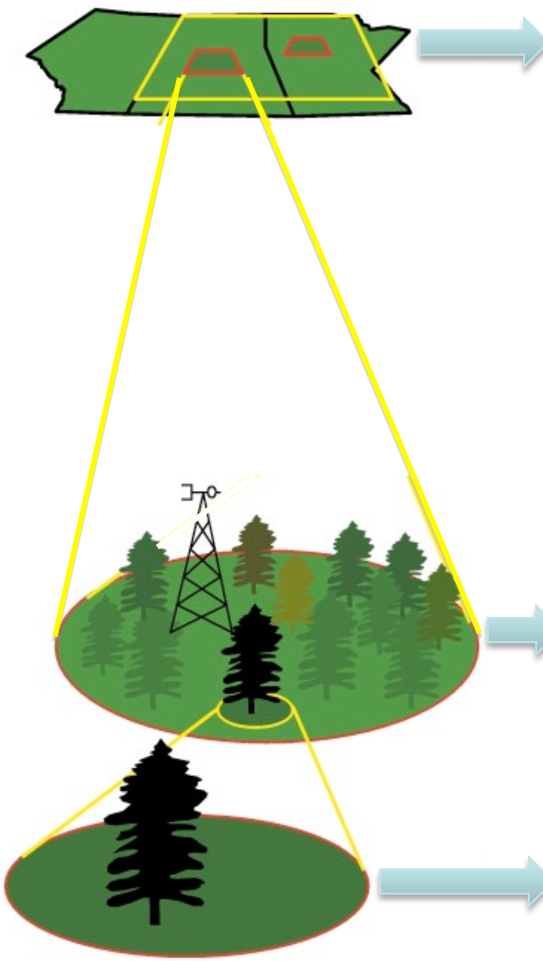
Scientific Approach (1)

Uncertainty in Annual and Seasonal Net Ecosystem Exchange Estimates over North America



Based on spatial resolution of ~ 0.5 degree

Bottom-up scaling



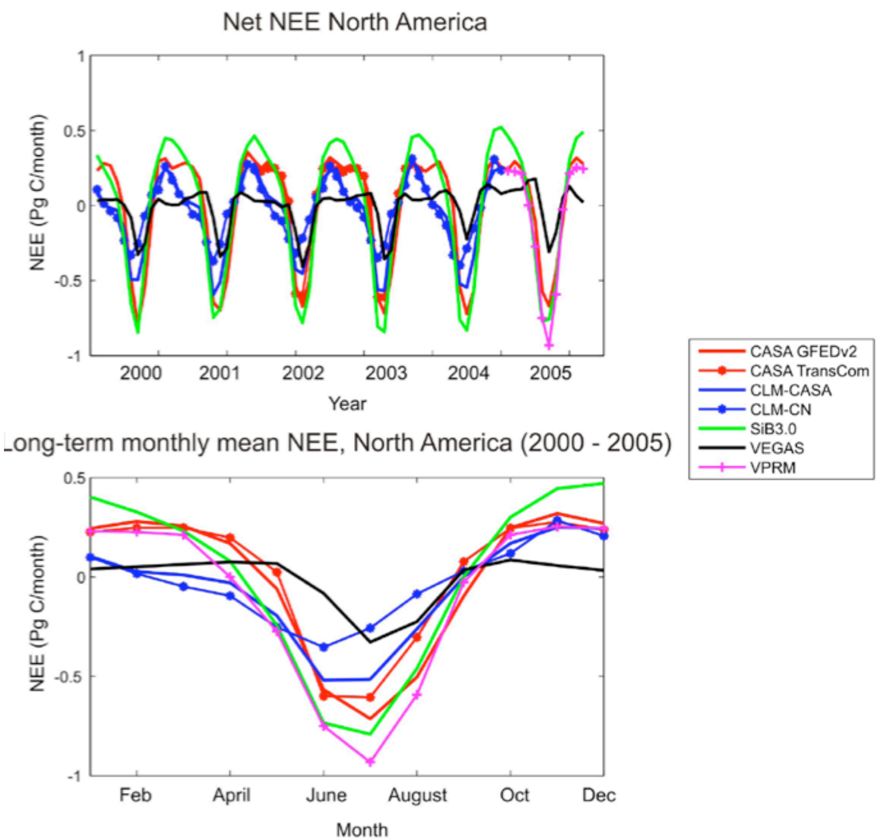
North America water and carbon fluxes

Tower site footprint
1km x 1km
Currently used to calculate NEE by routine scaling up; RZSM assumed homogeneous

Plot Level
(0-50m)

Scientific Approach (2)

Uncertainty in Annual and Seasonal Net Ecosystem Exchange Estimates over North America



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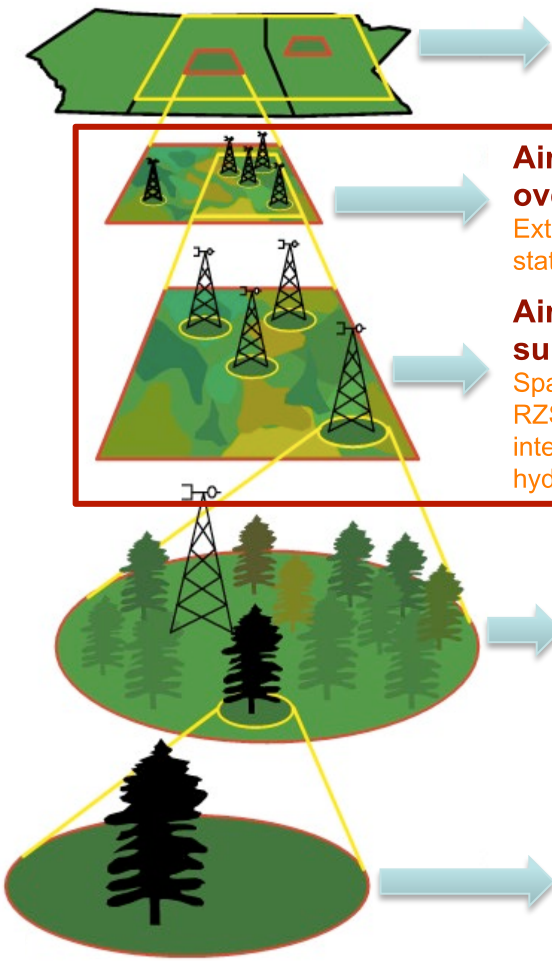
Bottom-up scaling



North America water and carbon fluxes
Reduce uncertainty of continental scale fluxes

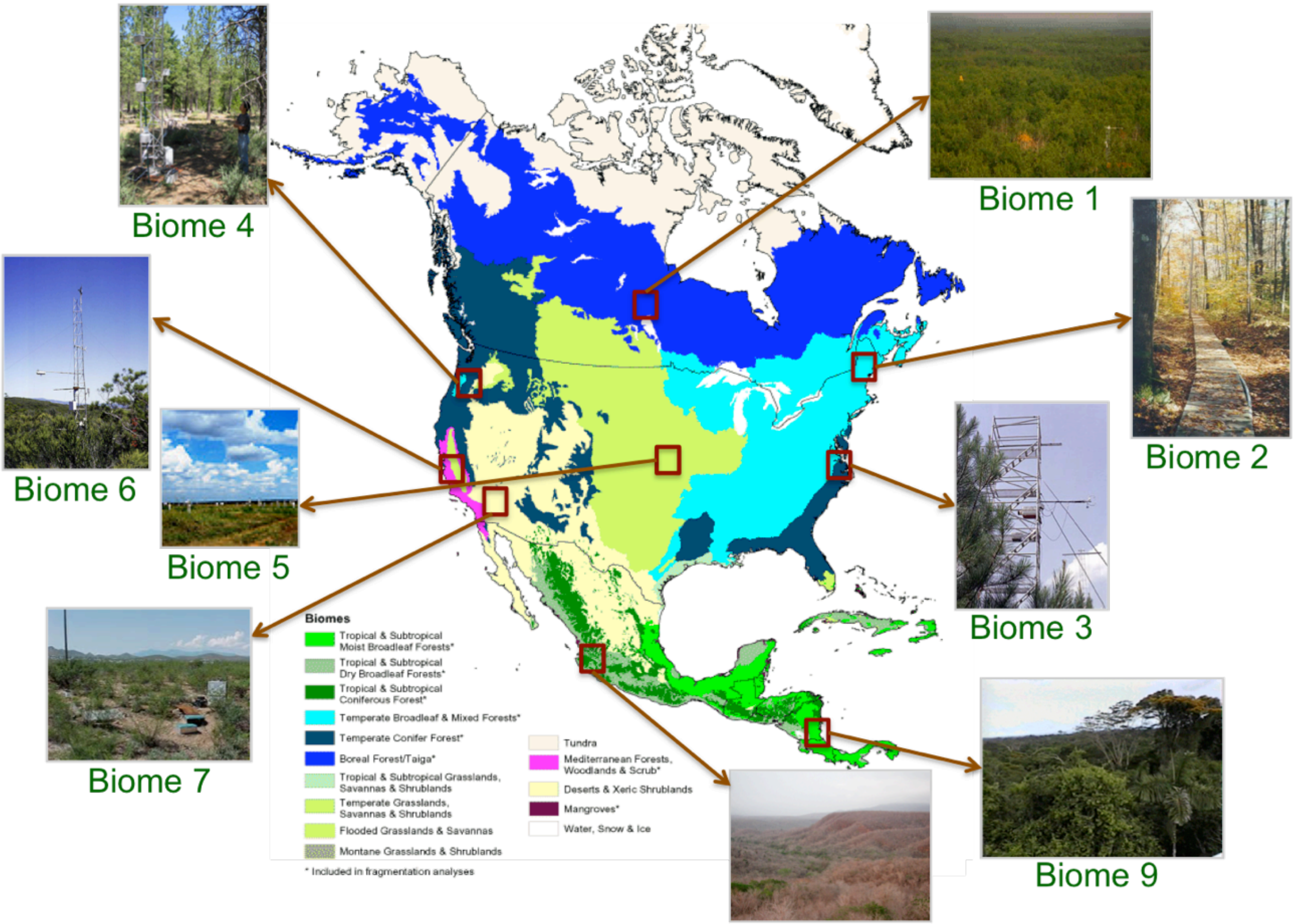
AirMOSS model integration over North American biomes
Extrapolate between biomes using stats derived at 50km scale

AirMOSS data over modeling sub-grid: 2500 km^2
Spatial and temporal distribution of RZSM @ 50m; capture seasonal & interannual variability (ED NEE & hydrology model runs).

Tower site footprint 1km x 1km
Currently used to calculate NEE by routine scaling up; RZSM assumed homogeneous

Plot Level (0-50m)

North American Biomes to Cover



AirMOSS P-band SAR

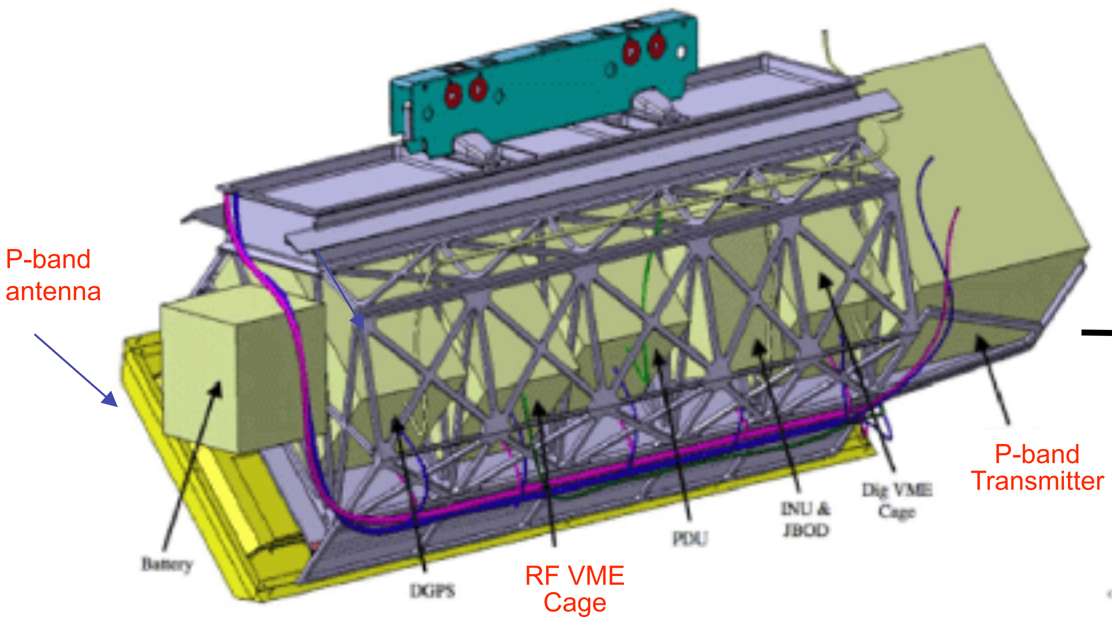
- Fully polarimetric P-band (aka UHF) synthetic aperture radar
- Hardware is capable of 80 MHz maximum contiguous bandwidth within 280-440 MHz band – frequency *permission* is a limiting factor
- First engineering flights to begin in Spring 2012
- Science flight campaigns to begin in Summer 2012

AirMOSS Mission Parameters	
Platform altitude	12 km above terrain
Platform velocity	215 m/s
Pulse width	40 microseconds
PRF (fast)	1200 Hz
Center frequency	420 MHz
Bandwidth	20 MHz
Transmit Power	1995W

AirMOSS Hardware Heritage

AirMOSS hardware is primarily based on UAVSAR heritage. In fact, UAVSAR was originally designed with accommodations for future P-band capability

- Antenna frame was sized to fit the GeoSAR P-band antenna
- Space in the nose cone was reserved for P-band transmitter



UAVSAR pod layout showing modularity of the electronic assemblies

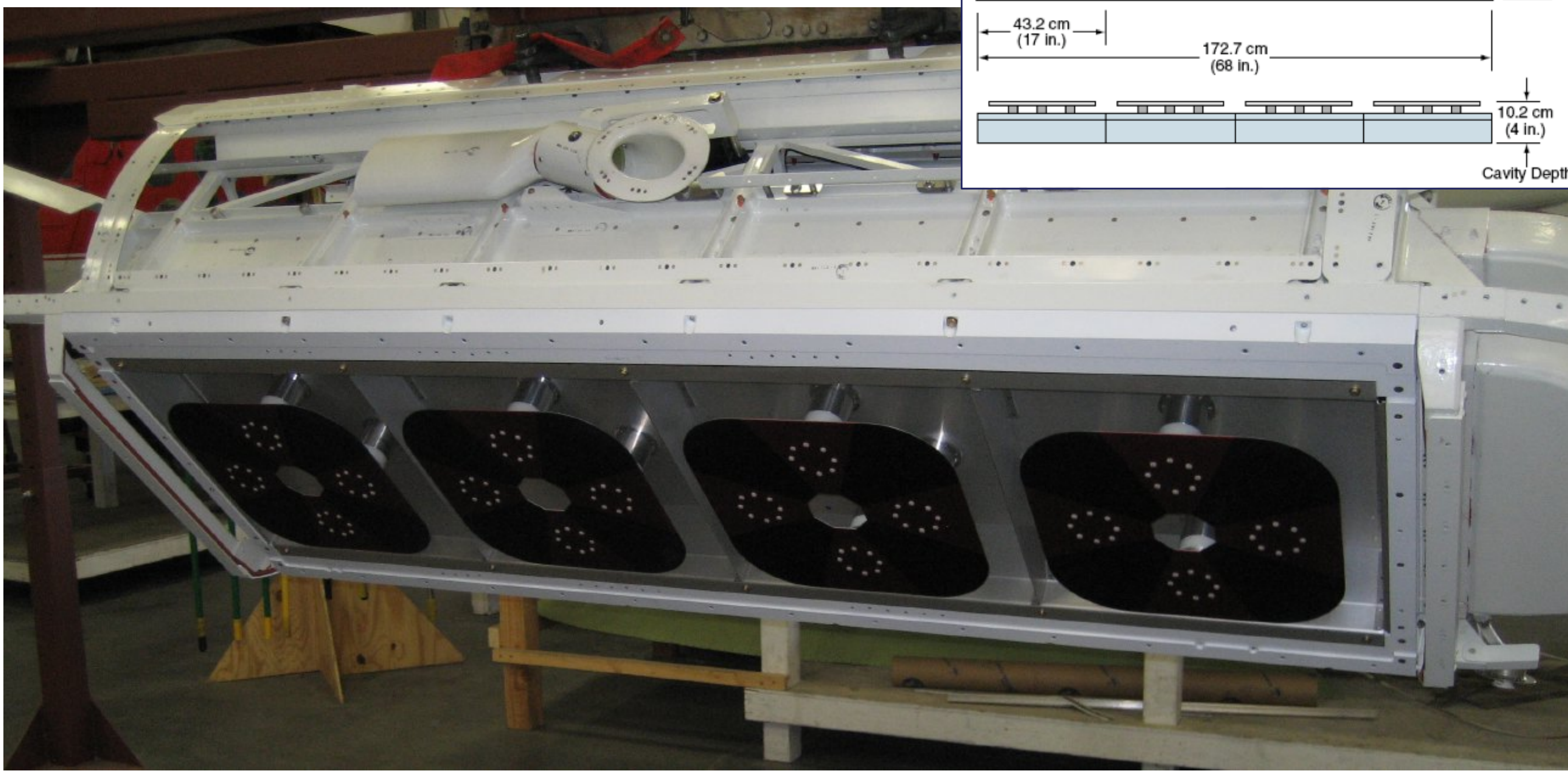
UAVSAR Instrument Pods

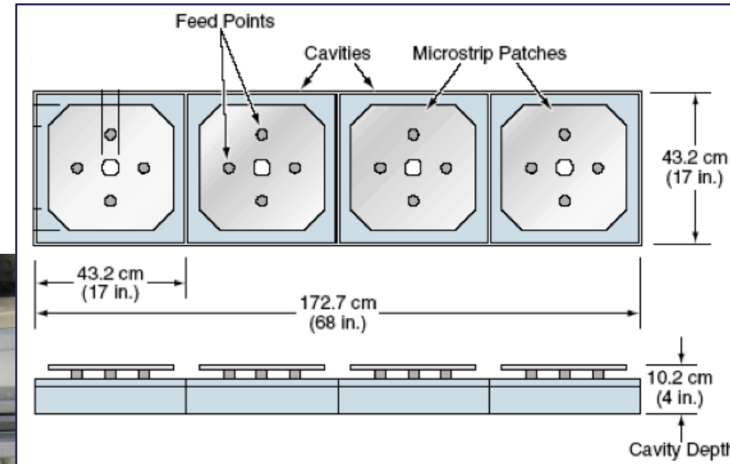
Operational L-band pod

Pod in experimental Ka-band configuration (includes a new passive Ka-band antenna)

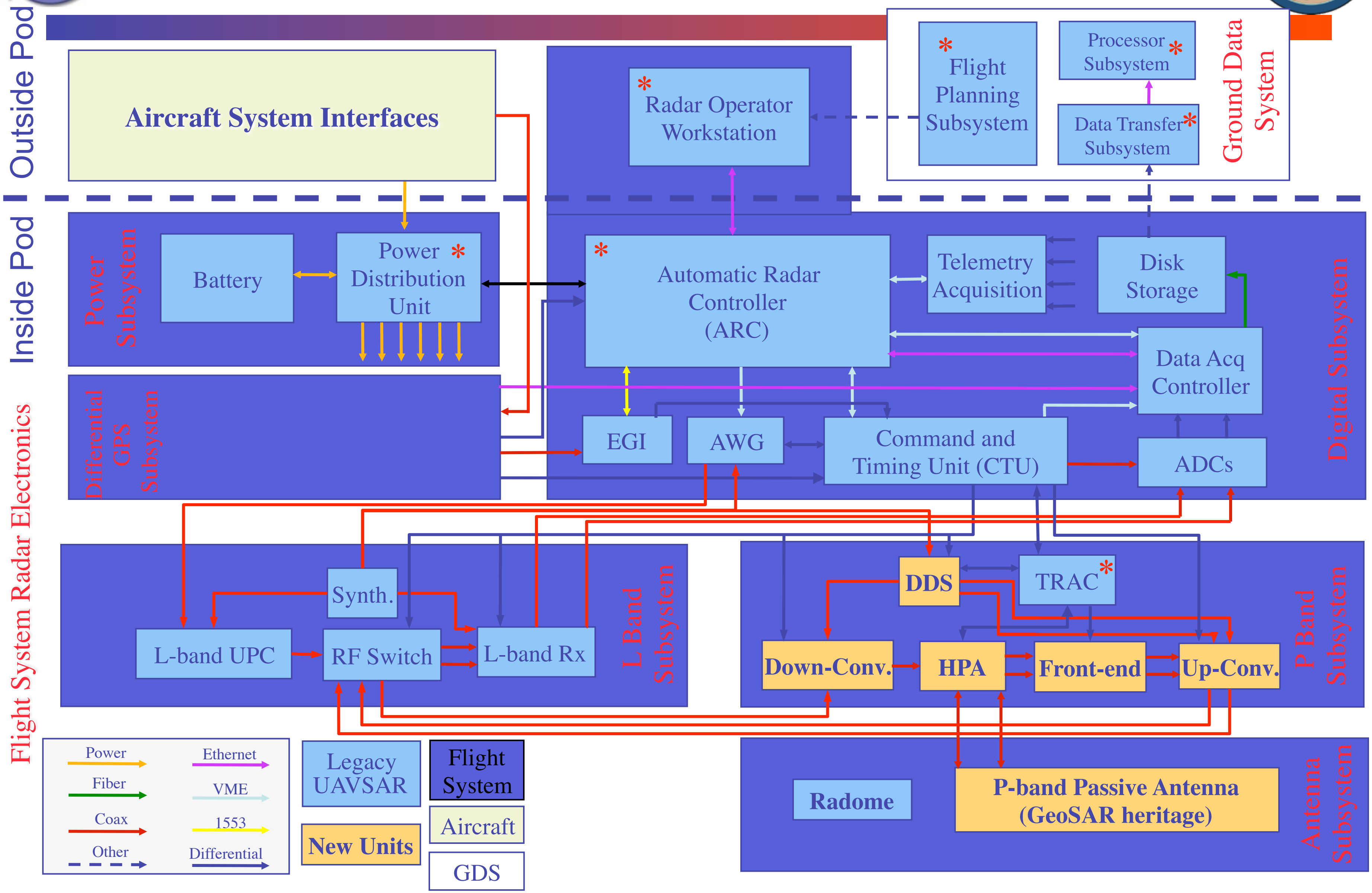
AirMOSS Heritage: GeoSAR Antenna

Passive GeoSAR antenna
(reduced in size by 3%)





AirMOSS Electronics Block Diagram

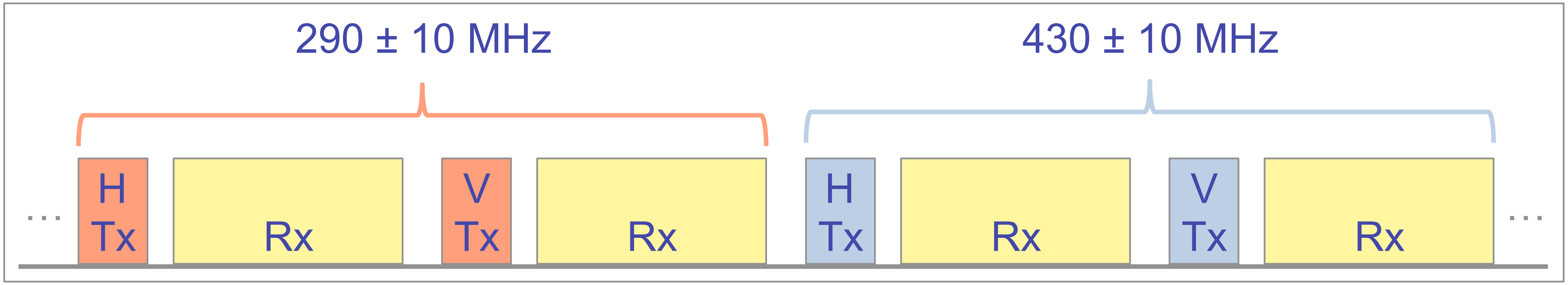


*Requires S/W, F/W or H/W Changes

Frequency Agility

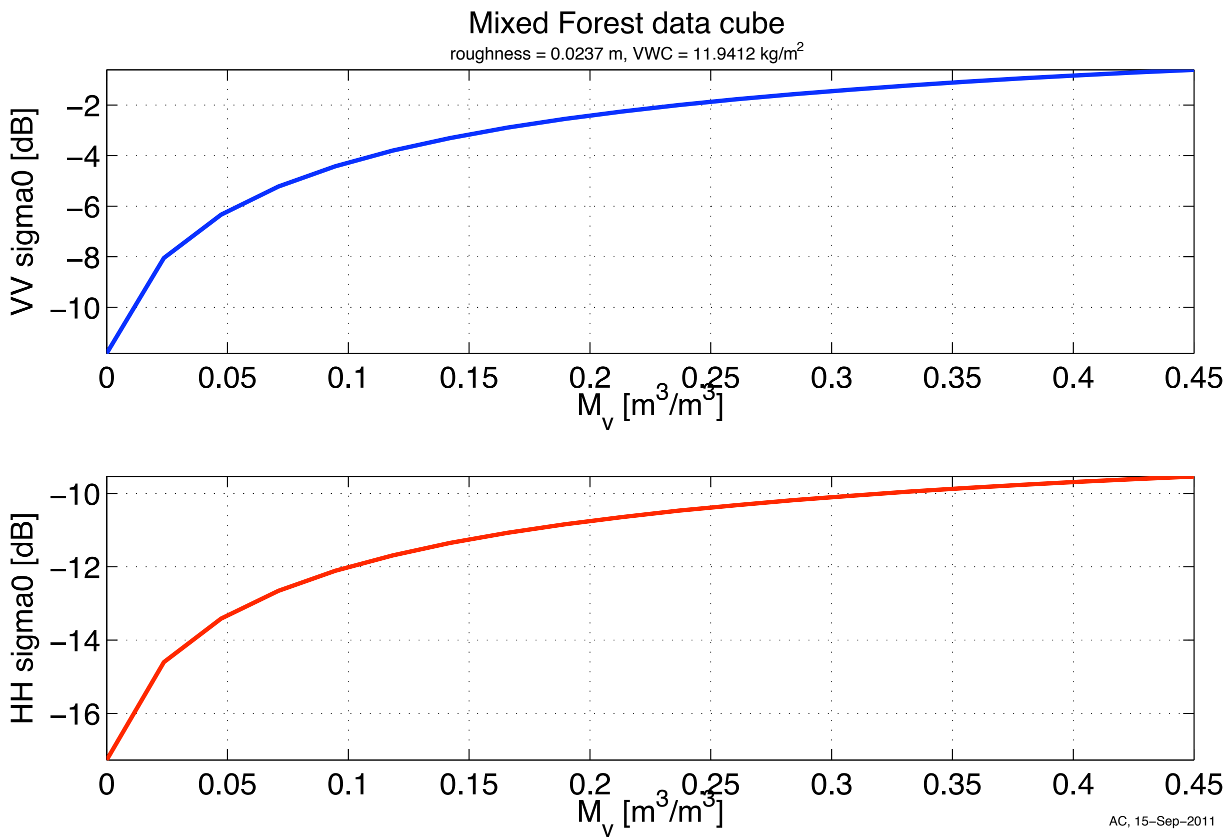
- AirMOSS P-band SAR reuses the L-band front end
- Direct Digital Synthesizer (DDS) generates signal to mix L-band chirp down to P-band
  - Commandable to generate any center frequency between 280 and 440 MHz
  - Commandable to any bandwidth between 6 and 80 MHz
  - Can be changed on a pulse-to-pulse basis

For example:



P-band for Soil Moisture Retrieval

- P-band is suitable for RZSM because it can penetrate tens of centimeters into the ground
- However, backscatter curves saturate with respect to soil moisture
  - Need well calibrated sigma0s for inversion algorithms!
    - *I.e.*, 0.5 dB calibration error to achieve desired 0.05 m^3/m^3 RZSM error



Calibration Strategy

- Monitor and correct for hardware variations
  - Temperature sensors (characterize temperature dependence during integration and test)
  - Calibration paths
- Corner reflectors for radiometric, geographic, range delay calibration

Calibration Paths

<u>Antenna Transmit Calibration Test</u>

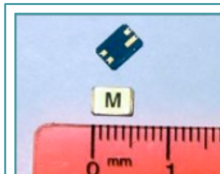
- Route (attenuated) transmitted pulse to receiver
- Interleave every ~256th pulse

<u>Caltone</u>

- Inject caltone into receive window for every pulse
- Use measured magnitude and phase to characterize receive path

<u>Resistive Load/Noise Diode Test</u>

- Send stable (better than 0.05 dB) signal into receive chain
- Group of pulses at the beginning and end of each data take
- Noise source is a combined resistive load/noise diode
  - With high attenuation, use strong signal from noise diode
  - With low attenuation, use weak signal from resistive load

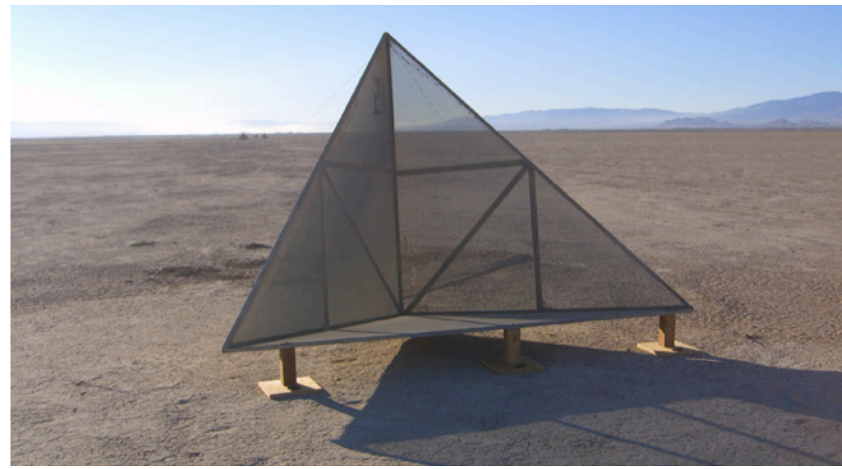


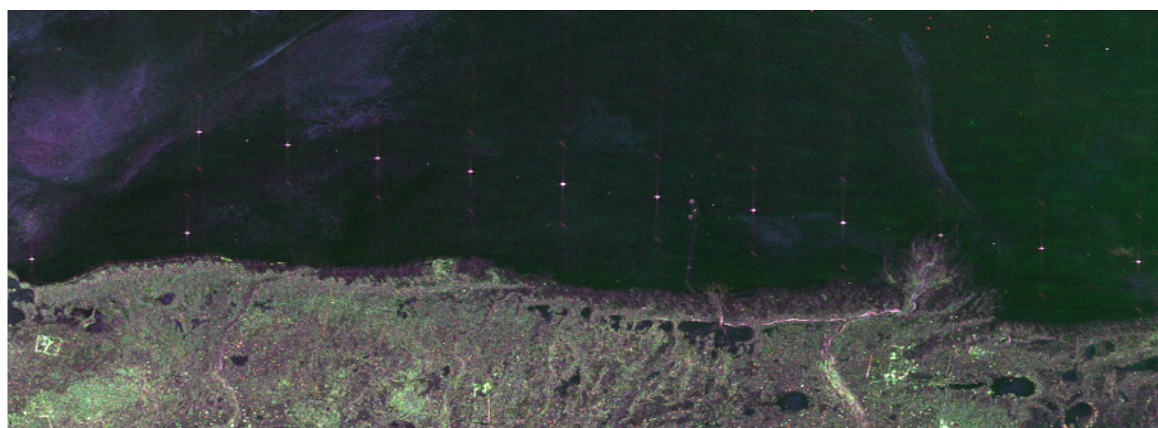
Micronetics SMN3018
"The world's smallest packaged noise source"

- Frequency: 200 MHz to 6.0 GHz
- ENR: 26 dB min
- Flatness: 3 dB max

2.4 m Corner Reflector Array

- JPL maintains an array of 23 corner reflectors at Rosamond Dry Lake, CA for UAVSAR calibration
- Each corner reflector is 2.4 m (short leg) and weighs ~ 50 lbs.

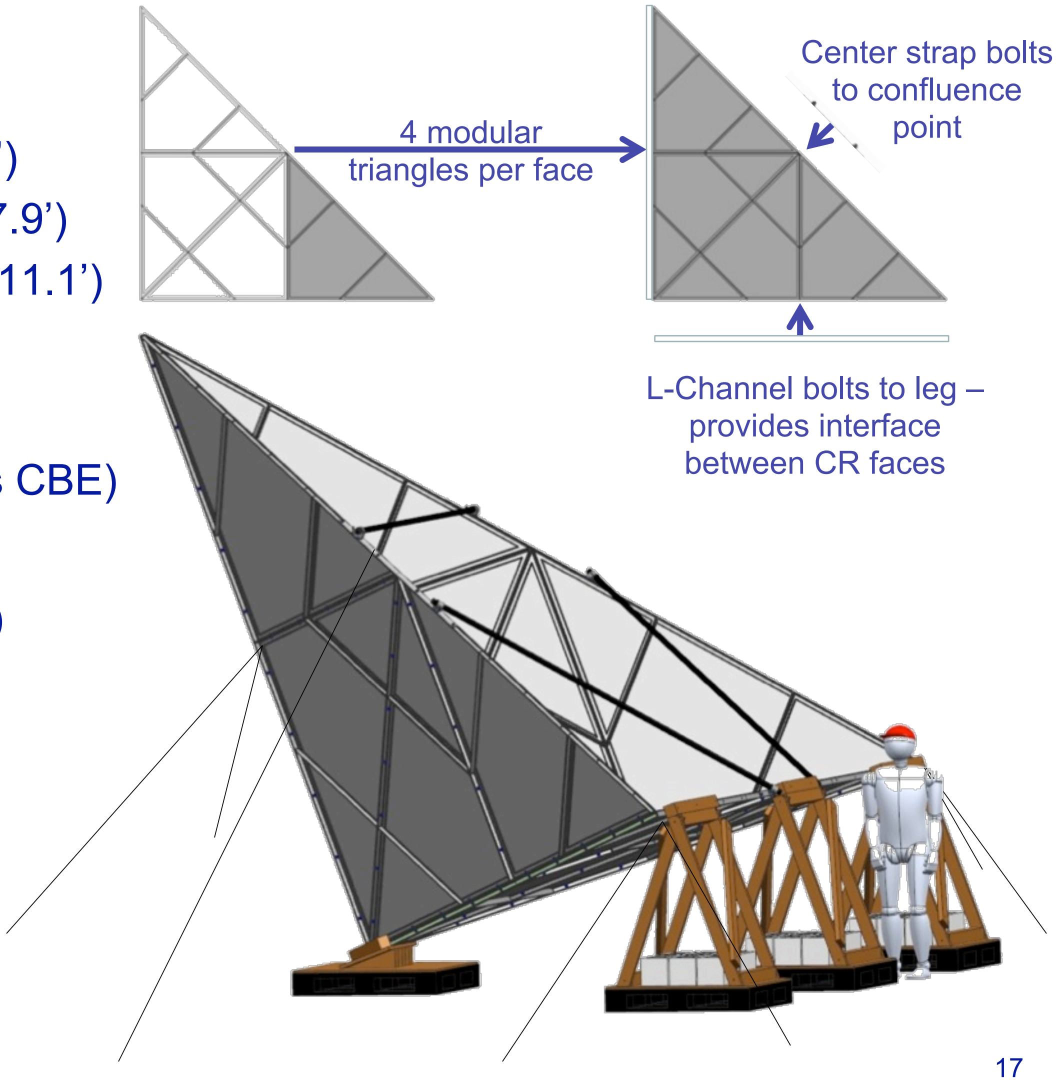




L-band UAVSAR image of CR array at Rosamond

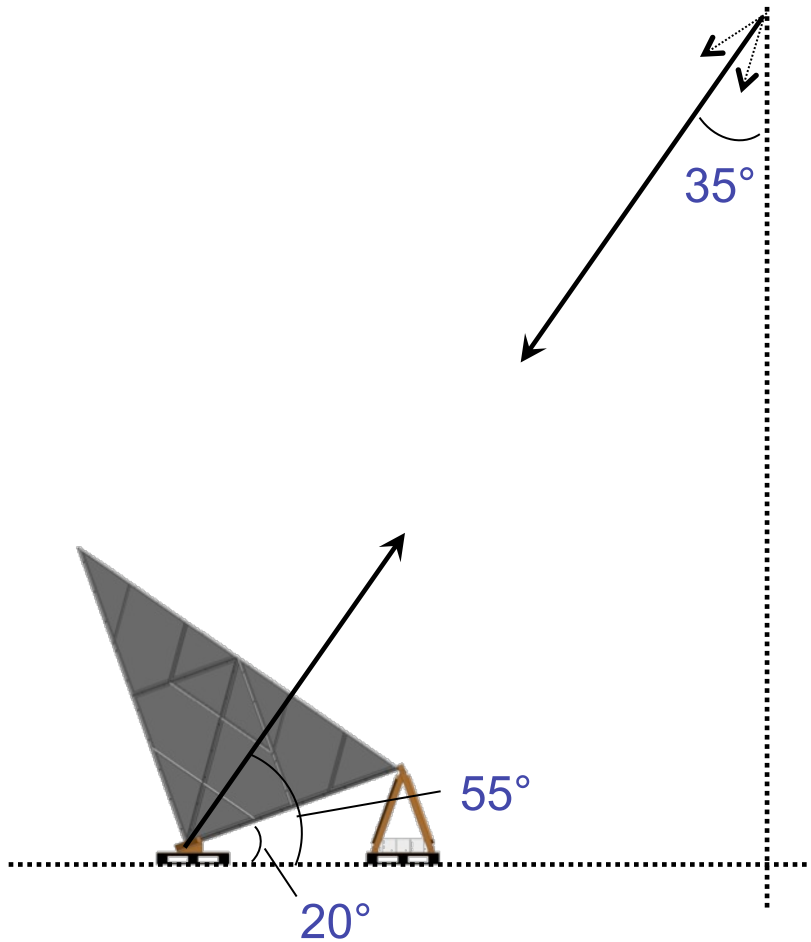
4.8 m Corner Reflector

- Corner Reflector (CR) comprised of 12 identical modular triangles
- Size:
  - CR Leg: 4.80 m (15.8')
  - CR Hypotenuse: 6.79 m (22.3')
  - Modular triangle leg: 2.40 m (7.9')
  - Modular triangle hyp: 3.39 m (11.1')
- Weight:
  - CR: 238 kg (525 lbs CBE)
  - Modular triangle: 17 kg (37 lbs CBE)
- Stands:
  - 1 Vertex Balance Stand (VBS)
  - 3 Leading Edge Stands (LES)
- Retention:
  - Cinder blocks on LES
  - Stakes through stand bases
  - Guy ropes running to stakes

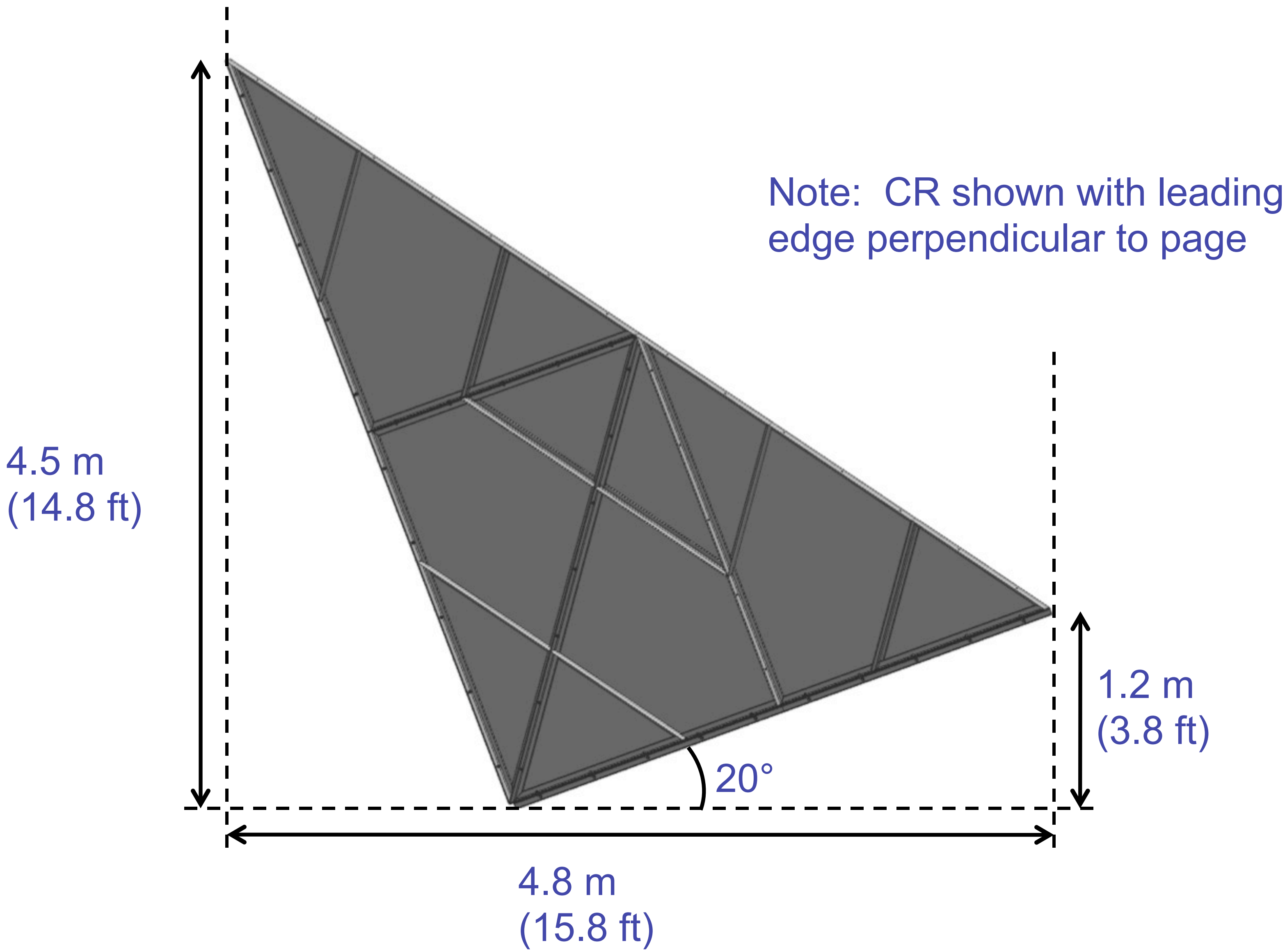


Boresight Pointing

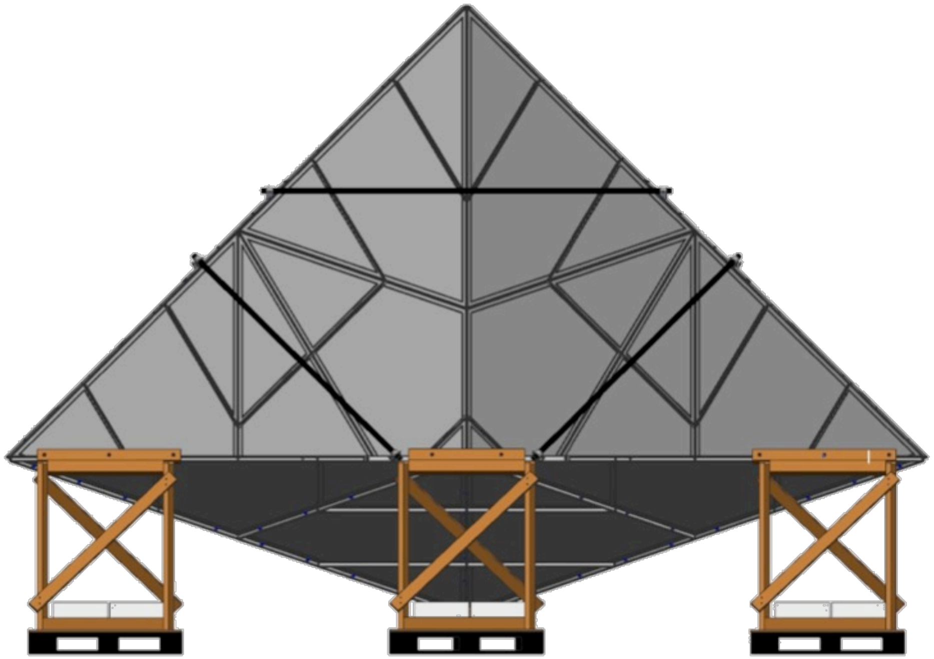
Boresight of CR co-aligned with center of AirMOSS radar look angle range (25° to 45°)

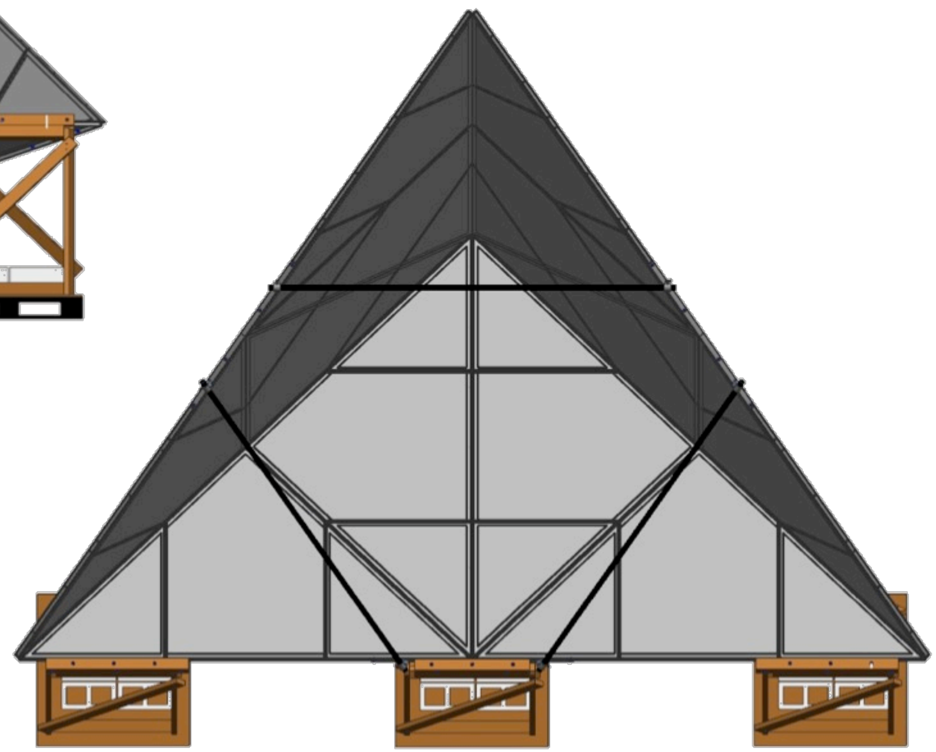


Profile Dimensions

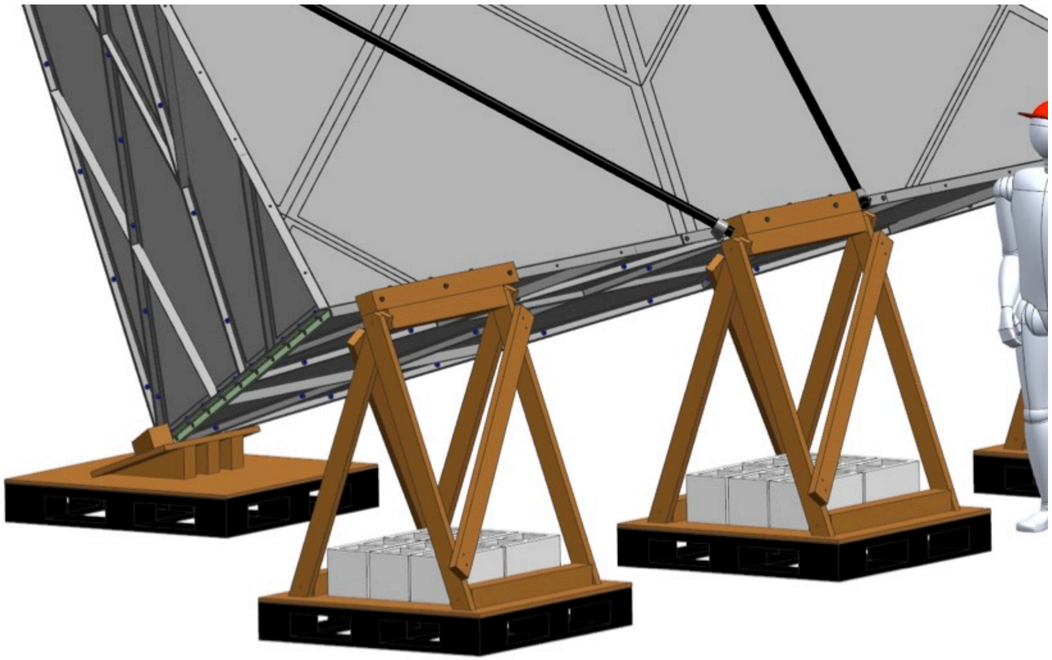


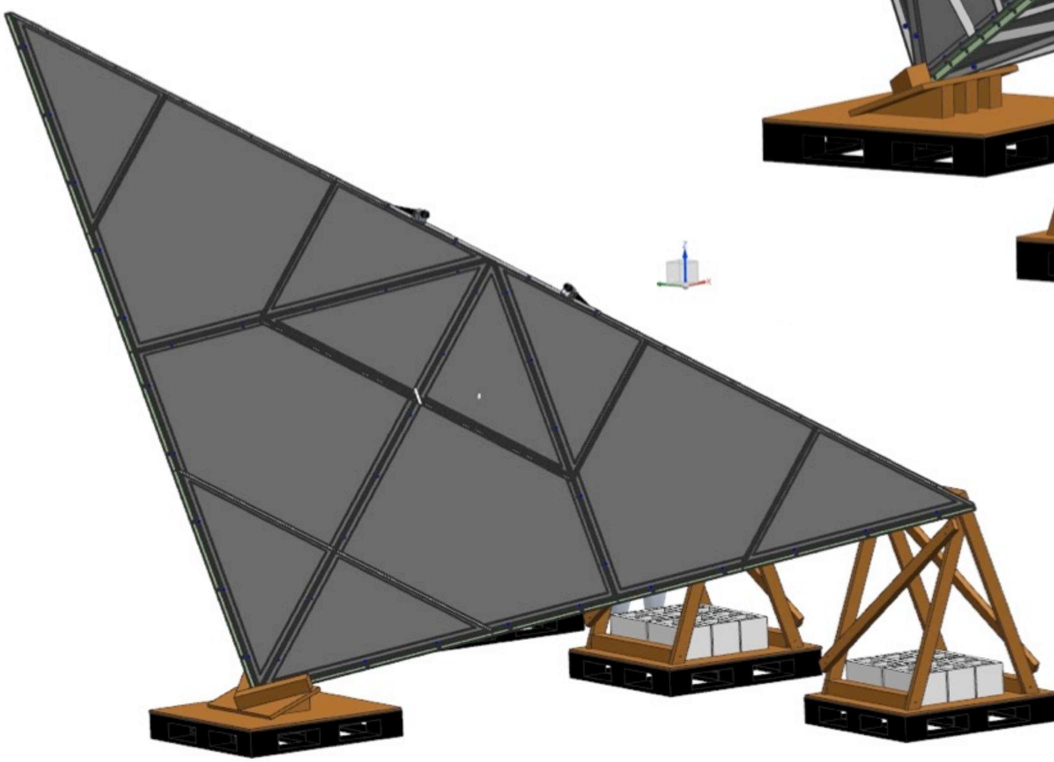
Front and Top Views





Additional Views





Materials

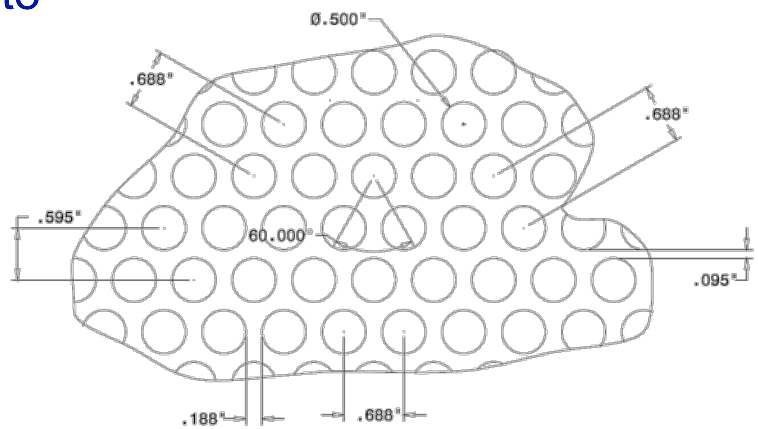
Structure: Aluminum Alloy 6061 T6

- Aluminum L-Channel chosen for light weight and uniformity
- Al Alloy 6061 T6 chosen for strength
  - Yield strength: 40 ksi
  - Cost: ~$6/ft

http://www.mcmaster.com

Mesh: Aluminum Alloy 3003 H14, ½" round holes, 48% open area

- Hole diameter of 1.3 cm chosen to allow CRs to be <u>compatible with L-Band radar</u>
  - P-Band: $\lambda = 0.68$ m (AirMOSS)
  - L-Band: $\lambda = 0.24$ m (UAVSAR)
    - RE-08: The active surface of the CR shall not contain gaps larger than $\lambda/10$
- Percent open area chosen to minimize drag coefficient and weight while maintaining structural integrity

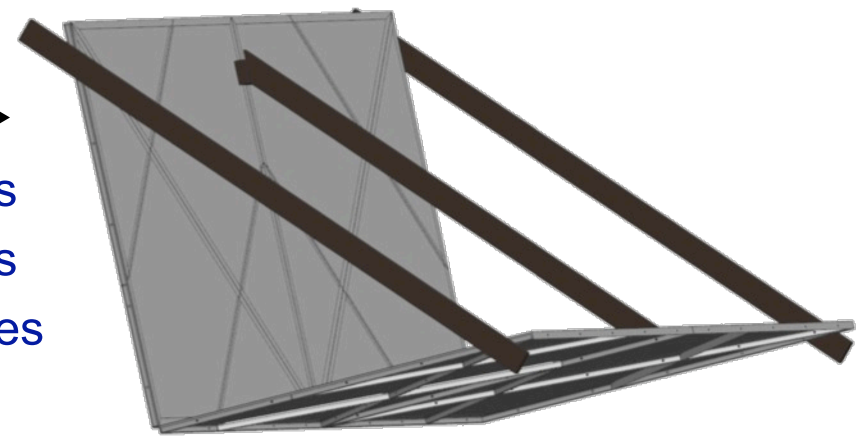


http://www.mcnichols.com/images/mediabin/products/caddrawings/1712616341_1002.pdf

Modular Design – Reconfigurable

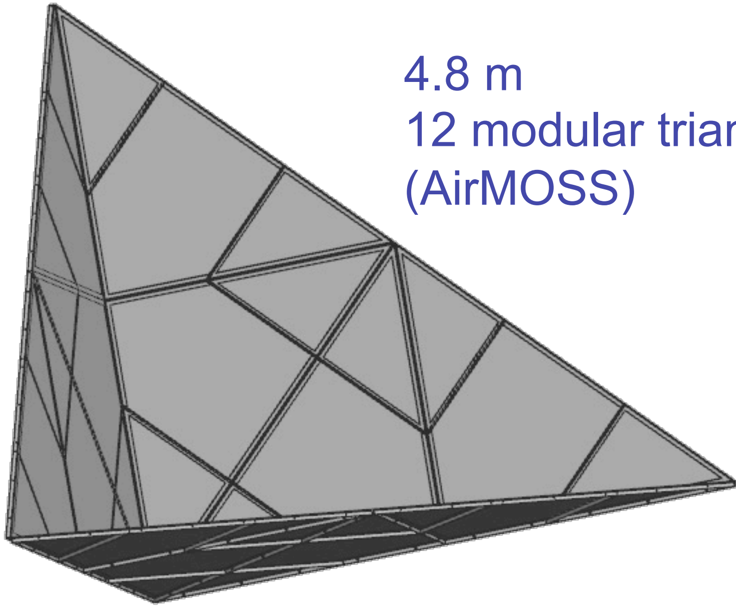
The modular design of the CR panels allow different size and shape reflectors to be constructed:

- Dihedral Corner Reflectors →
  - 2.4 m x 2.4 m 4 modular triangles
  - 2.4 m x 4.8 m 8 modular triangles
  - 4.8 m x 4.8 m 16 modular triangles
- Trihedral Corner Reflectors
  - 4.8 m 12 modular triangles (AirMOSS)
  - 3.4 m 6 modular triangles
  - 2.4 m 3 modular triangles (UAVSAR)

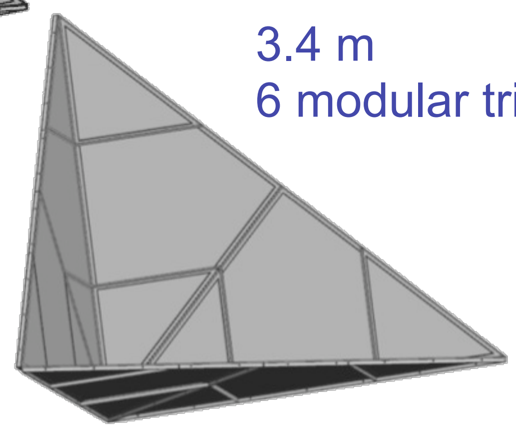


New mounting schemes are required for CR permutations

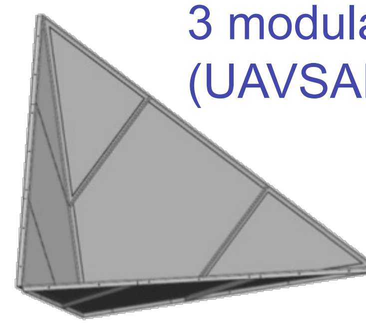
Modular Design – Trihedral CR Sizes



4.8 m
12 modular triangles
(AirMOSS)



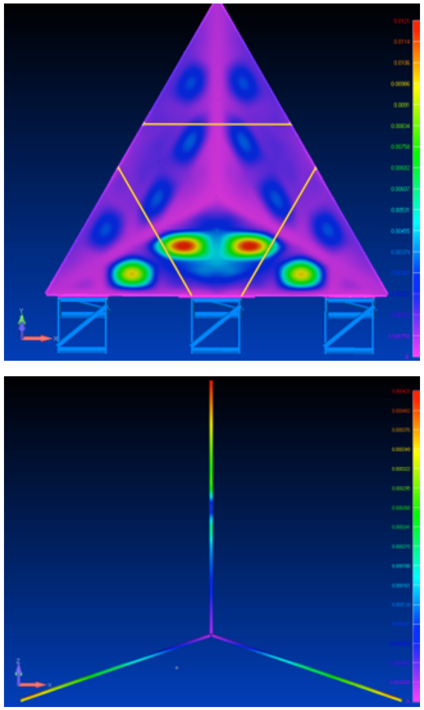
3.4 m
6 modular triangles



2.4 m
3 modular triangles
(UAVSAR)

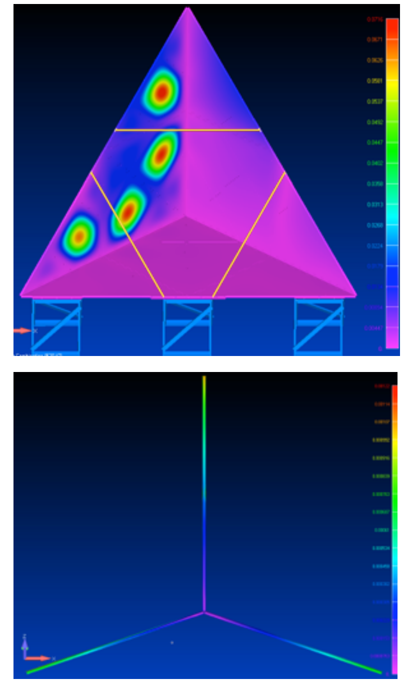
Resized mounting schemes and corner brackets
are required for trihedral CR permutations

Stress Analysis: Surface Deflection



0.25g Lat + 2g Vert

- Max displacement: 12.1mm (0.48in)
  - P-Band Requirement: <68mm (2.7in)
  - L-Band Requirement: <24mm (0.9in)
- Max angular deflection: 0.005deg
  - Requirement: <0.5deg

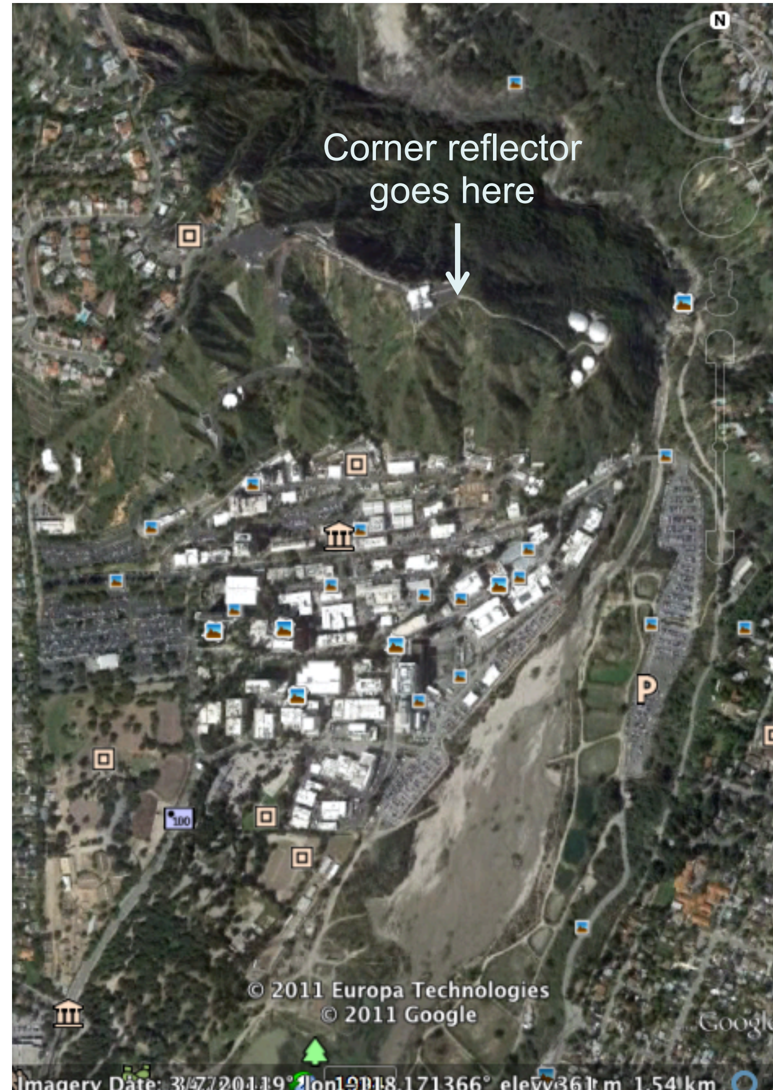


Wind Load LC4

- Max displacement: 71.6mm (2.8in)
  - Wind loads (parallel to ground) of 50mph assumed for this analysis (scales by v^2)
- Max angular deflection: 0.015deg

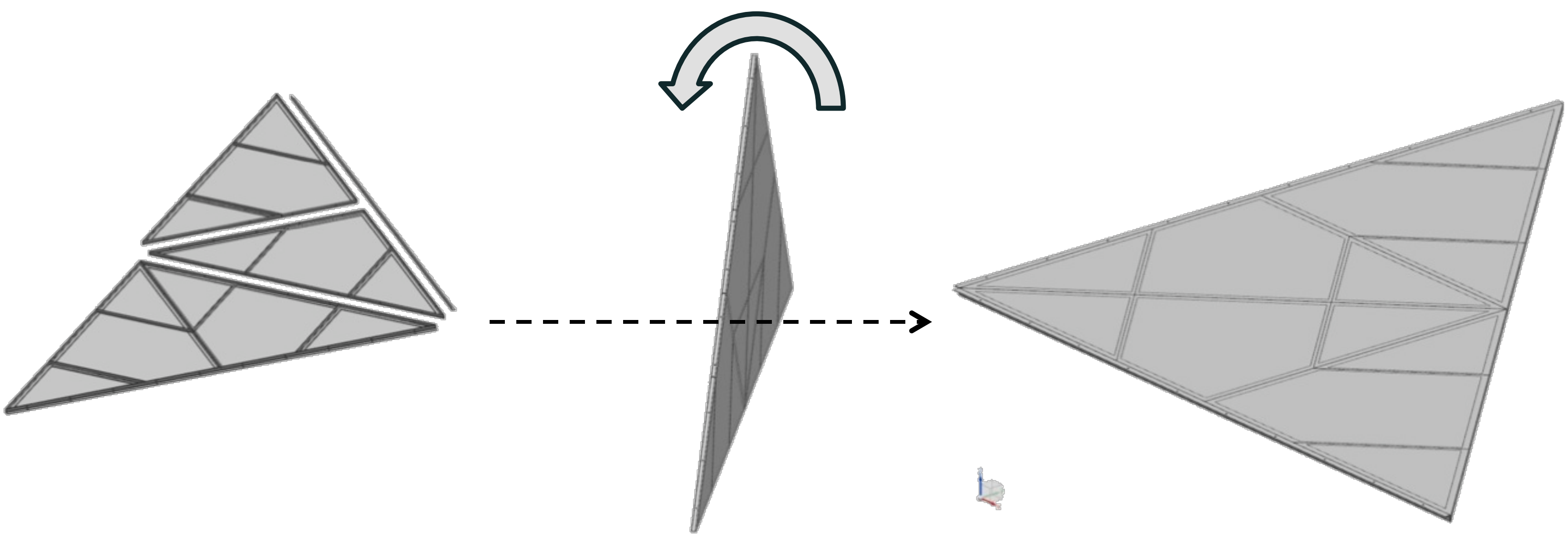
First Corner Assembly at JPL

- Assembled a prototype corner reflector at JPL on Oct 26, 2011
- We predicted it would take 7 people up to 8 hours to assemble



Assembly Procedure (1)

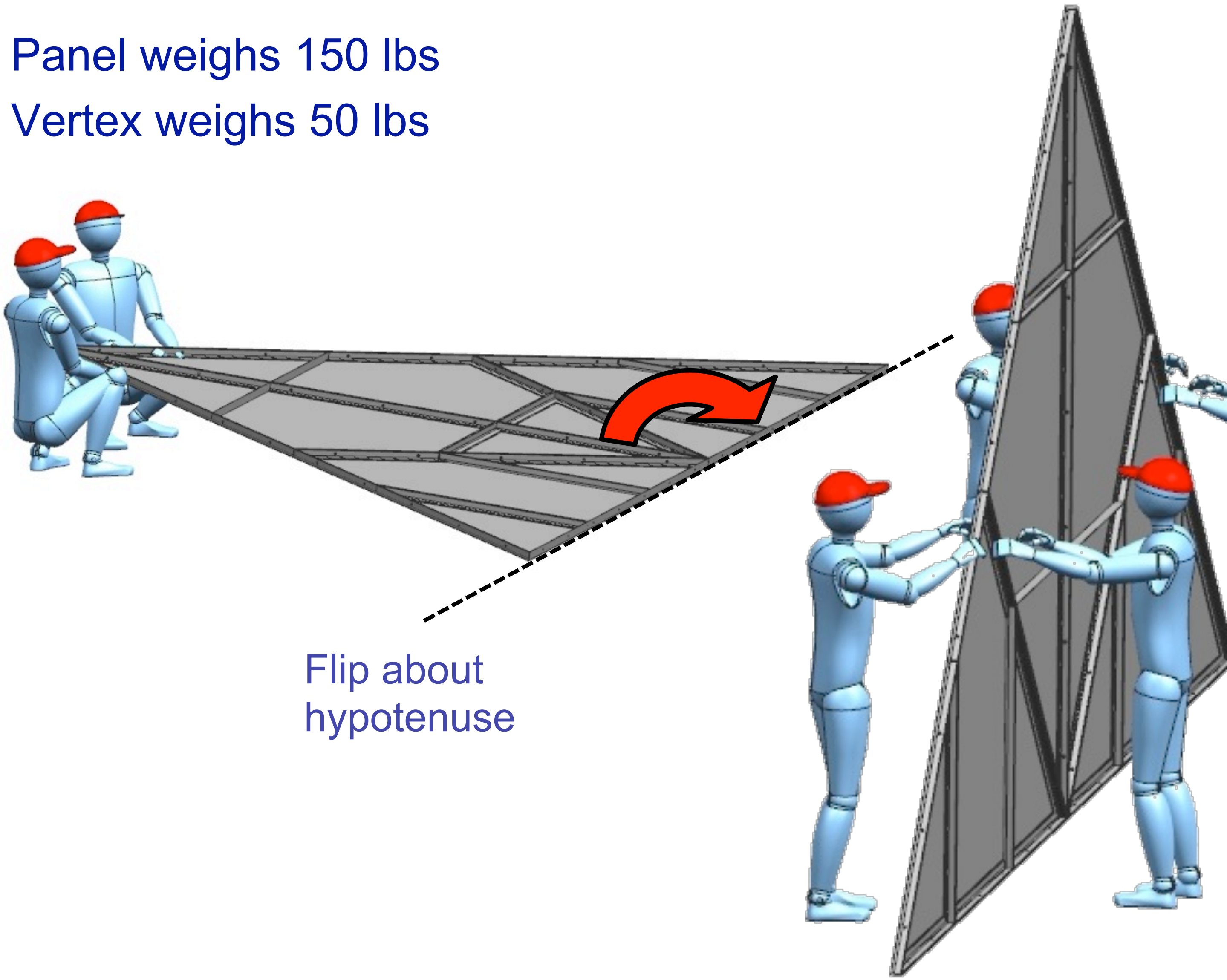
- Orient and assemble lower face on ground
  - Place face panels mesh down
  - Orient one flip about hypotenuse away from desired final position
  - Bolt panels together
- Bolt 2 corner L-channels and center strap to lower face
- Flip face about hypotenuse into desired position (mesh facing up)
- Verify azimuth of lower face is correct, adjust as necessary



Assembly: Individual Side Panels

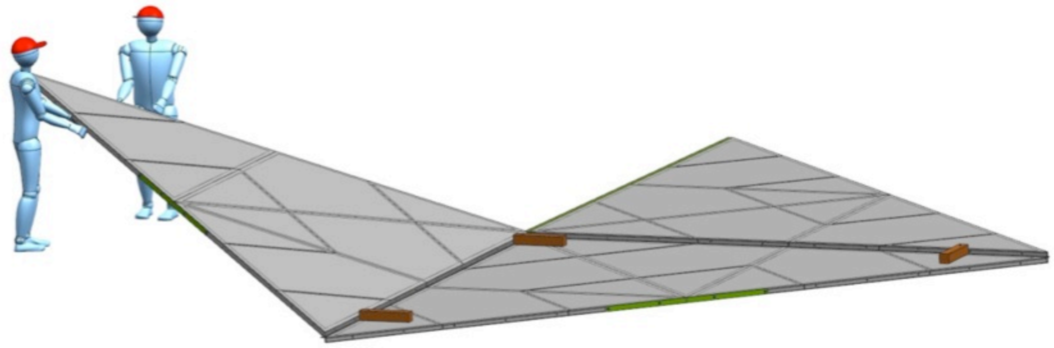
Assembly Procedure (2)

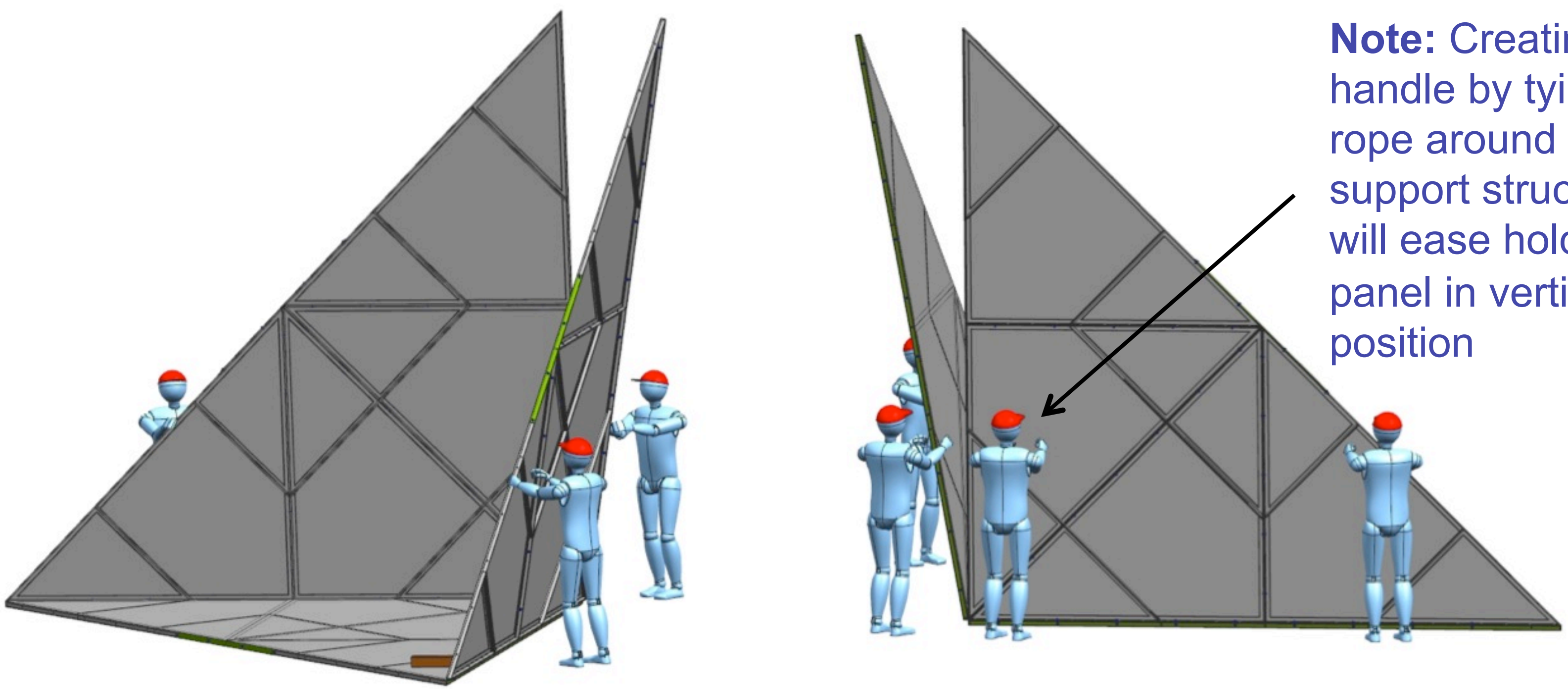
- Panel weighs 150 lbs
- Vertex weighs 50 lbs



Flip about hypotenuse

Assembly Procedure (3)



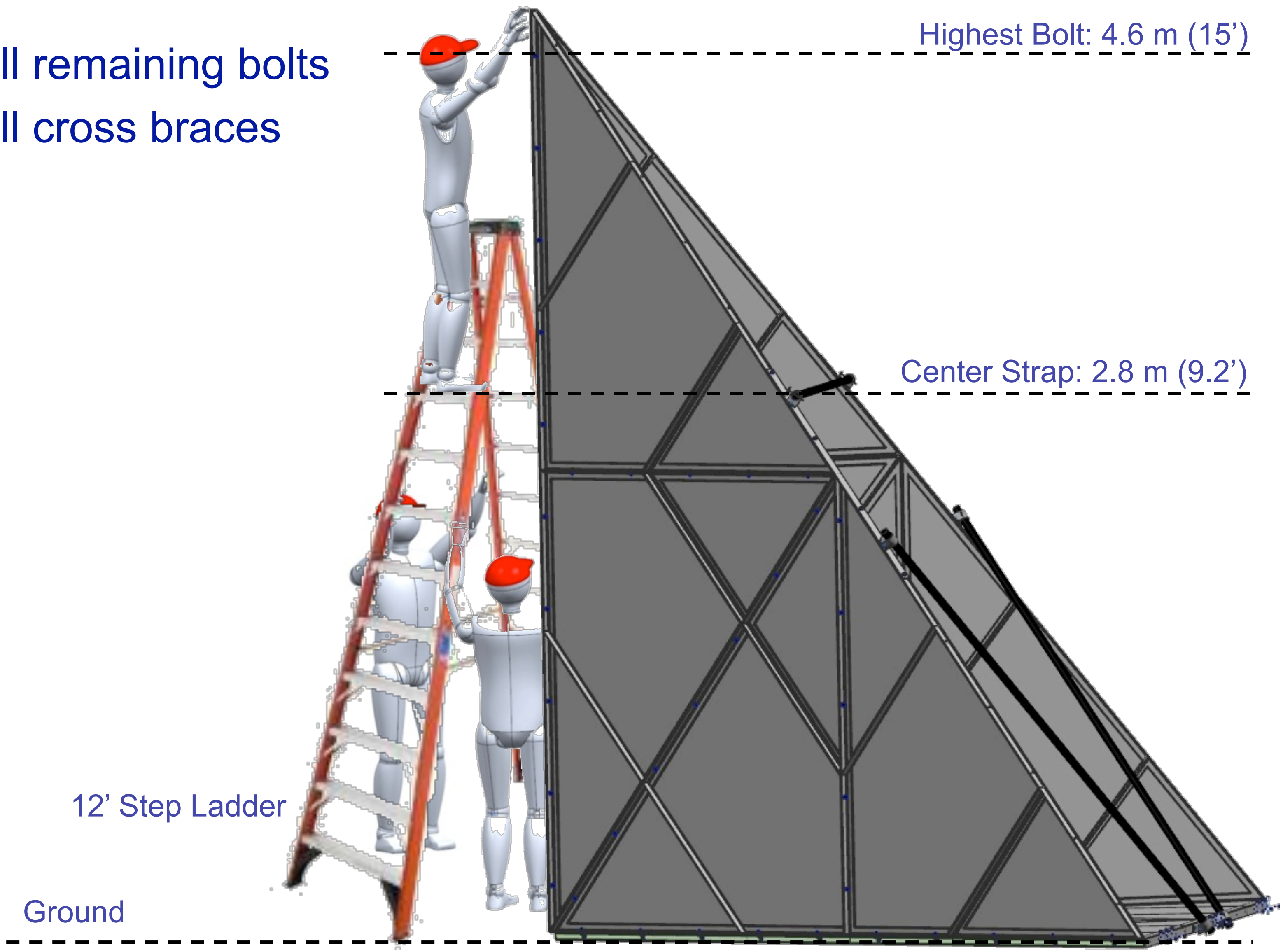


Note: Creating handle by tying rope around support structure will ease holding panel in vertical position

Assembly: Raising the Sides

Assembly Procedure (4)

- Install remaining bolts
- Install cross braces

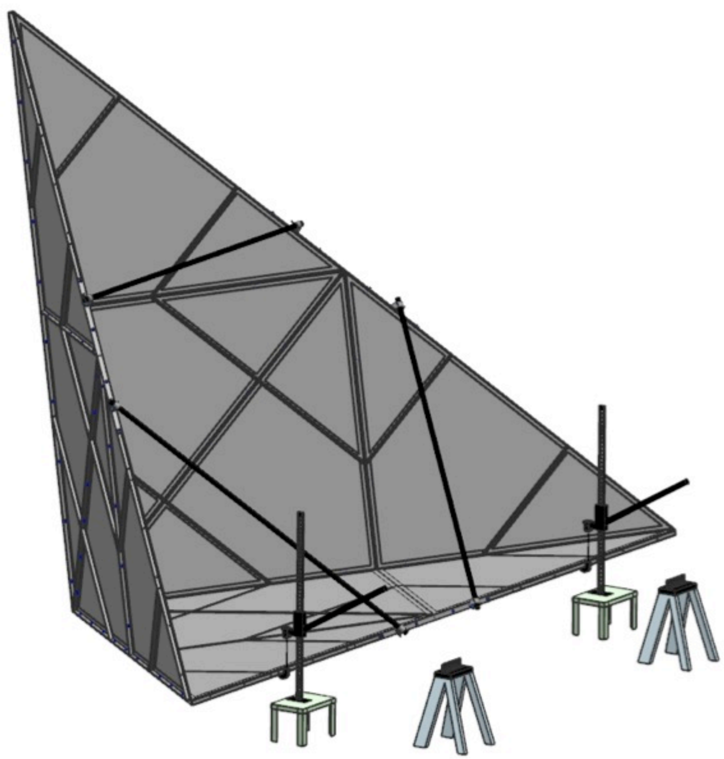


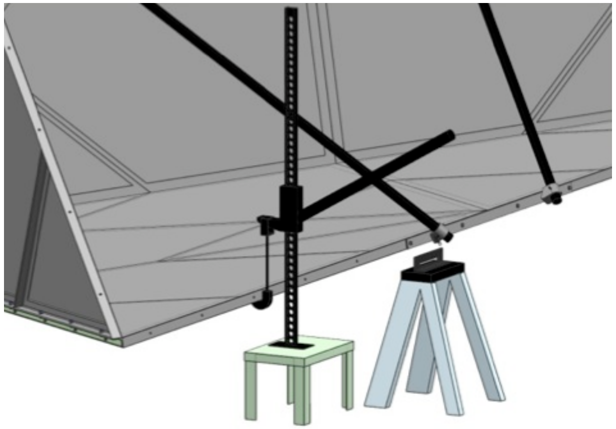
http://www.homedepot.com/Tools-Hardware-Ladders/h_d1/N-5yc1vZbttd/R-100664451/h_d2/ProductDisplay?langId=-1&storeId=10051&catalogId=10053

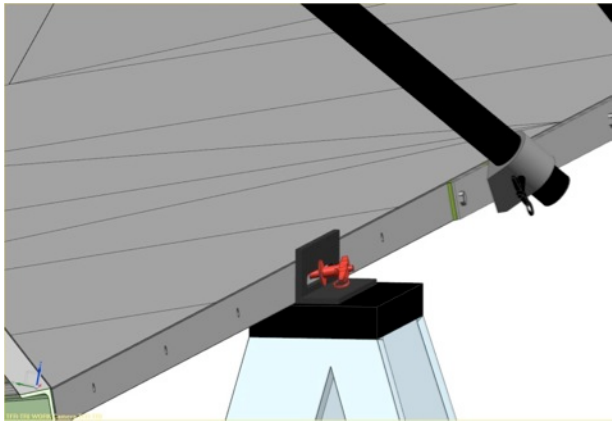
Assembly: Tightening Bolts

Assembly Procedure (5)

- Raise leading edge (LE) of CR using Hi-Lift jacks and bumper hooks
- Place step ladders near 4th bolt hole from ends
- Lower LE onto step ladders and secure with spring pins

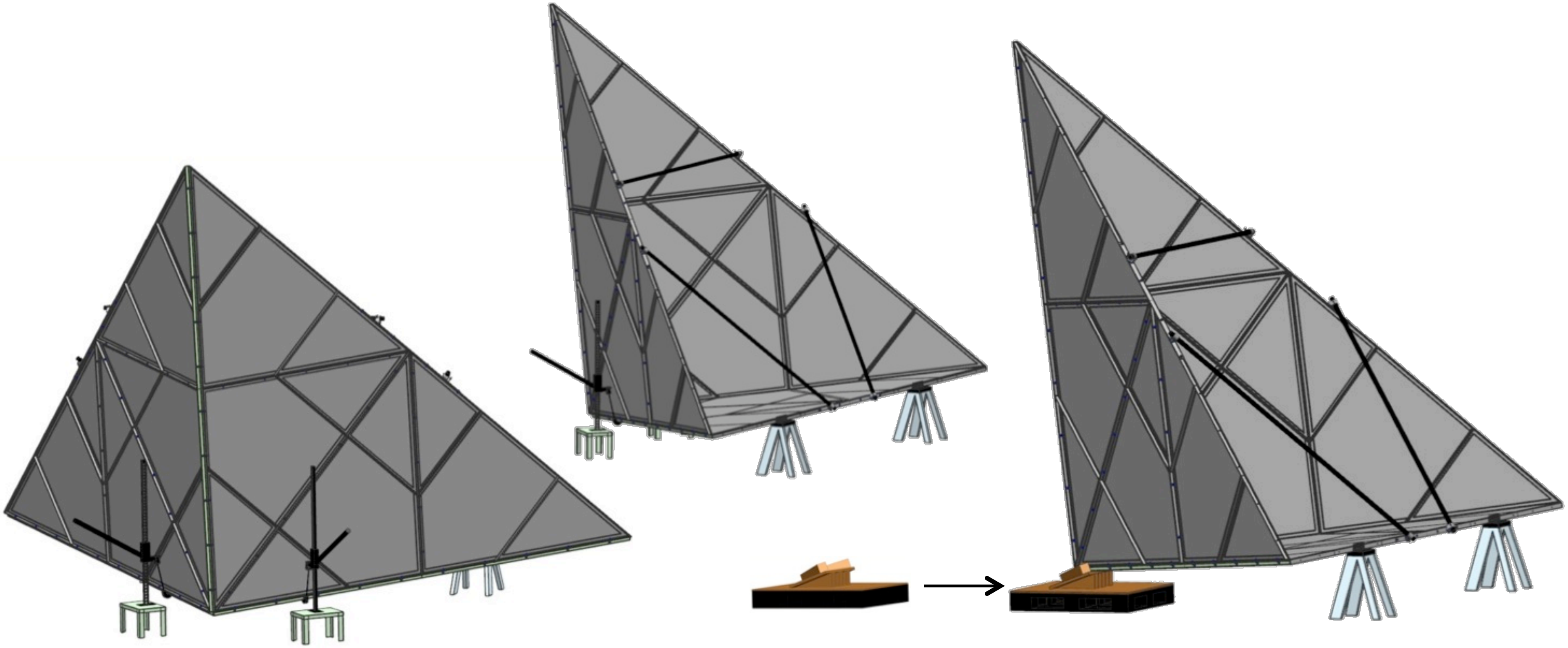






Assembly Procedure (6)

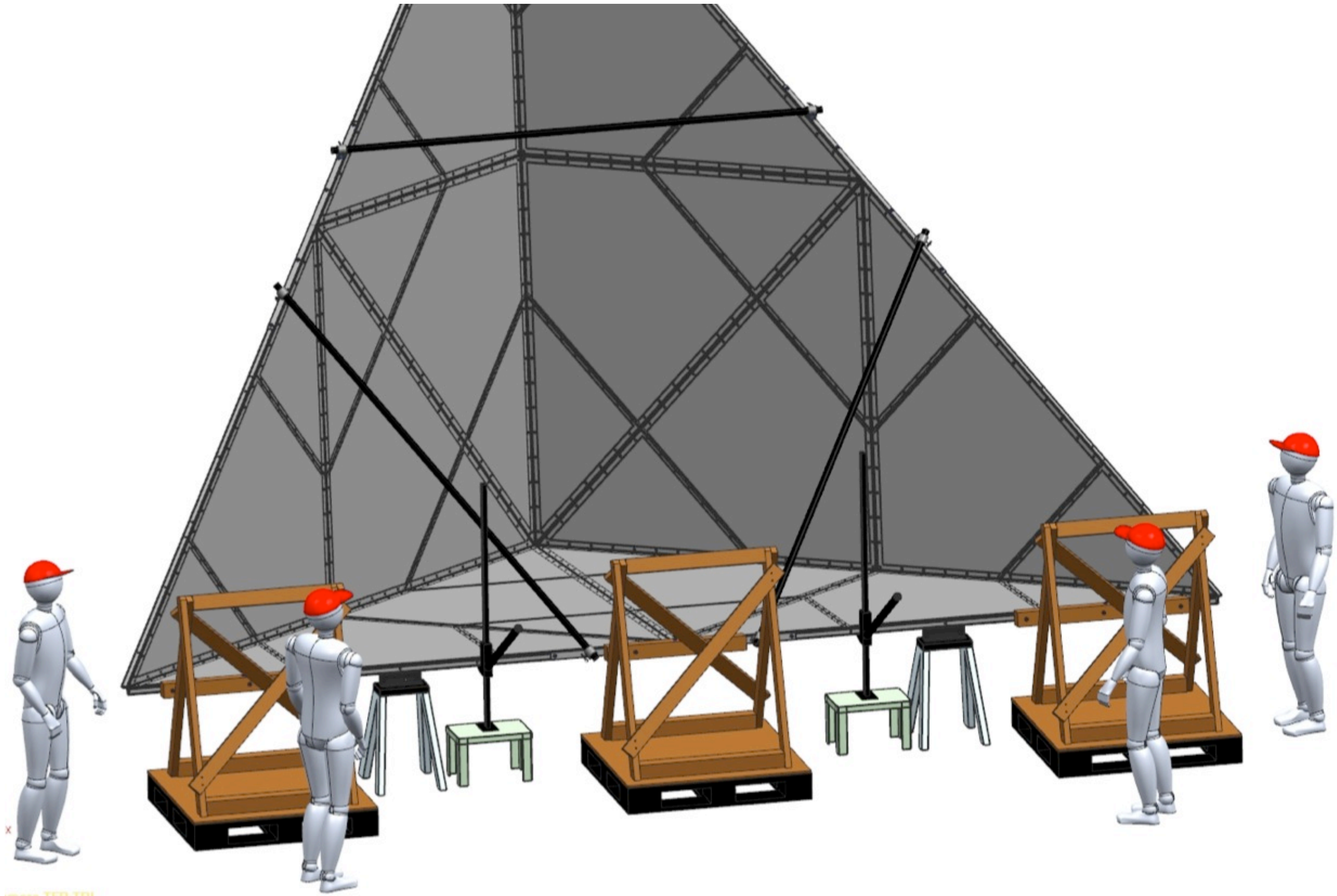
- Raise vertex of CR from jack points located 42” from vertex using Hi-Lift jacks and bumper hooks
- Position Vertex Balance Stand (VBS) under vertex
  - Verify azimuth of VBS is correct, adjust as necessary
- Lower vertex onto VBS



Assembly: Vertex Balance Stand

Assembly Procedure (7)

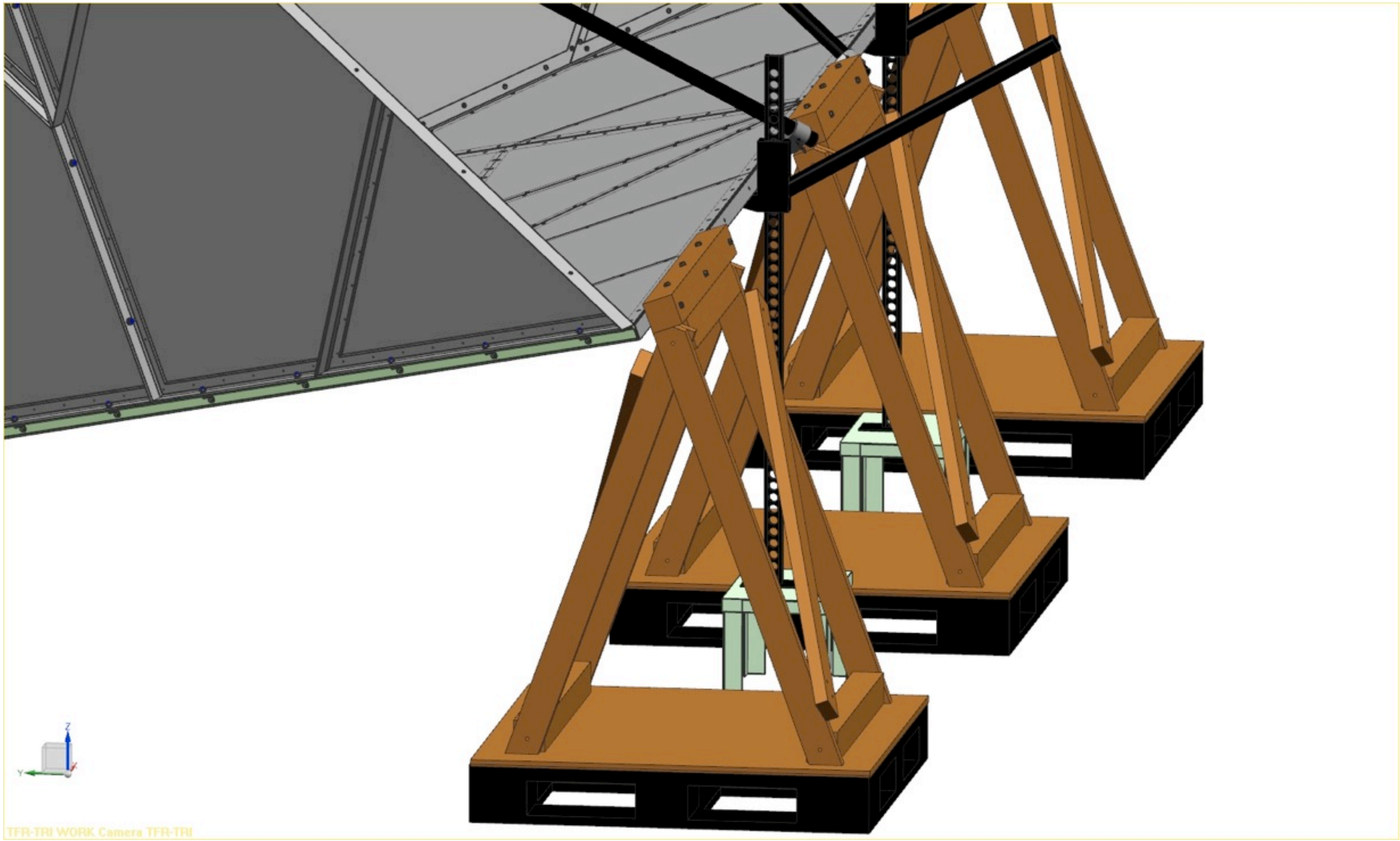
- Support LE with jacks and remove spring pins



Assembly: Jack the Leading Edge

Assembly Procedure (8)

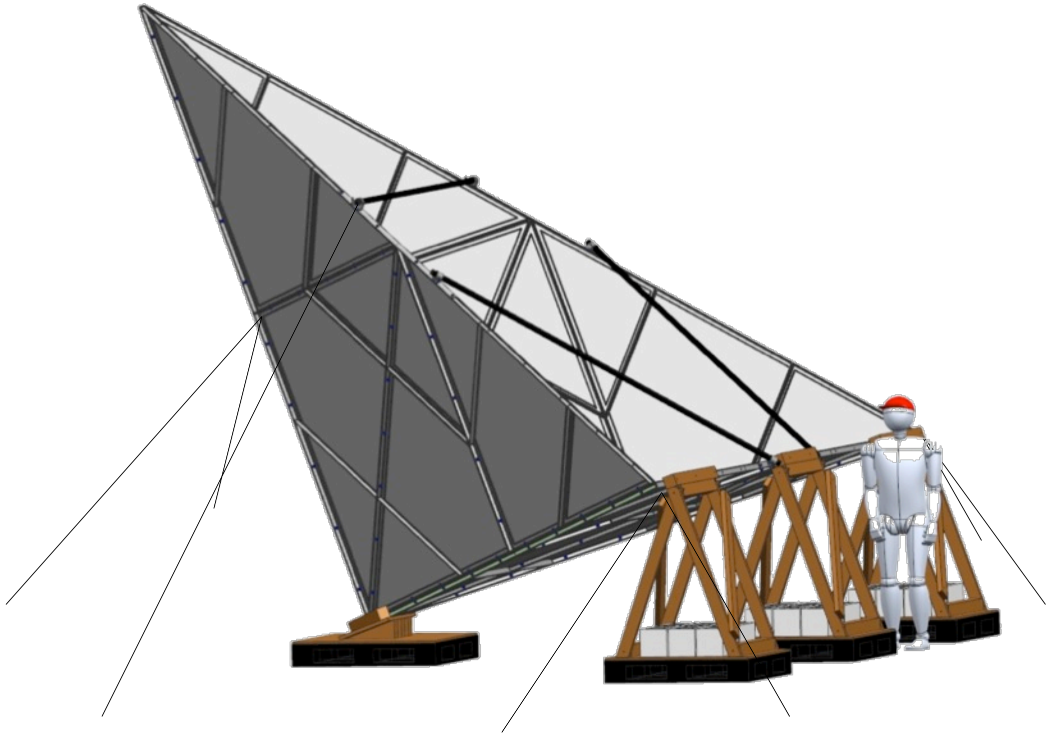
- Raise LE and slide leading edge supports (LESs) into position
- Lower LE onto LESs and install bolts



Assembly: Leading Edge Supports

Assembly Procedure (9)

After CR is oriented, load cinder blocks on LESs, drive in stakes and install guy ropes



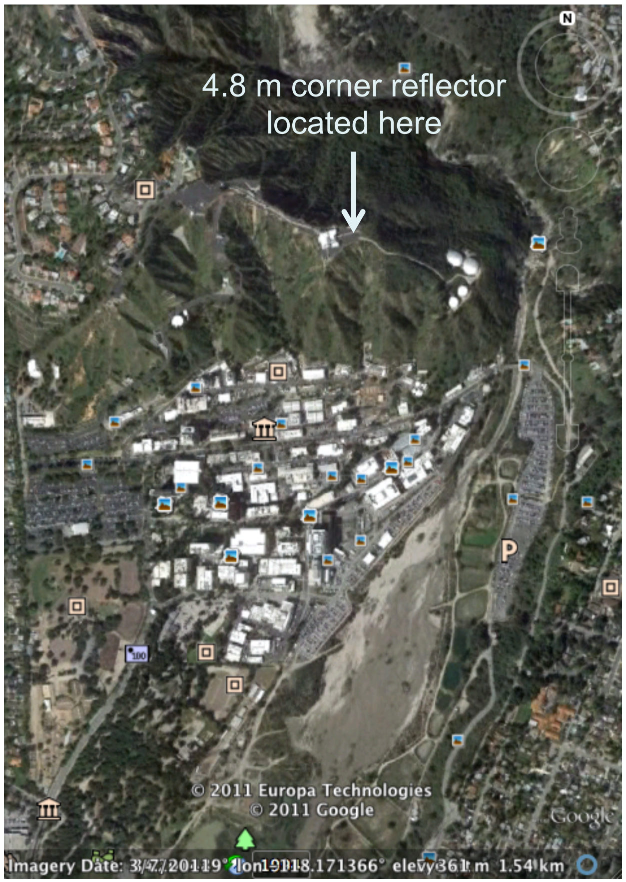
Assembly: Secure with Guy Ropes

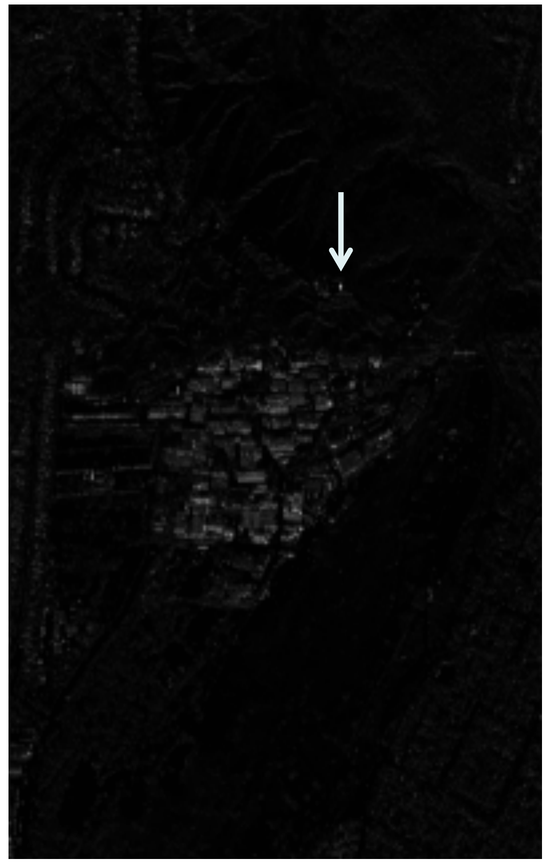
Assembly: Group Picture

Side View

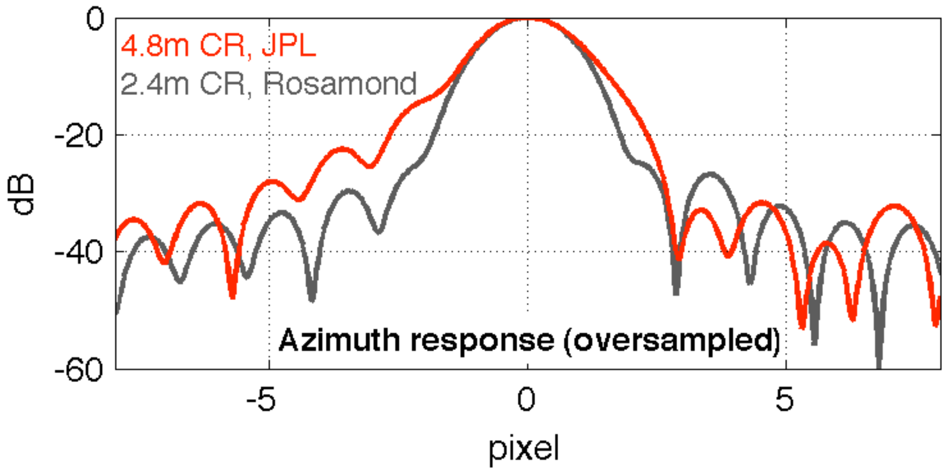
Cross Bars

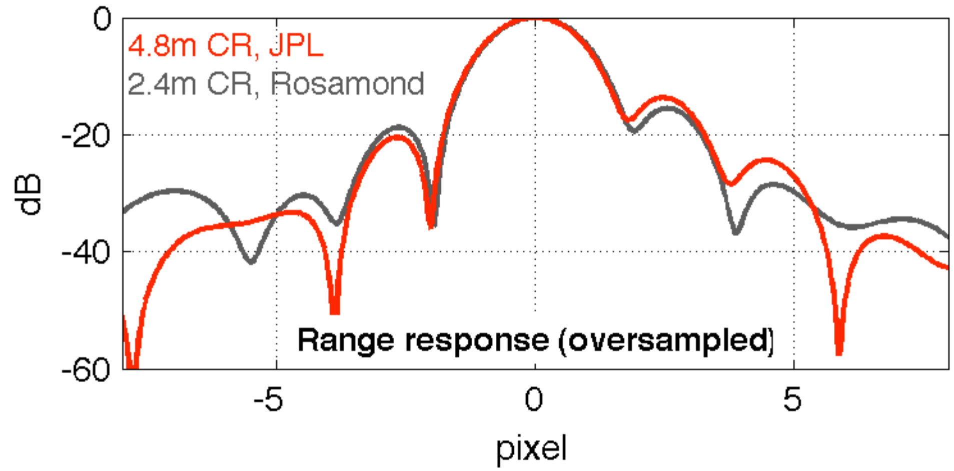
UAVSAR Image of 4.8 m Corner

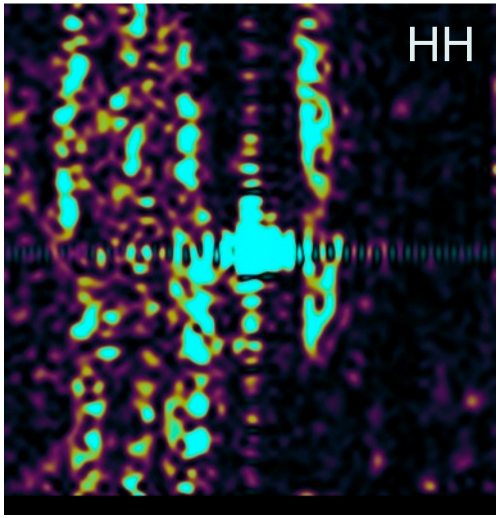


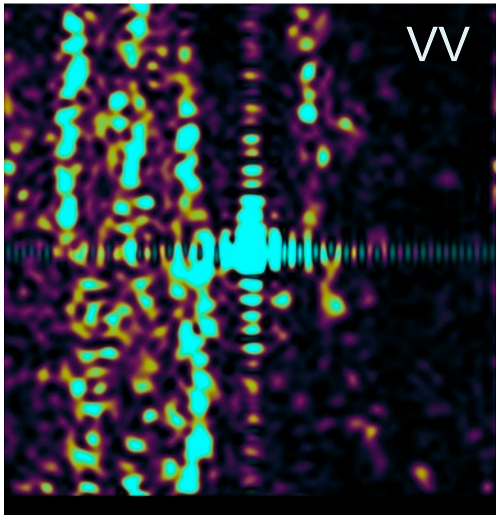


UAVSAR Corner Reflector Response









	RCS [dBsm]	Δ [dBsm]
Predicted	42.837	-
HH	42.148	-0.689
VV	43.668	0.839

Future Plans

- Characterize P-band SAR hardware and calibration paths (ongoing)
- Fabricate remaining corner reflectors for array (~5 at Rosamond Dry Lake)
- Deploy corner reflectors at Rosamond (spring 2012)
- Fly AirMOSS!

Questions

A time lapse video of the corner reflector assembly is at

http://airmoss.jpl.nasa.gov/science/calval/