Project Update

Eric J. Murphy, ngVLA Project Scientist
The Jansky Very Large Array

1972 – Approved by Congress
1975 – First Antenna in place
1980 – Full science operations
2001 – Complete electronics upgrade approved by NSF
2011 – Jansky VLA full science ops
A Next-generation Very Large Array

• Scientific Frontier: Thermal imaging at milliarcsecond-scale resolution
• Principle: Scientifically-compelling instrument for 2020s.
• Core Design Requirements
  • 10x sensitivity of JVLA and ALMA
  • 10x resolution of JVLA and ALMA
  • Frequency range: 1.2 –116 GHz
• Located in Southwest U.S. (NM+TX+AZ) & Mexico, building from JVLA site
• Reference design remains under continuous development
• Low technical risk (measured step beyond current state of the art)
• Stand-alone, multi-wavelength & multi-messenger scientific roles.

https://ngvla.nrao.edu
Community Participation
ngVLA 2018 Science Meeting

• Meeting was science-focused and wavelength agnostic
  • Brought together a broad cross-section of community

• 3 Parallel Sessions:
  • Origins of Exoplanets and Protoplanetary Disks
  • Mechanisms of Galaxy Evolution
  • Black Holes and Transient Phenomena

• 200+ registrants and **70+ students**!
  • We are creating our next-generation of users
ngVLA Science Book

• First draft of Science Book released in June 2018
  • 58 (refereed) contributions received
  • ~200 unique authors
  • 10+ contributions known to be in preparation, more expected

• Volume is culmination of:
  • Numerous science/technical meetings, beginning with Jan 2015 AAS
  • Community Studies Program:
    • 38 studies over 2 rounds, financially supported by NRAO
    • Community-led Science Use Cases: 80 submitted for ‘Reqs to Specs’ process (ngVLA memo # 18)

• Related: Kavli science meeting series: 2016-2017

• Science Book to be published by ASP
  • Distribute at 2019 Winter AAS Meeting
ngVLA Key Science Missions (ngVLA memo #19)

- Unveiling the Formation of Solar System Analogues on Terrestrial Scales
- Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry
- Charting the Assembly, Structure, and Evolution of Galaxies Over Cosmic Time
- Using Pulsars in the Galactic Center as Fundamental Tests of Gravity
- Understanding the Formation and Evolution of Stellar and Supermassive BH’s in the Era of Multi-Messenger Astronomy

Highly synergistic with next-generation ground-based OIR and NASA missions.

![Image of ngVLA Key Science Missions](image-url)
System Flow-Down

- Begins with Science Use Cases (>80)
  - Distilled into ~200 unique observations
- Prioritization by SAC
  - 5 KSGs born out of various use cases
- Converted into Level 0 Science Requirements
  - 36 Requirements to support KSGs
    - 18 Telescope Reqs.
    - 18 Performance Reqs.
- Translated into Level 1 Technical Requirements
  - 121 System Level Reqs.
ngVLA Reference Design

- A baseline design with known cost and low technical risk. Technical & cost basis of the Decadal proposal.

- 1.2 - 116 GHz Frequency Coverage

- **Main Array**: 214 18m offset Gregorian Antennas.
  - Fixed antenna locations across NM, TX, AZ, MX.

- **Short Baseline Array**: 19 6m offset Gregorian antennas
  - Use 4 x 18m in TP mode to fill in \((u, v)\) hole.

- **Long Baseline Array**: 30 x 18m antennas located across continent for baselines up to 8000km.
  - Designed for both integrated and subarray use.

### Band # Table

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Bridging SKA & ALMA Scientifically

Thermal Imaging on mas Scales at $\lambda \sim 0.3\text{cm}$ to $3\text{cm}$

Complementary suite from cm to submm arrays for the mid-21st century

- $< 0.3\text{cm}$: ALMA 2030 superb for chemistry, dust, fine structure lines
- $0.3$ to $3\text{cm}$: ngVLA superb for terrestrial planet formation, dense gas history, baryon cycling
- $> 3\text{cm}$: SKA superb for pulsars, reionization, HI + continuum surveys
Highly Synergistic with Other Facilities on Similar Timescales

- SKA/Lynx
  - Atomic/non-thermal
  - Molecular/thermal
- ALMA
  - Warm/star-forming
  - Cold/dense fuel for SF
- LUVOIR/HabEx
  - Image earth-like planets
  - Image terrestrial-zone planets forming
- OST (FIR surveyor)
  - C/WNM & WIM
  - Cold Molecular Medium
- TMT/GMT
  - Stellar Mass and Unobsceded SF
  - Dense Gas and Obscured SF
- JWST/WFIRST
  - Continuing its legacy in many areas of astrophysics
Unveiling the Formation of Solar System Analogues

A Young Solar Nebula

- $M_{\text{disk}} = 0.08 \, M_{\odot}$
- $d = 140$ pc
- ngVLA @ 3mm
- rms 0.3uJy/bm; 5mas bm ~ 0.7 au (~8hr observation)

Jupiter, Saturn, Uranus, Neptune
SMG at $z = 4.4$; SFR $\approx 400 \ M_\odot / yr$
Total molecular gas content largely missed by high-J lines

Credit: Caitlin Casey (UT Austin)
Understanding the Formation and Evolution of Stellar and Supermassive Black Holes in the Era of Multi-Messenger Astronomy

- Unaffected by dust obscuration and with the angular resolution to separate Galactic sources from background objects using proper motions, the ngVLA will enable a search for accreting black holes across the entire Galaxy.

- Key to understanding GW discoveries
Versatility: Remarkable breadth of Science Enabled by the ngVLA

- Galactic Center pulsars: *testing GR*
- Gravitational Wave EM Follow-up
- Extrasolar Space Weather
- Bursting universe (FRB, GRB, TDE...)
- Low surface brightness HI, CO
- Obscured Black Hole Growth and AGN Physics
- Quasar-Mode Feedback and the SZ Effect
- Black hole masses and $H_o$ with Mega-Masers
- $\mu$as Astrometry: ICRF, Galactic structure...
- Solar system remote sensing: passive and active radar
- Spacecraft telemetry, tracking: *movies from Mars*
Cost Estimates

• Most recent cost estimate for construction
  • ~$1.6 – 2.0B in 2018 base-year dollars

• Target operations budget of \(3\times \text{current VLA} + \text{Long Baseline Ops}\) (approx. $60 – 80M/yr)
  • Operations, maintenance, computing, archiving, etc.: optimize as part of design.
  • Expect changes to Observatory-wide operations model.

• Scope changes and cost data refinement have adjusted the initial estimate, examples of scope adjustments include:
  • Short Baseline Array (19 six-meter antennas)
  • Long Baseline Array (30 eighteen-meter antennas)

• All ngVLA components/data will be reviewed as part of ASTRO2020 process.
Partnerships (Science, Technical, Manufacturing)

- Possible U.S. Multiagency Interest (including long baseline option)
  - ICRF – DOD/Navy, Air Force
  - Spacecraft tracking/imaging, `burst-telemetry’ (mission-critical events) – NASA, DOD
  - Space situational awareness – DOD

- Strong International Partnership critical for success:
  - Current International Involvement in SAC/TAC/Community Studies:
    - Canada, Mexico, Japan, Germany, Netherlands, Taiwan

- Current Industrial Involvement through Community Studies:
  - General Dynamics, REhnu Inc., Minex Engineering Corp, LaserLaB, Quantum Design
Next Generation Very Large Array (ngVLA) Project Timeline

### Roadmap to the Astro 2020 Decadal Survey Submissions

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#### NAS DS2020 Roadmap

- ngVLA Splinter Session at American Astronomical Society (AAS)
- Inaugural Science and Technical Workshop
- ngVLA Splinter Session at AAS
- Science White Papers Posted on arXiv
- Second Science and Technical Workshop
- Technical Advisory Council Formed
- Technical Concept
- Reference Design Workshop
- Preliminary (Internal) Reference DR
- Final (External) Reference DR

#### NSF MREFC Roadmap

- MREFC Candidacy Submission
- Conceptual Design Review (CDR) Complete
- Preliminary Design Review (PDR) Complete (to include construction and operation cost estimate)
- Final Design Review Complete

### National Science Foundation (NSF) Major Research Equipment Facility Construction (MREFC) Roadmap

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- MREFC Candidacy Approval
- Preliminary Design
- Final Design

### Roadmap from Procurement to Full Scientific ngVLA Operations

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- Construction
- Commissioning
- Operations
- Array Transition to Full Scientific Operations

Key Dates:
- 2025: MREFC Candidacy Submission
- 2026: Conceptual Design Review (CDR) Complete
- 2027: Preliminary Design Review (PDR) Complete (to include construction and operation cost estimate)
- 2028: Final Design Review Complete
- 2034: Array Transition to Full Scientific Operations

Science Goals:
- Key Science Goals (KSG) Identified
- KSGs Identified
- Key Science Goals (KSG) Meeting in Socorro, NM
- Science Book Finalized
- Reference Design Workshop
- Preliminary (Internal) Reference DR
- Array Transition to Full Scientific Operations
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