ngVLA Offset Gregorian Antenna Design Community Study

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National Research Council Canada
Conseil national de recherches Canada
Canada

Scope

- Composite Reflectors
- Antenna Mounts
- Optical Analysis

Team

- Gordon Lacy
  - Lead Engineer
  - Composites design
- Mohammad Islam
  - Mechanical design
  - Analysis and optimization
  - Measurement and analysis
- Richard Hellyer
  - Manufacturing
  - Measurement
  - Procurement
- Matt Fleming
  - Mount design
- Lynn Baker
  - Optical design
  - Measurement data analysis
- Doug Henke
  - RF measurement and analysis
- Dean Chalmers
  - Project Management
  - Mechanical Design

Composite Reflectors

- Development of single piece composite reflectors at NRC began in 2006.
- Initial work targeted SKA @ 10GHz max frequency.
- Reflective material embedded in composite layup.
- Low CTE materials high specific stiffness = very stiff and thermally stable.

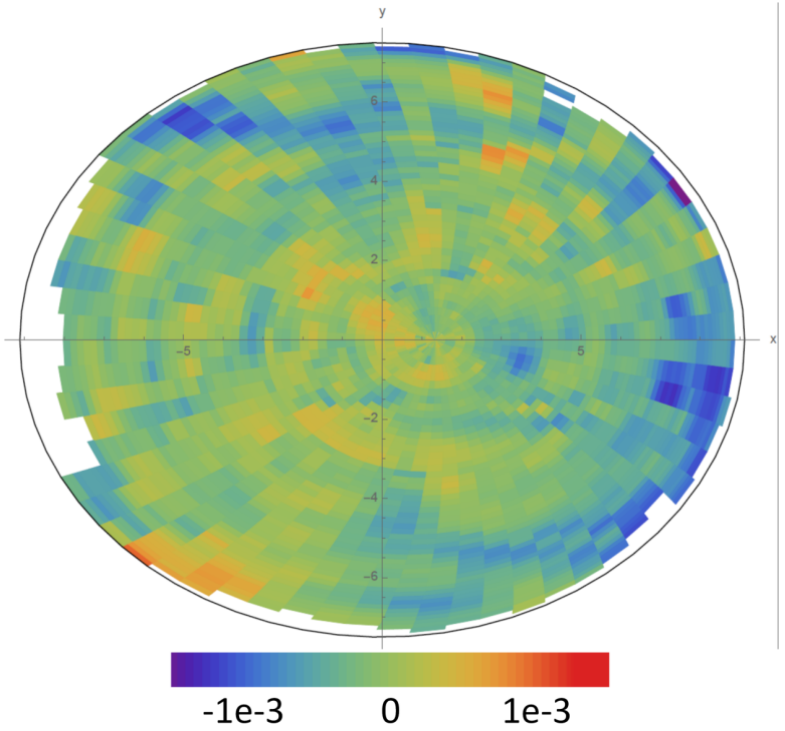
Composite Reflectors

NRC Single-piece Composite Reflector Development

- 2006 – 1m offset test
- 2007 – Mk1 10m symmetric
- 2008 – Mk2 – 10m symmetric
- 2009 – 4m offset test
- 2013 – DVA1 15m offset
- 2017 – DVA2 15m offset

Composite Reflectors: DVA2 – 15m Gregorian Offset Feed-up

- Target 50 GHz max frequency.
- Reworked DVA1 mold.

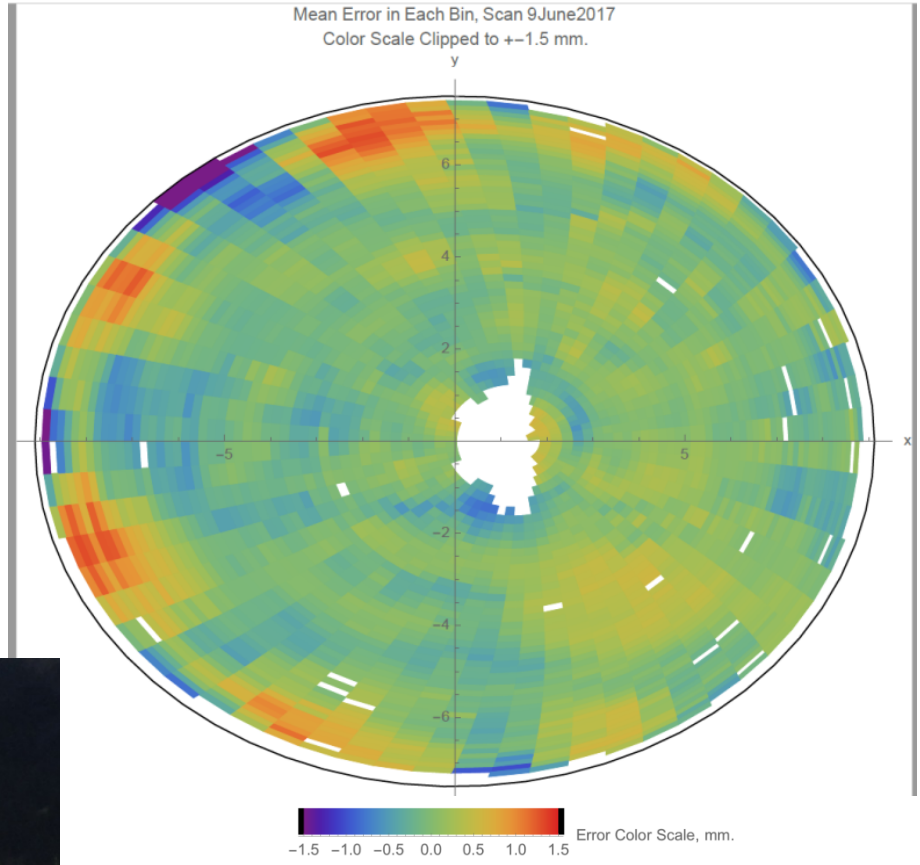


Mold RMS error = 210 micron

Composite Reflectors: DVA2 – 15m Gregorian Offset Feed-up

- Measurement Results
  - 335 microns (un-weighted)
  - 220 microns (power weighted)

- ~80% Ruze efficiency @ 50GHz



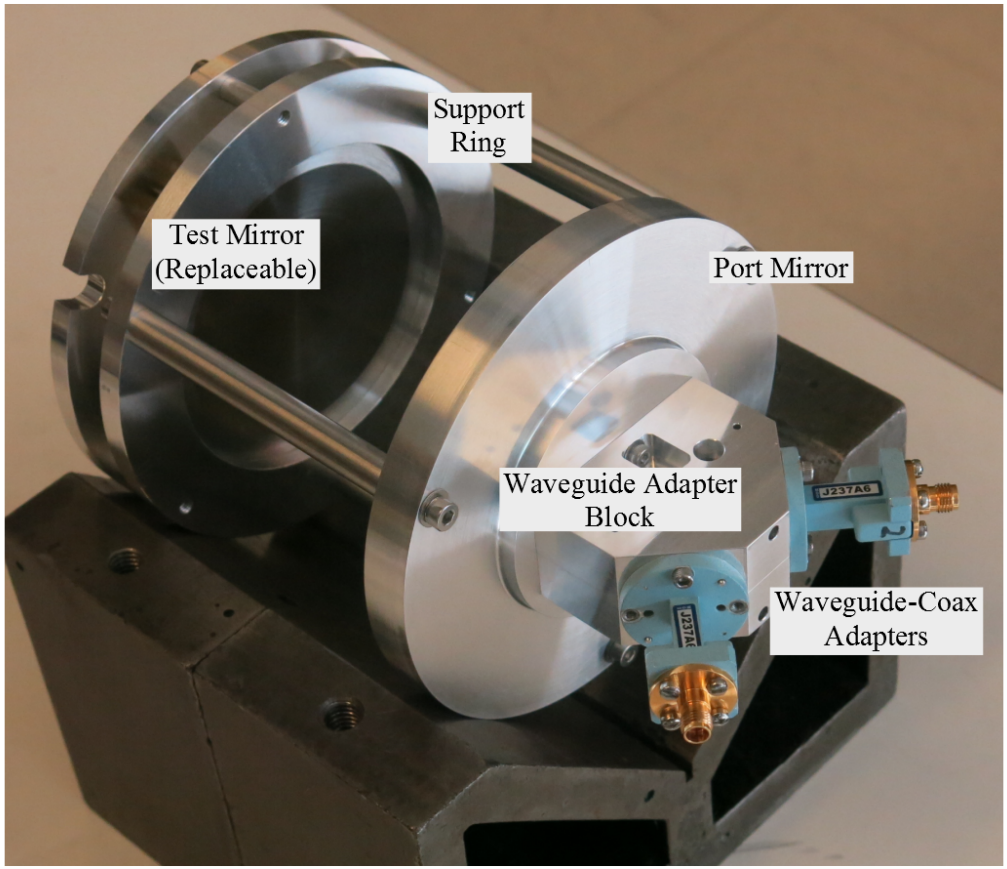
Composite Reflectors: Development Summary

		Surface Accuracy			Part Power Weighted/ Un-Weighted	Part/ mold
		mold	Part			
	Size	Un-Weighted	Un-Weighted	Power Weighted		
Reflector	**[m]**	**[microns rms]**	**[microns rms]**	**[microns rms]**		
Mk1	10	180	1200			6.67
Mk2	10	180	540			3.00
DVA1 Primary (damaged)	15	480	890	770	0.87	1.85
DVA1 Secondary	4	120	200	160	0.80	1.67
Meerkat Secondary	4	58	100			1.72
DVA2	15	210	335	220	0.66	1.60
ngVLA	?	170	270	180		

Composite Reflectors: Reflective Materials Development

Fabry-Perot Resonator

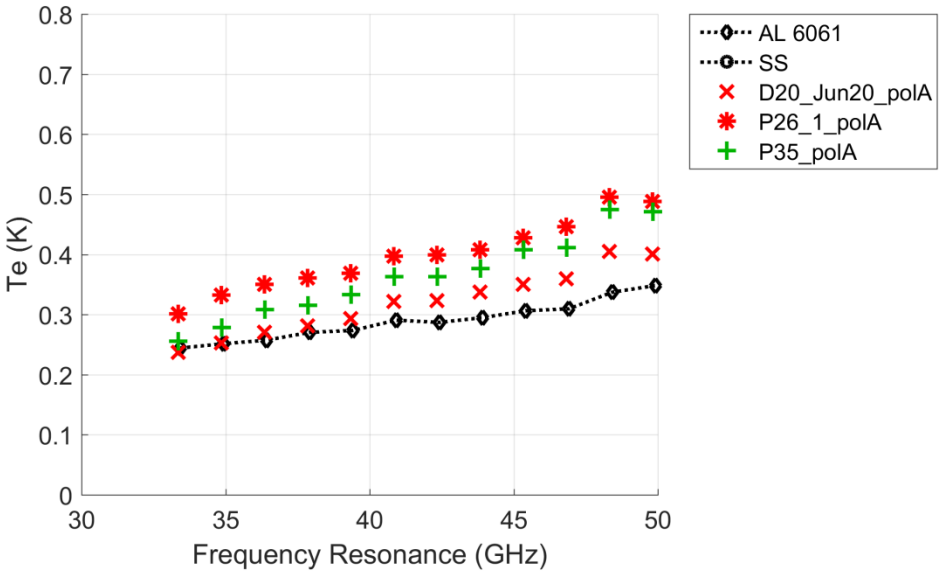
- 50GHZ tests completed
- New 100GHz resonator component fabricated.



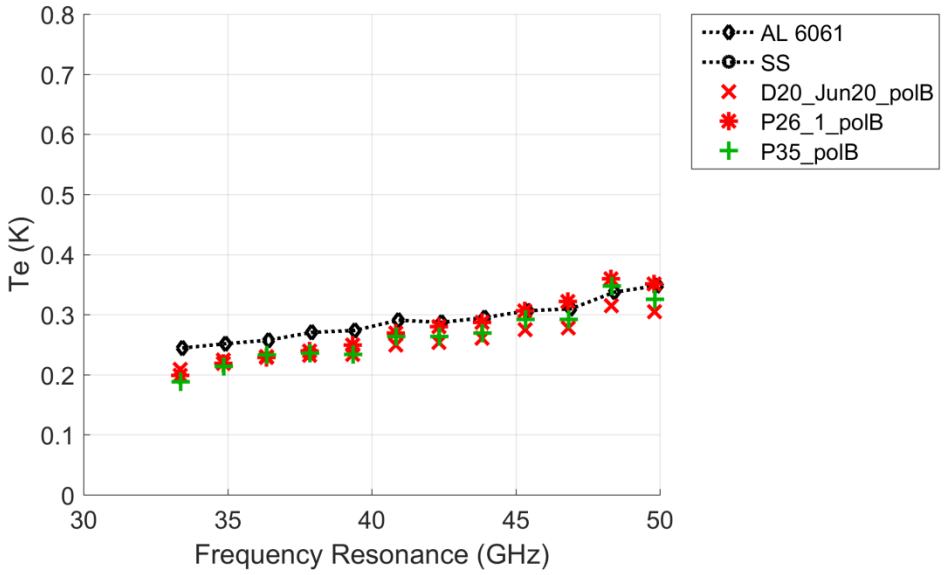
Composite Reflectors: Reflective Materials Development

DVA2 Material Results

- 50 GHz
- < 0.5 K Noise Temperature



Polarity A



Polarity B

- First 100 GHz tests completed data being processed.

Composite Reflectors: Manufacturing Development

Free standing building, one half removable

- Okay for one-off but not suitable for production.
- Similar building with gantry crane on rails would be better option for production.

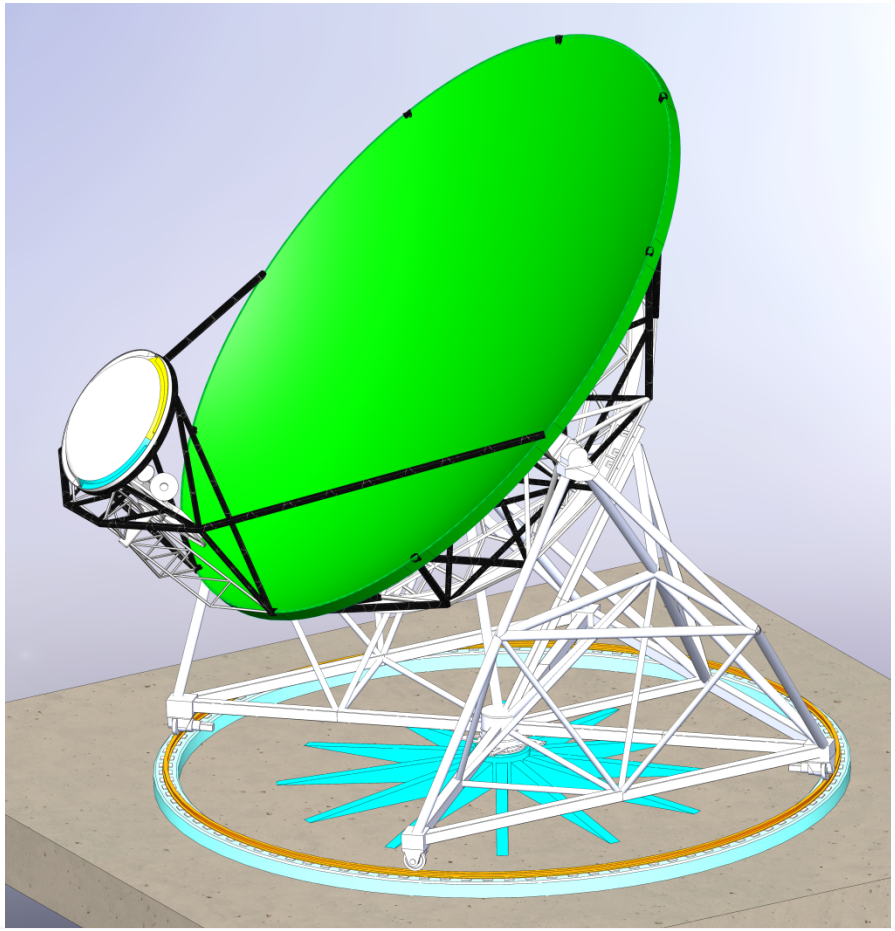
- Production planning development ongoing with industrial partners SED Research Inc.

Composite Reflectors: ngDVA 15m Offset Gregorian Feed-down

Concept design of a feed-down offset Gregorian antenna to meet ngVLA requirements.

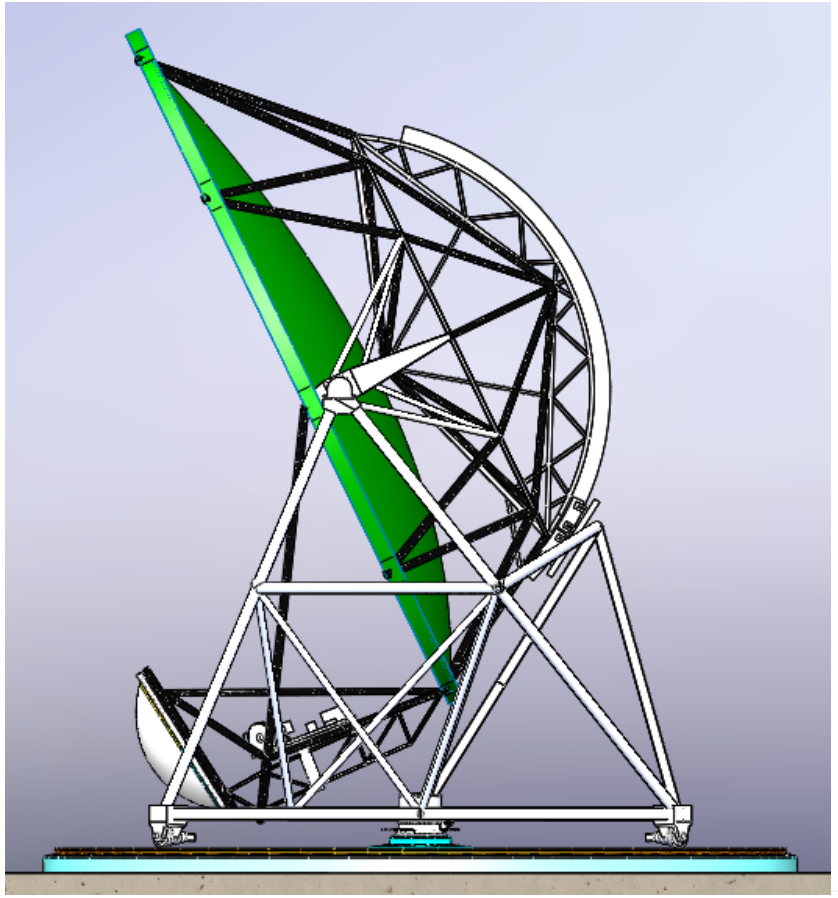
- NRC design single-piece rim-supported composite (SRC) reflector.
- Wheel and track mount being designed under contract with Minex Engineering.
- 15m primary diameter shaped optics.
- 4m secondary.
- Direct drive elevation actuator.

- SRC is well suited to wheel and track mount. Particularly in the feed down configuration.



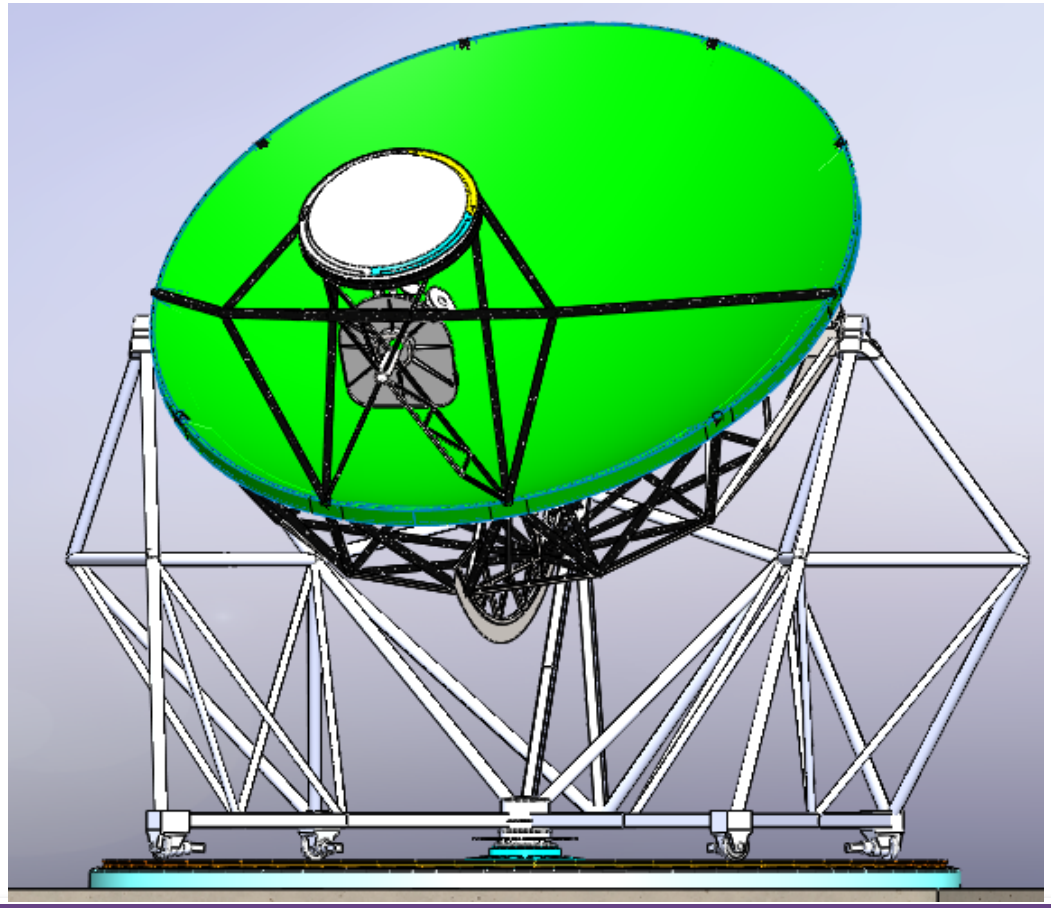
Composite Reflectors: ngDVA 15m Offset Gregorian Feed-down

- Stiff rim structure of SRC allows connection of secondary support structure to rim and avoids large structure protrusion below reflector rim. This allows for a lower elevation axis when compared to traditional designs.



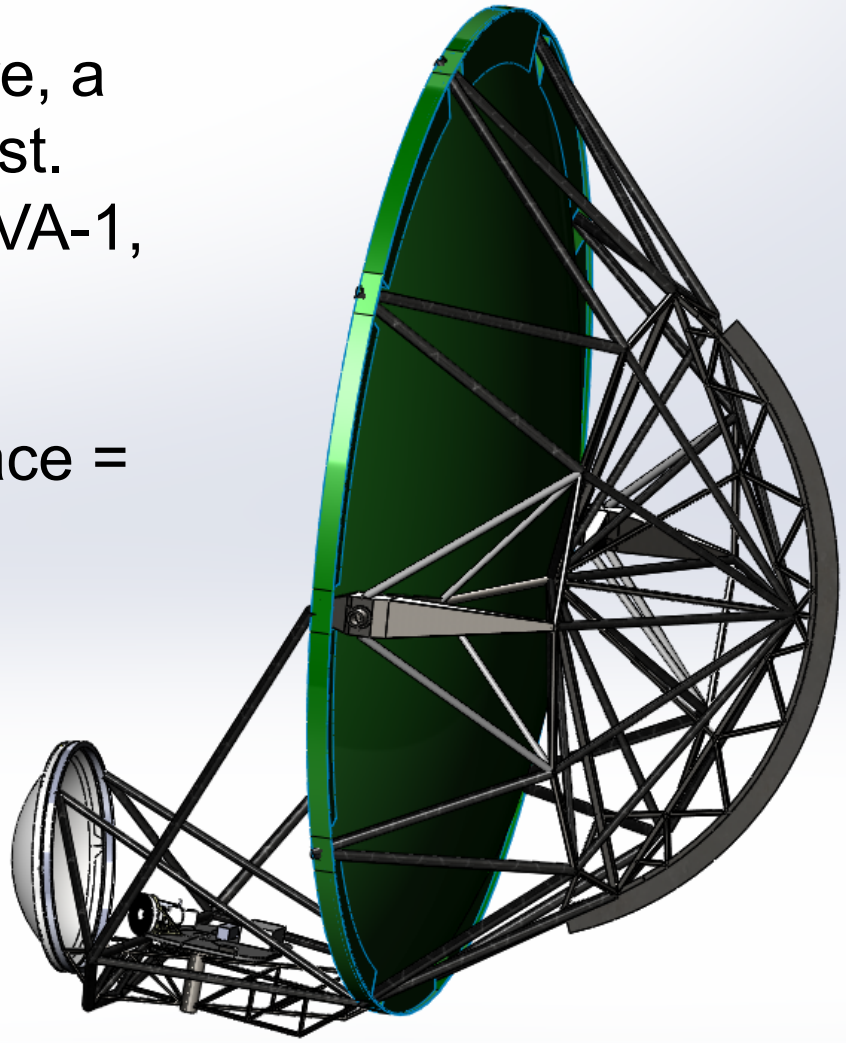
Composite Reflectors: ngDVA 15m Offset Gregorian Feed-down

- Feed down configuration requires large opening in azimuth rotating structure to achieve low elevation angles. Rim structure of SRC design provides stiff connection between elevation bearings.



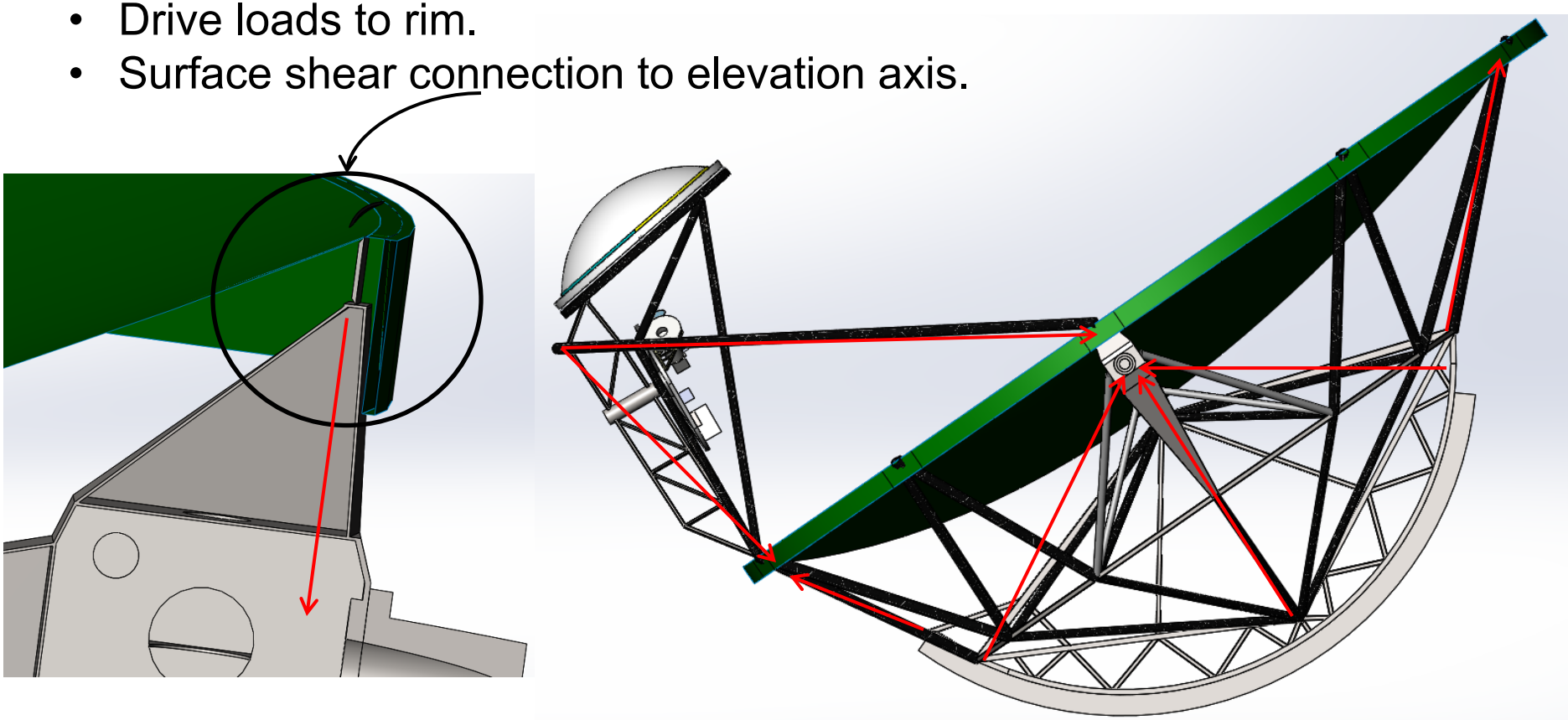
ngDVA Elevation Assembly

- Steel and Carbon Back Structure, a balance between weight and cost.
- Rim support design similar to DVA-1, except no central support.
- Elevation drive via linear motor.
- Very little stress in primary surface = smooth surface
- Balanced - no counter-weights required



ngDVA Elevation Assembly

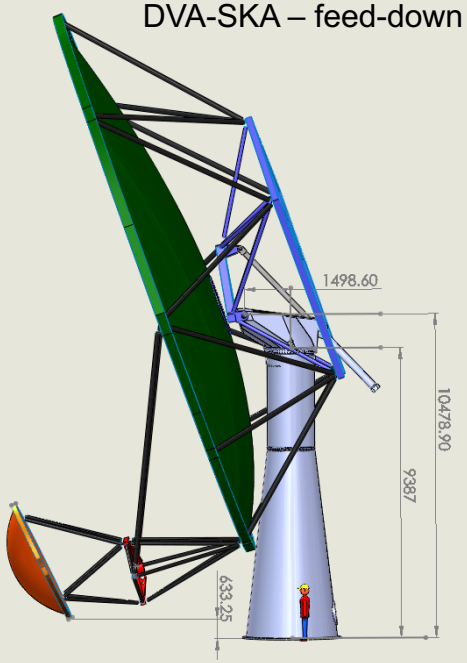
- Very direct load paths;
  - Elevation axis to stiff rim
  - Secondary support structure to stiff rim and elevation axis.
  - Drive loads to rim.
  - Surface shear connection to elevation axis.

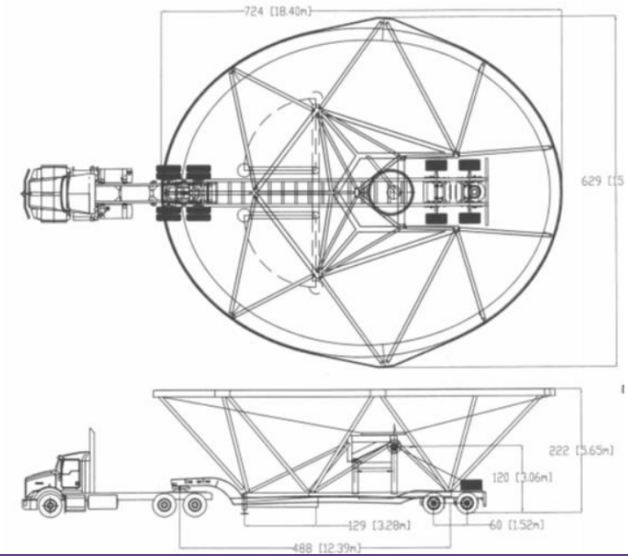


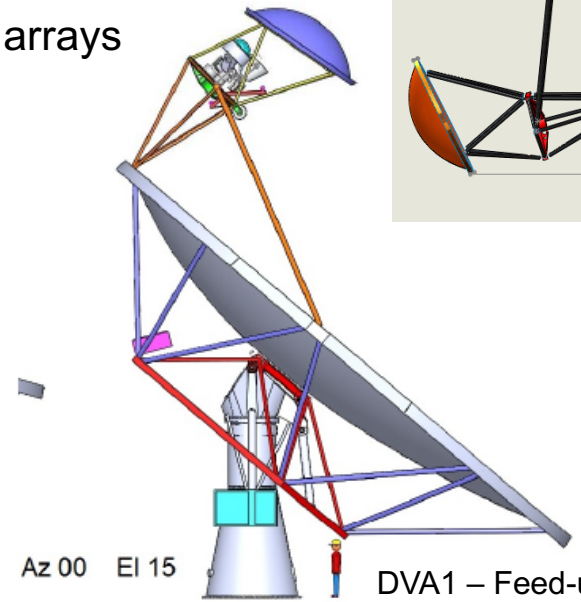
Single-piece Rim-supported Composite Reflectors

- SRC advantages and limitations
  - Smooth uninterrupted surface.
  - High thermal stability.
  - Low gravitational and wind deflections.
  - Mount: Wheel and Track or pedestal.
  - Orientation: Feed-up or feed-down.
  - Diameter: <~18 m
  - Frequency: ≤120 GHz
  - Array Size: High mold cost favors larger numbers.
  - Baselines: Transport logistics favor compact arrays

DVA-SKA – feed-down



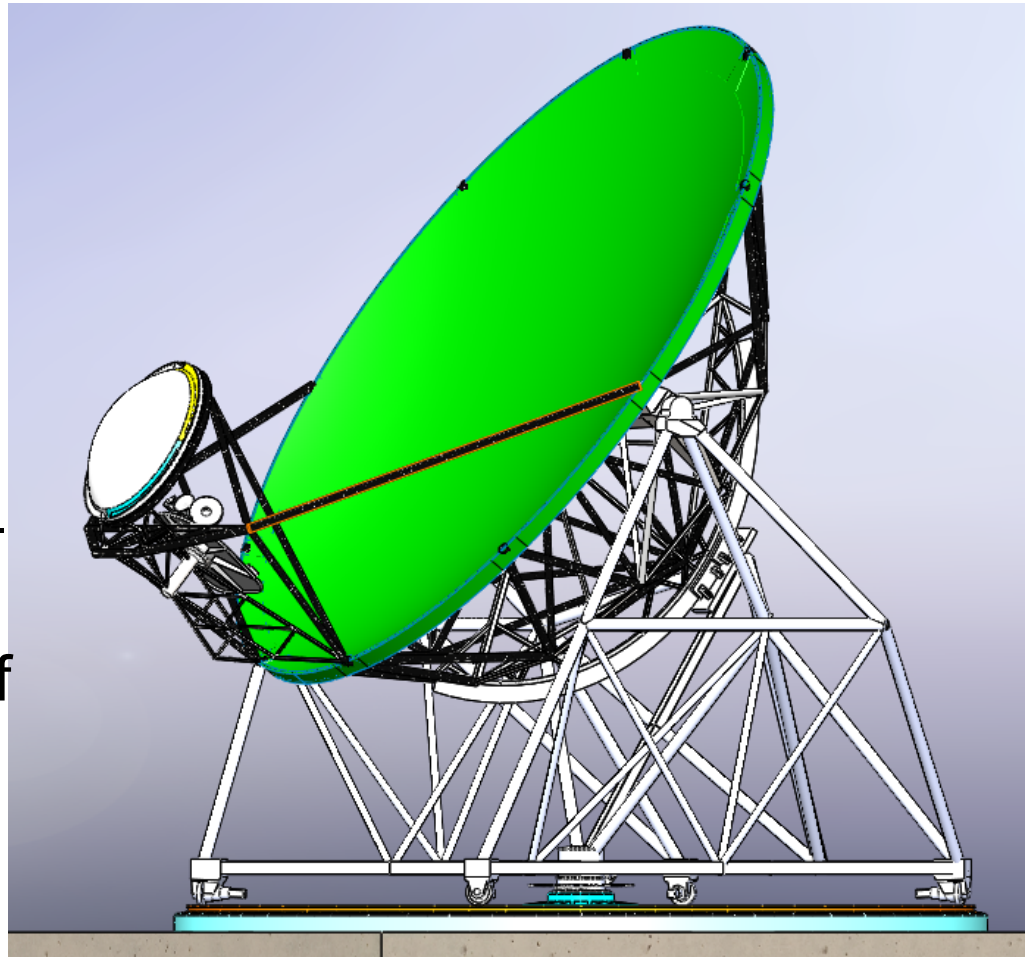




DVA1 – Feed-up

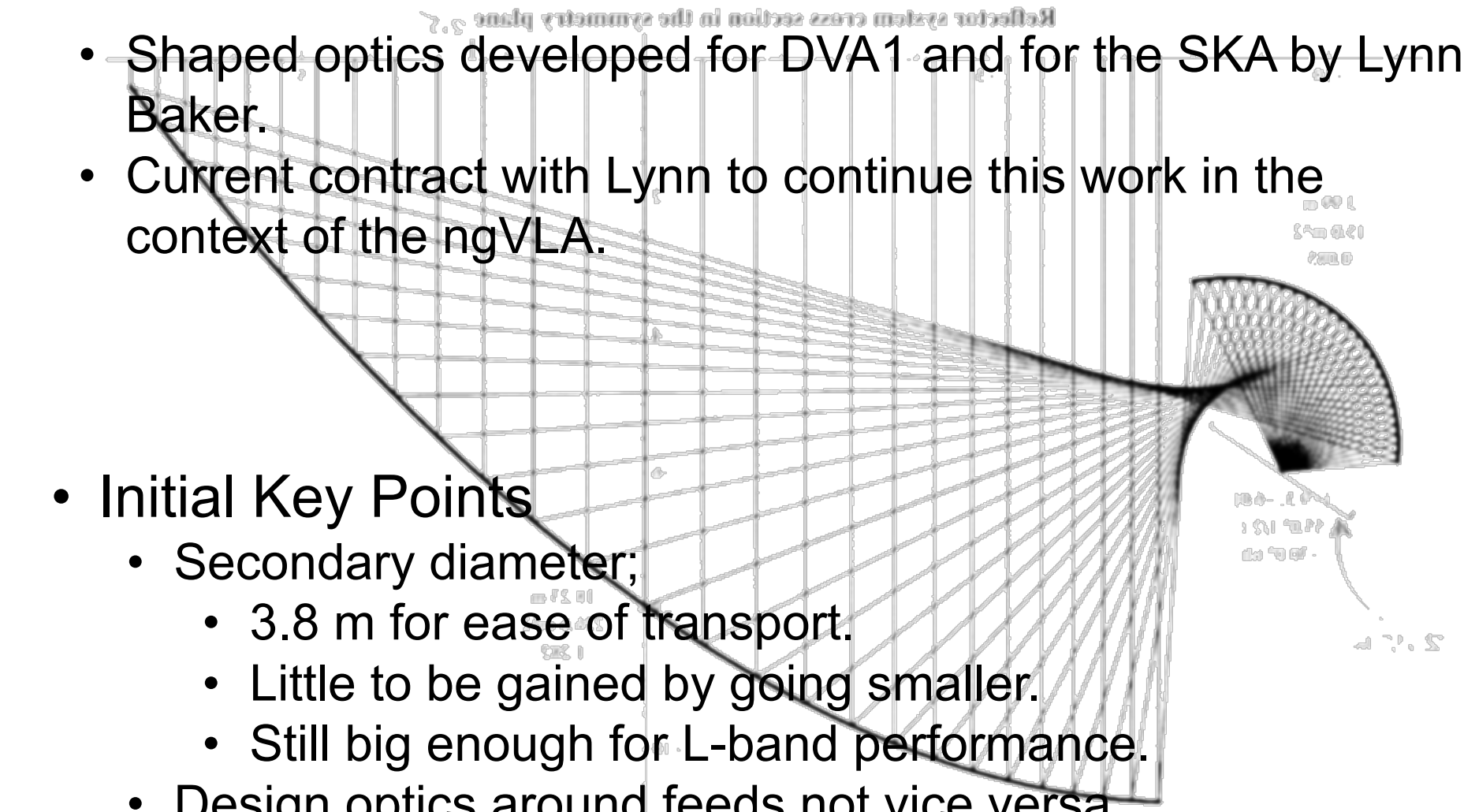
Antenna Mounts

- Wheel and track design contract with Minex Engineering.
- Pointing specification is design driver.
- Integrated azimuth/elevation assemblies design.
- Direct drive elevation drive – in discussion with Phase Motion Control – suppliers of ALMA AEM drives.



Optical Analysis

- Shaped optics developed for DVA1 and for the SKA by Lynn Baker.
- Current contract with Lynn to continue this work in the context of the ngVLA.



- Initial Key Points
  - Secondary diameter;
    - 3.8 m for ease of transport.
    - Little to be gained by going smaller.
    - Still big enough for L-band performance.
  - Design optics around feeds not vice versa.

Community Study Outputs

- 15m feed-down offset Gregorian antenna concept design.
- Cost/performance for concept design.
- Lessons learned from SKA optics work.
- Optics analysis strategy input for the ngVLA.

Beyond Community Study

- Continue development of feed-down offset Gregorian antenna design and construction of antenna prototype. *(Dependent on ngVLA Reference Design decisions.)*

- Provide a test bed, DVA2, for potential ngVLA Q-band receivers.

NRC·CNRC

Questions?

Thank you

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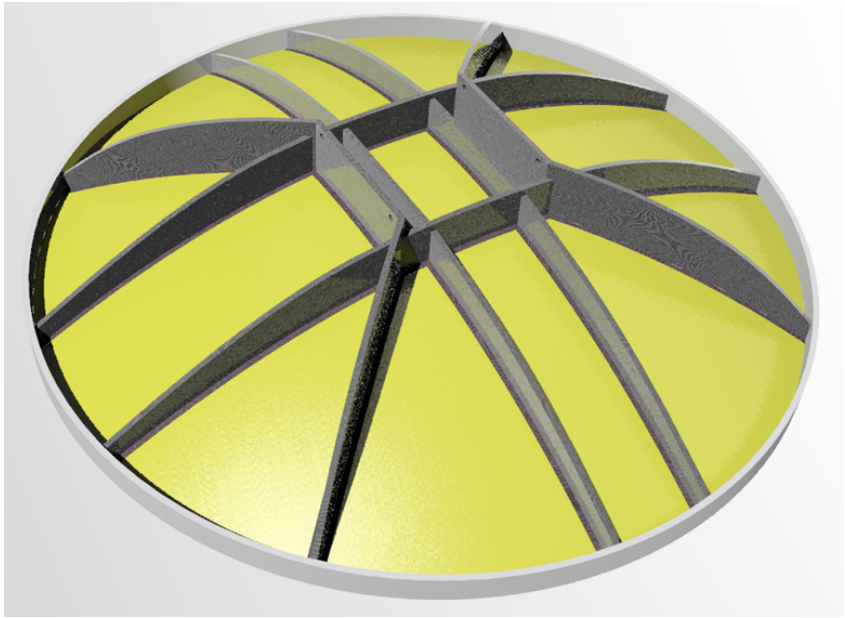
Composite Reflectors: 1m Offset

- Started small
- Used to test process
- Measured reflectivity

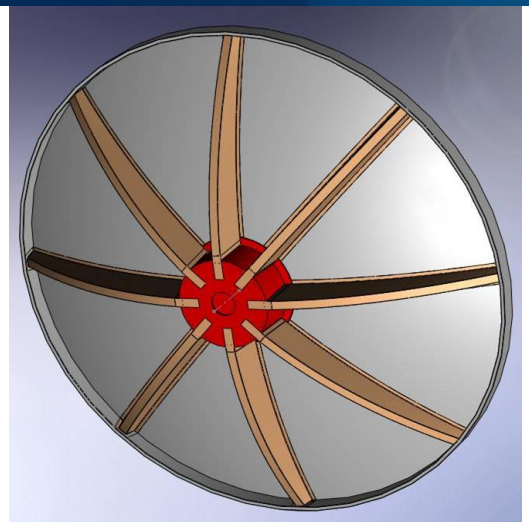
Laying up first 1 metre dish part.

Composite Reflectors: Mk1 – Symmetric 10m



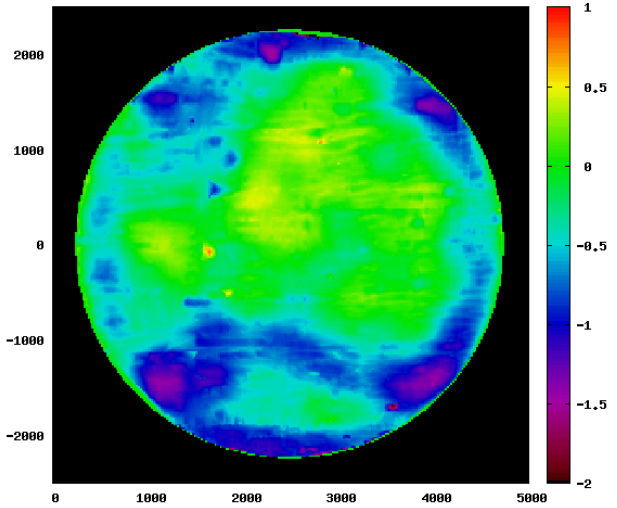
- Single piece surface, rim and beams.
- Foam cored Kevlar w/carbon beams
- Surface accuracy 1.2 mm rms
- Large processed induced distortion

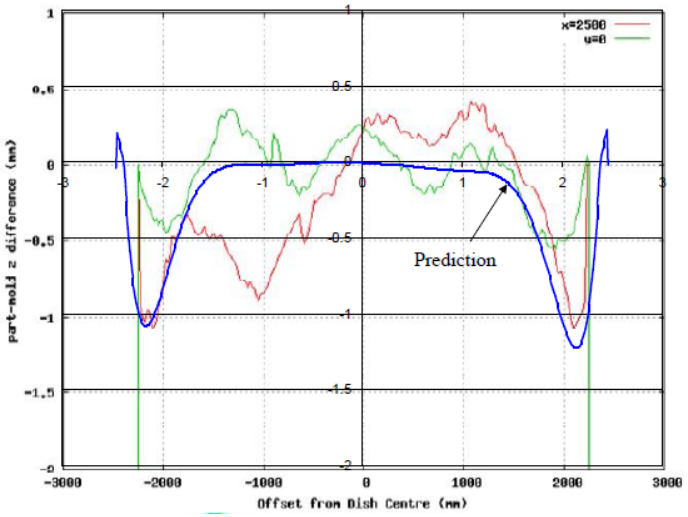
Composite Reflectors: Mk2 – Symmetric 10m



- Single piece surface and rim of foam cored Kevlar.
- Bonded on hollow carbon beams and hub.
- Surface accuracy 0.54 mm rms
- Less processed induced distortion.

Composite Reflectors: 4m Offset

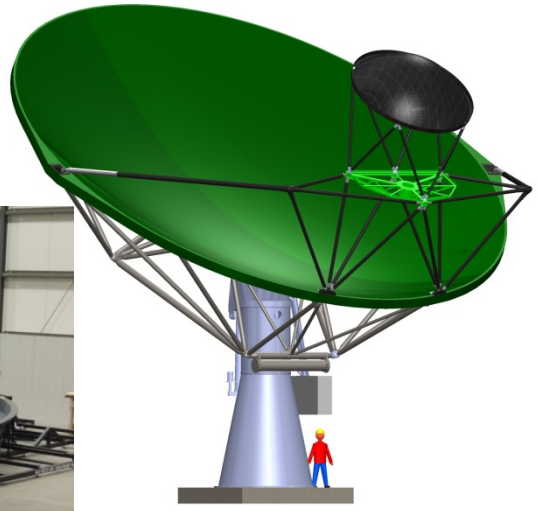




- Validation of modeling performed by Convergent Technologies.
- Process induced distortion test.
- Still a thin foam core in surface, uniform layup, carbon fiber.
- Much less processed induced distortion.
- Good agreement with modeling.
- Results indicate a core-less design would be even better so,
- DVA-1 has no core in the reflector surfaces

Composite Reflectors: DVA1 – 15m Gregorian Offset Feed-up

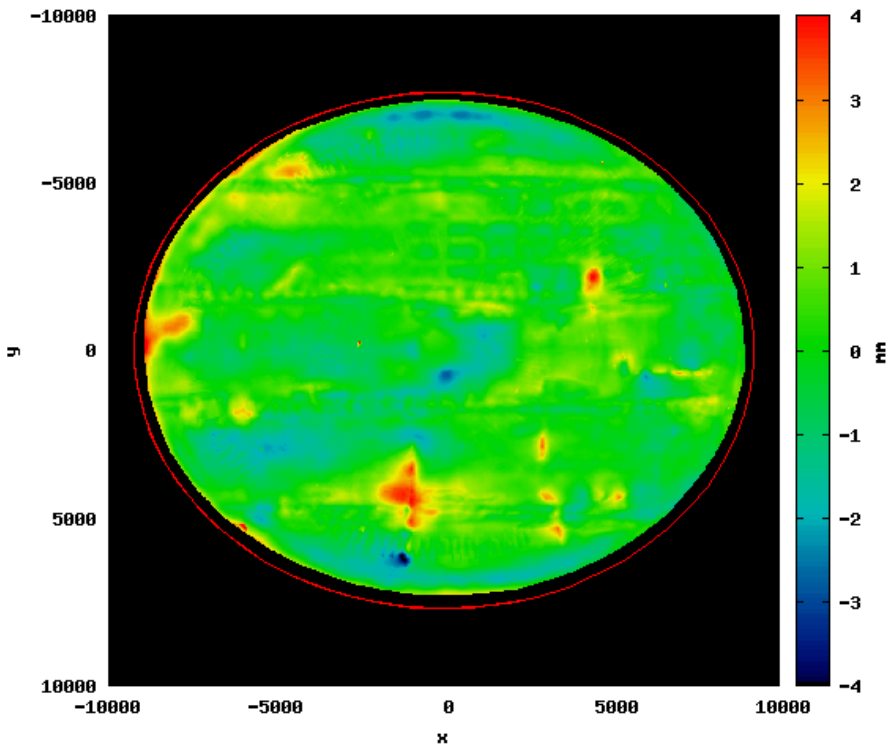
- SKA Precursor
- Adopted rim-supported concept from ATA
- Target 10 GHz max frequency



Composite Reflectors:
DVA1 – 15m Gregorian Offset Feed-up

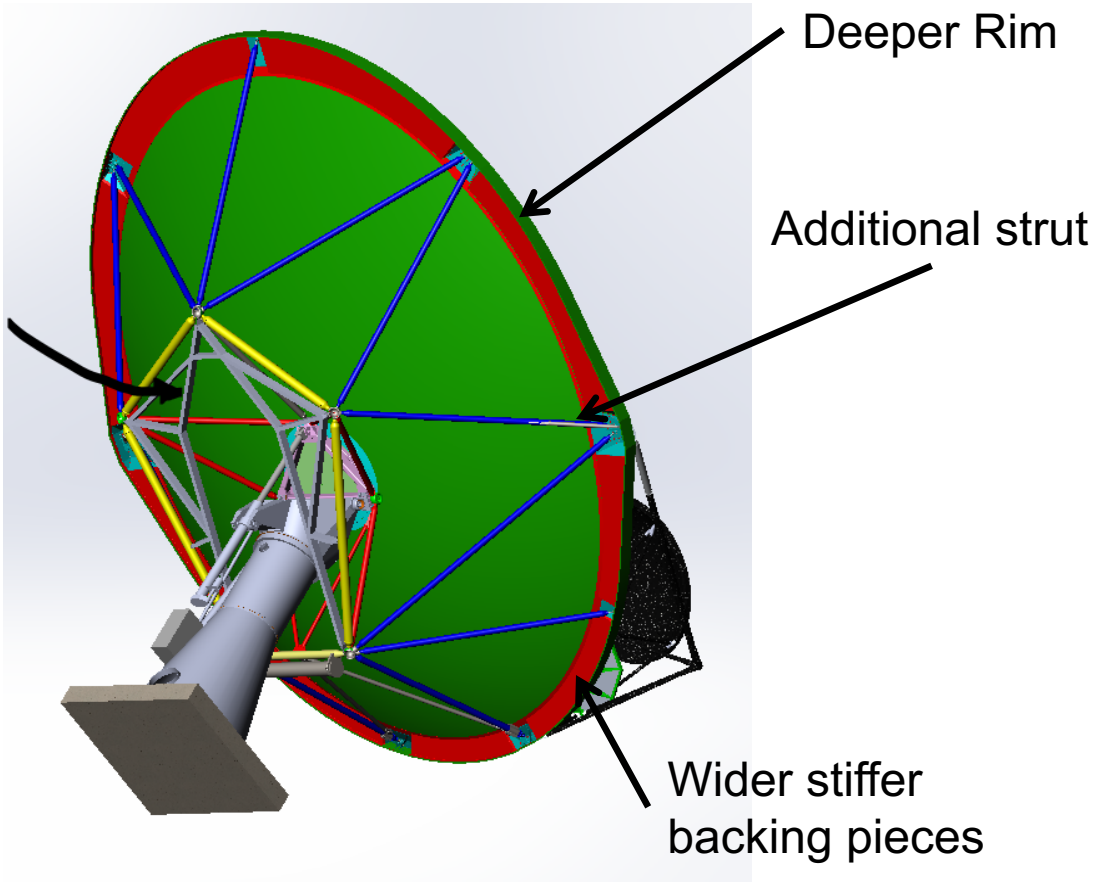
- RMS Surface Error;
  - 0.89mm Un-weighted,
  - 0.77mm Power weighted

Including repaired areas



Composite Reflectors: DVA2 – 15m Gregorian Offset Feed-up

- Target 50 GHz max frequency.
- Low shrink resin
- Changes to composite structure
- Stiffer backup structure



Composite Reflectors: DVA2 – 15m Gregorian Offset Feed-up

- Status;
  - Primary reflector fabricated.
  - Primary backup structure installed.
  - Initial adjustment and measurement completed.
  - Secondary reflector fabrication in progress.

Composite Reflectors: DVA2 – 15m Gregorian Offset Feed-up

- Measurement Results
  - 335 microns (un-weighted)
  - 220 microns (power weighted)
- ~80% efficiency @ 50GHz