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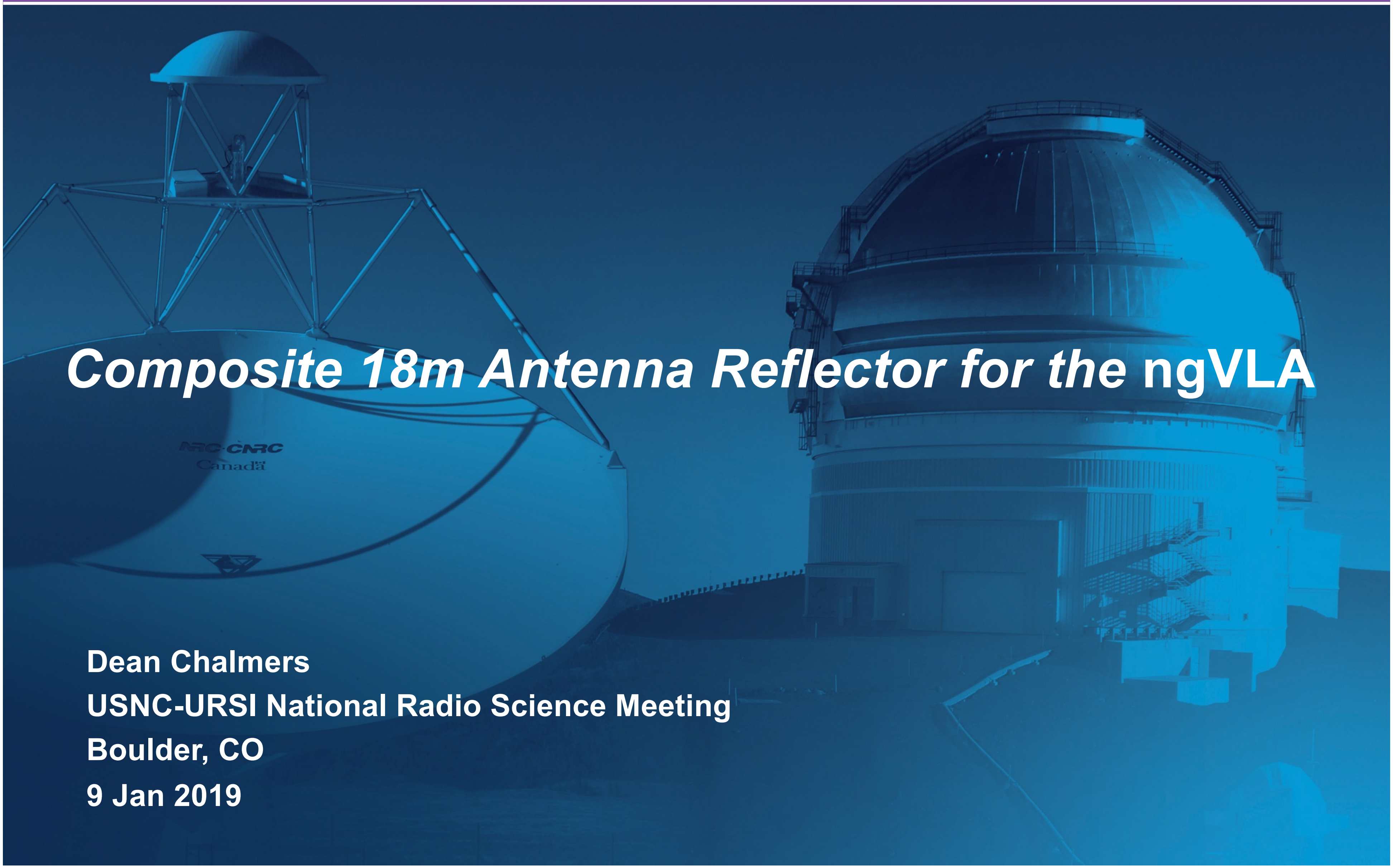

Composite 18m Antenna Reflector for the ngVLA

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USNC-URSI National Radio Science Meeting

Boulder, CO

9 Jan 2019

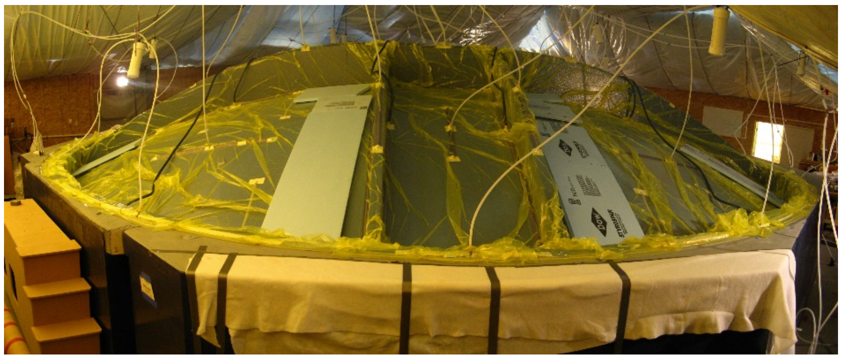
National Research Council Canada — Conseil national de recherches Canada

Canada

Single Piece Composite Reflectors at NRC

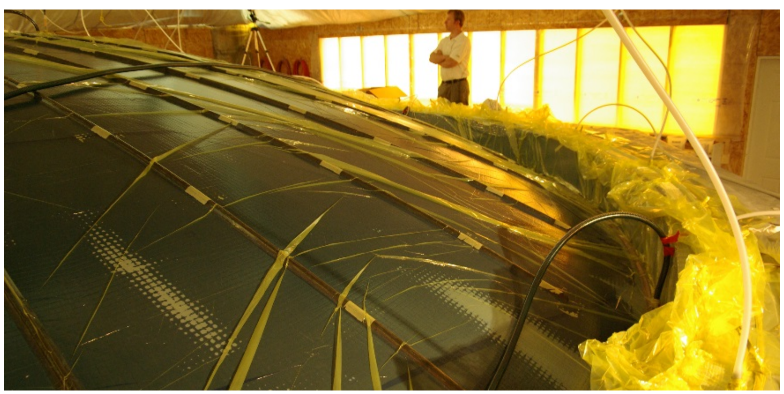
10m Symmetric Parabolic Dishes Targeted at the SKA

2007: Mk1 – Single piece surface, rim and beams in one infusion.



Surface Accuracy: 1.2mm RMS

2008: Mk2 – Single piece surface and rim in one infusion. Hub and beams bonded on after.



Surface Accuracy: 0.5mm RMS

The Rim-Supported Concept

Collaboration with the US Technology Development Program led to the integration of the rim supported concept used in the ATA antennas with the single piece composite reflector surface. The result is the Single-piece, Rim-supported Composite (SRC) Reflector concept.

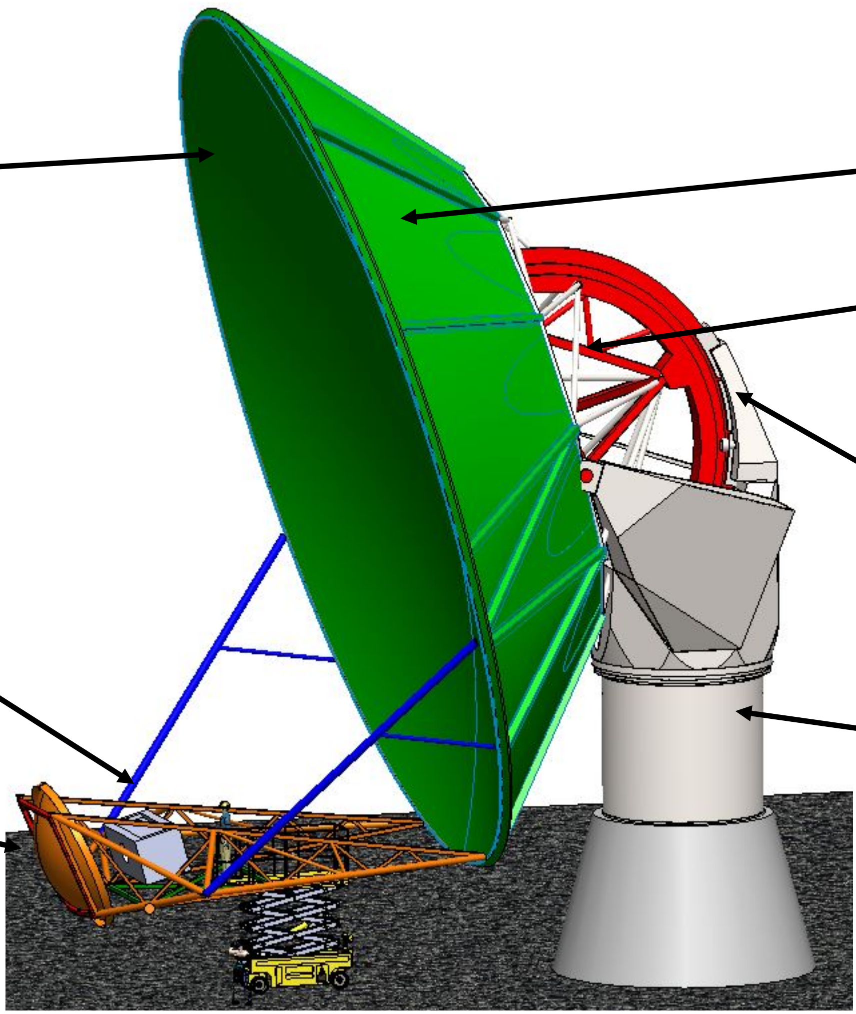
NRC SRC Reflectors

2014: DVA1 15m offset Gregorian antenna completed in. Surface accuracy 0.8mm RMS.

2017: DVA2 15m offset Gregorian antenna completed in. Surface accuracy 0.3mm RMS.

ngVLA 18m Offset Gregorian, Shaped Optics, Single-Piece Rim-supported Composite Reflector, Alt-Az Pedestal Mount

- Single piece composite primary reflector surface.
- Composite feed/secondary support structure
- Single piece composite secondary reflector surface.



- Composite outer backup structure.
- Steel inner backup structure.
- Direct drive elevation and azimuth axis drives.
- Steel yoke and pedestal structures.

Key Challenges for SRC Reflectors for the ngVLA

1. Surface Accuracy

- ngVLA Requirement:
  - Precision Operating 160 μm
  - Normal Operating 300 μm

2. Transportation

- 171 ngVLA 18m antennas located on St. Agustin plain.
- 73 18m antennas will require transport off of the plain.

Surface Accuracy Budgets

Precision

Primary	Value [µm RMS]	Secondary	Value [µm RMS]
Mould	**100**	Mould	50
Process	86	Process	18
Gravitational	53	Gravitational	20
Wind	20	Wind	4
Thermal	45	Thermal	10
Ageing	7	Ageing	2
Total	149	Total	58
Combined Total (RSS)		**160**	[µm RMS]
Requirement		**160**	[µm RMS]

Normal

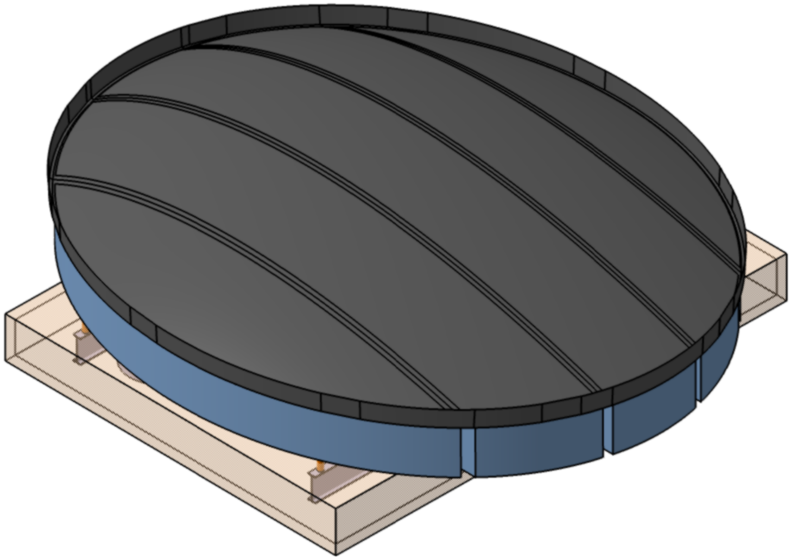
Primary	Value [µm RMS]	Secondary	Value [µm RMS]
Mould	**100**	Mould	50
Process	86	Process	18
Gravitational	53	Gravitational	20
Wind	41	Wind	9
Thermal	68	Thermal	15
Ageing	16	Ageing	3
Total	158	Total	59
Combined Total (RSS)		**169**	[µm RMS]
Requirement		**300**	[µm RMS]

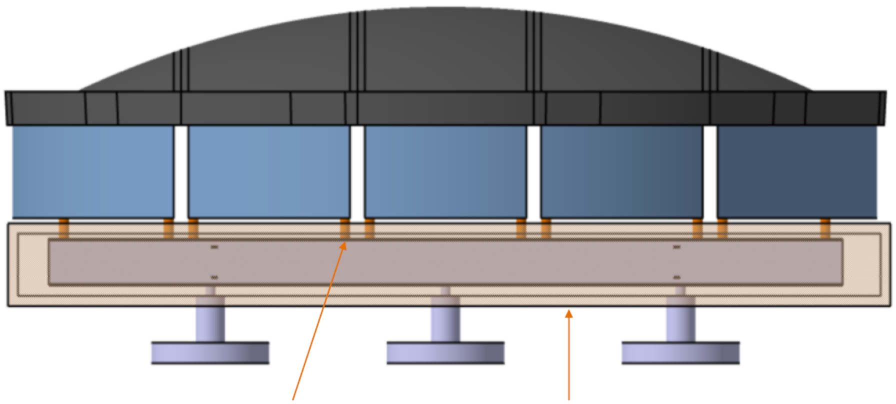
- **Load induced distortions low due to high stiffness and low thermal expansion of carbon/epoxy.**
- **Initial part accuracy depends largely on the accuracy of the mold but also on the materials, layup, design and process.**

Strategies to Address Surface Accuracy

Fabrication

- Fully carbon/epoxy mold on an isothermal base.
- Uniform thickness primary surface only infusion (no rim, beams or other features).
- Low-shrink epoxy resin.
- Quasi-isotropic fabric layup.

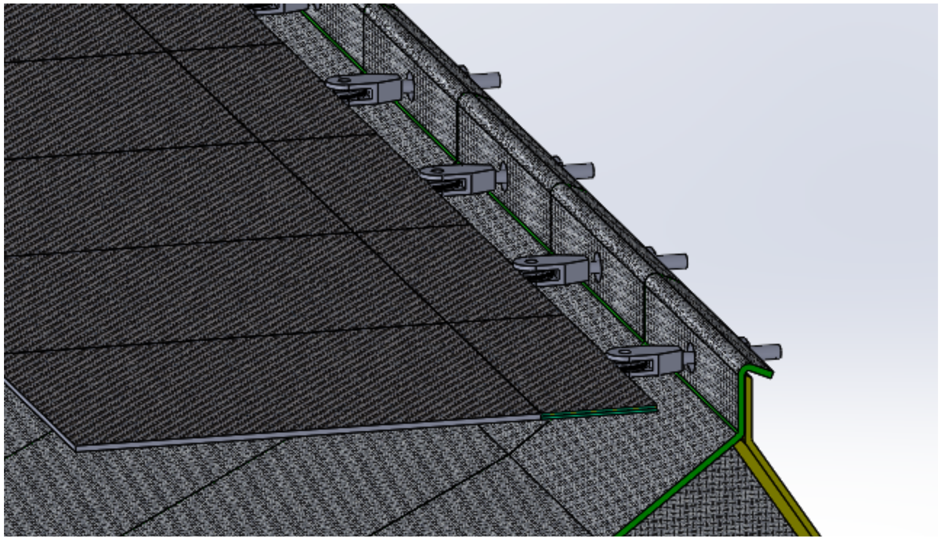


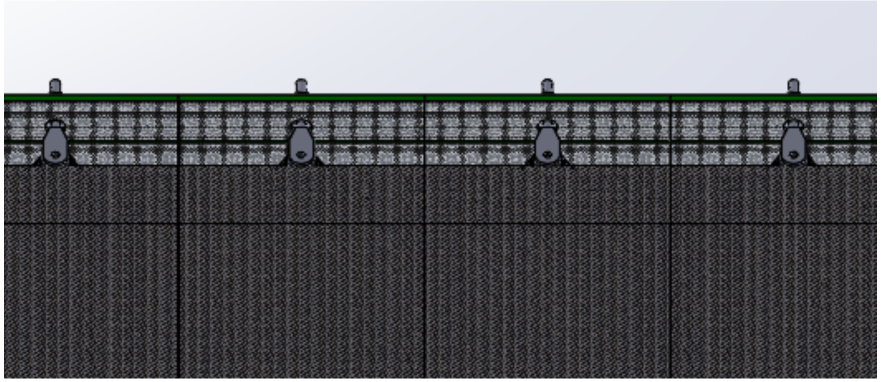


Strategies to Address Surface Accuracy

Design

- Carbon composite outer backup structure.
- Quasi-continuous primary surface support.
- Surface adjusters around perimeter of primary surface connecting to outer BUS.





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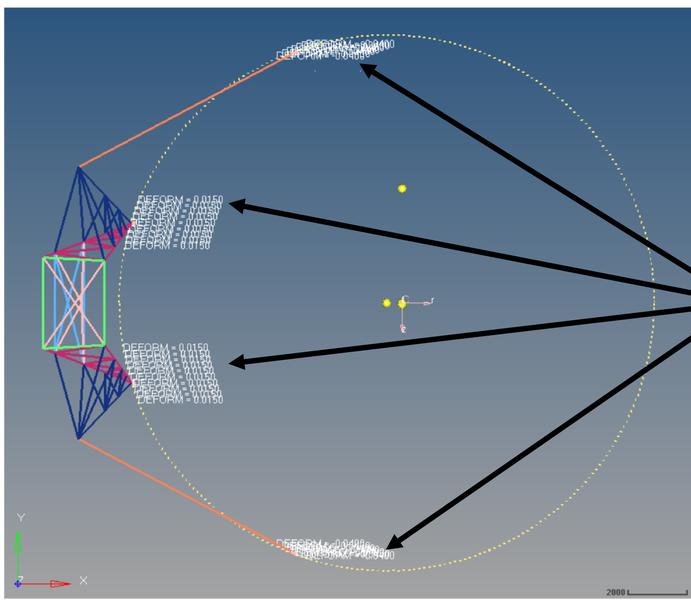
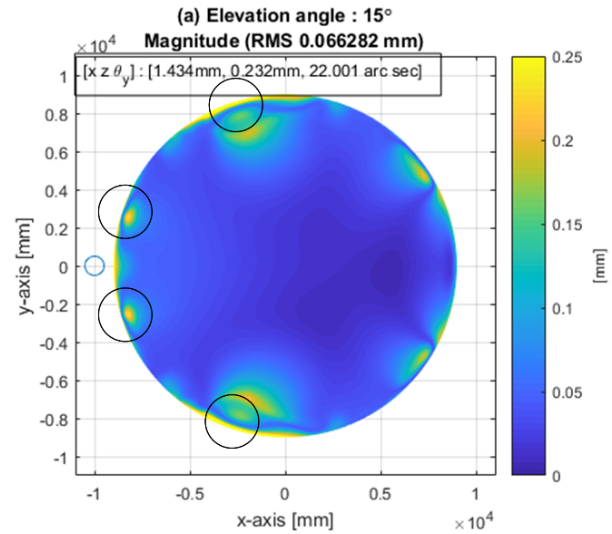
Strategies to Address Surface Accuracy

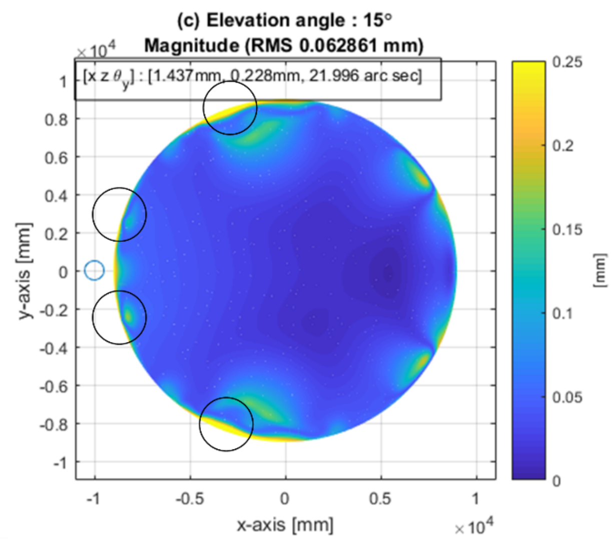
Adjuster Modeling

- Experience with DVA1/2 has shown adjustment is required to compensate for tolerances in large backup structure and “set” initial surface shape.
- Modeling shows that the adjusters can be effective at reducing gravitational distortions.



Adjustment applied in these areas.





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Surface Accuracy and Shaped Optics

Classical analysis of parabolic reflector antennas;

1. **Analyze reflector deformations (FEA).**
2. **Best fit a new parabola.**
3. **Calculate RMS of deviations from new parabola.**
4. **Calculate efficiency w/ Ruze Equation.**

With shaped optics step 2 of this does not work. In addition we now have much better tools.

New method;

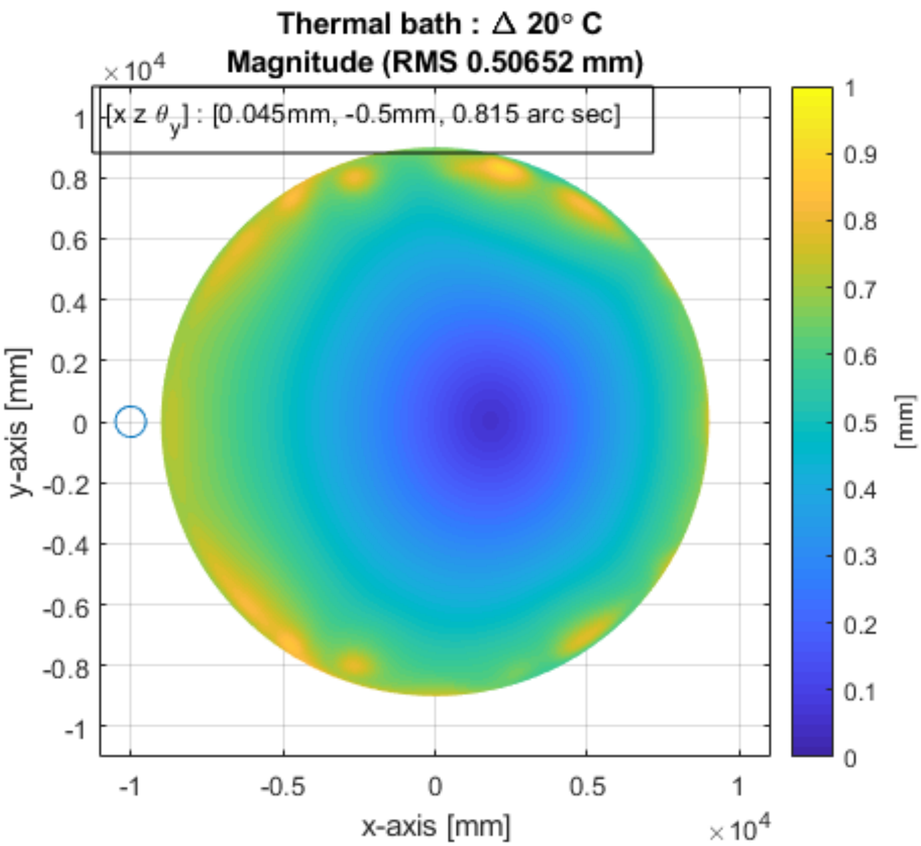
1. **Analyze reflector deformations (FEA).**
2. **Import design (undeformed) optical surface into GRASP and calculate gain (G_0).**
3. **Import FEA deformed optical surface into GRASP and calculate gain (G_ϵ).**
4. **Calculate efficiency ($\frac{G_\epsilon}{G_0}$).**

Example; ngVLA 18m Thermal Analysis

ngVLA 18m Antenna uses shaped optics.
Thermal analysis; ΔT = 20C thermal bath

Classic Analysis;

1. Analyze reflector distortions.
   - Entire structure grows relatively uniformly.
2. Not possible to best fit new surface.
3. Calculate RMS of deviations from original surface.
   - Result = 506μm RMS
4. Calculate efficiency using Ruze equation
   - η = **67%** @30 GHz



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Example; ngVLA 18m Thermal Analysis

New Analysis;

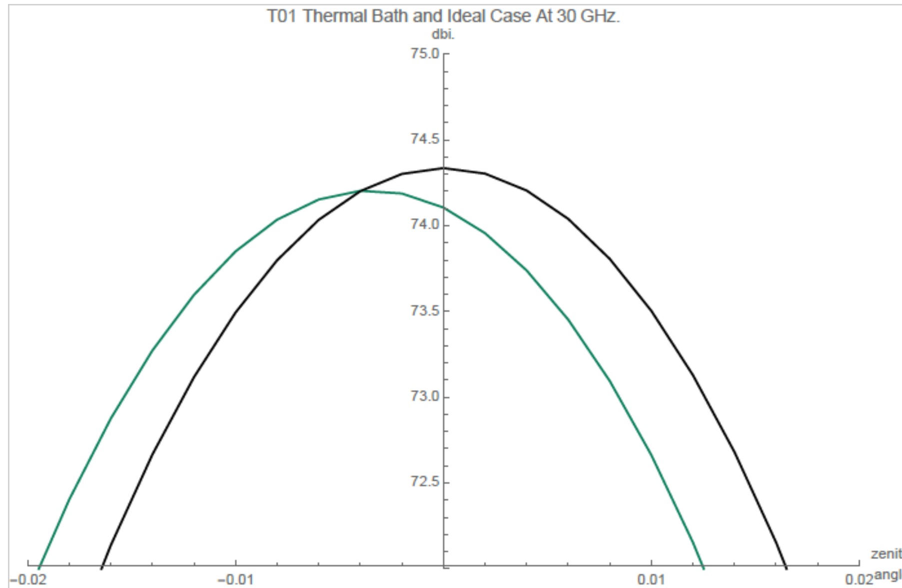
1. Analyze reflector distortions.
   - Entire structure grows relatively uniformly.

2. Import design (un-deformed) optical surface into GRASP

3. Calculate gain for design optical surface
   - G_0 = 74.326 db

4. Import FEA deformed optical surface into GRASP

5. Calculate gain for deformed optical surface
   - G_ϵ = 73.583 db



6. Calculate efficiency
   - η = $\frac{G_\epsilon}{G_0} = \mathbf{84}\%$ @30 GHz
   - Effective Ruze surface accuracy ~330μm RMS

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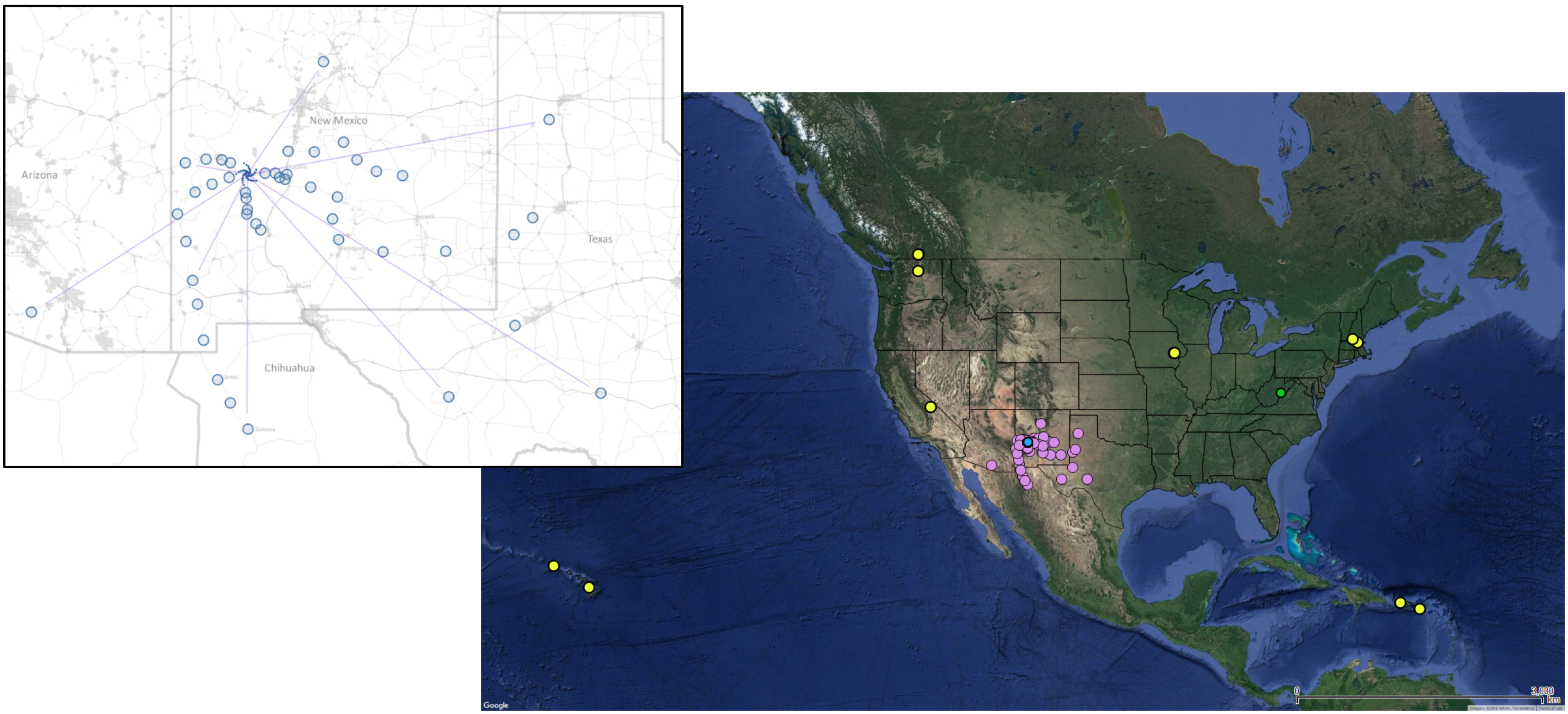
Transportation

244 ngVLA 18m antennas spread across North America plus Hawaii, Puerto Rico and St. Croix



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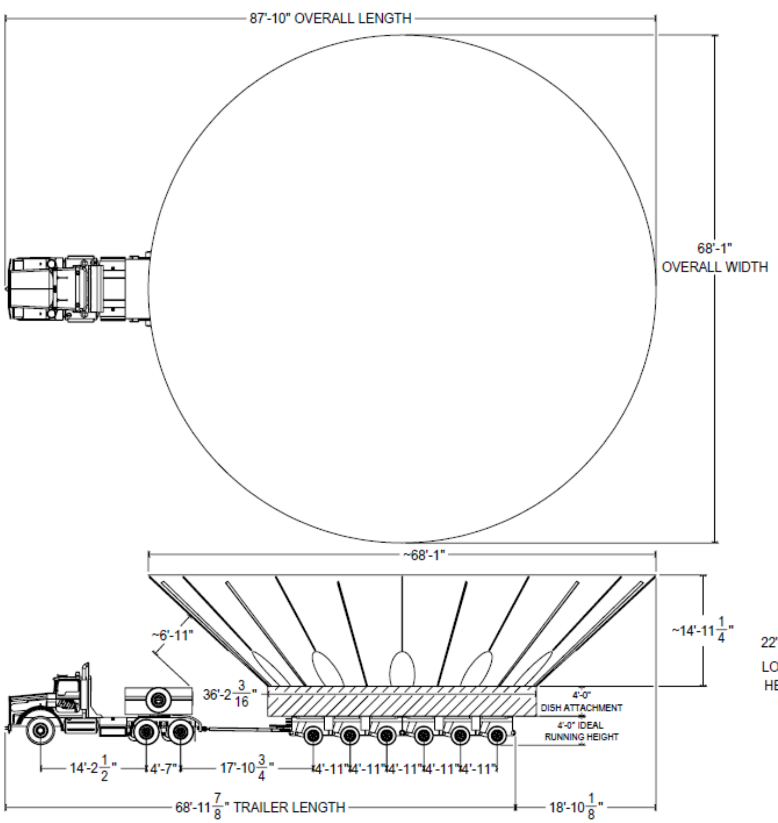
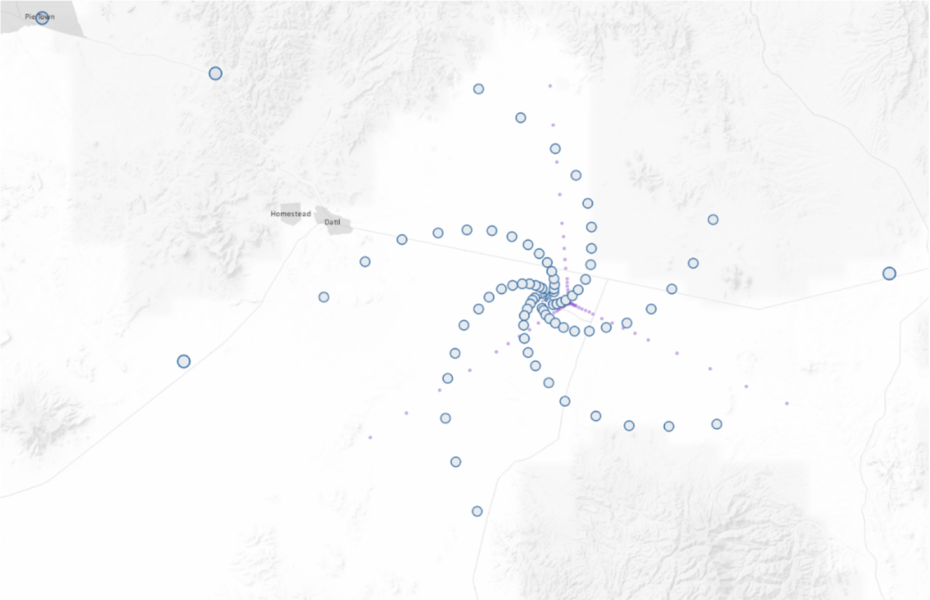
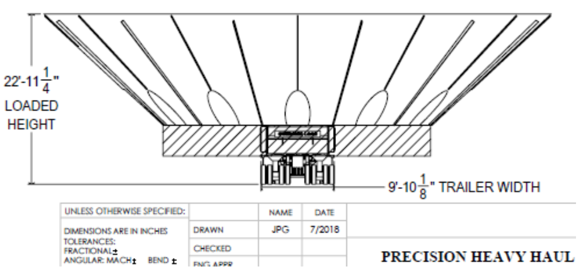
Transportation

171 antennas located on the Plains of St. Agustin and can be transported in one piece.







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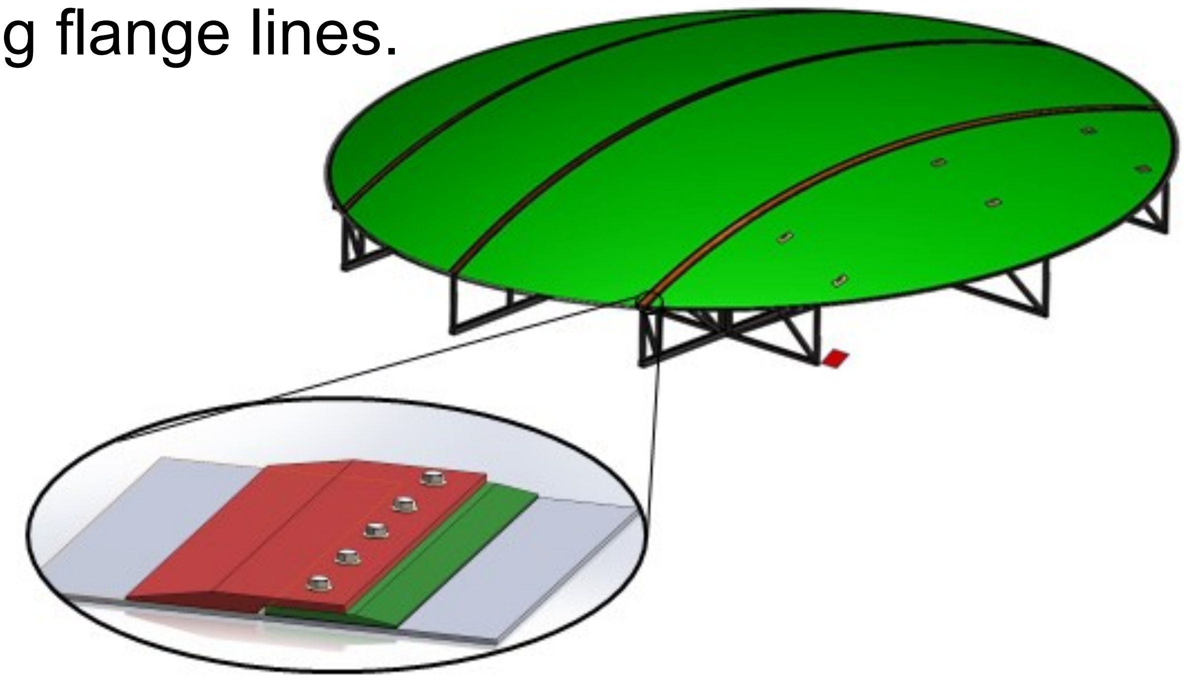
Transportation – Multi-piece Concept

A multi-piece concept is being developed for the remaining 73 antennas.

- Primary surface is fabricated in one-piece.
- Flanges bonded on while still on mold.
- Surface moved to cutting jig.
- Cut into 4 pieces along flange lines.



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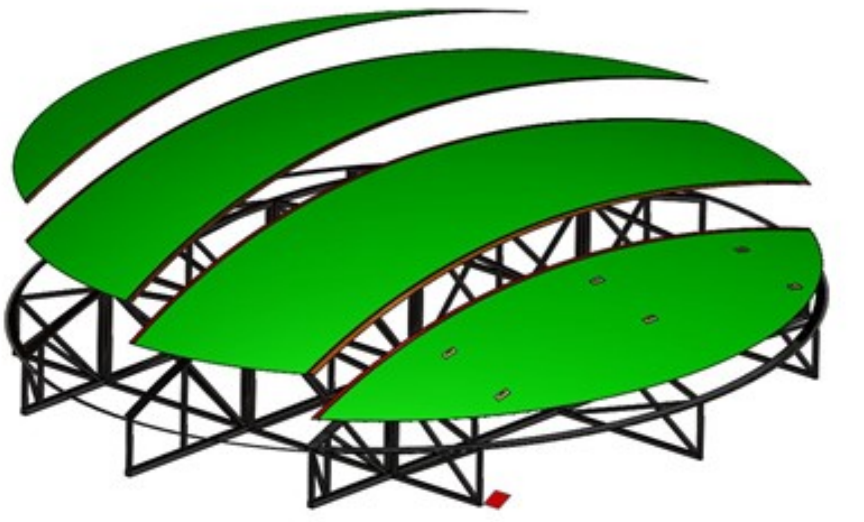
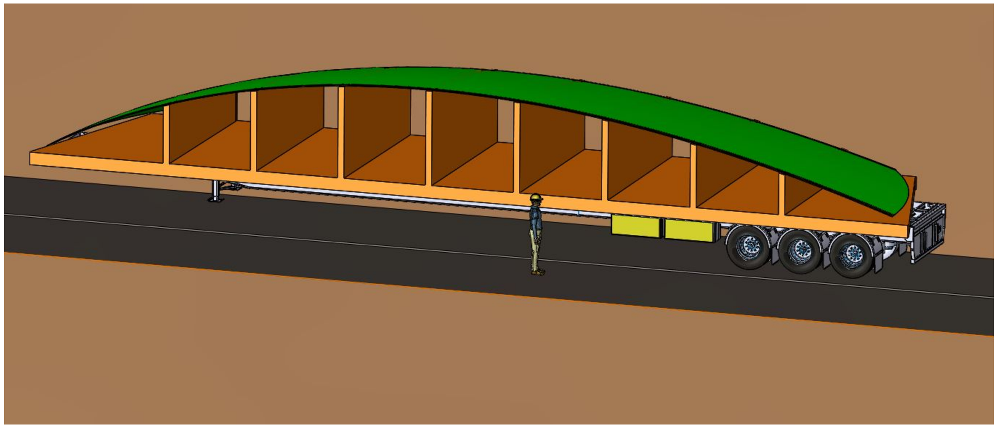
Transportation – Multi-piece Concept

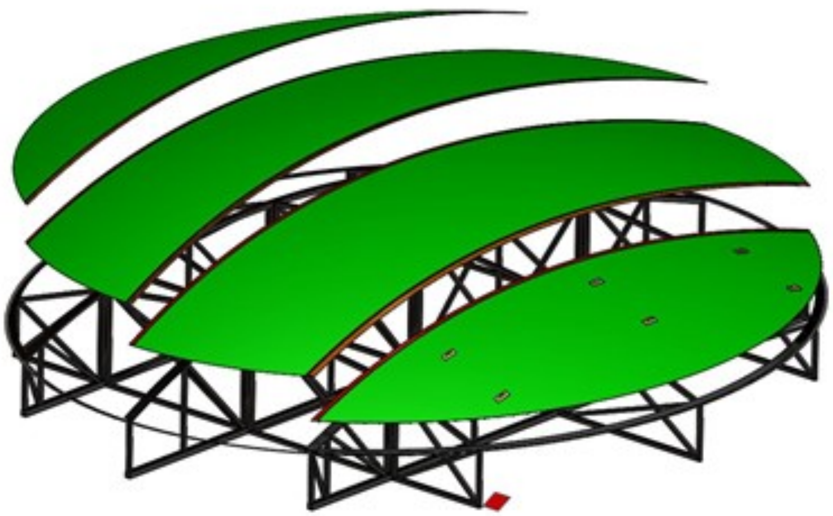
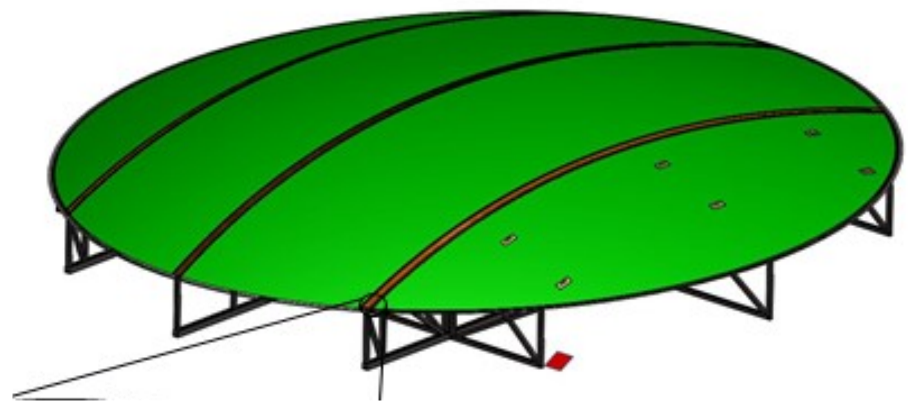
- Pieces removed from jig and placed on trailers.
- Transported to antenna station.





Transportation – Multi-piece Concept

- Surface reassembled on portable jig at antenna station.
- Outer backup structure assembled onto surface as per single piece.

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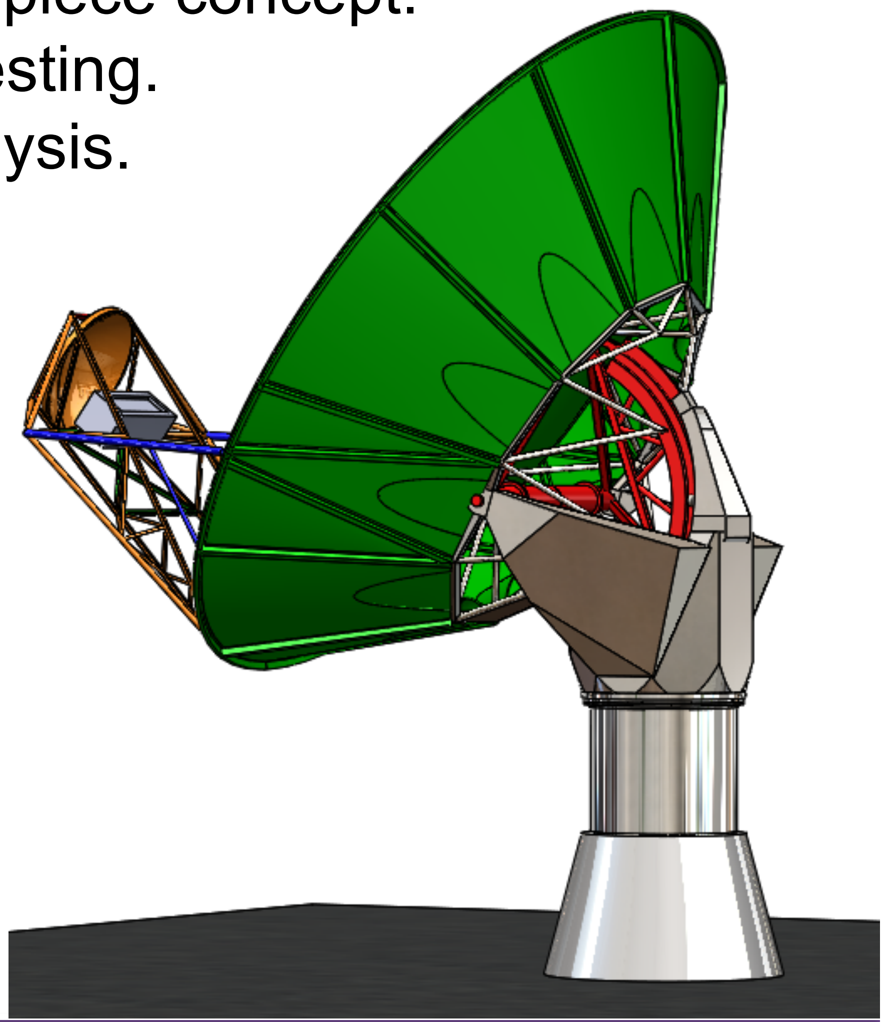
Future Work

- Continued development of multi-piece concept.
- Materials characterization and testing.
- Process induced distortions analysis.
- Detailed design.
    - Adjusters.
    - Inner BUS.
    - Secondary/feed support structure.
- Prototyping.
    - Multi-piece joints.
    - 6m single and multi-piece.
- Production planning.



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Thanks to contributors;

Gordon Lacy, Mohammad Islam, Richard Hellyer - *National Research Council of Canada,*
Matt Fleming - *Minex Engineering,*
Ron Osterried, Matthew Wessel, John Grey - *SED Systems,*
Mike Matusky, Giovanni Bonomi - *Phase USA*
Lynn Baker - *Consultant,*

Thank You

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Vacuum Infusion Process

- **Structural fabric materials are placed on the mold dry, covered with a thin plastic membrane and placed under a vacuum.**
- **The activated resin is then drawn into the part by the vacuum.**

- **The process can produce high quality large structures without the need for high cost infrastructure such as an autoclave.**

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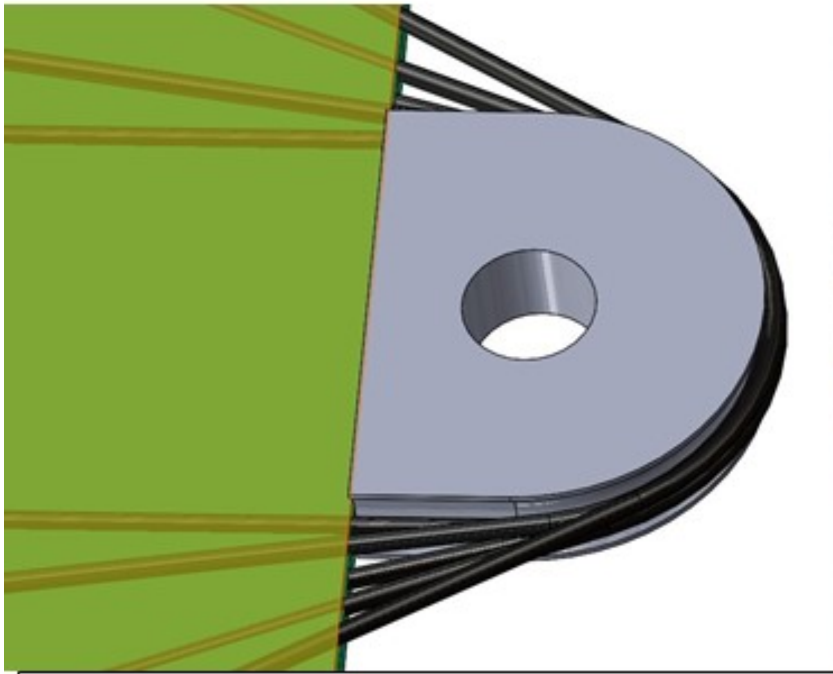
Dish Surface to oBUS Connection Detail



Proposed primary surface edge connector spool

Commercial 'Sailboat Carbon Rod Rigging' End Termination Fitting

Metal spool-type end fittings are commonly used as the final point load distribution fixture in ultra high strength carbon structures.

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