Nov. 30, 2001

Expanded Very Large Array Project

Report of the Correlator Review Panel

Conceptual Design Review (CoDR)

November 2, 2001, Socorro, New Mexico

Background

The Expanded Very Large Array (EVLA) is a project funded by the US National Science Foundation (NSF) to upgrade and expand the Very Large Array (VLA) radio telescope in New Mexico. The VLA is operated by the National Radio Astronomy Observatory on behalf of NSF for US and international astronomers. Recently an agreement has been signed between NRAO/NSF and the Herzberg Institute of Astrophysics (HIA) of the National Research Council of Canada (NRC) to form a North American Partnership in Radio Astronomy (NAPRA). As part of this program, NRC has agreed to provide a correlator for the EVLA project. Planning and design work for the EVLA Correlator is proceeding at the Dominion Radio Astrophysical Observatory, an HIA laboratory.

The correlator is the single most important telescope component and a major determining factor of scientific performance. Moreover, since the correlator design is closely coupled to that of many other parts of the telescope, it is important to review the design at critical junctures of the EVLA project, when system decisions are about to be made. The EVLA project will undergo a System Preliminary Design Review in December, 2001, necessitating a review of the correlator design beforehand.

The Conceptual Design Review (CoDR) is one of three formal reviews planned, not including less important, but more frequent, internal reviews. The others will be the Preliminary Design Review (PDR) and a Critical Design Review (CDR). At the PDR, detailed designs of individual correlator sub-systems will be reviewed, giving the go-ahead to spend significant capital on hardware prototypes, and to expend significant effort to carry out software plans. At the CDR, the entire design is reviewed in the light of prototype performance, giving the go-ahead to begin production, when most of the funds will be spent.

The EVLA project is currently funded by NSF for planning work, and approval for construction is expected by the US National Science Board (NSB) on November 14, 2001.[1] The first correlator prototypes will arrive at the VLA site in 2006. First "shared risk" observations will start in 2007. The correlator will be operational in 2009, and the overall EVLA project completed in early 2010.

The review was a one-day event, held in Socorro, NM on November 2, 2001. Presentations were made to the review panel on the following topics:

1. Agenda and plan for the review.
2. Background - general state of progress, funding plans.

[1] As of writing the final draft of this report, the NSB has met and approved construction of the EVLA project in the US. The design and construction begins immediately.

3. Overall EVLA project plan.
4. Science Drivers for the Correlator.
5. The overall design of the correlator (architecture and functional design, based on specifications derived from astronomical requirements).
6. A broad-brush description of the correlator implementation and its external interfaces.
7. More detailed information on critical components, as necessary and available at the time.
8. A cost and schedule projection.

The full agenda is given in Table 1.

Table 1: EVLA CoDR AGENDA

Time	Subject	
08:30-08:45	Project overview and current status	*P. Dewdney*
08:45-09:00	Context and overall EVLA schedule	*P. Napier*
09:00-09:20	EVLA science requirements	*R. Perley*
09:20-09:35	Requirements and additional capabilities	*B. Carlson*
09:35-10:00	Correlator architecture walk-through	*B. Carlson*
10:00-10:15	Break	
10:15-11:00	Correlator architecture walk-through cont'd	*B. Carlson*
11:00-12:30	Lunch	
12:30-2:30	Project plan - design tools. - personnel. - schedule + budget. - de-scoping options.	*B. Carlson*
2:30-3:00	Discussion.	
3:00-3:15	Break	
3:15-4:00	Detailed technical points - FIR filter. - Re-circulation Controller. - Correlator chip functionality & interfaces + development plan. - LTA Controller and output data interface.	*B. Carlson*
4:00-4:30	Discussion	
4:30-5:30	Committee meets to draft report	
5:30-6:00	Committee presents verbal report	

Review Panel Members

Panel members were selected in two categories: a) experts in the field who are outside the project b) EVLA project management and others who will be required to provide compatible systems that interface to the correlator. Dr. Peter Dewdney, Manager of the EVLA Correlator Project, was the ex-officio Panel moderator.

Outside Specialists

Dr. B. Anderson, Jodrell Bank Radio Observatory, UK: Senior scientist at Jodrell Bank in the area of correlator construction and procurement, involved in the design of many correlators for radio astronomy, most recently in the design of the Mark IV correlator for the Joint Institute for VLBI in Europe (JIVE).

Mr. R. Escoffier, Central Development Labs (CDL), NRAO, Charlottesville, VA: Senior correlator designer, in charge of all correlator systems built for all NRAO telescopes in the last several decades, currently overseeing the design and construction of the ALMA correlator system.

Mr. F. Schwab, NRAO scientific staff, Charlottesville, VA: Senior systems analyst at NRAO.

Dr. J. Webber, CDL, NRAO, Charlottesville, VA: Head of CDL, and experienced VLBI correlator designer.

EVLA Project Management

The following persons are involved in the EVLA project as a whole. Their purpose on the review panel is to ensure that the correlator meets project standards, scientific requirements, and system engineering standards. This includes all persons in charge of designing EVLA sub-systems that interface directly to the correlator.

Dr. P. Napier, Project Manager, EVLA, Socorro, NM.

Dr. R. Perley, Project Scientist, EVLA, Socorro, NM.

Mr. J. Jackson, System Engineer, EVLA, Socorro, NM.

Mr. G. Hunt, Software Systems, EVLA, Socorro, NM.

Dr. T. Cornwell, Data Management, NRAO, Socorro, NM.

Mr. W. Sahr, Monitor and Control System Software, EVLA, Socorro, NM.

Mr. S. Durand, Fiber Optics Systems, EVLA, Socorro, NM.

Mr. T. Cotter, IF Systems, EVLA, Socorro, NM.

Mr. G. Stanzione, Civil Works, EVLA, Socorro, NM.

Charge to Review Panel

The review panel was asked to review the material presented (Appendix I contains copies of viewgraphs) and supporting written documentation (Appendix II). In addition to making either general or specific comments on the design, they were asked to address the following questions:

1. Coherency of plan - Will the plan lead to the result proposed (or something close or even better)? Are there any gaps in the planning?
2. Will the correlator work properly with the EVLA as a whole?
3. "Show-stoppers" - Are there aspects of the plan which are extremely risky, and do not avail themselves of an apparent solution?
4. Budget - Is there a good chance that the project can be carried out for the allowed budget. Is contingency allocated in proportion to the risk?
5. Implementation Effort - Is there a good chance that the project work can be carried out in the allotted time with the proposed personnel?

The review panel may also suggest major design changes if the current design cannot meet specifications, or the cost/schedule can be dramatically improved without loss of performance.

Results

General Comments

No major design changes were suggested.

Enabling Science: The committee felt that the design meets aggressive scientific requirements, which are suitable goals for the world's most important radio telescope. They also noted that the EVLA's projected science capability has followed that of the correlator as its design has evolved. The correlator design has reached the state where all the important astronomical and planetary radar observations currently envisioned can be carried out. The Project Scientist predicts that this correlator, if implemented as presented, will have the same relative impact on radio science as the original VLA/correlator combination. Most importantly, it must be started as quickly as possible.

General Quality of the Work to Date: The panel was impressed by the high quality, thoroughness, and documentation of the work done so far - a very high standard for a Conceptual Design Review.

General Technical Points:

- A great deal of attention will have to be paid to software development so as to be able to take full advantage of the design. Programming the correlator will be a very complex task that will need specific attention. Correlator "modality" must be analyzed thoroughly so that it can be efficiently set up for a huge variety of observational tasks. This should be a shared responsibility of both the correlator group and the other EVLA project groups, although the bulk of the work will be the responsibility of the overall EVLA project.
- Transfer of knowledge and technology will be a challenge that should be planned for at the outset. A specific plan was presented for joint development of software in overlapping areas,

but no plan for transfer of hardware knowledge. It may be helpful to transfer technology as "smaller deliverables" than outlined in the presentations.

- The correlator must be capable of correlating signals delivered over the internet (or with internet-style, packet-switched protocols). This implies a large input data buffer in the system.
- One of the products of the design review was a short list of detailed technical issues. These issues pertain mainly to the EVLA project as a whole. None of them are sufficiently important or relevant to be included here.

Review Questions

1. *Coherency of plan - Will the plan lead to the result proposed (or something close or even better)? Are there any gaps in the planning?*

One of the external reviewer's comments aptly expresses the Panel's overall opinion - "The proposed WIDAR EVLA correlator has been planned as well or better than any project I have ever seen. The plan should lead to a completely acceptable result if properly financed."

No major gaps in the correlator plan have been detected by the Panel. There was some concern that it may take longer to commission than presented in the plan. This concern is directed mainly at making sure that the overall project is ready for the correlator, especially at the stage when first correlator prototypes will be tested at the VLA site.

On a specific technical point, it was noted that there is still some uncertainty in the implementation of the FIR filters, with cost implications. Although a credible plan to deal with this issue was presented, it will be important to verify this plan at an early stage. The performance of these crucial components is worthy of sacrifice elsewhere, if necessary.

2. *Will the correlator work properly with the EVLA as a whole?*

The Panel believes that the correlator will work properly with the EVLA, mainly because the other components of the EVLA will be tailored to fit the correlator. Extensive computer simulations of the signal processing methods have proved to be very fruitful in demonstrating correctness (to the extent possible without actually building it). It will be most important to provide interface definitions for the Virtual Correlator Interface (VCI, the correlator software interface), and to analyze how information for the most difficult observations will flow through this interface.

3. *"Show-stoppers" - Are there aspects of the plan which are extremely risky, and do not avail themselves of an apparent solution?*

The Panel cannot identify any "show stoppers". Nevertheless, like most large projects, there are risk areas:

- Dependency on key personnel. This is the most critical risk area at present. However, the Panel noted that measures are being taken to spread this risk by hiring at least one additional

senior person, who could carry on in the event of key personnel loss to the project. Alacrity here is critical.

- Assembly of a project team. It will be important to demonstrate that a skilled team can be assembled. This must receive urgent attention to bring credibility to the project.
- The number of high-speed data interconnections is very large. Technologies do exist, however, to deal with this issue, but careful attention will be warranted.
- On the one hand the number of different circuit boards is modest, leading to low risk and ease of operational maintenance. However, the complexity of these boards may strain the most competent manufacturing facility. In later reviews it will be most important to scrutinize manufacturing issues at the finest level of detail.

4. *Budget - Is there a good chance that the project can be carried out for the allowed budget. Is contingency allocated in proportion to the risk?*

Noting the finely divided budget statement, and the fact that many of the costs are based on quotations, the Panel believes that there is a good chance that it can be carried out for the projected amount. The Panel is generally impressed with this aspect of the planning. Although some allowance for cost reductions has already been factored in, further cost reductions may be possible during the life of the project. The Panel would be somewhat concerned on the cost side if the project takes longer than scheduled, as many projects do. This would affect labor costs, which are about 20% of the total budget.

The Panel notes that the budget was presented in 2001 $US, appropriate since the majority of the component parts will be sourced in $US (whether purchased in the USA or elsewhere). The Panel is very concerned with two funding aspects that cannot be finalized until funding is available:

- The project will be highly vulnerable to currency fluctuations if the majority of the funding cannot be made available in $US.
- The project will be quite susceptible to inflation if the funding cannot be provided in constant 2001 dollars. The Panel notes that the balance of the EVLA project funding will have built-in inflationary compensation, as mandated by the National Science Foundation.

5. *Implementation Effort - Is there a good chance that the project work can be carried out in the allotted time with the proposed personnel?*

The Panel believes that the project can be carried out with the presented distribution and number of staff. There is some concern that the Herzberg Institute is not large enough (i.e. has insufficient personnel depth) to successfully prosecute such a large project, especially if there are “rough spots”. As noted above, it will be important to assemble a project engineering team right away to dispell these concerns. The Panel also notes that the two software staff will be critically important (one to be provided by NRAO).

Appendix I - Viewgraphs Presented at EVLA Correlator Conceptual Design Review

Appendix II - Correlator Documentation (as of Nov. 2, 2001)

Efficient Wideband Digital Correlation, B. Carlson and P. Dewdney, Electronics Letters, IEE, Vol. 36 No. 11, p. 987, 2000.

EVLA Correlator Development Plan (prepared for the Nov. 2, 2001 Conceptual Design Review), B. Carlson, Oct. 11, 2001.

EVLA Correlator Technical Memo Series				
EVLA No.	**Title**	**Author(s)**	**Date**	**pages**
31	Refined EVLA WIDAR Correlator Architecture	B. Carlson	10/02/01	112
28	Operator Interface Concepts for Array and Correlator On-line Monitor and Control	B. Carlson	2/01	7
27	Concepts for an "Observation Builder" for Array and Correlator Configurations	B. Carlson	2/01	9
26	WIDAR Correlator Sensitivity Losses	B. Carlson	1/01	3
25	Requirements for 8-bit Processing in the Proposed WIDAR Correlator for the EVLA	B. Carlson	1/01	7
23	Summary of Discussions Held During the July 10-14, 2000 Workweek in Socorro Regarding the EVLA-WIDAR Correlator	B. Carlson	8/00	31
19	Simulation Tests to Quantify the Spectral Dynamic Range and Narrowband Interference Robustness of the WIDAR Correlator for the EVLA	B. Carlson, P. Dewdney	11/01/00	20
18	Simulation Tests of Phasing Subsystem Signal Processing in the WIDAR Correlator for the EVLA	B. Carlson	11/07/00	14
17	Simulation Tests of Sub-Sample Delay Tracking in the Proposed WIDAR Correlator for the EVLA	B. Carlson	10/03/00	8
16	Two Correlators for the Price of One: How a VLBA Correlator Could Fit Within the Proposed 40-Station WIDAR EVLA Correlator	B. Carlson	09/28/00	22
14	A More Detailed Analysis of Recirculation Architecture, Algorithms, and Limitations in the Proposed WIDAR Correlator for the EVLA	B. Carlson	06/06/00	7
13	A Closer Look at 2-Stage Digital Filtering in the Proposed WIDAR Correlator for the EVLA	B. Carlson	005/29/00	10
12	An Analysis of the Effects of Phase Dithering in a Lag-based Fringe-Stopping XF Correlator	B. Carlson	05/26/00	4
11	A Proposed WIDAR Correlator for the EVLA Project	B. Carlson	05/18/00	123