EVLA MEMO 52
Operations Plan for the Expanded Very Large Array

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Abstract

When complete, the Expanded Very Large Array will comprise 38 antennas – 28 on the Plains of San Agustin, 8 new New Mexico Array antennas at fixed locations in New Mexico, and two converted VLBA antennas. These, and the eight other VLBA antennas will all be operated and maintained from a common operating site, using a single correlator and single operations crew. This memorandum describes how the NRAO will operate and maintain these 46 antennas, located at 19 sites.

1 Introduction

EVLA Phase II proposes to build and operate eight additional antennas and to modify the two VLBA stations located in New Mexico in order to reach the EVLA science goals. This new combination will be called the New Mexico Array (NMA). NMA antennas are required to be compatible with Ultrasensitive Array antennas and will be connected to the EVLA operating software and hardware via fiber optic cables for realtime correlation by the WIDAR correlator. NMA antennas will often participate in VLBA observations, and so the eight new antennas must have a compatible data acquisition system that works with the VLBA. At this time, the recording equipment is presumed to be the Mk V, PC/disk-based system being developed at Haystack Observatory. All VLBA observations will be processed through the WIDAR correlator. NRAO's Socorro operations will be responsible for the additional duties associated with the expanded subarraying capabilities the NMA provides to EVLA and VLBA, and for the additional maintenance support. Annual operating costs will be estimated.The appendix will provide a list of capital costs not associated with the antenna construction.

2 New Mexico Array Operations

In this section, we outline how operations will accomplish these tasks and describe requirements and costs. Operational expenses for the NMA fall into the following six categories:

1. Routine and Special Antenna Maintenance;
2. Technical Support for NMA Equipment;
3. Site Facilities and Upkeep;
4. Array and Antenna Monitor and Control;
5. NMA Scheduling;
6. Education and Public Outreach.

2.1 Routine and Special Antenna Maintenance

Of the eight new NMA stations, seven will be located in the southwest quadrant of the state. One will be located in the eastern half of the state. The PTVLBA station will remain in its present location. The LAVLBA station is expected to be moved to an eastern location sometime before the completion of the NMA, and at the time of its move, be equipped with the fiber optic connections and other electronics to make it a NMA antenna. Travel distances from the VLA to the farthest prospective site may be as long as 220 miles one way, and a similar distance from the AOC. Although much of this distance is on paved highways, some will be in more remote areas with access to the site via several miles on unpaved roads. Maintenance needs will require a visit to each of the ten NMA antennas once a week for routine work. To effectively perform the routine, weekly maintenance, the technicians will need at least six to seven hours at the site, but a daily human presence at each site will be un-necessary. This routine maintenance can be scheduled so that each site is visited once weekly on a rotating basis. To minimize travel time and personnel, the NMA maintenance can be managed by dividing the sites into three regions, with each region staffed by a team of two all-purpose technicians, similar to the VLBA site technician model. Each team would need a base station from which shipping/receiving and other administrative functions could be handled. But, instead of being limited to a single station, the NMA tech-teams would assume the maintenance duties for a group of 3-4 sites using the following geographical scheme:

1. The Western field group - handles PTVLBA, and three other sites within the 100 mile radius of the VLA; technicians would be based near or at the VLA, or possibly the PTVLBA site. The PTVLBA field group can be re-assigned, with no additional personnel costs. The VLA (or PTVLBA) would act as the base and shipping/receiving locale for the technicians.

2. The Southern field group - handles sites within a 100/150 mile radius of Silver City; technicians based/live near Silver City. This would require two new FTE's. Office space in the city can be rented to serve as a base and shipping/receiving locale. Alternatively, a service building similar those at VLBA sites can be constructed at one of the sites in this region for this purpose.

3. The Eastern field group - handles sites east of Socorro, plus any south of Socorro near to I25; technicians based/live near Socorro. The LAVLBA field group can be re-assigned, with no additional personnel costs (assuming the LAVLBA operations will have been moved to within this area. Space in the AOC would need to be designated, and access to copiers faxes and telephones provided. Alternately, if LAVLBA site has a service building identical to PTVLBA, it may serve as the base and delivery point for these technicians, should it be more convenient.

Maintenance of the sites must also provide for overtime compensation caused by off-hours problems that only an on-site technician presence can resolve (e.g. replacing blown fuses,resetting tripped circuit breakers, responding to fire/trouble alerts). Therefore, a rotating system of trained technicians to be on-call 24 hours a day is necessary. Additionally, a long-term major maintenance visit to each NMA site will be required about once every three years. These would be similar to VLBA Tiger Team and done by the same personnel, so the total number of site visits per year for major maintenance by this team would increase to six - three VLBA, three NMA. Since Tiger Team personnel will have more of their work hours devoted to this type of work, additional FTE's will be required. This will be addressed in the next section.

2.2 Technical Support for NMA Equipment

As of 2003, the Electronic and Engineering Services Divisions support 37 VLA and VLBA antennas. The addition of eight NMA antennas will increase the need for spares by 20 percent. Additional personnel in the Electronics Division for the FE, LO/IF, Cryo, DCS, Fiber, and Drafting groups will be required to maintain and repair the additional NMA components and to support the additional major maintenance visits each year. Engineering services will require an additional seven new FTE's in the Antenna Mechanic, Servo, HVAC and Automotive groups. The total of new FTE's is sixteen. See Operating Costs Analysis

for details on capital expenditures for test equipment, benches, etc. Supervision of the NMA field group technicians can be designated to the existing VLBA field group supervisor. No new FTE's to support the software specific to NMA operations will be necessary, as the NMA will use existing EVLA tools for that work.

The main work area for the additional personnel will be primarily at the VLA and the AOC. This will require an additional 2000 sq. ft of lab/assembly space along with appropriate test equipment. Warehouse space of approximately 5000 sq. ft. will need to be constructed to house the extra spares and repair parts.

2.3 Site Facilities and Upkeep

Each NMA antenna will require the following basic facilities and services at each site - an access road, security fencing around the perimeter, weed and pest abatement, ramp for unloading equipment, tank for water storage, commercial power and phone service. Each site will require a small building to house electronics (including the maser, UPS, backup generators); work space for trouble shooting; storage for supplies, equipment, spares; toilet and sink; HVAC equipment for the building as well for the room housing the maser; PCs; fiber connections. Each site will need a weather station. Each field technician will need a cellular phone and a laptop computer.

Because NMA site equipment will be limited to some electronics components and some workspace for maintenance crews, a building equivalent to the VLBA sites is not necessary. Each site will need a building to house electronics under temperature control and also include room for a workbench, PC, phone and some storage. On-site water and bathroom facilities in the building will be required, since tech-team may need to spend over six hours there. A water tank, will be needed. Water tanks should to be located inside the site building, so space requirements for the tanks need to be factored into building costs. The water must be resupplied periodically, either by VLA personnel or by contract with a local provider, whichever is most cost effective for a particular site. Either a modified shipping container, or a modular building should suffice for the service building. The building must include restroom facilities - a low maintenance, biological toilet that does not require water or septic system, and a sink with potable water supplied from the tank. For additional security and for energy efficiency, this building need not have windows, but will need to be modified with a secure door and bars on any windows to discourage vandalism and theft. VLBA-like fire, burglar and power failure alarms with sensaphone (or the equivalent) callouts to the technicians and the operators will needed for additional safety. At least one, and possibly two web cameras, one focused on the antenna and another at or in the building will also be necessary.

Each of the three field groups would require a specially outfitted vehicle to enable the technicians to transport all test equipment and spares required to perform preventive maintenance tasks and repair work. A high clearance, 4-wheel drive truck with an enclosed bed, outfitted with proper tools, meters, spare parts, etc. would be purchased for this purpose. Cost estimates indicate that it would be cheaper to purchase the vehicle, rather than to rent from GSA. It is assumed that the vehicle would last approximately 7 years before replacement was necessary. A fourth vehicle, outfitted identically and left at either the AOC or the VLA site, would also be required as a spare and to provide transportation for backup technical support.

For most of the sites, some annual grading of a dirt road from the paved highway will be required. A grader would be purchased and VLA site personnel can be scheduled to accomplish this as needed. Alternatively, this can be contracted locally if that is more cost effective.

For the major maintenance visits, purchase of a container, equipment for the container, a tractor with flatbed trailer, a cherry picker and a water truck (antenna washing) will be required. Other expenses associated with the visits will be the cost for overnight stays at local motels at the farthest sites, vehicle depreciation, fuel costs, per diem and overtime.

2.4 Array and Antenna Monitor and Control

The NMA will have the fiber connections in place for all antenna monitor and control functions to be performed remotely, and software and hardware to manage these functions will be the same as that developed for EVLA antennas. The astronomical data from NMA antennas will be processed in realtime by the WIDAR correlator at the VLA site. To retain compatibility with VLBA observations, NMA must also be able to write VLBA astronomical data with the MKV recording system for later processing of VLBA data on the WIDAR correlator. It is essential that all the NMA antennas MKV recording units be located at or near the VLA control room. This will eliminate the need for the NMA site technicians to service the units, deliver and ship out disk packs to and from each site daily. It is assumed that the twenty-four MKV playback units will be relocated to the WIDAR at the VLA site. PTVLBA and LAVLBA sites will be considered NMA stations, so their MKV data acquisition systems will have to be moved from those sites and placed with the other NMA MKV units. A capital cost for the LAVBLA site will be to lay the fiber to connect the electronics on site to where access to the commercial fiber begins, a distance of up to three miles. Complete fiber connections between PTVLBA and the VLA already exit.

After the completion of Phase II, array operations will operate three NRAO arrays from New Mexico: EVLA, NMA and VLBA. Currently NRAO-SOC operations currently separates the operation of the VLA (soon to be EVLA) and the VLBA as distinct groups, with different supervision, duties and responsibilities, even during periods of joint observations such at PT-link and phased/single dish VLBI/VLA experiments. The NMA will not increase the need for more array operators, and with the move of the VLBA data correlation to the WIDAR correlator and distinctions between EVLA and VLBA groups blur, a more efficient operations model for operating the three arrays by a reduced operator pool is possible.

But to do this, the hardware and software managing operating functions must be available from both the VLA site and the AOC. This will enable EVLA (Phase I and II), VLBA array and correlator personnel to cross-train for both EVLA and VLBA and to merge the duties that are now split among correlator operations, data analysts and array operations. However this will only be possible if that EVLA Phase I plans DO NOT exclude the capability of operating EVLA and NMA array antennas from the AOC. Phase II hardware and software designs must include it. Specifically, the fiber to connect the AOC with the EVLA correlator and antennas must be available.

Operator tasks that must take place at the VLA site will include loading and unloading the MKV disk packs for recording/playback, changing output disks or tape from the WIDAR correlator and monitoring the traffic on the wye from personnel working on the EVLA antennas, as well as monitor and control of the antennas. With monitor and control capabilities available at the AOC, an operator presence at the VLA site would only be necessary from 6:30am to 4:30pm on weekdays. The weekday EVLA operator would take the bus(or his own vehicle) to and from the site during normal weekday site working hours, operating the EVLA/NMA from there. EVLA operators working evening, night, weekend and holiday shifts would perform their duties at the AOC in space allocated in the VLBA control room. This would eliminate the need to supply VLA operators with a designated GSA vehicle to travel 300 miles per day, and eliminate travel time as part of their compensation.

During weekdays, an additional operator located at the AOC would assist in monitoring VLBA observations, including any NMA recording, and correlator playback operations. It would be too much work for the one operator at the VLA to manage all functions during the day. However, evening, night, weekend and holiday shifts when there is no EVLA array traffic to control, can be managed by a single operator. This assumes that both recording and storage disk capacities will be large enough to hold multiple days worth of observations. Transport of disks can be accommodated by utilizing the bus and the morning shuttle on weekdays. If an operator is required at the VLA site at other times, he or she may take one of the NRAO GSA vehicles to the site. If all operators are cross-trained in both VLBA and EVLA operating tasks, there will be additional savings by reducing the overall number of operators and supervisors. If the operating software for EVLA and VLBA can be unified, it may be possible to reduce the number of FTE's in Array Operations by 7.

2.5 Scheduling

For EVLA Phase II, the WIDAR correlator will be responsible for all realtime processing of EVLA/NMA observations up to 45 stations. It will also be able to process up to 20 station VLBA/VLBI MKV data concurrently. Scientific observations of EVLA data will be scheduled primarily through dynamic scheduling software to be developed by the Data Management Division described in e2e EVLA software requirements. This programming will take into account scientific priorities, atmospheric conditions at both the VLA site and the NMA sites, and equipment limitations and schedule array usage to make the most effective use of the instruments. The dynamic scheduling software designed for EVLA must be build so that it is easily expanded to include the additional NMA input. It must also take into account that the WIDAR correlator will be managing the VLBA MKV observations simultaneously, and resolve any conflicts that may occur during simultaneous correlation of the VLBA MKV data with realtime EVLA data. A new FTE would not be required to extend the dynamic scheduling software to include NMA, since the task can be assigned at a high priority to existing personnel.

2.6 Education and Public Outreach

A program for education and public outreach has been developed for EVLA. An expansion of this program in Phase II which will include NMA site visits by teachers and students, on-going improvements to existing displays and educational materials is described elsewhere, but an estimation of operating costs will be included in the listing of annual operating costs. The salary costs of the 2 FTE's will also be included in the annual operational costs below.

3 Annual Budget Increment for The New Mexico Array

The total additional annual operating cost for operating the New Mexico Arrayis summarized in Table 1.

Table 1: **NMA Operations Cost Summary**

Group	Cost (k$/yr)
Field Group costs	914
Maintenance Costs	144
Personnel Costs	1032
Other	14
Total	2104
Savings	(300)
Net Total	1803

This increment is approximately 10% of the current annual operating costs of the VLA – showing the enormous advantage of leveraging this project using the current instrument and infrastructure. As the operations impact of Phase I of the project is expected to be negligible, we conclude that the total increment for operating the completed EVLA will be only 10%. In other words, the EVLA will provide orders-of-magnitude increases in capability for a 10% increase in operating costs.

Table 2: **Annual Operations Costs for the New Mexico Array**

	Description	Cost/Yr. (k$/yr)
	Field Group Costs	
1	Depreciation of field group vehicles over 7 years (assuming 4 vehicles, initial cost $30K ea.	17
2	Yearly Fuel costs for vehicles (assuming 500 miles per week per vehicle for 3 vehicles @ $2.00/gal, ave. 15 mpg)	11
3	Annual maintenance on four vehicles (oil, filters,windshield, tires etc.)	5
4	Vehicle insurance	10
5	Annual building rental,facilities and office costs for Southern Field Group	12
6	Electricity, land phone for 8 sites, cell phones for 2 additional technicians (based on similar costs for LAVLBA)	104
7	Water (cost of trucking for eight sites)(total guess here	2
8	Fiber rental (yearly)	750
9	Annual Grading (cost for local contractor for eight sites - 2 sites close enough to VLA for personnel there to grade)	4
	Subtotal	**914**
	Maintenance	
	Costs based on three major maintenance visits per year, requiring 5 persons per visit, average round trip distance from VLA is 250 miles, 2 GSA vehicles, container and tractor, water truck, grader.	
10	Per diem of $38/day for 5 people/5 days	23
11	Mileage ($.48/mile on 2 GSA vehicles)	1
12	Fuel costs ($2.00/gal for 5 vehicles)	1
13	Overnight accommodations ($80/day/person) (needed for 5 people, 5 days for at least one of the three visits per year)	5
14	Routine maintenance and hardware upkeep: replacement parts, depreciation of Lab Equipment, heavy equipment, etc. (calculated as 10% of the capital outlay for these items which total $1,178,000 see Appendix)	145
	Subtotal	**153**
	Personnel Costs (Salaries and Benefits)	
15	2 additional FTE's to service Southern field group	150
16	Overtime for 2 FTE's (assuming 9 hours of call-outs/week)	14
17	9 FTE's for Electronics Division 1 FE engineer, 2 FE technicians, 2 LO/IF technicians 1 Cryo technician, 1 DCS technician, 1 Fiber Optic technician, 1 drafter	500
18	7 FTE's for Engineering Services Division 1 Engineer (EE or ME), 3 Antenna mechanics, 1 Servo technician, 1 HVAC technician/electrician, 1 Auto mechanic	305
19	1.1 FTE's for Education and Public Outreach 1 outreach specialist, .1 website maintainer	63
20	FTE Programming support for NMA related software (covered under EVLA phase I operations)	0
	Subtotal	**1032**
	Other Operations Costs	
21	MkV disks – annual replacement costs (assuming loss of 3 disk packs per year at cost of $1.2K per pack)	4
22	Replacement/depreciation of PC's, data storage disks, DAT copies for distribution, etc.	10
23	Yearly depreciation on cost of 6 laptop PC's for home and travel use by field group technicians (assuming each costs $1000, needs replacement in 3 years)	2
	Subtotal	**14**
	Savings	
24	Eliminate operator shuttle:$250/month rental for 12 months, $.16 mile @ 300 miles/day	(20)
25	Reduce array operation by 7 FTE's	(280)
	Subtotal	**(300)**

4 Appendix

Capital Costs for Equipment		
Description	Purpose	Cost($K)
Tractor w/ flatbed trailer	Move heavy equip to sites	150
Cherry picker	Antenna access, tiger team	150
Water truck	Site water, antenna clean.	80
Grader	Antenna site/road maint.	140
Mech. maint. vehicle	Mechanic visits to sites	60
Pickup (4 @ $30K ea)	VLA site, tiger teams, & FO	120
Portable air compressor	Tiger team	10
Portable generator	Tiger team	10
Misc. handtools/test equip	20	
Subtotal for Heavy Equipment		740K
Description		Cost ($K)
Network Analyzer		150
Spectrum Analyzer		100
Digital Oscilloscope		80
Fiber fission splicer		35
Fiber test bench		75
Site PCs, 8 @ $1K		8
Misc. test equip., meters		20
Subtotal for Lab Equipment		$468K
Totals for Equipment Costs:		
Heavy Equipment		740
Lab Equipment		468
Total		1208K

II. Capital Costs for Facilities (eight sites)	
Description	Cost ($K)
Site Soil investigations	80
Foundation Engineering	80
Architectural Drawings	28
Site work (250'x150') (basecourse site, gravel)	328
Antenna Foundation (concrete)	2080
Road fill, basecourse,gravel, road size 15'w x 1000'long	290
Site cleaning and grading	48
Contractor fees	168
Fence	96
Subtotal for Site Preparation	**3076**
Description (totals for eight sites)	Cost ($K)
Container(used) or prefab building	56
Insulation,Doors, Windows	32
Crane to set	24
Power distribution, lighting	56
HVAC (2)	40
Toilets with sink	24
Power Utility to site per mile	240
Transformer (100KVA)	56
Engine generator(100KW	320
UPS 25K at 1000/KWH	200
Electrical Installation	160
Water Suppy Tank	24
Plumbing	24
Security cameras and alarms (eight @$5K	40
Weather station 7 24	
Laptop PC's for field group technicians (6 @ $1K ea.)	6
Video monitoring equip., 8 @ $5K	40
Subtotal for Site Service Buildings	**1366**
Description	Cost ($K)
Lab/assembly space for electronics, 2000 sq ft min	400
Warehouse @ VLA site for EVLA2 spare parts, 5000 sq ft	200
VLA site Control Bldg improvements	50
Subtotal for Off-site Improvements	**650**
Total Costs for Facilities (for Eight sites)	
Site Preparation	3076
Service Buildings	1366
Off-Site Improvements	650
Total Facilites Costs	**5092**

III. Capital Costs for VLBA-related Upgrades

Description	Cost ($K)
Mk V Data aquisition and Playback equipment for eight sites (16 units total @ $15K per unit)	240
Disks to support MKV recording, assuming NMA participates in VLBI observing 25%, $1.2K per disk pack and a 60 day turnover)	144
Cost to connect local fiber access to LAVBLA site (assume 3 miles at $30K per mile)	90
Total for VLBA-related Capital Costs	**474K**
Total for All Capital Costs	
I: Equipment	1208
II: Site	3012
III: VLBA	474
Grand Total	**4694K**