# Response to the EVLA Advisory Committee Report of 30 September , 2003

4 November, 2003

The NRAO Director and EVLA Project Team wish to thank the members of the EVLA Advisory Committee for their time and hard work at the meeting and for the valuable advice which they provided. This document provides the response of the EVLA Project Team to the Committee's comments and recommendations.

## 1. Management Issues

The Committee notes that a noticeable schedule delay due to overload in the work of the electronics engineers has started to accumulate over the last six months. This schedule slippage is being addressed by authorization for the use of overtime, by the filling a number of temporary engineering and technical positions and by advancing some positions originally budgeted to begin later in 2004.

## 2. Hardware Issues

### 2.1 Electronic Systems

The Committee suggested that it might be possible to reduce receiver noise temperatures by locating the polarization-forming hybrids after the low-noise amplifiers. Following the Committee's suggestions, measurements and simulations are being made to evaluate the effects of locations of the hybrid and of the noise couplers.

The Committee is concerned 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. This issue has now been clarified and it is possible to calibrate the effect of selecting the solar amplifier by correlating against a reference antenna, which will provide sufficient signal-to-noise.

A test of the phase stability of the local oscillator (LO) system was recommended in which the phase of the output of two complete LO chains, each distributed on its own fiber, is directly compared. The project will attempt to make this test.

The Committee expressed concern that, given the long period over which construction is scheduled, many parts will become obsolete . We agree that this is a significant concern. The plan is, within budgetary constraints, to place lifetime orders for the most critical components in the first year or two of the project. It is encouraging that for the 2004 budget the Senate has proposed accelerated funding for the EVLA project. If these funds do become available it will be possible to purchase the highest risk components.

### 2.2 Correlator

The Committee is concerned that the level of contingency in the correlator construction schedule is optimistic (particularly with respect to the correlator chip).

The first part of this answer relates to the steps to minimize the need to exercise a contingency plan. Because of the cost, considerable pre-production effort will be put into a Test & Verification Plan for the correlator chip design. The plan relies on a 'C' level behavioral simulation of the correlator chip. This is the gold standard that is simple enough to trust and produces output that can be predicted theoretically, at least on a statistical basis. It was used in the original WIDAR simulations. Its heritage stems from the VSOP correlator, which has correlated many VLBI observations. The VSOP correlator's results have been compared with those from the VLBA correlator with good agreement between the two.

Various computer tools are used beyond this to ensure that the digital implementation of the chip functions the same as the behavioral simulation. Slight differences occur here due to digital delays in the chip used for "pipelining". These tools are used to test the design at various levels, ending in simulations at the fabricator's facility. The fabricator's simulations also take into account actual signal propagation within the chip and assesses the power requirements. The simulations at all levels utilize a large number of test cases to test the design. The test cases are meant to cover all the input signal conditions and correlator chip configurations that could be encountered.

A draft of this plan is already in place, and a contract has been let to carry out the following work to finish the plan and execute it:

**A. Test and Verification Plan**

1. Analyze correlator system and functional role of correlator chip.
2. Evaluate existing test cases.
3. Develop new test cases so that all modes are sufficiently tested.
4. Document the complete set in a revised Test & Verification Plan.
5. Complete Test & Verification Plan.

**B. Finalize Correlator Chip "Test Bench"**

1. Write Verilog code to implement the remaining test cases in the "test bench" formalism.
2. Execute the test bench code and evaluate the results.
3. Document and archive the outputs for later use.
4. Execute the behavioral simulator program for all the test cases. Compare results with test bench outputs.

**C. Reporting**

1. Write a final report on the functional test and verification results.

This will be followed by a design review.

The second part of the answer relates to the contingency, itself. There is no contingency plan to mitigate the "damage" associated with a production failure of prototype chips. Thus we are not, for example, carrying out independent design fabrications of several chips in parallel). The rough schedule after receipt of order for a typical supplier goes as follows:

- from receipt of our order and our design to final design review: 10-12 weeks. On the first attempt this may be longer, but if we had to repeat, this may be quite a bit shorter, depending on the problem.
- from design review to prototypes delivered: 8 weeks.
- validation of prototype chips (about 4 weeks).

Thus the schedule could be delayed for these reasons up to 24 weeks, but may be delayed by less.

The cost could be as high as the entire Non-Refundable Engineering (NRE) cost ($US400k), but would likely be less, depending upon the problem. However, the schedule could be further delayed if we have to unexpectedly find additional funds, or if there is a dispute over liability.

## 3. Software Issues

We can digest the comments of the Committee regarding software into a few major topics: the structure of computing at NRAO, and notably the interactions between the different subgroups within that structure; specific post processing issues, including AIPS++; specific RFI issues; software engineering issues, including interfacing with the WIDAR software group; and a few miscellaneous issues.

### 3.1 The NRAO Computing Structure, ISD, and EVLA Software Management

We are cognizant of the fact that the new NRAO structure for computing will require close monitoring. We are still convinced that it is better for the EVLA in the end (and in fact took part in the discussions defining the new structure), but intend to be vigilant when it comes to assessing the productivity under the new organization.

It is clear that the interaction of the project with the Interferometry Software Division (ISD) is critical, given that it is one area where the project does not have complete control over resources. We will monitor this area closely. However, we note that it is clearly in the best interest of NRAO to have some oversight where software that can be common is concerned. Our feeling is that about 80% of post-processing software (mostly what ISD is concerned with, i.e., AIPS++ and the pipelines) is common between ALMA and the EVLA, and hence a coordinated effort makes the most sense. This number needs to be verified, and will be during the post processing requirements audit this winter. We note that the organizational structure has been set up with parity in mind between the ALMA and EVLA projects. The EVLA has equivalent representation in all areas for post-processing development. We believe this parity does enforce a project-driven nature despite the multiple project responsibilities of the ISD - essentially, for those targets that are specific to EVLA, the ISD members will be a part of the EVLA effort, communicate/prototype in collaboration with EVLA members and only obtain authentication from EVLA project staff. This is no different than for ALMA specific tasks. For targets which are present in both areas, we may need to institute a dual authentication as the functionality may need to pass different levels of criteria to be 'acceptable'. This setup is seen as a benefit (if managed properly) to the EVLA, since we can take advantage of effort from those not paid directly by the project. We note that full

control can be had only if the effort is totally funded within the project, which is not the case here. If the project had to fund all the software engineers, and all the testers, internally, this might well take $1M or more annually, out of the total $5M annual budget, which would require an enormous down-scoping of the electronics part of the project - obviously not desirable. In any case, we will be involved directly with the ISD, and in fact we partly control it anyway, since Jim Ulvestad is the co-manager of that division. This is a key point - even though we do not fully control all of the resources of ISD, with Jim as co-manager we certainly have considerable input into resource allocation.

In order to aid in this oversight of computing in general, and the ISD in particular, we are in the process of undertaking a requirements audit, which will then lead to a more defined development and testing plan for all EVLA project software, but notably AIPS++. This development and testing plan will have clearly defined deliverables, acceptance criteria, and a schedule for reviews. Specifically, in terms of AIPS++, the first step in making sure that EVLA requirements are met is a modification of the existing off-line development plan to include those requirements. Currently, the targeted development is keyed to specific ALMA requirements. In most cases for recent, current,and future work, these have analogs to requirements in the EVLA requirements document as well. We intend to go through the EVLA requirements document in detail, comparing it to the current AIPS++ ALMA development plan, and identify those areas that are missing from the current plan. We will then make sure that these requirements are covered in the post-June 2004 plan. If there are areas that we feel absolutely cannot wait that long, we will negotiate to get them into the current work plan.

**3.2 Specific Post Processing Issues, Including AIPS++**

We recognize that having a significant fraction of the interferometry data produced by the VLA and VLBA analyzed in a new data processing package as soon as possible is an important goal. However, formally this is outside the scope of the EVLA project itself, except as it impacts the ability of the post processing software to successfully reduce EVLA data. As such, we have not adopted a formal schedule wherein such a date is defined. We note, however, that the ability to process VLA data within AIPS++ is clearly part of the ALMA test plan, and it is intended to adopt that stance when the test plan for EVLA is formalized.

We intend to direct more effort toward algorithm development in the near future (specifically within AIPS++). This is one of the charges of the new Project Scientist for Software. It is our feeling that algorithm development is generally done by scientists who are actively working on reducing data, and hence work in this area will require the engagement of such scientists, both at NRAO and from the outside community. We intend to actively recruit such scientists at NRAO, and solicit the help of those in the outside community. There must also be a clear communication path from these scientists to the programmers working on the software, and we intend to make sure that such a path remains open, in coordination with the ISD. Finally, communication between the groups active in this area at other observatories (either currently operating or in design - e.g., the

ATCA, WSRT, MERLIN, ATA, ALMA, LOFAR, and SKA) will clearly benefit the EVLA, and we intend to foster such communication whenever possible.

The concerns of the Committee over the AIPS++ interface and robustness are valid. We note that the question of robustness will be one of the key considerations during the AIPS++ review for ALMA in June 2004. The interface is not one of those considerations, but we believe the revised framework for the code base (separating out the science from the system infrastructure and liberating us from the restrictions that Glish has imposed) will provide access to improved interface tools (GUI widgets, visualization tools, etc). However, we need to proceed carefully with this change. The current effort in this respect is concentrated in the prototype pipeline. More technology research will be required before development of a general scalable framework can proceed. The goal is to complete the research phase in early 2004. The EVLA will be involved in this effort, of course. There are several levels of solution that can be accommodated - 'light' versions of CORBA to a completely new framework; each has implications for the timing of delivery of new interfaces. In the mean time however, the issues of end-user involvement and robustness can be treated independently. This is being tackled through the overall testing efforts (function based and integrated) and the NAUG efforts which provide a forum for prototyping and coordination of user involvement at all stages (design through implementation). These efforts are currently all script-based to allow deferring the interface question. These efforts also focus on existing VLA and other existing instrument analysis as suggested.

AIPS++ does not currently have the resources to perform the required development and maintain a full operational/user support effort. We believe that the combined NRAO and external (ALMA) testing will provide the needed interaction to ensure a working system. Once this has been confirmed to be accurate and robust, a broader involvement on the interfaces will be sought as recommended.

**3.3 Software Engineering Issues**

We feel that if we follow good (and modern) software engineering practices during the design and implementation of the system, we will arrive at a final system that will be appropriate for the job without being over designed. Following these practices should assure that the design will be robust and modular, meaning that it can grow in a sensible way.

The EVLA Computing Division (ECD) plans to begin a formal effort to develop an overall design for all e2e and M&C components of the EVLA software in a Nov 2003 - Feb 2004 timeframe. It is expected that a first draft of an overall design will be produced in approximately 4 to 6 months after the effort has begun. This overall design will include a specification of the interfaces between the e2e and M&C system. In addition, a document, "Requirements and Functional Specifications - Correlator Backend" now exists in draft form. A joint meeting to discuss correlator software, and the interfaces between the NRAO and Canadian developed software has taken place in late October in Socorro. This document was discussed at that meeting. Among other things, this document contains a preliminary description of the interface to the e2e system.

Furthermore, discussions which occurred at that meeting should allow us to document the interfaces between the NRAO and WIDAR software systems adequately. This, along with the documentation for the overall design, should provide an adequate basis for the separate designs to proceed sensibly. Specifically, the definition of the Virtual Correlator Interface is a joint responsibility of the M&C software group and the Canadian correlator software group. It is not yet very advanced because the correlator software group has only recently had the personnel to work on the problem. Enough preliminary discussions have taken place that no particular problems are anticipated. A document, "Virtual Correlator Interface (VCI) - Protocol Specification" has now been prepared in draft form, and was discussed and reviewed at the October meeting.

**3.4 RFI**

Post-correlation RFI excision requires adequately fast time sampling, plus algorithmic advances, and sufficient processing power. Only the first of these can be connected to observing time decisions. We will need to consider a means of knowing when RFI of a type which can be removed in post-processing is present, and of adjusting the correlator integration dump time in response. Schemes for doing this will be considered as post-correlation excision methodologies are developed. In the schemes considered most likely to be attempted, the information for post-correlation RFI excision is extracted from the correlator data itself. Additional information (for example, when the interference is exceptionally bad) may be passed through the monitor data stream, which is sufficiently fast and capacious to handle such information. Hooks are in place for various sorts of flagging (based on sampler values; based on subband resampler values; based on total power detectors).

We feel that the continuing effort of the Project Scientist in the area of algorithmic advances will be sufficient to stay on top of this problem. It is clear that the R&D studies need to be coupled to the software. We continue to try to recruit from current staff for help in testing our concepts of post-correlation RFI excision, but this has not yet been successful, presumably due to higher priority needs. Designation of an individual to work on these issues will be considered in the future. The AIPS++ group already has a data editing application in place which utilizes data statistics for automated flagging, which is appropriate for RFI. A detailed, simulated experiment could be set up to ascertain whether this existing tool is adequate or can be adapted for the anticipated RFI issues. Such an experiment could be done for little cost, however, the R&D is obviously more open-ended and hard to scope.

We will, in addition to our own efforts, clearly need to pay close attention to what is being done at other NRAO sites, and other radio observatories around the world. NRAO has a strong RFI R&D group at Green Bank which we are in close contact with. We intend to either continue, or initiate, collaborations with other institutions and observatories with significant RFI R&D efforts, including ATCA, WSRT, and ATA.

**3.5 Miscellaneous**

**Scheduling Simultaneous Observations with VLA, NMA, and VLBA**

The NMA will be controlled by the same system that controls the VLA. To simplify the scheduling, we may have designated time intervals in which the VLA and NMA are scheduled as a unit, and others in which the VLA and NMA are allocated separately from separate queues. Scheduling the correlator for processing recorded observations during times when it has available resources not needed by the real-time arrays is another question. If the real-time arrays are given absolute priority, this is similar to the resource allocation problems of computer operating systems, which are well understood. The phase II proposal budget includes programmer time for an implementation which should be satisfactory if the total correlator resources are adequate.

**Pulsar Observations**

The WIDAR correlator can separate pulsar observations into phase bins. This feature will be supported in the correlator backend processing. AIPS++ measurement set definitions have provision for handling pulsar phase bins. For pulsar periods fast compared to the correlator integration time, we will be able to use this feature in a straightforward manner. For slower pulsars, this may need to be handled by the correlator backend. There is currently no work in progress in utilizing this feature, although the general purpose display routines from AIPS++ will be adequate for many purposes.

**User (and Scientist) Involvement**

It is clear to the project that active participation by the NRAO scientific staff specifically, and the entire outside user community in general, are very important in arriving at an overall system that is most productive for the entire astronomical community. EVLA Phase I provides for 5 FTE scientific staff positions per year in in-kind contribution from Socorro Operations. Our intent is to have part of this assigned effort be software related. We are currently assessing and discussing this issue. In addition, we have a very active scientific staff effort in the AIPS++ testing effort, a large part of which is actual testing on VLA data. This produced the VLA AIPS++ Audit in the last year, and is now working on further assessment of AIPS++ for VLA data reduction (under the auspices of the ALMA testing). Meetings of the NAUG (the NRAO AIPS++ Users Group) are bi-weekly - again, a good fraction of what is discussed at these meetings applies directly to VLA and EVLA issues. We have also had contributed effort from the scientific staff within the e2e project, which we expect to continue (under new direction from within ISD or ECD). Our intent is to have a scientific staff member attached to each software team, likely as what we are referring to as a "team consultant." This will all be coordinated by the new Project Scientist for Software. Once a complete enough system (or constituent parts) is fully implemented and tested in-house, we will actively lobby to have outside users become involved in further testing and development. We must be careful not to repeat past mistakes of promising more than is delivered, however, to make sure that future users are not alienated or discouraged by the current state of software being tested and developed.

## 4 Phase II Issues

The proposal has been reviewed by AUI and was approved, subject to completion of some suggested changes, by the AUI Board at their October meeting. We are now working to prepare the proposal for its submission to the NSF on the fastest possible timescale.

With respect to the addition of low frequency receivers, we have concluded that our implementation plans are not sufficiently well developed to warrant proposing them for funding at this time. We have removed the low frequency receivers from the proposal and will continue to study the various ideas for providing a low frequency capability for the VLA. A separate low frequency proposal will be prepared when we have completed the studies necessary to determine the best technical solution to the problem.