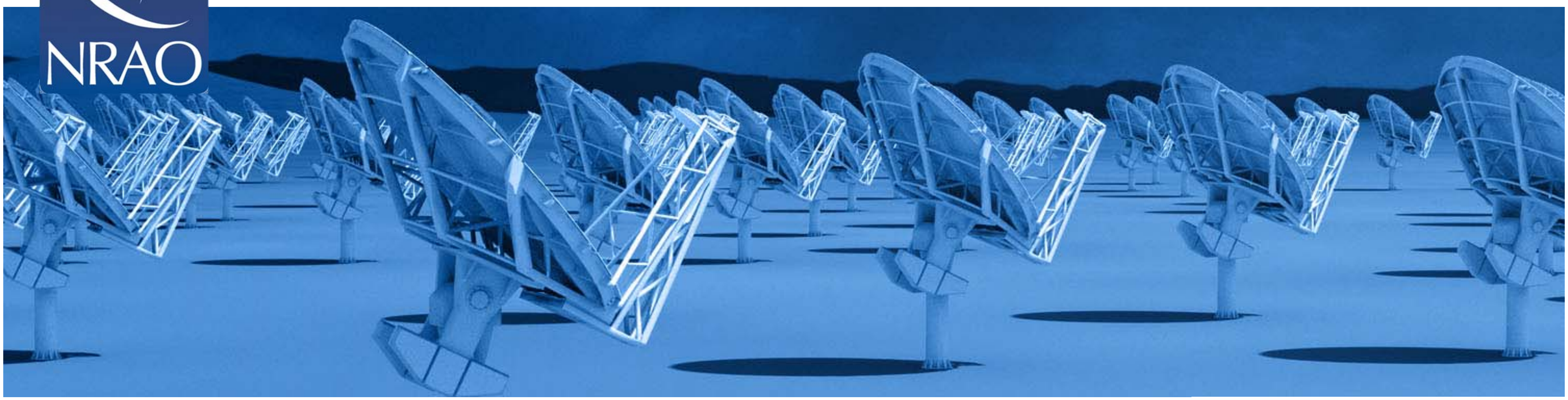
NRAO

NATIONAL RADIO ASTRONOMY OBSERVATORY



Reference Design & Optics Requirements

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NSF

Associated Universities, Inc.

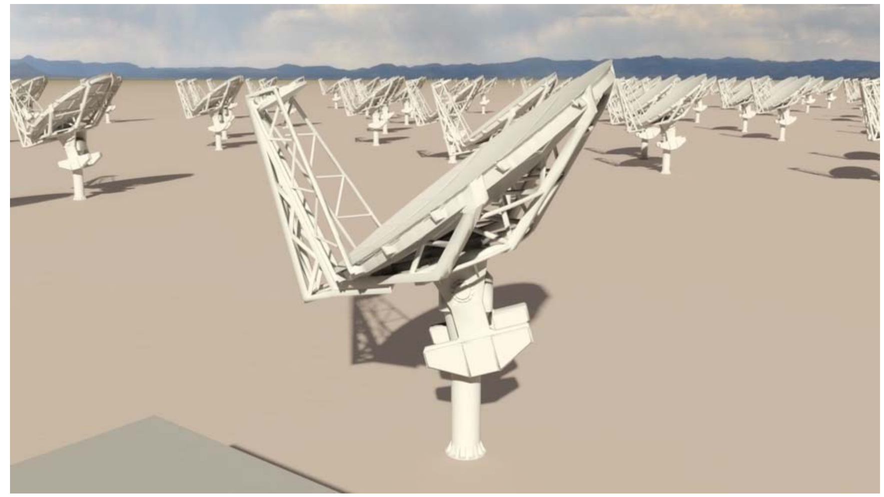
ngvla

Next Generation Very Large Array

ngVLA Reference Design

- **A baseline design with known cost and low technical risk. Technical & cost basis of the Decadal proposal.**
- **Leading-edge technologies to be developed through to CoDR before a down-select.**
- 214 18m offset Gregorian Antennas.
- Fixed antenna locations across NM, TX, AZ, MX.
- 19 6m short baseline array + 4 18m in TP mode to fill in (*u, v*) hole.

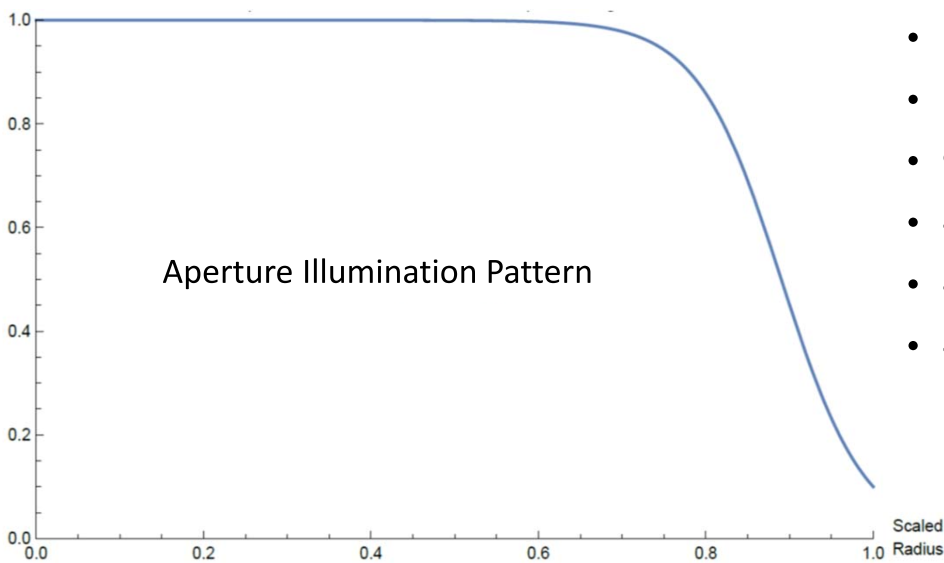
- Continuum Sensitivity: ~0.1 uJy/bm @ 1cm, 10mas, 10hr => T_B ~ 1.8 K
- Line sensitivity: ~20 uJy/bm @ 1cm, 10 km/s, 1", 10hr => T_B ~ 25 mK



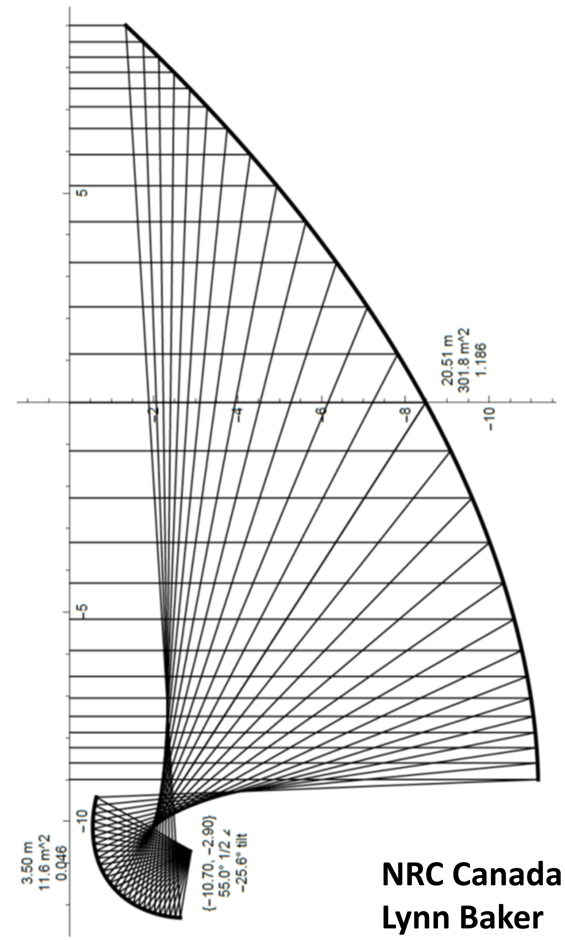
Band #	Dewar	f_L GHz	f_M GHz	f_H GHz	f_H: f_L	BW GHz
1	A	1.2	2.35	3.5	2.91	2.3
2	B	3.5	7.90	12.3	3.51	8.8
3	B	12.3	16.4	20.5	1.67	8.2
4	B	20.5	27.3	34.0	1.66	13.5
5	B	30.5	40.5	50.5	1.66	20.0
6	B	70.0	93.0	116	1.66	46.0

Reference Optical Design

- **18m Aperture**: Based on cost and performance modeling.
- **Offset Gregorian**: Off-axis geometry minimizes scattering, spillover, and sidelobe pickup. Wide subtended angle of the subreflector for small feeds.
- **Shaped:** Aperture efficiency optimized for single pixel feeds.

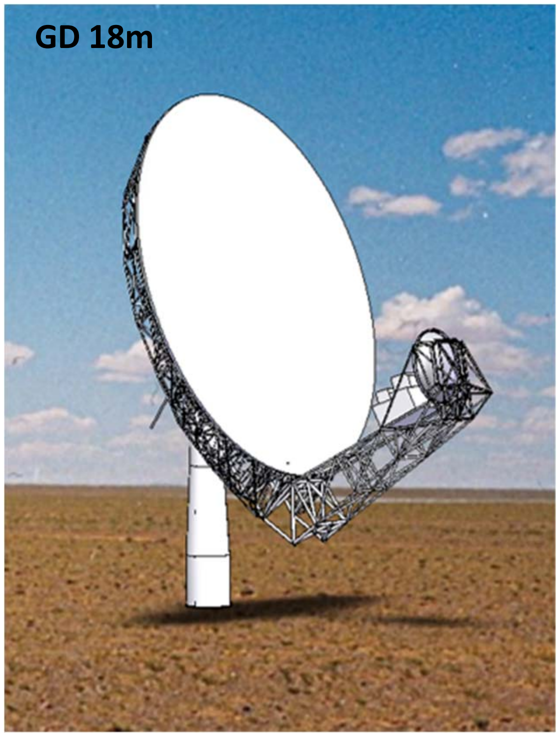


- **3.5m Subreflector**
- **55° Half Angle**
- **95% Illum. Eff.**
- **-16dB Edge Taper**
- **-19dB First SL**
- **-27dB Second SL**

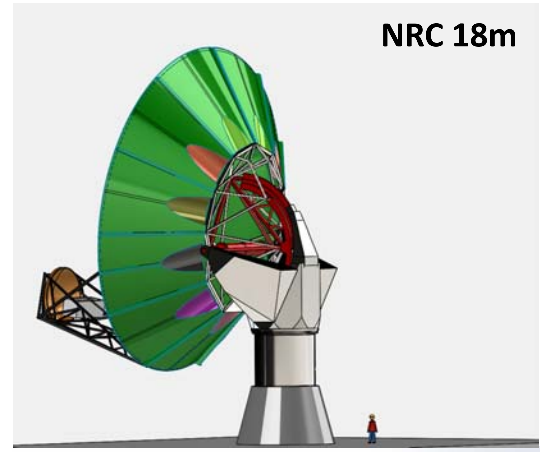


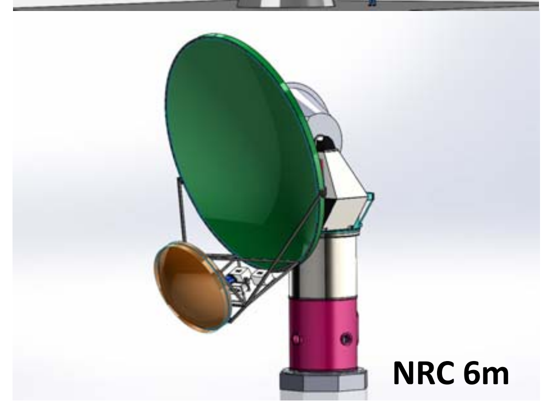
NRC Canada / Lynn Baker

Antenna Mount Concepts



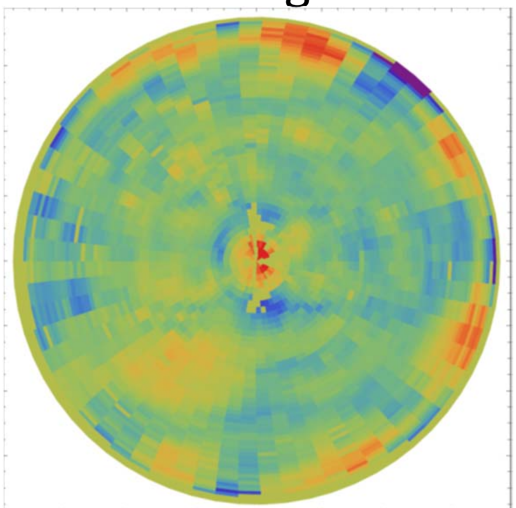
- **Feed Low**: Performance and maintenance requirements favor a receiver feed arm on the low side of the reflector.
- **Mount concept**: Leaning towards pedestal concepts for life-cycle cost.
- **Drives:** Jack screw & gearbox vs. direct drives?
- **Materials:** Traditional Al panels & steel BUS vs. composite materials?
- ***GDMS Reference Design and NRC Composite Design Studies in Progress***





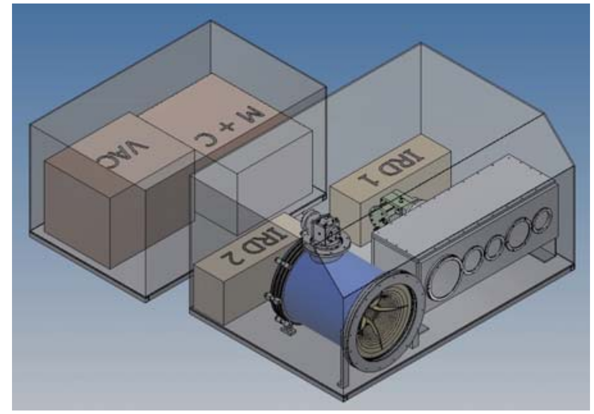
NRC DVA-2 Dev.

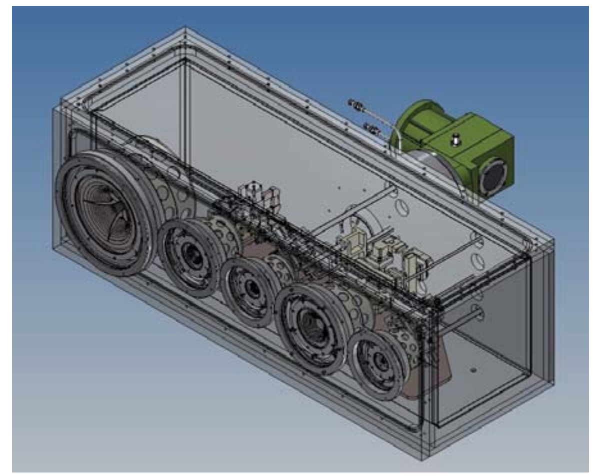
- NRC Proof-of-Concept
- 15m aperture
- 335 µm rms surface, uniform weighted



Front End Concept

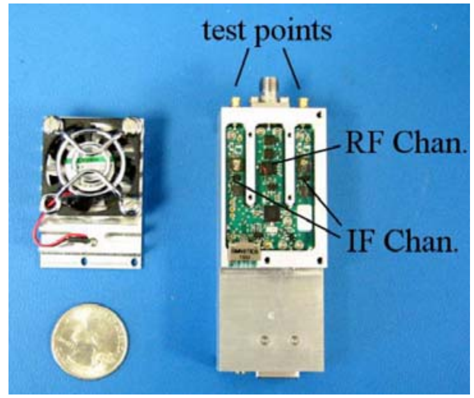
- 6 Bands in 2 Cryogenic Dewars
- 1.2-3.5 GHz and 3.5-12.3 GHz Quad-Ridge Horns, 3:1 to 3.5:1 bandwidth, coaxial LNAs.
- 12.3-50.5 GHz using three 1.67:1 BW corrugated horns and waveguide LNAs.
- 70-116 GHz 1.67:1 BW corrugated horn and waveguide LNAs with block down conversion.
- Single stage down-conversion to baseband for 5 bands. Direct SSB or IQ sampling using modular devices @ FE.
- Two-stage Gifford-McMahon cryogenic system with variable-speed cryocoolers and compressors for reference design.
- Maintenance-free two-stage Sterling-cycle pulse tube hybrid cryogenic system to be developed.

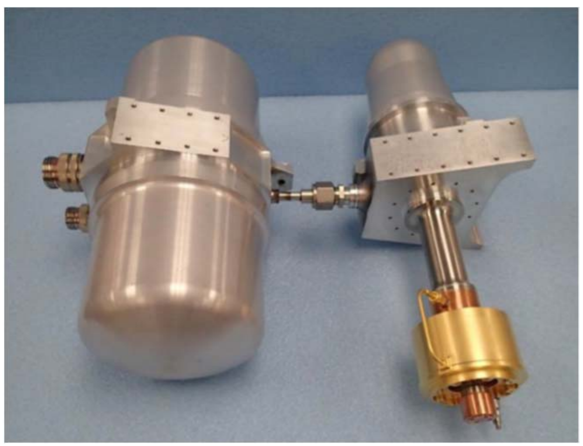


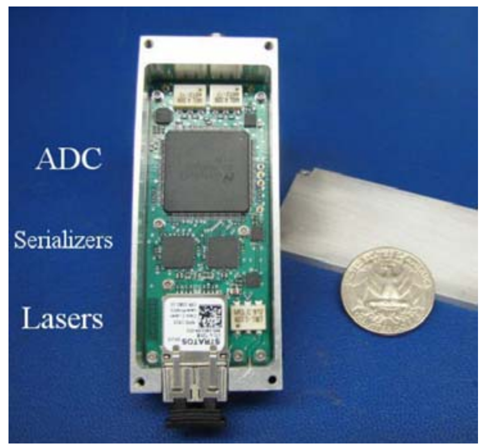


Front End Development

- Prototype Band 1 Feed, Caltech
- Prototype Band 5 Feed, NRC
- Integrated receiver / digitizer prototype, NRAO CDL
- Two-stage hybrid sterling refrigerator, Raytheon LT-RSP2







Key Antenna Optics Requirements

- Sensitivity/$
  - A_{eff}/T_{sys} is the parameter to optimize. Impact on mount cost hard to quantify…
- Minimize Operations Cost
  - Feed aggregation in to a minimum number of dewars.
  - Band Selection Mechanism feasibility
- Operating Frequencies:
  - 1.2 GHz – 10 GHz: Secondary Operating Range. 5-10 GHz more important.
  - 10 – 116 GHz: Primary Operating Range, most important.
- Minimal Impact on Antenna Pointing
  - Minimize wind loads / gravity deformations from feed arm, subreflector.
- Polarization
  - Squint & Cross-pol OK/expected; need *stability* over time and temperature.
  - Eliminate cross-pol at center of field.
- Beam Uniformity
  - Uniformity in beam patterns across array and over time and temperature.

Key Omissions / Exclusions

- Sidelobes not a driver due to focus on >10 GHz operation
  - VLA: -13dB to -16dB 1st slidelobe.
    - "Good enough" for high dynamic range imaging at >10GHz.
    - Lower would be better…
  - ngVLA Ref design: -19dB 1st sidelobe.
  - Vary to optimize G/T with the feeds in the primary operating frequency range.

- Do <u>not</u> design for future prime focus LF instrument
  - Optimize for secondary focus, take what we can get at prime focus.
  - There is community interest in a commensal LF system, but don't let it drive the design.

- Do <u>not</u> design for a future PAF.
  - HF FPA slightly more interesting….
  - Optimize for single pixel feeds.

CoDR – Expected Deltas

- Subtended Angle of Subreflector: 45-60° ?
  - More likely narrower than wider. W-band feed fabrication a concern.
- Aperture Illumination & Radiation Shield
  - 1^{st} or 2^{nd} sidelobe level constrained by high dynamic range requirements?
  - More likely: Optimize for maximum A_{eff}/T_{sys} with real feed over primary operating frequency range. Sidelobes a free parameter.
- Feed arm length vs primary reflector tilt angle.
  - Long feed arm reduces elevation axis offset, but is now 1^{st} mode of structure.
  - Optimum not clear, should be driven by structural design of the antenna.
- Aperture Diameter: 16-18 m ?
  - Pointing difficulties pushing aperture size down, but ops cost restricts it...
- Feed Lo vs Feed Hi ?
  - Maint. still favors feed low, but structural $ penalty may force a review.
- Subreflector size: 2.5-3.5m? Nearfield effects a concern?
  - Pointing a driver. 3.5m corresponded to largest oversized load w/o pilot vehicle.

CoDR – Big (Less Likely) Deltas

- Many factors point towards a symmetric Cassegrain solution...
- Pro:
  - Cost/Area.
  - Pointing Performance.
  - Delay/Phase Performance.
  - Traditional, well-characterized, corrugated feed horns.
- Con:
  - 1.2 GHz LF cut-off makes feed ring too large to combine dewars…
  - Multiple dewars a cost driver in ops? (Case for Cryo research?)
  - Sidelobe level (not a driver)
- Is there a sensible alt. feed arrangement that we need to consider?

Thanks!

- Thank you to Sandy for organizing the event.
- Thank you to our attendees for lending their time and expertise to our project.
- Still early days for this project, nothing set in stone, we’re interested in your ideas.

ngvla

Next Generation Very Large Array

ngvla.nrao.edu

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