NATIONAL RADIO ASTRONOMY OBSERVATORY

A New Approach to Inexpensive Radio Dishes

ngVLA

The Next Generation Very Large Array

A New Approach to

Inexpensive Radio Dishes

- Current Radio Dish Manufacturing Processes
- Custom Glass Slumping for Solar Concentrator Dishes
- Adapting Solar Glass Slumping for Aluminum Dish Manufacture
- Prototype for sub mm astronomy

ngVLA Requirements

- Frequency range of 1.2 - 116GHz (2.6 mm to 250 mm).
- 100 micron system rms for 116 GHz
  - 50 micron target for panels alone
- 300 off axis dishes
- 16 m diameter

Manufacturing Methods of Various Telescope

Telescope	Dish Diameter (m)	Frequency Band (GHz)	Surface Method	Surface Accuracy
ngVLA	18	1 - 115	TBD	~50 µm RMS
MEERcat	13.5	0.58 – 14.5	glued elastic deformation	0.6 mm RMS
VLBA	25	1.2 - 96	aluminum panels	150 µm RMS
VLA	25	0.23 - 50	aluminum panels	0.5 mm
Green Bank	100	0.1 - 116	aluminum panels	76 µm RMS
Arecibo	305	1 - 10	aluminum panels	3.2 mm RMS
ALMA	12	31 - 950	anodized nickel/composite	25 µm RMS

Current Dish Manufacturing Processes

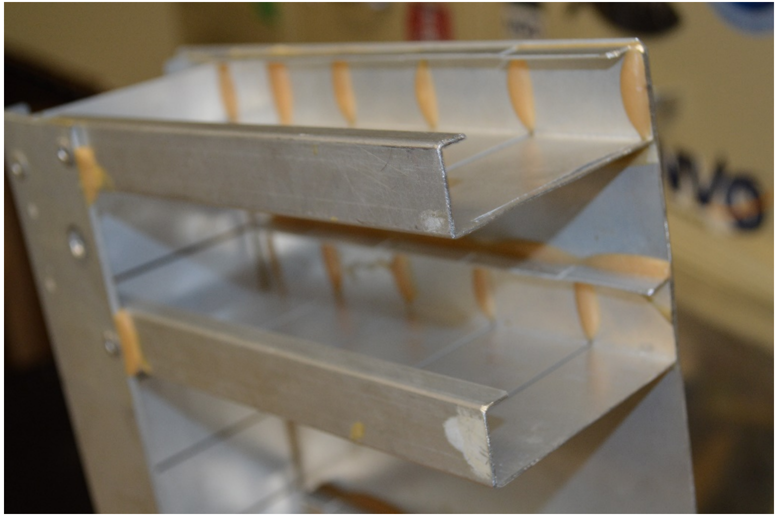


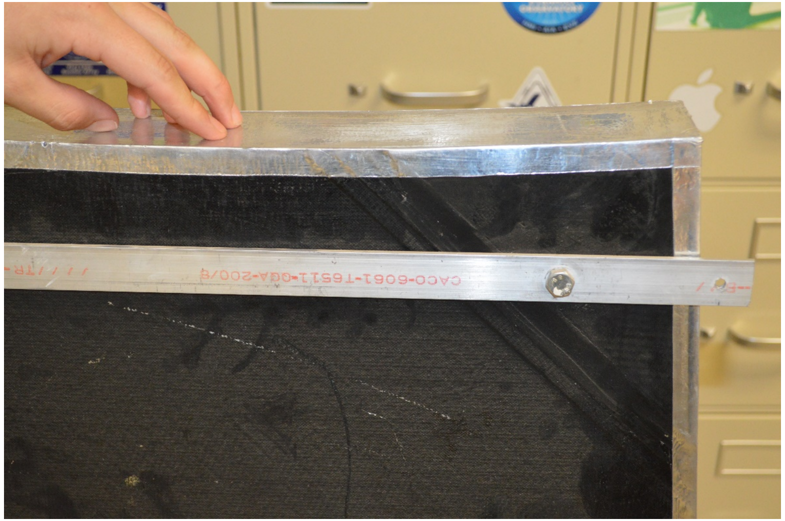
Photo Credit: ska.org

Old UA 12m Telescope

MeerKAT Array (Part of SKA)

Ribs Glued on to Aluminum Sheet

Current Dish Manufacturing Processes



Arizona SMT

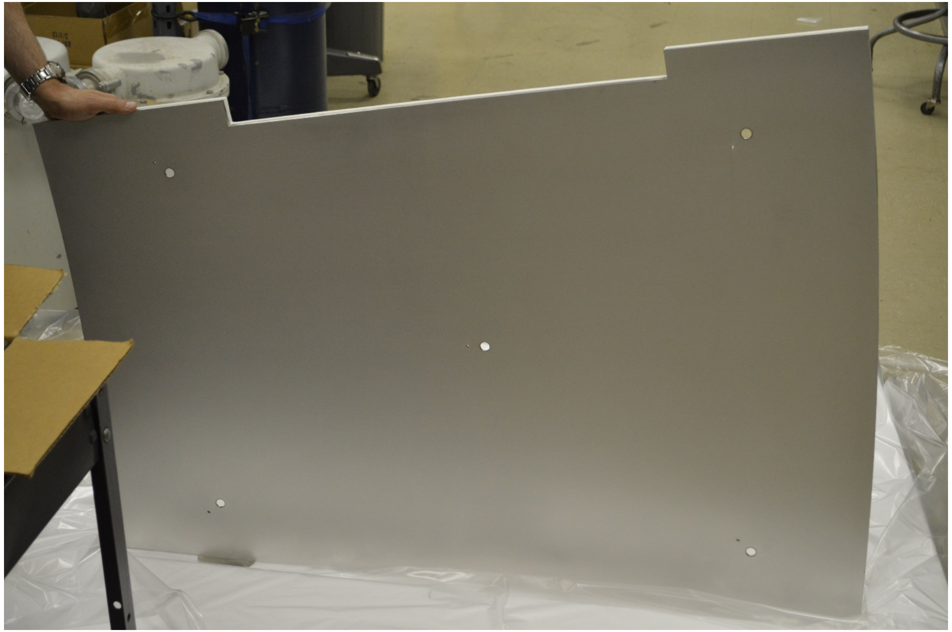
North American (NRAO) ALMA Dish

Composite

Current Dish Manufacturing Processes

ALMA ESO Dishes

Electroformed Nickel



ALMA ESO Prototype

- 12m Diameter
- Surface Accuracy <25 µm rms
- Electroformed Nickel

Cost

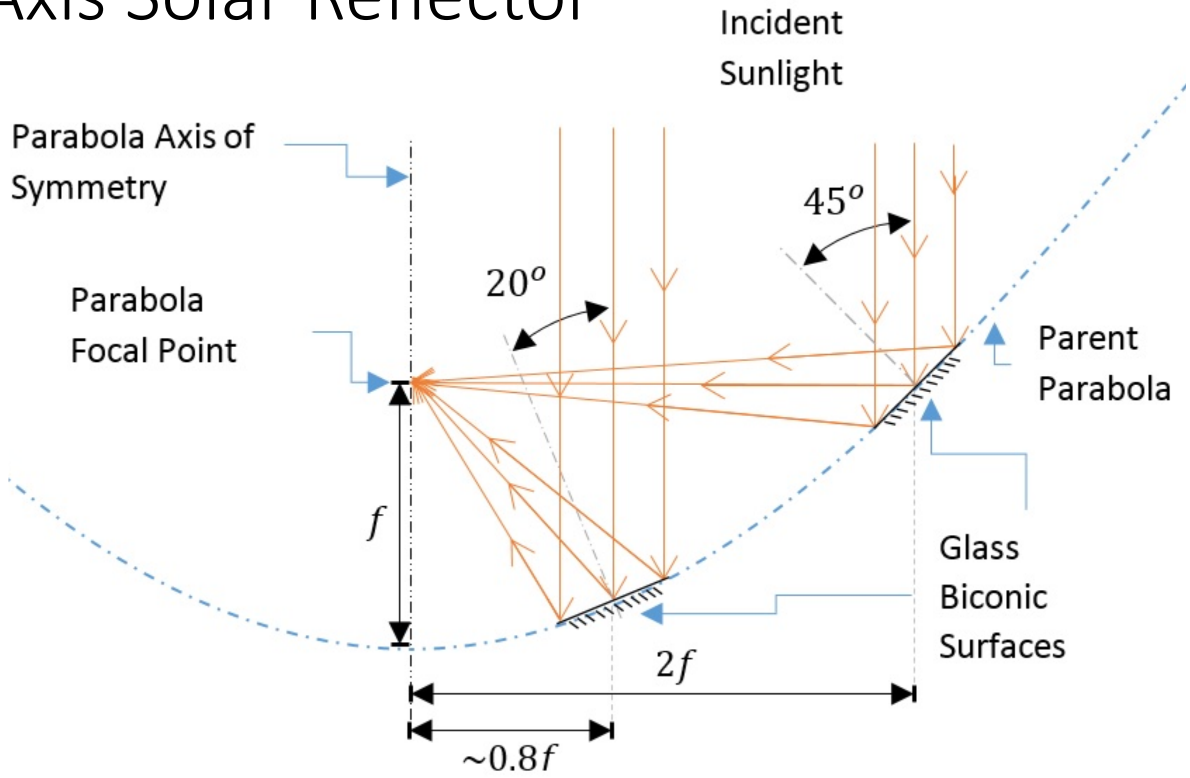
- Dificult to find out
- SKA-1 dishes (15m off-axis Gregorian operating to 25GHz) apparently cost ~$900K including electronics (3 receiver bands).
- ALMA $5M per telescope $1M of that for the surface.

Solar Solution

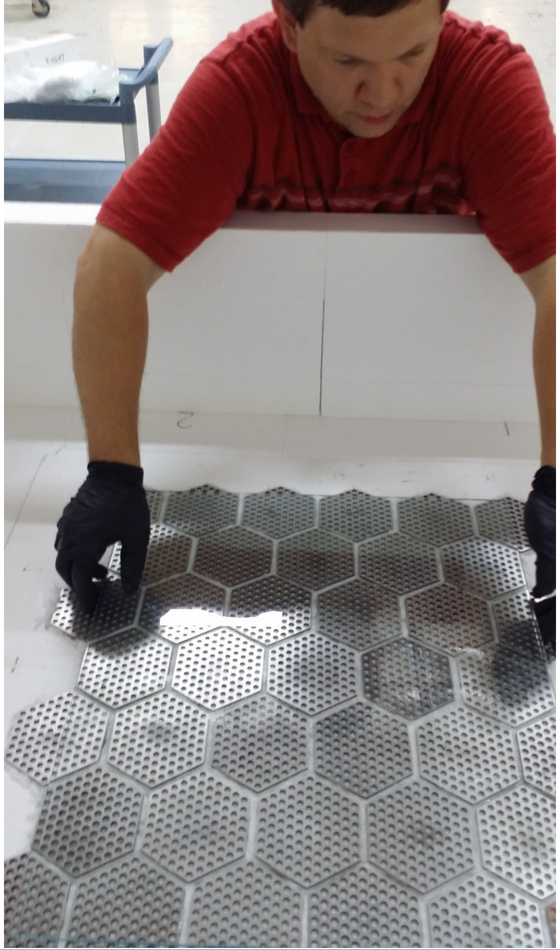
REhnu and U A have pioneered unique technology to sag 1.65 m square glass reflectors into dish shape. Here a 1.5 m focal length reflector formed on a stainless steel mold

On-Axis Solar Applications

New challenge – One Mold for Multiple Shapes for Off-Axis Solar Reflector



Adaptive tile mold prototype being assembled on machined faceted aluminum support



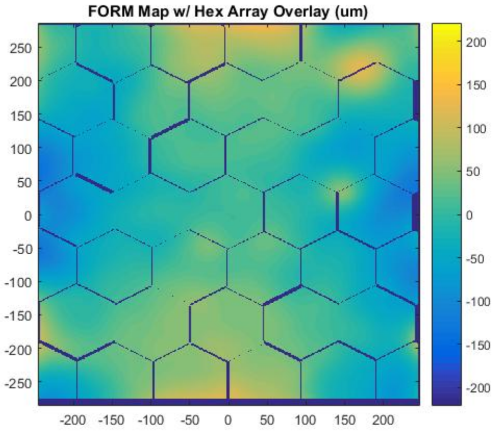

DANGER

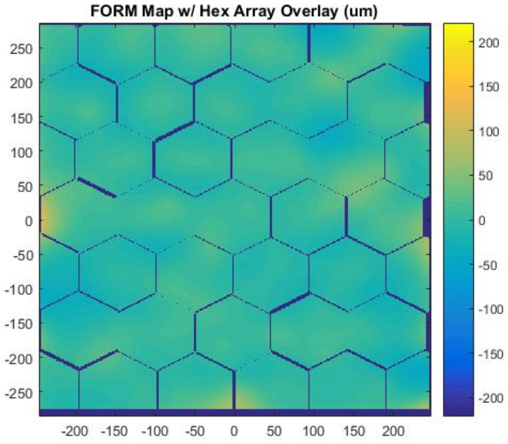
Segments made with two different shapes from the prototype mold

19” x 22” Panels

Replica #20 - spherical curve R= 20 m
RMS surface error **47 μm**
RMS slope 1.2 mrad
(remaining residual error of astigmatism)

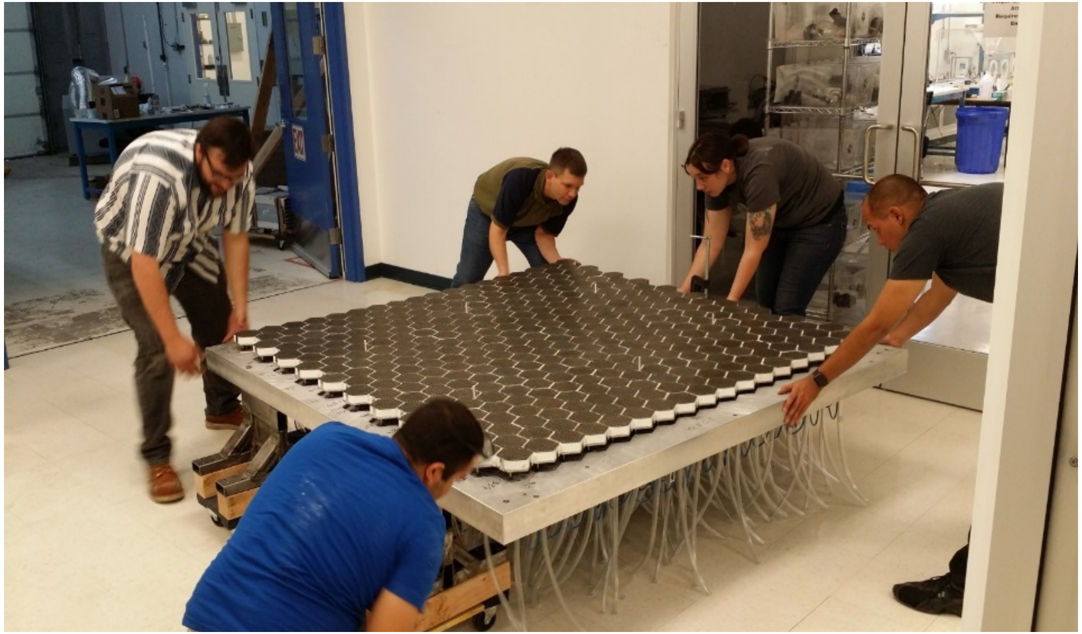
Replica # 23 - biconic
R_{radial} = 39.2 m $R_{tangential}$ = 20.9 m
RMS surface **15 μm**
RMS slope 0.8 mrad





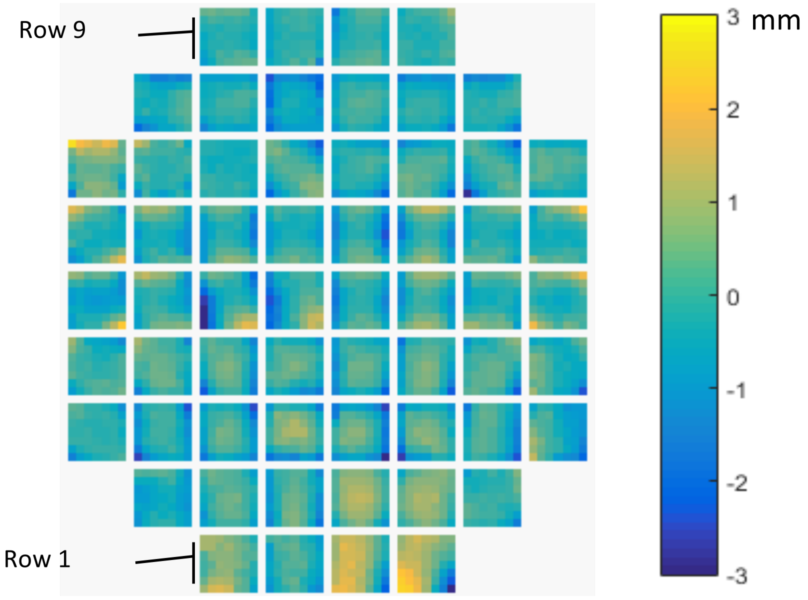
Full Size Computer Controlled Mold developed by Rehnu for 1.65 m Square Panels

- Mold surface segmented
  - 350 insulated hexagonal tiles
- Each tile articulated by a kinematic support
  - 3 micrometer actuators under computer control
  - 20 mm travel
  - radii of curvature from 14 m – 30m



Set of glass panels made with CCM for Off-axis Solar Collector

- Parent dish parameters
  - Diameter 13 m
  - Focal length 7.68 m
  - Bottom row (1) is 3.3 m off axis
  - 60 panels, each 1.65m x 1.65 m
- Color contour maps from the final panel accuracy verification
  - Surface error maps for all 60 panels
- rms panel surface error over the entire dish is 0.63 mm
  - Assuming accurate support structure



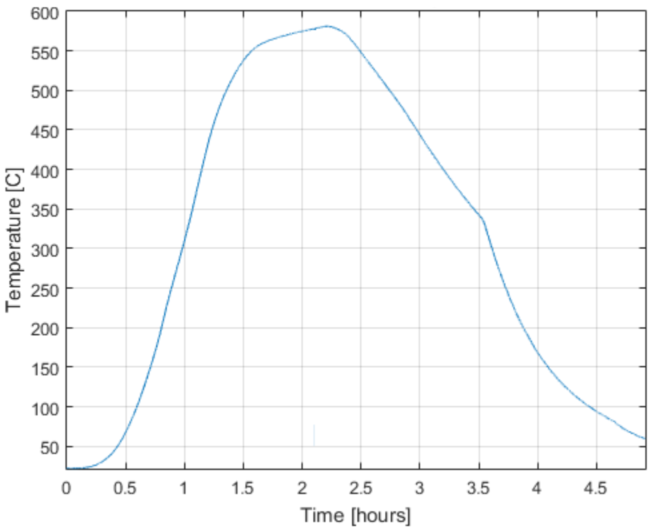
- Parent Vertex

Aluminum Shaping from the Same Mold

	B270 Glass	Aluminum
Strength	Ultimate: 33 MPa	Yield: 55.2 MPa
Elastic Modulus	71.5 GPa	68.9 GPa
Annealing Temperature	541 °C	413 °C
Melting/Softening Point	724 °C	582 - 652 °C
Density	2.55 g/cm^3	2.7 g/cm^3

Initial test of aluminum shaping with CCM

- 1.65 m square replica of 4.7 mm thick aluminum sheet
- 5052 aluminum alloy chosen as immediately available in this size and thickness

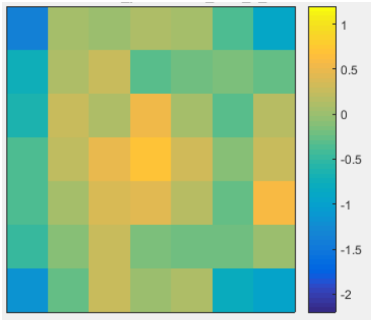


Thermal cycle, 4.5 hours

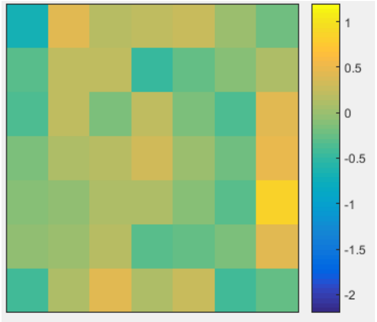
Panel being painted after shaping

Initial metrology results – **0.26 mm rms** surface error

- 1.65 m square aluminum replica with concave surface
    - corner-to-corner sag of 42 mm
- Shape compared to glass replica made from same mold setting
- Laser sag measurements made on 7 x 7 grid
- Only difference is a small change in curvature
    - aluminum shows 5% longer focal length than glass
    - center high by 2 mm relative to corners
    - likely result of residual elastic deflection at forming temperature
    - easily correctable by CCM shape adjustment



Aluminum – glass shape difference
Center high by 2 mm
0.48 mm rms surface error



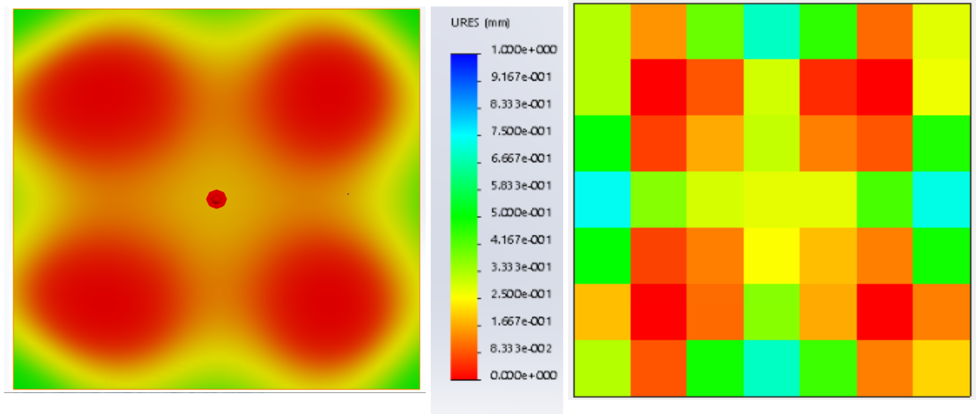
Focus removed
0.26 mm rms residual error

Calculated and measured surface gravity deflection

0.20 mm RMS under 1 g load

- 1.65 m square aluminum panel 4.7 mm thick
  - Four supports on 0.91 m square
- 1 g deflection derived from shape change on inverting the panel

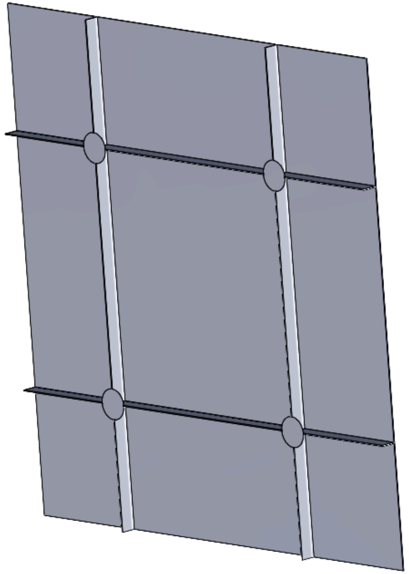
- Finite element analysis
- Made for glass 4 mm thick



Color scale 1 mm P-V

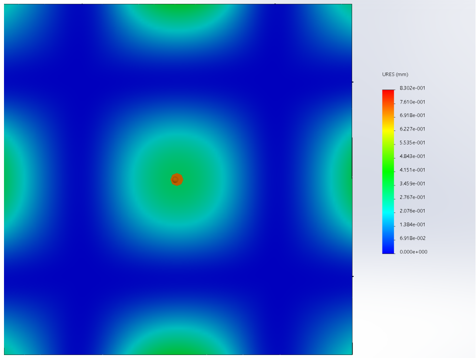
•Laser CMM measurement of shaped aluminum panel

Potential for CCM shaping of lighter aluminum panels with stiffening ribs

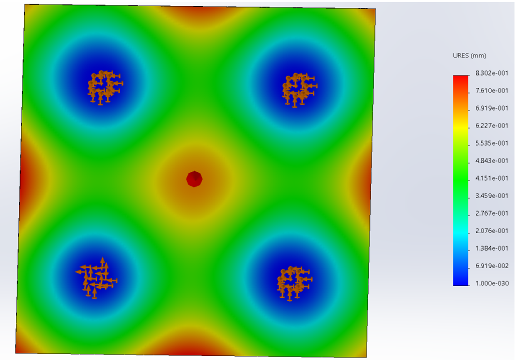


Un-optimized model: 2.5 m^2 panel with hash sign ribs

- CCM method extended to lighter weight and higher stiffness
- Rib structure welded to flat preform sheet before shaping
- Preform set face down on convex CCM for shaping
- Initial model: 20% lighter and twice the stiffness

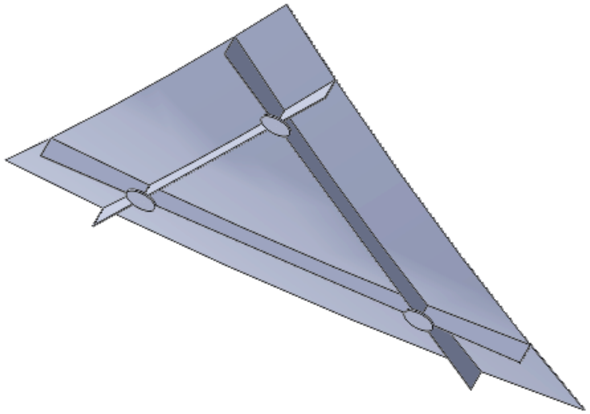


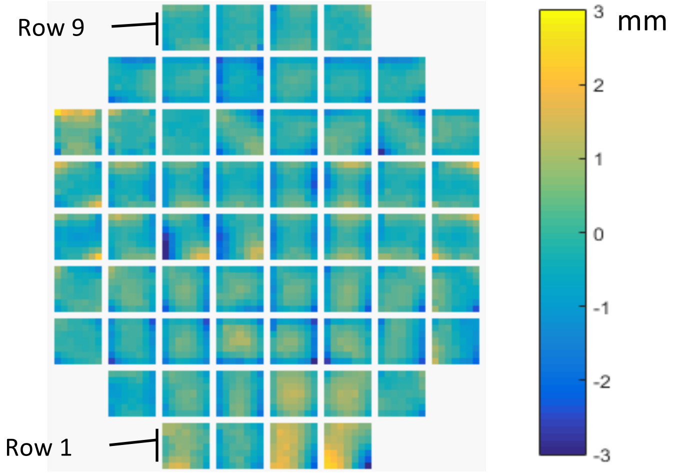
- 3 mm thick, 50 mm deep hashtag ribs
- 51 lbs
- Supports on 0.9 m square
- 1g P-V surface deflection 0.37 mm

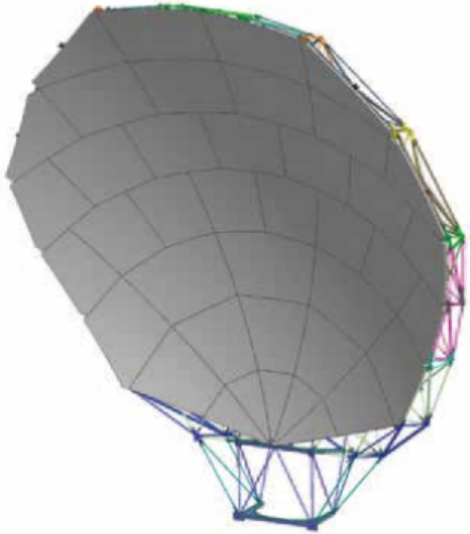


- Simple plate 4 mm thick, no ribs
- 64 lb
- Supports on 0.9 m square
- 1g P-V surface deflection 0.83 mm

Different Panel Shapes







- Parent Vertex

Arizona Slumped method can make any shape.

Arizona Slumped method with square segments

Meerkat arcs of similar segments

Advantages of New Panel Shaping Method

- Simple production and mounting
- Panel preforms are flat and of any shape
- Rapid, inexpensive manufacturing
- One mold makes all segments of off axis dish
- Compatible with diverse backup structures

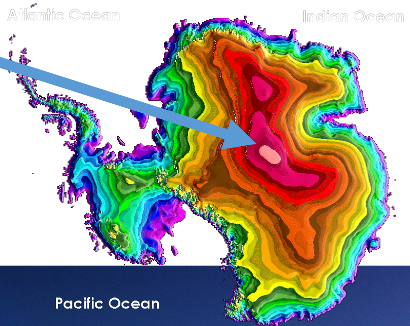
Achievements to Date

- ½ m glass replica 15 µm RMS accuracy
- Single 1.65 m aluminum panel 260 µm RMS accuracy
- Full set of 60 panels for 13 m off-axis dish 630 µm RMS accuracy

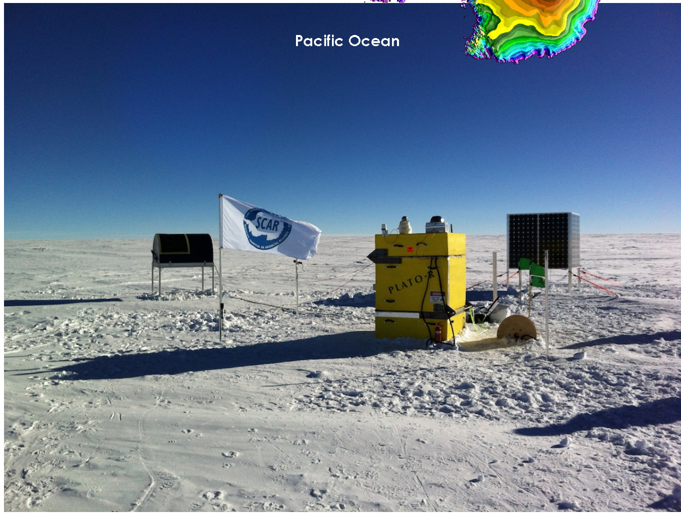
Next Steps

- Test slumping ribbed panels
- Test various mounting methods
- Assemble multi panel dish

Prototypes for the High Elevation Antarctic Terahertz (HEAT) telescope

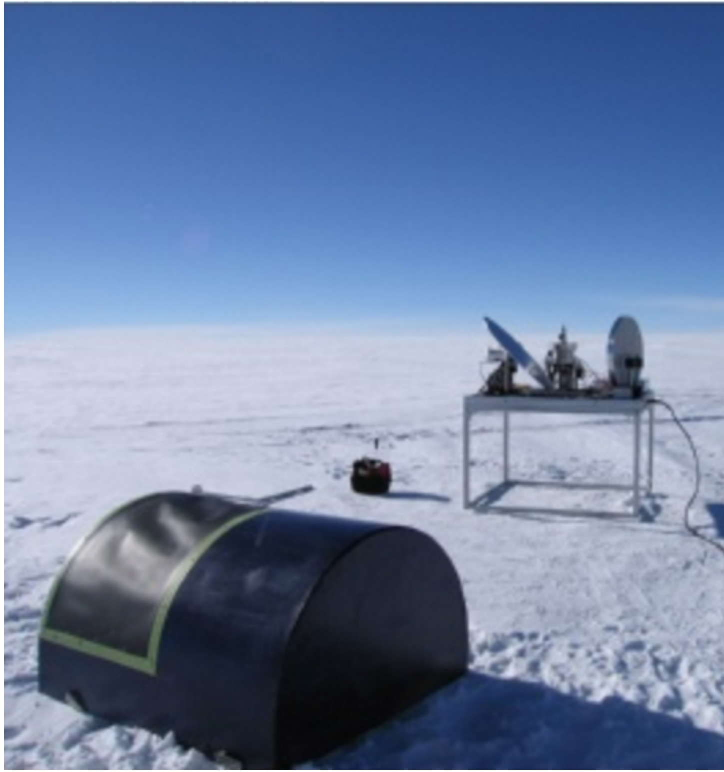


- 61 cm off-axis Gregorian telescope, deployed in 2012, with 500-1500 GHz heterodyne receivers cooled to 45K
- First fully robotic ground-based THz telescope with cryogenic instrumentation. 1 year between servicing missions.
- Deployed to the summit of the Antarctic Plateau. Median winter precipitable water vapor (PWV) is 0.1 mm. Over 100 days observable per year at ALMA Band 11 (1-1.5 THz)
- Ideal site for wide field THz mapping and THz interferometry.
- **Next phase of development is a low-cost 5-10 element interferometer w/ 1-2m apertures for use from 0.8 – 1.9 THz.**
- Single solar mirrors with active surface control are a cost-effective way to prototype such an interferometer.
- A 492 GHz prototype antenna is being constructed and tested at Arizona for deployment on Mt. Lemmon this winter.



High Elevation Antarctic Terahertz Telescope (HEAT)

- 61 cm off-axis Gregorian telescope
- 492 and 809 GHz heterodyne receivers
- First robotic ground-based THz telescope with cryogenic instrumentation .
- 1 year between servicing missions.
- Next step is a 6 telescope interferometer.



Thanks to

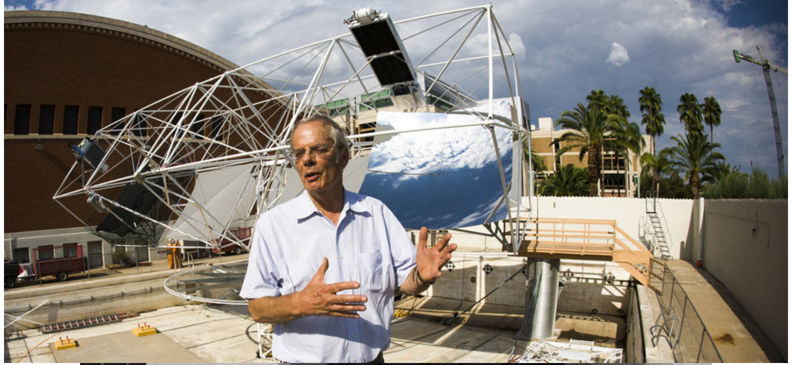
Dr. Roger Angel and

Steward Observatory Solar Lab

UA Colege of Optical Science

My Family

God



Questions?

Square Kilometre Array

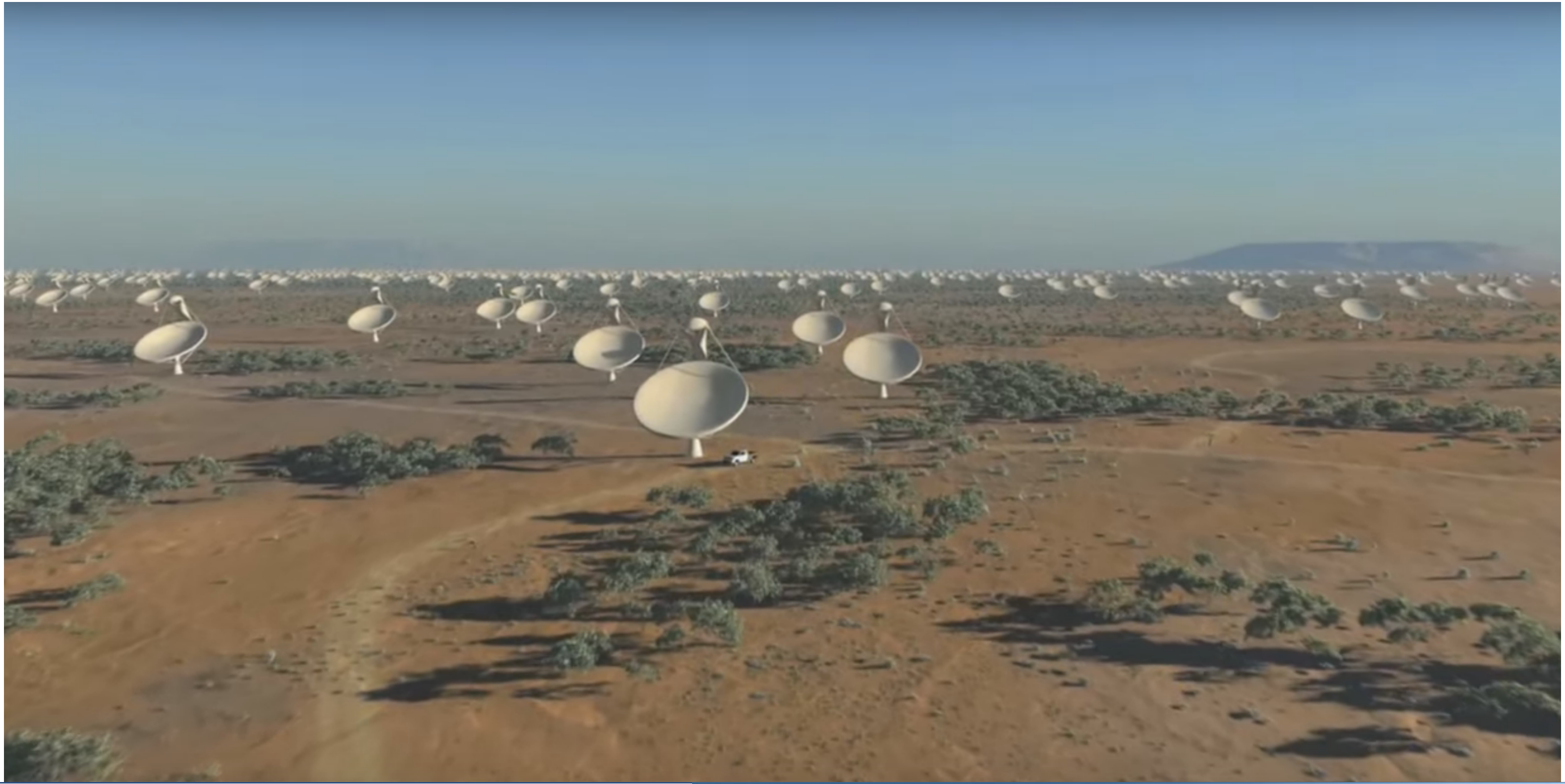


Photo Credit: ska.org

HEAT Prototype

- 1.65 m square primary mirror