NATIONAL RADIO ASTRONOMY OBSERVATORY

ngVLA Option: Continent-scale Baselines

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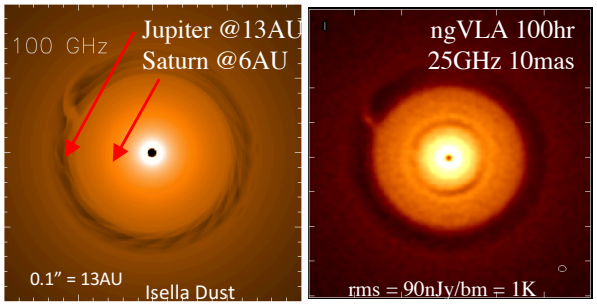
Associated Universities, Inc.

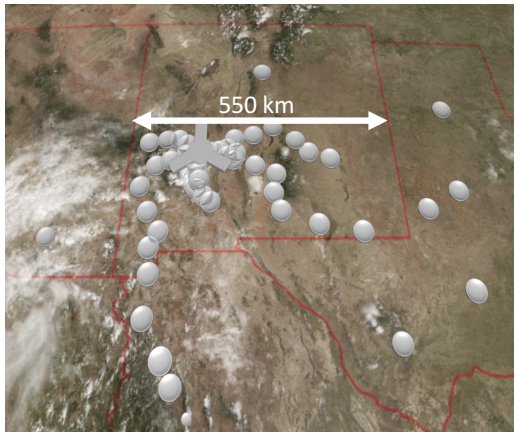
ngVLA

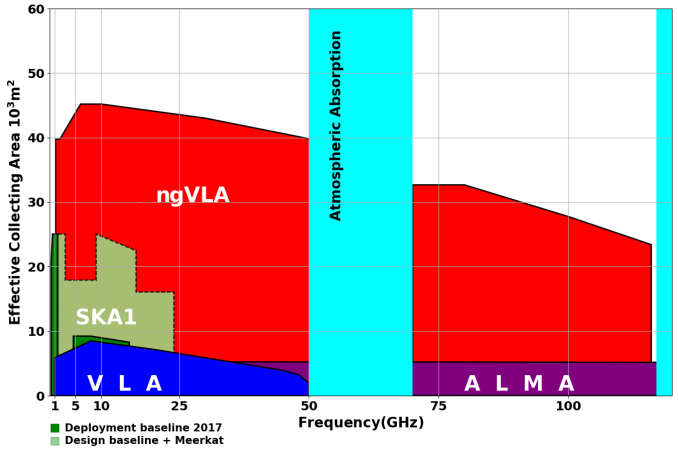
The Next Generation Very Large Array

A next-generation Very Large Array (ngVLA)

- Scientific Frontier: ***Thermal imaging at milli-arcsec resolution***
- Sensitivity/Resolution Goal:
  - ***10x sensitivity & resolution of JVLA/ALMA***
- Frequency range: ***1.2 –116 GHz***
- Located in Southwest U.S. (NM+TX) & MX, centered on VLA
- Baseline design under active development
- Low technical risk (reasonable step beyond state of the art)







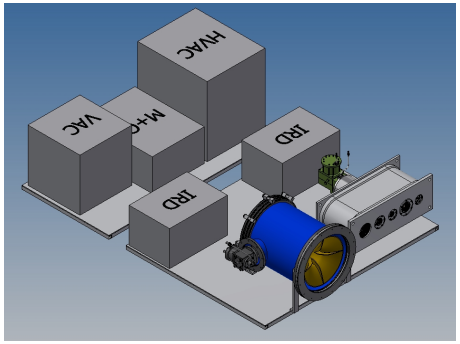
Complementary suite from meter to sub-mm arrays for the mid-21st century

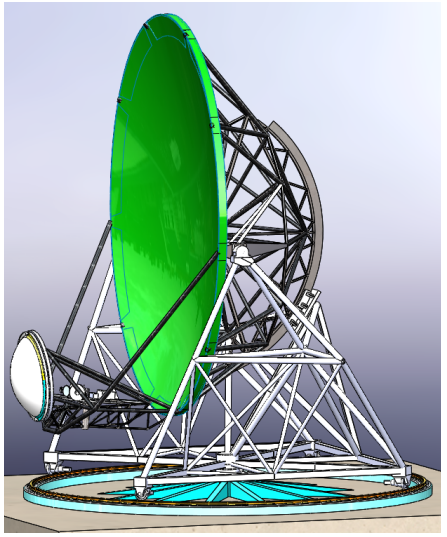
- **< 0.3cm:** ALMA 2030
- **0.3 to 3cm: ngVLA**
- **> 3cm:** SKA

NEW WEBSITE:
https://ngvla.nrao.edu

Current Reference Design Specifications

- 214 18m offset Gregorian (feed-low) Antennas
- Fixed antenna locations across NM, TX, MX
  - ~1000 km baselines being explored
- 1.2 – 50.5 GHz; 70 – 116 GHz
  - Single-pixel feeds
  - 6 feeds / 2 dewar package
- Short-spacing/total power array under consideration

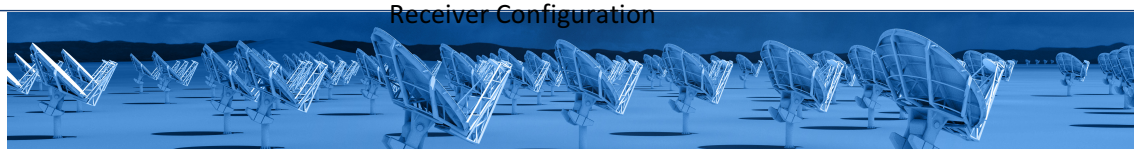




Band #	Dewar	f_L GHz	f_M GHz	f_H GHz	f_H: f_L	BW GHz
1	A	1.2	2.35	3.5	2.91	2.3
2	B	3.5	7.90	12.3	3.51	8.8
3	B	12.3	16.4	20.5	1.67	8.2
4	B	20.5	27.3	34.0	1.66	13.5
5	B	30.5	40.5	50.5	1.66	20.0
6	B	70.0	93.0	116	1.66	46.0

- Continuum Sensitivity: ~0.1uJy/bm @ 1cm, 10mas, 10hr => T_B ~ 1.75K
- Line sensitivity: ~21.5uJy/bm @ 1cm, 10 km/s, 1", 10hr => T_B ~ 35mK

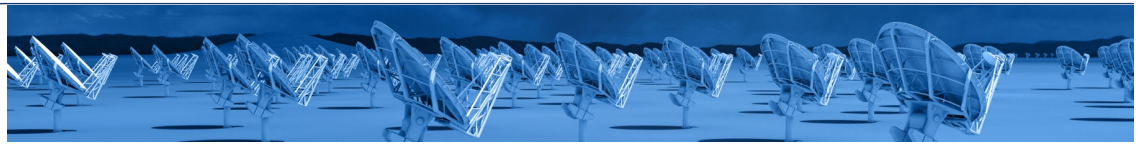
Receiver Configuration



Estimated Price Tag

- Target construction baseline budget **~ (2016) $1.5B**
- Target operations budget of **< (2016) $75M** (< 3x current VLA)
  - ➢ Operations, maintenance, computing, archiving, etc.: optimize as part of design
- **Partnerships:**
  - ➢ Possible U.S. Multiagency Interest [including VLBI 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 & Awards
    - General Dynamics, REhnu Inc., Minex Engineering Corp, LaserLaB, Quantum Design

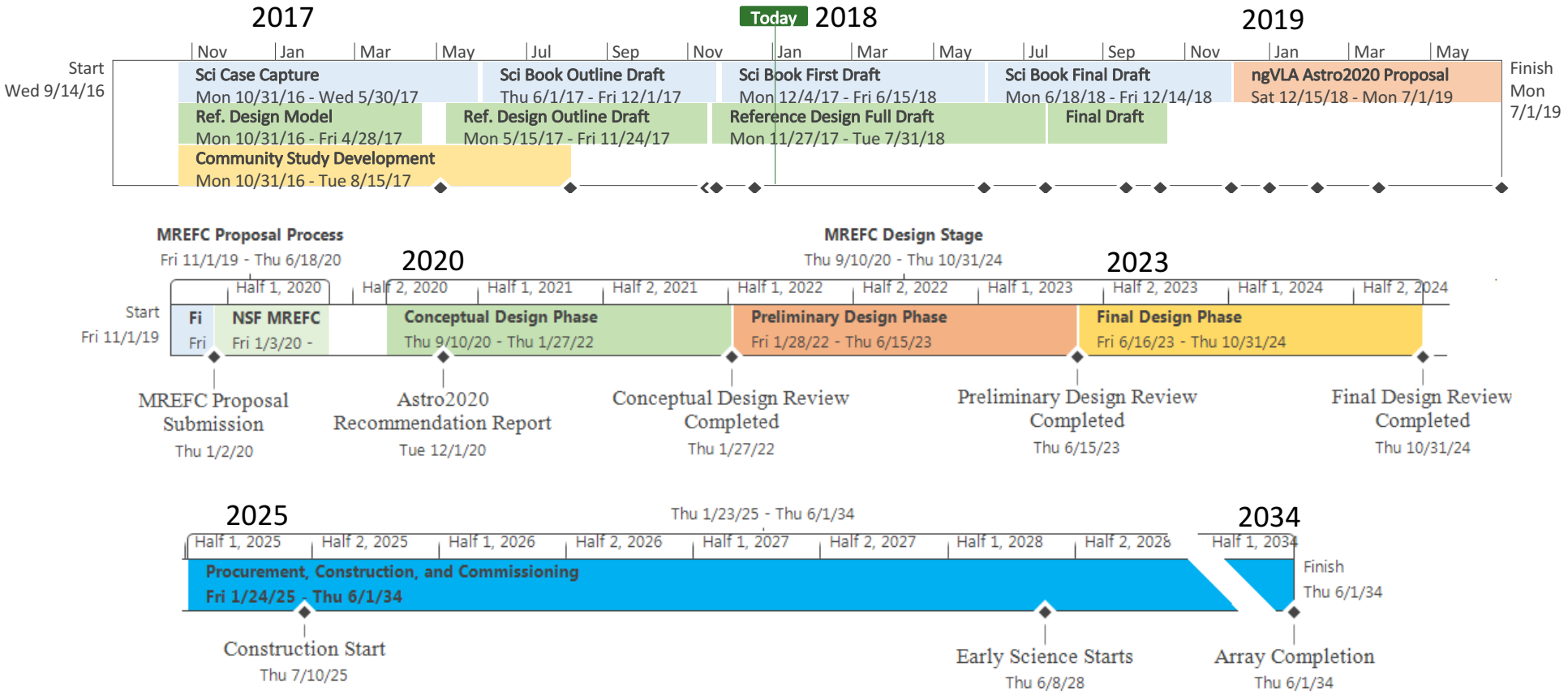
- **NSF Support**: **$11M** Allocated for Development in FY18 and FY19



The Road to Astro 2020

Goal: NRAO CoDR-level 'proposal' to 2020 Decade Survey

Compelling science program & defensibly costed design of all major elements



Scope of Continent-scale Baseline Option

- Very much TBD; to be based on:
  - Community input.
  - Amount & source of funding.
  - Timescale of funding & development.
- Some plausible constraints:
  - ~20% of ngVLA cost ($300M).
  - 15-20% of ngVLA collecting area.
    - Perhaps 12 stations of 3 antennas?
    - ngVLA to provide “short” (50-1000 km) spacing.
  - Use ngVLA antenna and electronics designs.
  - Electronic (fiber) transfer of data.
  - Unmanned sites, periodically visited.

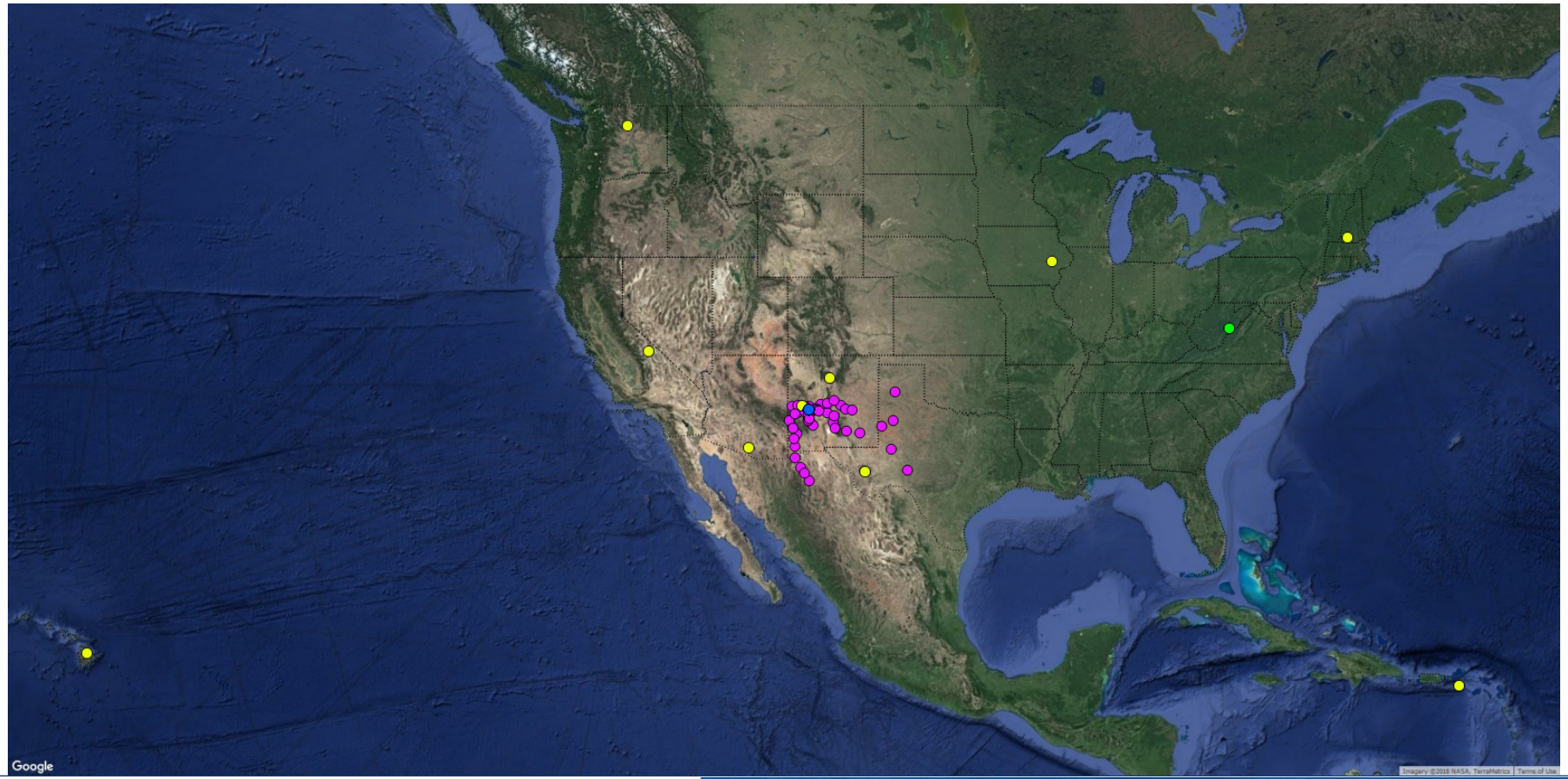
Plausible Constraints (continued)

- Part of ngVLA plan but funding to be pursued independently.
- Timescale:
  - "Continent-scale baseline Option" should be established before the ASTRO-2020 submission.
  - Reference design concept complete in time for detailed ngVLA configuration design reviews (2019).
  - Plan to take advantage of the ngVLA Technology.
  - Deployment during/heels of ngVLA project, during 2030s.

In 2025, ngVLA Continent-scale baseline Option may include:

- VLBA sites and ngVLA outer antennas
- VLBA antennas replaced with clusters of ngVLA antennas (phased)
- VLBA connected via high-speed fiber optics links
- Additional VLBI Correlator
  - Include required Delay Buffers
  - Correlate full ngVLA data rate, also lower and mixed data rates
  - Goal – real-time, but recorders may still be required.
- May require ngVLA correlator to support 100 phased subarrays/beams
  - Easier to plan for these needs now (2018/2019) than later.

Concept: ngVLA + VLBA



Unknowns & Choices

- Maximum required baseline length to achieve science goals
  - Restrict to continent, or extend to islands?
  - Improved North-South baseline length over VLBA?
- Calibration model
  - Antenna clusters may play large role
- Correlate all baselines?
  - Or phase clusters & ngVLA?
  - Separate correlator for long baselines. How many inputs?
- Full-field and/or multi-phase center correlator capability?
- Option for conventional VLBI via data recorders?
- Does VLBA get wholly replaced? Add more sites?
  - Or does it get retrofitted with ngVLA electronics & high-speed fiber optics?

Conclusions

- ngVLA can be central to American VLBI in 2030s
- The long baseline option is being studied, but at much lower intensity than ngVLA. More community participation will increase odds of inclusion and funding.
- There is much to do:
  - Science use cases for long baselines need to be developed and collected
    - Both evolution of current use cases and exploration of fundamentally new ones
  - Estimate performance requirements and possible array configurations
- “Continent-scale baseline Option” should be established before the ASTRO-2020 submission, December 2018.
- Contact ngVLA Project Scientist, ngVLA SAC members, or ngVLA SWG Chairs to participate. (contact info @ ngvla.nrao.edu)

Astrophysical Frontiers in the Next Decade:

Planets, Galaxies, Black Holes, & the Transient Universe

Workshop Portland, OR USA June 26-29, 2018

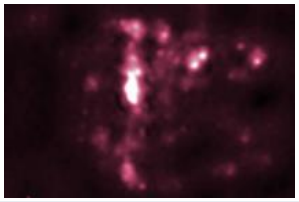
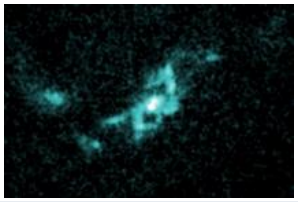
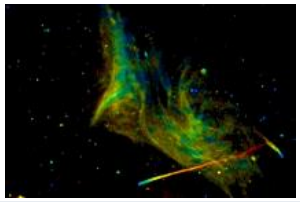
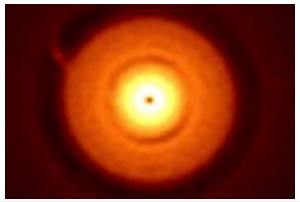
Pre-Registration open: http://go.nrao.edu/ngVLA18

New research facilities and the scientific vision outlined by New Worlds, New Horizons have motivated the exploration of vast new discovery space, and astrophysics has seen extraordinary progress in the past decade, opening new frontiers across many fields. Sponsored by the National Radio Astronomy Observatory, this conference will bring together a substantial cross-section of the astronomical community to discuss how to effectively address the highest priority astrophysical questions of our time. Plenary sessions will feature invited speakers, and three parallel sessions of contributed presentations will address (1) Exoplanet and Protoplanetary Disk Origins, (2) Galaxy Evolution Mechanisms, and (3) Black Holes & Transient Phenomena. Each session will canvas recent observational and theoretical progress, address key unanswered questions, and motivate future research directions in the context of next-generation facilities that would span the electromagnetic spectrum, including a Next Generation Very Large Array, the Large Synoptic Survey Telescope, 30m-class optical-infrared telescopes, the Advanced Laser Interferometer Gravitational-Wave Observatory, and the Square Kilometre Array.

SOC co-Chairs

Brenda Matthews (NRC – Cradle of Life)
Caitlin Casey (UT – Galaxy Evolution)
Laura Chomiuk (MSU – BHs and Transients)

ngvla

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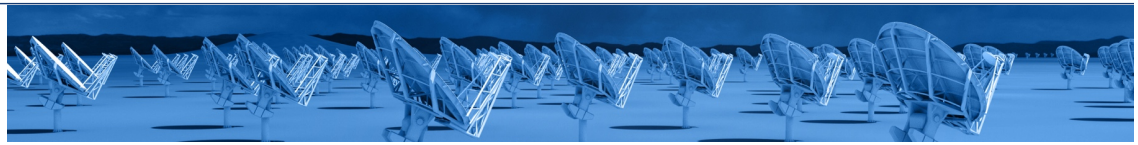

ngvla.nrao.edu

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