VLB ARRAY MEMO No. 473

The VLBA Options List

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The VLBA Options List enumerates proposed cost-saving and/or performance-enhancing variations on the current Array specifications. It includes both extensions ("positive options") of, and reductions ("negative options") in the basic specifications. The List is intended to facilitate a coherent, coordinated, and timely selection among the options under the constraint of a fixed budget for construction of the VLBA. It will be reissued aperiodically, as existing options are decided or new options added.

In general, the nominal specifications from which the options depart are those presented in the current chapters of the "VLBA Book". I have attempted to include all options seriously considered at the date of compilation, although this necessarily involves an exercise of judgement. Not included in the List are choices of a strictly technical nature which have a negligible impact on both cost and performance.

The options are grouped into major areas generally paralleling the group structure of the VLBA project with some exceptions to allow a more unified presentation. A special final section is devoted to options which extend the scope of the Array beyond the current 10-station project. References are given for each group (and occasionally under particular options) to documents outlining the nominal specifications and, where possible, the options. These should be consulted for more complete information, as the Options List is deliberately terse.

Each option is given a mnemonic name for reference, and briefly described. Its effect on the Array's performance is outlined and any dependencies on associated options mentioned. The estimated cost or saving, *always expressed for the 10-station VLBA*, is given where available; those few cases where provisional allocations have already been budgeted are noted. Finally, a decision point — the latest time at which the option must be selected or rejected to avoid an adverse impact on another, critical project area — is established if possible.

SITES

Reference(s):
VLBA Book, Section 2.

No RFI Shielding

Description: Delete RFI shielding from equipment and control rooms.
Effect: Possible interference from local digital signals.
Saving: 755 k$.
Decision point: ASAP; required for first site contract.

No Backup Generator

Description: Delete generator, fuel system, and building; increase UPS capacity.
Effect: Operation shutdown during failure of commercial power; critical equipment stays up only until UPS batteries discharge.
Saving: 300 k$.
Decision point: ASAP; required for first site contract.

No Backup Power

Description: Delete generator, fuel system, and building, and also UPS.
Effect: Complete shutdown during failure of commercial power; possible difficulty restarting.
Saving: 500 k$.
Decision point: ASAP; required for first site contract.

No Fire Suppression

Description: Delete Halon fire suppression system.
Effect: Increased damage in event of fire.
Saving: 110 k$.
Decision point: ASAP; required for first site contract.

Smaller Building

Description: Reduce size of building.
Effect: Depends on details.
Saving: 1.5 k$/sq.ft. of building design (current design: 1176 sq.ft.).
Decision point: ASAP; required for first site contract.

ANTENNAS (including SUBREFLECTORS)

Reference(s):
VLBA Book, Sections 3 & 5.

High-surface-accuracy Subreflector

Description: Improve specified subreflector surface accuracy from current 0.008 to 0.004 inches rms; may require different fabrication technique.
Effect: Increased total aperture efficiency at 43/86 GHz (from .50/.16 to .55/.23).
Cost: 550 k$ (net); *already budgeted.*
Decision point: ASAP, pending receipt of price quotes.

86-GHz Operation

Description: Improve pointing performance by grinding azimuth track and/or implementing circulating-coolant system.
Effect: Satisfactory pointing for 86-GHz operation. [Dependencies: high-surface-accuracy subreflector; 86-GHz receivers.]
Cost: To be determined from operating experience; probably less than 120 k$.
Decision point: Late.

RECEIVERS & FEEDS

Reference(s):
VLBA Book, Sections 5 & 6 (especially 6.10).

10.7-GHz Receiver

Description: Provide 9 additional 10.7-GHz receivers *and feeds*; include feed in feed circle. (One such receiver already under construction.)
Effect: Additional X-band capability beyond planned 8.4 GHz (for continuity of ongoing observing programs, and compatibility with global array).
Cost: 270 k$.
Decision point: ASAP; required input for feed-circle design and dual-frequency pairing;

6-GHz Receiver

Description: Add 6-GHz receivers (sharing 4.8-GHz feeds).
Effect: Observation of 6.035-GHz OH line possible (reference: VLBA Memo 306).
Cost: 200 k$.
Decision point: Late.

No 2.3-GHz Receiver

Description: Delete 2.3-GHz receivers *and* 2.3/8.3-GHz dichroic reflector systems.
Effect: Reduced frequency commonality with the DSN and other antennas used in geodetic/astrometric programs; no dual-frequency observations with 8.3 GHz.
Saving: 600 k$.
Decision point: Before beginning of design and construction (planned 1986).

86-GHz Receiver

Description: Add 86-GHz receivers *and feeds.*
Effect: Observations at 86 GHz possible. [Dependencies: high-surface-accuracy subreflector; 86-GHz antenna operation.]
Cost: 600 k$.
Decision point: Late.

4.8/22-GHz Dual-Frequency Pair

Description: Implement additional dichroic reflector systems.
Effect: Dual-frequency observations possible.
Cost: ~80 k$.
Decision point: Late.

10.7/43-GHz *or* 15/43-GHz Dual-Frequency Pair

Description: Implement additional dichroic reflector systems.
Effect: Dual-frequency observations possible.
Cost: ~80 k$.
Decision point: Late.

Remote Dual-Frequency Operation

Description: Equip dichroic reflectors for remotely commanded operation.
Effect: Improved sensitivity for single-band observations, and unimpeded observation using neighboring feeds.
Cost: ~100 k$ *per pair* equipment cost, plus design cost.
Decision point: Late.

Solar Cal

Description: Add high-level noise signals *at one antenna* (see also VLBA Electronics Memo 30).
Effect: More accurate calibration of solar observations.
Cost: 1.4 k$ *per frequency.*
Decision point: Late.

AUXILIARY STATION ELECTRONICS

Reference(s):
VLBA Book, Section 6.

Water-Vapor Radiometer

Description: Design and build 22/31-GHz radiometers to measure atmospheric water vapor content.
Effect: Improved calibration of atmospheric phase fluctuations for observations at high frequencies.
Cost: 500 k$.
Decision point: Late; hope for development progress elsewhere.

Absolute Time

Description: Acquire receiver for satellite timing signals at *one* station.
Effect: Absolute timing linked to UTC; essential for geodetic/astrometric observations.
Cost: 25 k$.
Decision point: Late.

Time Reference

Description: Acquire receivers for satellite timing signals at *all* stations.
Effect: Convenient comparison of station clocks to UTC.
Cost: 250 k$.
Decision point: Late.

Baseband Electronics, Record & Playback Systems

Reference(s):
VLBA Book, Sections 8 & 9.
VLBA Acquisition Memo 42.

4 Recorders

Description: Increase number of recorders to 4 per station.
Effect: Doubled maximum record rate (1024 Mb/s), continuously sustainable.
Cost: 920 k$.
Decision point: Late (assuming design allows for later retrofit).

64 Tracks

Description: Increase number of tracks to 64 per recorder.
Effect: Doubled maximum record rate (1024 Mb/s), non-sustainable.
Cost: 580 k$.
Decision point: Late (assuming design allows for later retrofit).

16-MHz Channels

Description: Implement 16-MHz channel bandwidth in baseband converters; upgrade formatter for 32-Mb operation.
Effect: Doubled maximum recorded bandwidth (512 MHz); possibly poorer stability in 16-MHz mode. [Dependency: 32-Mb correlator channel.]
Cost: To be determined.
Decision point: Before final design of acquisition/recording system.

Half-Speed Playback

Description: Implement data playback at half as well as full tape speed, using same reproduce heads (but different equalizers).
Effect: Correlation at half real-time speed possible (supporting wider field of view); some degradation of playback SNR at half speed.
Cost: 48 k$.
Decision point: Late (design will allow later retrofit).

Eighth-Speed Playback

Description: Implement high-speed (480 ips) recording and low-speed (60 ips) playback using special-purpose heads in each case.
Effect: Correlation at one-eighth real-time speed possible (supporting much wider field of view); technically questionable.
Cost: 634 k$.
Decision point: Late (design will allow later retrofit).

Station Phase-Cal Detectors

Description: Transfer phase-cal detection from correlator to stations.
Effect: No significant effect on performance. [Dependency: no correlator phase-cal detectors.]
Cost: To be determined; probably minimal *net* cost.
Decision point: Before final design of acquisition/recording system.

Mark 2 Terminal

Description: Build or borrow Mark 2 VLBI formatters and recorders for first several VLBA stations during "transition period".

Effect: Continued and improved scientific activity during Array construction.

Cost: 6 k$ *per station*; none if equipment can be borrowed.

Decision point: Before completion of first VLBA antenna.

Reduced Formatter ("Option 1")

Description: Combine formatting of all 32 baseband channels, onto at most 32 tracks, in one unit.

Effect: Halved maximum record rate (256 Mb/s); increased vulnerability to formatter failure.

Saving: 176 k$.

Decision point: Before final design of acquisition/recording system.

Single Sideband Converter ("Option 2")

Description: Eliminate LSB baseband channels.

Effect: Halved maximum number of channels (16) and recorded bandwidth (128 MHz); degraded de-dispersion of pulsar observations.

Saving: 98 k$.

Decision point: Late (assuming design allows for later retrofit).

16 Tracks ("Option 3")

Description: Reduce number of tracks to 16 per recorder *and* playback unit.

Effect: Halved maximum record rate (256 Mb/s), requiring high-speed recording on two tape transports, and correlation without speedup.

Saving: 284 k$.

Decision point: Late (assuming design allows for later retrofit).

8 Baseband Converters

Description: Reduce number of baseband converters to 8.

Effect: Halved maximum number of channels (16) and recorded bandwidth (128 MHz); degraded bandwidth synthesis observations.

Saving: 200 k$.

Decision point: Late (assuming design allows for later retrofit).

CORRELATOR

Reference(s):
VLBA Book, Section 10.
VLBA Memo 375.
VLBA Correlator Memos 41 & 47.

Accelerated Correlator Dump

Description: Upgrade internal data paths to accommodate accumulator dump rates up to 10 Hz (while maintaining aggregrate data rate limit of 0.5 Mbyte/sec).
Effect: Expanded field of view or higher time resolution, using subset of stations, channels, or lags.
Cost: To be determined.
Decision point: Before final design of correlator electronics.

32 Channels ("Option +1")

Description: Increase number of channels to 32.
Effect: Doubled maximum correlator bandwidth (256 MHz) or frequency resolution (2048 lags).
Cost: 1700 k$.
Decision point: Late.

Computer Expansion ("Option +2")

Description: Add output tape or disk drives, upgrade CPU.
Effect: Increased computing capacity for more rapid data output and greater calibration capability.
Cost: Depends on specific choices; range 50–250 k$.
Decision point: Late.

12/17/24 Stations ("Option +3")

Description: Expand design to 12/17/24 stations in full/half/qtr modes.
Effect: Single-pass processing of enhanced array (VLBA plus 2 other stations at full spectral resolution, VLBA plus 12 stations in continuum).
Cost: 650 k$.
Decision point: Before final design of station and correlator electronics.

High-Speed Archive Dump ("Option +4")

Description: Design and build buffer and high-density tape system to record RAM accumulator output.
Effect: Archiving (and reprocessing during slack correlator time) with minimal restriction of field of view.
Cost: 300–400 k$ (very uncertain).
Decision point: Before final design of accumulator, digital filter, and TOP.

32-Mb Correlator Channel ("Option +5")

Description: Exploit 2 um CMOS VLSI to run at 32 Mb/s clock rate.

Effect: Correlation of 16-MHz baseband channels [dependency]; doubled maximum correlator bandwidth (256 MHz); technically questionable.

Cost: ~150 k$.

Decision point: ALAP, but before final design of station and correlator electronics.

Oversampling at Full Resolution ("Option +6")

Description: Add extra delay stages to correlator VLSI chip.

Effect: Correlation of oversampled bits (with some sensitivity enhancement in narrowband spectral observations) with full spectral resolution.

Cost: ~150 k$.

Decision point: Before final VLSI design.

32-Lag EC ("Option +7")

Description: Expand elementary correlator to 32 complex lags.

Effect: Doubled frequency resolution for spectroscopy.

Cost: 1100 k$.

Decision point: Before final design of correlator electronics; possibly before final VLSI design.

1-to-1 Phase-Cal Detectors ("Option +8")

Description: Provide 1 phase-cal detector per channel (instead of 1 per 4 channels).

Effect: Higher sensitivity to phase-cal signals; simpler or more flexible switching among detectors.

Cost: 75 k$.

Decision point: Before final design of station electronics.

No Digital Filter ("Option -1")

Description: Delete sample-rate-reduction module.

Effect: Narrower field of view (by factor of 2 or 4) for fixed output data rate.

Saving: 325 k$.

Decision point: Late (module designed for later retrofit).

No Correlator Phase-Cal Detectors ("Option -2")

Description: Transfer phase-cal detection to stations.

Effect: No significant effect on performance. [Dependency: station phase-cal detectors.]

Saving: To be determined; probably minimal *net* saving.

Decision point: Before final design of station electronics.

8 Channels ("Option -3")

Description: Reduce number of channels to 8.

Effect: Halved maximum correlator bandwidth (64 MHz) or frequency resolution (512 lags).

Saving: 900 k$.

Decision point: Before construction of station and correlator electronics.

4 Channels ("Option -3")

Description: Reduce number of channels to 4.
Effect: Halved maximum correlator bandwidth (32 MHz) or frequency resolution (256 lags).
Saving: 1300 k$.
Decision point: Before construction of station and correlator electronics.

5/7/10 Stations ("Option -4")

Description: Reduce design to 5/7/10 stations in full/half/qtr modes.
Effect: Single-pass processing of entire VLBA only with quarter resolution.
Saving: 1000 k$.
Decision point: Before final design of station and correlator electronics.

POST-PROCESSING

Reference(s):
VLBA Book, Section 11.

Expanded Post-Processing Capacity

Description: Expand post-processing hardware configuration from 4 to 5 fully-equipped VAX 11/780's (or modern equivalent); partial steps also possible.
Effect: Increased throughput for post-processing.
Cost: 600 k$.
Decision point: Late.

Reduced Post-Processing Capacity

Description: Reduce post-processing hardware configuration from 4 to 3 fully-equipped VAX 11/780's (or modern equivalent); partial steps also possible.
Effect: Decreased throughput for post-processing.
Saving: 600 k$.
Decision point: Late.

CONTROL & MONITOR

Reference(s):
VLBA Book, Section 4.
VLBA Memo 299.

Satellite Communications Link

Description: Replace leased telephone lines with satellite link.
Effect: Increased reliability of communications; reduced operating cost.
Cost: 1200 k$ (equipment costs only).
Decision point: Late.

OPERATIONS

Reference(s):
VLBA Book, Section 12.

Expanded Operations Center

Description: Expand AOC floor area to 40000 sq.ft. (from 33000 sq.ft.)
Effect: Expansion of VLBA/VLA operations possible.
Cost: 525 k$ (@ 75 $/sq.ft.)
Decision point: Before AOC construction contract.

Reduced Operations Center

Description: Reduce AOC floor area to 26000 sq.ft. (from 33000 sq.ft.)
Effect: Dependence on NMIMT or VLA for deleted resources.
Saving: 525 k$ (@ 75 $/sq.ft.)
Decision point: Before AOC construction contract.

EXTENDED ARRAY

Reference(s):
VLBA Book, Sections 1.3 & 6.7.
VLBA Memos 213, 240, & 246.
VLBA Electronics Memo 1.
VLBA Acquisition Memo 42.

These options represent extensions of the 10-station VLBA project to cover more uniformly the range of baselines available on the surface of the Earth and approach a "matched u-v filter" appropriate to any mapping observation. The extensions provide facilities to integrate the VLA and VLBA apertures into a fully-capable joint instrument, and to broaden the aperture coverage more generally by providing or facilitating the incorporation of additional stations. While this extended array is not formally part of the VLBA project, the following options are included in the Options List to remind designers of the Array that we may have to implement and support such additional facilities in the future.

Pie Town VLA Station

Description: Implement digital data and phase-stable LO links between Pie Town site and the VLA; provide VLA electronics at Pie Town, and upgrade VLA correlator delay *etc.*
Effect: Pie Town usable as VLA "outrigger".
Cost: ~500 k$ for links (including design costs); VLA equipment cost to be determined.

Additional Acq./Rec. System(s)

Description: Provide complete or partial acquisition/recording systems for fixed sites (e.g., the VLA, Green Bank, ...) or as portable units.
Effect: Enhancement of the Array (in particular to include elements with large collecting areas or high-frequency performance).
Cost: 195 k$ per station.

Additional Southwest VLBA Stations

Description: Build additional fully-equipped stations at the following sites in the vicinity of the VLA: Dusty, NM; Bernardo, NM; and Roswell, NM.
Effect: VLBA aperture extended inwards from 200 km towards 35 km outer envelope of VLA aperture.
Cost: ~4.5 M$ *per station.*

South American VLBA Station

Description: Build an additional fully-equipped station in northern South America, probably in Ecuador.
Effect: Improved north-south aperture at equatorial and southern declinations.
Cost: ~4.5 M$.