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# Report of the 2003 EVLA Advisory Committee

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# 1 Executive Summary and Major Issues

Overall the committee was very pleased with the progress being made on the entire EVLA project. The project seems to be well managed, on-schedule, and on-budget.

There has been excellent progress made on designing, prototyping, and constructing the hardware needed for the Phase I work. The committee was especially pleased to see the extensive amount of work on minimizing internally generated RFI. Some concerns include the following:

- 1) Lowering system temperatures by changing the polarizers.
- 2) Tightening up the management of the correlator, especially relating to the interface between the correlator and monitor & control.
- 3) Developing contingency plans to manage electronic component obsolescence during the long construction period.

The committee was pleased to see that most of our concerns and recommendations from last year related to software issues have been acted upon. The re-organization of software development under project driven management should be more productive than the previous NRAO-wide approach. However, the changes are very recent and it is too early to evaluate the success or failure of the changes—careful monitoring of progress is essential. Specific concerns include the following:

- 1) The new Interferometry Software Division has responsibility for several projects (ALMA, EVLA, VLA/VLBA) and, thus, does not follow the new project-driven management philosophy.
- 2) It is unclear when NRAO expects that a significant fraction of its interferometry data will be analyzed in a new system.
- 3) Interferometer algorithm development has had stunted growth for over a decade and needs improving. Post-processing software designed to remove the effects of RFI is one critical area.

The Phase II proposal looks very strong. It highlights the Decadal Survey recommendations which strongly endorse the project. The science case remains extremely solid, undoubtedly why the Decadal Survey gave the project such a high ranking. The committee is worried that the low frequency upgrade, originally deferred from Phase I to Phase II for funding reasons, may be “dangling.” The science case for this upgrade, especially the study of galaxy evolution via red-shifted HI observations, remains strong. We encourage NRAO to continue to carefully study all options that would lead to a successful completion of the low frequency upgrade. The Phase II proposal will undoubtedly elicit comparisons between the capabilities of the EVLA and other telescopes being constructed or planned, and we recommend extra attention in this area. Finally, it is critical that the Phase II proposal proceed as rapidly as possible. Delays in submission or funding could seriously jeopardize the entire project.

## 2 Management

The EVLA Advisory Committee was pleased to see significant advances in the overall management of Phase I of the EVLA. About one-third of the milestones have been achieved, although a noticeable delay due to overload in the work of the electronics engineers has started to accumulate over the last six months. With the Canadian funds now in place, the building of the correlator should accelerate, hopefully leading to a delivery according to schedule. This is a key ingredient of the project and the committee congratulates the Canadian partners for this advance.

The committee is also pleased to see that software development has been made project-dependent and not a goal in itself. The e2e project is now part of the EVLA project. However, the work on post-processing software currently depends on the ALMA project, not the EVLA project, and this is cause for concern (see §5.2). Given the problems faced in software development over the last decade, we recommend a careful follow-up of these projects via a rigorous schedule of deliverables.

The Phase II of the EVLA is an integral part of the project, as clearly stated in the 2000 Astronomy Decadal Survey. We recommend prompt submission of the proposal to NSF and ask NRAO to support enthusiastically this phase. The completed EVLA will not only be the most powerful centimeter interferometer in the world, but will maintain the science lively and vibrant to justify the design and building of other instruments in the decades to come. The present science drivers for the EVLA are extremely timely. In particular, the EVLA will certainly contribute in a unique way to the solution of most of the the five key problems for which “astronomers are poised to make progress” in the coming decade as identified by the 2000 Astronomy Decadal Survey (Chapter 2, p. 53). Furthermore, the instrument will be so powerful that, as stated in the Phase II proposal, “the greatest impact of the EVLA will be measured not by the answers to today’s questions, but by the answers to the questions raised by tomorrow’s observations.”

## 3 Hardware (except the Correlator)

The progress in all areas of the hardware since our last meeting in June 2002 is very impressive. The designs for Phase I are complete, the hardware has been prototyped and, in most cases, tested to verify the required performance.

### 3.1 Antennas and Feeds

The feeds have been designed. The mechanical layout of the feeds and receivers has been prototyped on VLA antenna 13 and is on schedule for overall system tests. In order to meet the very stringent polarization requirements the quadrature hybrids have been placed ahead of the LNAs. There is some concern that the hybrids add significantly to the system temperature. The committee suggests that the performance and cost of placing the quadrature

combining (needed to obtain circular polarization) after the LNAs be studied. It was also suggested that the noise injection coupling could be moved to a probe within the feed to reduce the added noise from the couplers, but it was pointed out that this makes lab testing more difficult.

### **3.2 Receivers**

The receiver design looks good but there was some concern that the method of bypassing the LNA and using the coupler output for solar observing might result in system temperatures that are so high that calibration sources could no longer be observed. The current design has a 30 dB attenuation ahead of the first amplifier so that the system temperature might be as high as  $3 \times 10^5$  K, if the solar mode amplifier and calibration attenuator are outside the dewar. It was suggested that a design with a step attenuator between the first and second LNA stages be considered. Another possibility being considered is putting the calibration attenuator and the LNA used in the solar mode inside the dewar to lower the system temperature. In this case it may be possible to get the system temperature in the solar mode down to  $3 \times 10^4$  K, which is low enough to calibrate on strong sources and to observe the quiet sun without an unacceptably large loss of SNR. We recommend further study and resolution of this issue. A telecon discussion of the solar mode with solar observers, receiver engineers and interested committee members might be useful in optimizing the design within the budget allocation.

### **3.3 L.O. Synthesizers and Reference Distribution**

The L.O. system is currently under test and no problems are anticipated. Tests of the L.O. reference transmission on the optical fibers show that almost all of the phase changes will occur in the sections of the cable which are above ground and subject to the largest and most rapid temperature changes. Fibers in the same jacket change by the same amount to within one part in 137. This factor is small enough that differential phase change between fibers is small enough that the round trip phase correction, which uses a separate fiber in the same jacket to return the signal, should be sufficiently accurate to ensure the L.O. phase stability specification is met. It would be useful to have a test set-up which involves sending a reference out and back on two legs, then producing the LO1 tones from each reference using the actual LO system, and then comparing the phase stability of these two “antennas” in the lab with an analog phase detector.

### **3.4 Digitization and Digital Data Transfer**

The digitization and data transfer is running in the lab. The fiber has been buried on the east and west arms of the VLA and much of the fiber has been connected into the configuration patch panels.

### 3.5 RFI Shielding

The layered approach being taken to prevent locally generated RFI is most impressive. The radiation from individual PC boards has been reduced by having modules racks with RFI gaskets. Shielding factors have been measured using an RFI test chamber. A total shielding factor of more than 110 dB has been achieved.

### 3.6 Parts Obsolescence

The committee expressed concern that, given the long period over which construction is scheduled, many parts will become obsolete. One solution, is to make an initial procurement of enough parts for lifetime of the EVLA. In most cases the parts which are likely to become obsolete are small, relatively low cost, surface mount components so that large initial procurements should be possible within the budget constraints. In some cases it may be necessary to redesign printed circuit boards after a few years. For example, when the Infineon TC-111B microprocessor in the monitor interface board (MIB) is no longer available, a redesign of the MIB will be needed. However the technology of any replacement is likely to be less expensive and since the MIB interfaces are well defined this should be a relatively easy project which might be considered as part of the EVLA maintenance.

## 4 Correlator

The Advisory Committee welcomes the news that the EVLA correlator project has received funding in Canada, and we congratulate our Canadian colleagues. The correlator is a critical element of the EVLA, and efficient and timely construction of the correlator will facilitate early scientific use of the EVLA. We identified two areas of concern with respect to the correlator development: contingency plans and the interface between Monitor & Control and the correlator.

The level of contingency in the correlator construction schedule is optimistic. In particular, the schedule relies on a successful first run on the production of chips. This assumption has high risk associated with it, and we would like to see a contingency plan that either mitigates this risk, and/or a scenario of the consequences of an unsuccessful production run both on the timeline and the funding.

The interface between the Monitor & Control and the correlator is poorly defined. This situation has made it difficult for the Canadians to make progress on the design/requirements of the correlator software. There is a critical need to carefully define and document the architecture of the system, in order to ensure that the Monitor & Control and e2e systems serve the diverse needs of observing with the EVLA. Some questions that impact the correlator interface include the following:

- 1) How will the observing system control the EVLA when it is making several types of observations at once (which may ultimately include the NMA and VLBA)?

- 2) How will information be passed to enable post-correlation RFI excision?
- 3) What limits must one place on the design, and how will it grow in an orderly manner?
- 4) How will pulsar observations be processed?

The architecture that will be defined by these types of questions provides the context for the software interface to the correlator. This task will require input from a broad group of people, but must be captured and documented by the EVLA Computing Group. Considering that that Canadian group is remote, the project should ensure that a well documented software interface between the two groups is in place as soon as possible.

## 5 Software

The committee is pleased that NRAO has taken to heart many of its recommendations in last year's report that concerned software. The new management structures put in place by NRAO for software development appear to be an improvement over the previous AIPS++ and e2e management structures. In particular, there appears to be a new emphasis on responsiveness and interaction with users. It will be interesting to see how things "shake out" and which individuals emerge as the real leaders of the new groups.

The much increased involvement of astronomers and other end-users in writing up requirement specifications is a good start toward providing users of the various systems with applications that fit their needs. However, it is critical that NRAO continue to be aware that user involvement remains important in all stages of software development—design, coding, and testing etc. There appears to be some concern among NRAO staff that there are not enough EVLA end-users, particularly from the scientific/astronomy staff, to fully support the amount of anticipated work in this area.

### 5.1 Monitor & Control and e2e

The Monitor & Control (M&C) system has interfaces to both the WIDAR correlator and the e2e system. It is particularly important that interfaces between the M&C system and the WIDAR correlator be firmed up as soon as possible so that software development of the Virtual Correlator Interface (VCI) does not get delayed. Lack of interface design and definition could also slow down or impact on various components of e2e that interface with the M&C system.

### 5.2 Post Processing

To a large extent, the recent improvements in AIPS++ (speed of execution) have come about because of pressure from the ALMA project. We are concerned that in the not-too-distant future the EVLA project must begin to exert corresponding pressure on the various software groups/managers, in

order to avoid being bypassed entirely in the rush to ALMA. As we understand it, the policy for management of software development at NRAO is that it be “project-driven.” However, the committee is concerned that the Interferometry Software Division is responsible for several projects. Thus, the allocation of resources is decided by management based on the priorities of several projects. In particular, since this committee is entrusted with attempting to ensure that the EVLA project proceeds on schedule, we are concerned that ALMA is now consuming, and may continue to consume (even after the AIPS++ ALMA “drop dead” date of June 2004), nearly all of the Interferometry Software Division resources.

The current emphasis on improvement of performance in AIPS++ through the ALMA benchmarking efforts will also benefit the EVLA. However, while AIPS++ performance has been a serious concern, the AIPS++ user interface and its overall robustness have also proved problematic in the past. So far, presumably because of lack of resources, these issues have not been addressed. With limited resources, priorities dictate where resources are devoted, and these priorities are not necessarily those of the EVLA project.

One of the critical reasons for continued end-user involvement throughout the course of the project is that only by such involvement will users end up with interfaces that they find easy to use and understand. However, there is a “Catch-22” here: end-users must be involved to produce the user interfaces that they want, but it is precisely the lack of usable interfaces that is currently preventing an end-user community from getting more involved in the AIPS++ development. We firmly believe that a (relatively) small effort in the early stages on interface (and installation, and documentation) issues could pay off with a wider community able to test, debug, and contribute to AIPS++.

Perhaps the best way to ensure that a post-processing package for the EVLA (and ALMA), would be to have a system working *in the near future* for current VLA and VLBA analysis. This would attract a large number of users, thoroughly exercising the system and stimulating further development. Thus, we strongly encourage NRAO to aim for an interferometry analysis system that can be used with current interferometers, and not simply aim for a new package that would be ready in the 2010 time-frame for the EVLA and ALMA.

### 5.3 RFI

Although the EVLA project has made great strides in control of locally generated RFI by means of various shielded enclosures, the EVLA will remain susceptible to externally generated RFI as observations are made far outside the standard frequency bands allocated to radio astronomy. Examples of various types of interference produced by airplane position locating systems show the seriousness of this problem. This type of RFI will most likely have to be removed from collected data during the post-processing phase. The committee feels that it is very important for NRAO to designate someone to work on algorithm research in this area; it will almost certainly be a long term effort. Other radio observatories are also faced with similar problems,



and we suggest that active collaboration and communication with these other groups would benefit all parties concerned.

## 6 Phase II

### 6.1 Strategic Issues

As mentioned in the previous EVLA Advisory Committee report, the Astronomy and Astrophysics Survey Committee ("Decadal Survey") prioritized new initiatives in astronomy for the decade 2000-2010. The EVLA was ranked second among ground-based major initiatives, behind only a Giant Segmented Mirror Telescope (GMST). This extremely high ranking was for the entire EVLA project, with no relative prioritizings of phase I and phase II. Indeed, in the Executive Summary of the Survey report, phase II projects are prominently discussed:

"...The addition of eight new antennas will provide an order-of-magnitude increase in angular resolution. With resolution comparable to that of ALMA and NGST, but operating at much longer wavelengths, the EVLA will be a powerful complement to these instruments for studying the formation of protoplanetary disks and the earliest stages of galaxy formation."

Thus, the EVLA Advisory Committee feels that it would be both scientifically and politically unwise to delay approaching the NSF for funds to complete the entire EVLA project.

At this point, were a Phase II proposal to be delayed significantly, it might then be subjected to re-evaluation by the next Decadal Survey (which could start in 2008/9). This would add a few more years of deliberations and push a Phase II start beyond 2010. Should this occur, Phase II would probably be compared with the much larger SKA project and it might never be funded. This would be most unfortunate for NRAO and the astronomy community. The EVLA, including Phase II, lies on a very reasonable "road-map" leading to a "northern-SKA." NRAO would have 10 VLBA, 8 NMA, and 27 VLA stations. The land, power, and (hopefully by then) fiber connections would be in place for placing SKA "antenna-patches" at these stations. This would greatly reduce costs and simplify SKA construction. (Imagine the costs and environmental impact complications were the SKA to seek entirely new sites for the very large numbers of widely dispersed antennas!). If, as seems likely, budgetary considerations limit the SKA to frequencies below 10 or 20 GHz, then the North American Array and the SKA could operate together, efficiently sharing sites, infrastructure, and staff, far into the future. Finally, in order to get an ambitious, complex project like the SKA going in the future we need an active, expert community of centimeter interferometrists, and this will not be possible without the complete EVLA.

## 6.2 Low Frequency Upgrade

The Committee finds that the case for the low frequency upgrade looks very strong, even if it costs more than previously anticipated. The science case for this upgrade, especially the study of galaxy evolution via red-shifted HI observations, remains strong. The extension of the EVLA's frequency coverage below 1 GHz would make the VLA the only instrument, until the SKA comes on line, that could probe the evolution of the gas content of galaxies in an unbiased way to redshifts approaching  $z = 1$ . Since more than 50% of the stars we see now must have formed since  $z = 1$ , strong evolution of the gas content is to be expected. Knowledge about evolution of the gas reservoirs around galaxies is an essential ingredient in understanding galaxy evolution. These studies require long integration times, and it is the combination of large field-of-view and large instantaneous velocity coverage that makes the EVLA uniquely suited to do this kind of work. This is complementary to ALMA, which probes with a molecular tracer (CO), although ALMA with small fields-of-view (which are good for individual galaxies but not for surveys) cannot do this efficiently. The GMRT, which has adequate sensitivity, lacks the large instantaneous velocity coverage to do such surveys.

While the low frequency upgrade might appear as “an add-on” and its focus differs from that of the NMA, it should be remembered that this upgrade was originally planned for Phase I (where many different upgrades are involved). It was deferred from Phase I to Phase II mostly because of funding profile issues and the lack of a mature engineering plan. Neither of these reasons detract from the science. Thus, we strongly encourage NRAO to continue to carefully study all options that would lead to a successful completion of the low frequency upgrade.

The main concern of the committee for the hardware design needed for Phase II is the design of the low frequency feed and LNA. The “baseline” design is to provide a mechanical means of rotating the subreflector out of the way so that a low frequency feed can be brought to the prime focus. This approach is expensive but should provide the best performance. We note that the system temperature specification of 90 K for the 0.24-0.41 GHz range is high, given that there are regions of the sky below 50 K even at 240 MHz. The committee recommends that the following alternatives should continue to be studied:

- 1) An off-axis array
- 2) An array which moves into place over the subreflector
- 3) A “fold-out” opening in the center of the subreflector

An array study was presented to the committee. This study looks promising, especially if non-cryogenic active antenna elements can provide low noise temperature at very low cost for the large number of elements required.