Commissioning the VLA and EVLA

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The VLA – A Groundbreaking Telescope Array

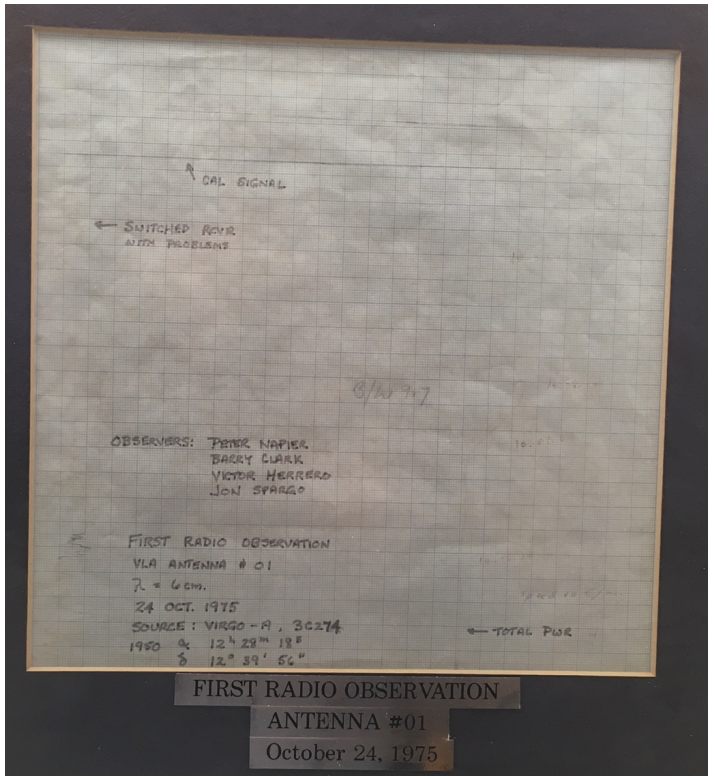
- With the successful development of aperture synthesis during the 1950s in England and Australia, the NRAO conceived a major new synthesis array in the 1960s.
- NSF funding began in 1973.
- Originally conceived as a 4-year construction project (for $64M), funding rate limitation imposed by the NSF at $10M/yr resulted in an 8 year construction project for $78M.
- A site selection process located at excellent site in west-central New Mexico, elevation 7000' (2200 m), on an ancient lake bed (flat), in a very dry climate (~25cm precip/year).
- Closest 'liveable' community is Socorro, 80 km to the east.
- The remote location (both the site, and Socorro, located in empty New Mexico) was an important factor in the sociology:
  - Virtually everybody lived in Socorro
  - Travelled to work in the same bus
  - Worked in the same building.

The VLA in D configuration

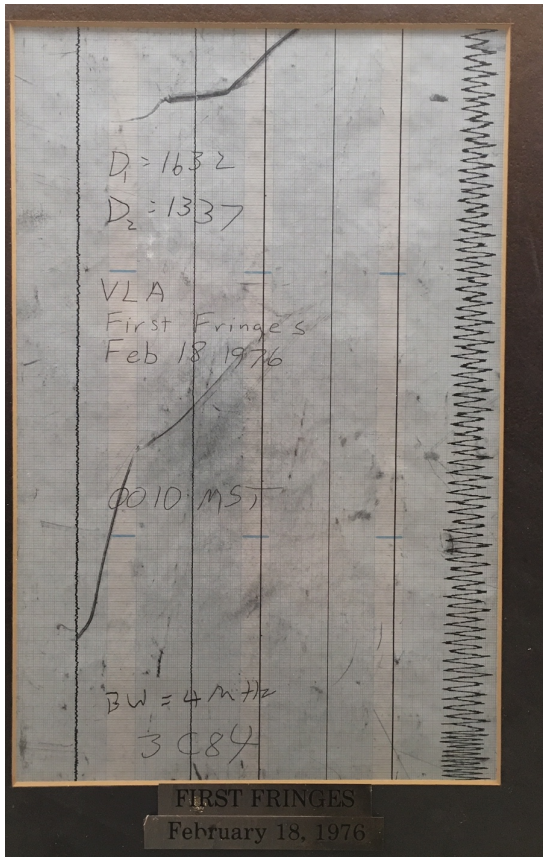
- 27 antennas, reconfigurable array.
- Baseline range 30 m to 35 Km.
- Original complement of four receivers (L, C, Ku, K bands)
- 200 MHz maximum BW
- Digital correlator enabled up to 512 channels in spectral line mode.
- Two-dimensional design allowed for ‘snapshot’ observations.

VLA Construction Timeline

- A timeline may help:
  - Project approved August 1972
  - Construction begins April 1973
  - First antenna signals: October 1975
  - Second antenna: November 1975
  - First Fringes: February 1976
  - Five antennas in use: January 1977
  - Ten antennas January 1978
  - 15 antennas January 1979
  - 21 antennas January 1980
  - Full array January 1981



First Light – Oct 1975



First Fringes – Feb 1976

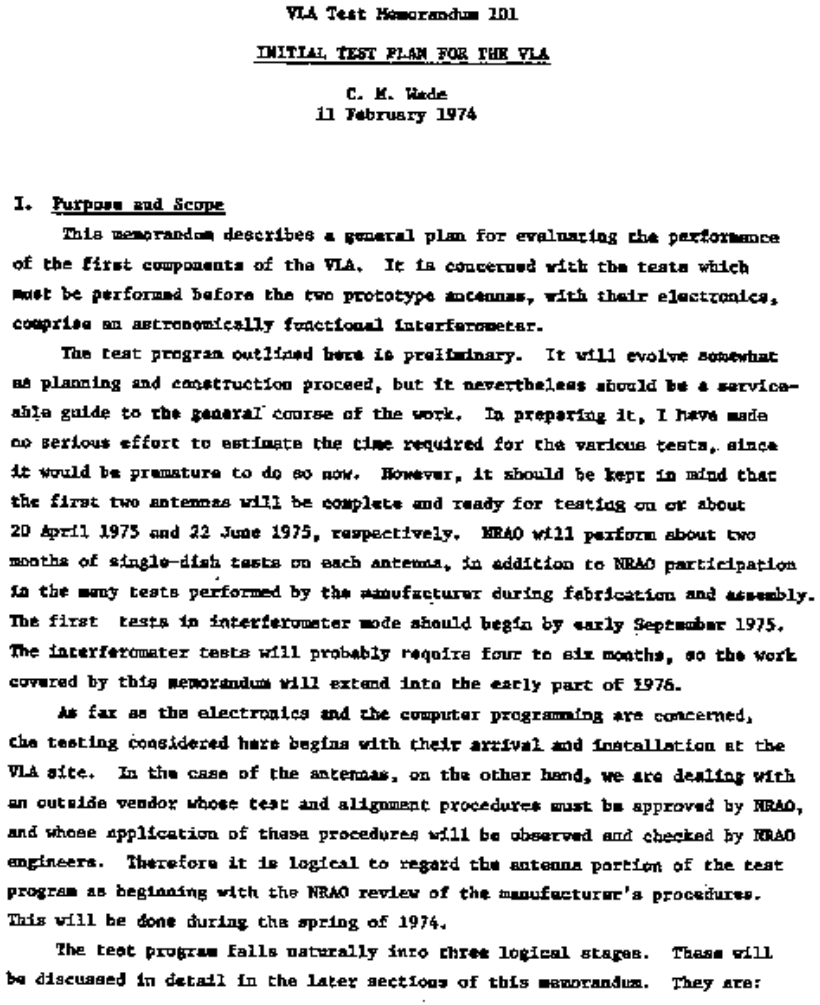
- I arrived in October, 1977 – 9 antennas working
- My focus was on new science, not on commissioning
- But these activities are tightly linked for a new array…

VLA Commissioning – the early years ('74 – '77)

- As I was not involved in this phase, I consulted those who were – notably Barry Clark, Ken Sowinski, Larry D'Addario, and Peter Napier.
- Also of great assistance are two reports:
  - Very Large Array Completion Report, July 1982, by Jack Lancaster (VLA Project Manager)
  - The First 7 Years of VLA Operations, 1987, R.D. Ekers
- What is notable overall is the very small staff involved, the extremely informal management structure, and the short lines of communication.
- The nexus of the effort was Barry Clark. All directions, instructions, timescales, activities, emanated from him. He had been given this authority by the Director, Dave Heeschen.

Early Commissioning – The Memo Series

- A Memo Series was started early on. There were five separate series:
  - Science, Electronics, Computing, Test, and Technical Reports
- The first memo in the Test Series (1974) outlines the 'Initial Test Plan'
  - The memo is short – 11 pages. It presents a concise summary of basic tests for single dish and interferometer observations , with a rough timescale.
  - Seven months later, a more detailed memo, (#104) by Dick Thompson (15 pages) expands on Memo 101, with names and times.
  - But it appears that neither was utilized in the commissioning!
  - (BGC, on 20 Nov 2019: 'First I've heard of those memos').



VLA Test Memorandum 101

INITIAL TEST PLAN FOR THE VLA

C. M. Wade
11 February 1974

I. Purpose and Scope

This memorandum describes a general plan for evaluating the performance of the first components of the VLA. It is concerned with the tests which must be performed before the two prototype antennas, with their electronics, comprise an astronomically functional interferometer.

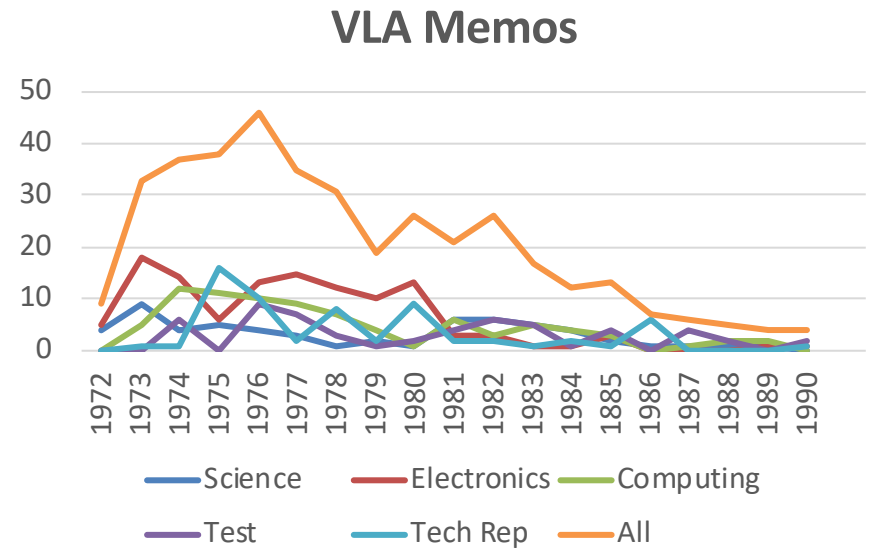
The test program outlined here is preliminary. It will evolve somewhat as planning and construction proceed, but it nevertheless should be a serviceable guide to the general course of the work. In preparing it, I have made no serious effort to estimate the time required for the various tests, since it would be premature to do so now. However, it should be kept in mind that the first two antennas will be complete and ready for testing on or about 20 April 1975 and 22 June 1975, respectively. NRAO will perform about two months of single-dish tests on each antenna, in addition to NRAO participation in the many tests performed by the manufacturer during fabrication and assembly. The first tests in interferometer mode should begin by early September 1975. The interferometer tests will probably require four to six months, so the work covered by this memorandum will extend into the early part of 1976.

As far as the electronics and the computer programming are concerned, the testing considered here begins with their arrival and installation at the VLA site. In the case of the antennas, on the other hand, we are dealing with an outside vendor whose test and alignment procedures must be approved by NRAO, and whose application of these procedures will be observed and checked by NRAO engineers. Therefore it is logical to regard the antenna portion of the test program as beginning with the NRAO review of the manufacturer's procedures. This will be done during the spring of 1974.

The test program falls naturally into three logical stages. These will be discussed in detail in the later sections of this memorandum. They are:

Early Commissioning – Memo Series

- An important aspect of early commissioning was the various VLA Memo Series, started in 1967 (during the planning phases).
  - Computing (1973 – 1996) 77 memos
    - 15 of the first 18 were single-authored by Barry Clark
  - Electronics (1967 – 2015) 248 memos
  - Science (1967 – 2003) 178 memos
  - Technical (1973 – 2001) 79 memos
  - Test (1974 – 2005) 136 memos



- These memo series was largely supplanted by EVLA Series in ~2005.
- Test Memos mirror the state of progress (and problems).
  - Pointing, antenna positions, polarization, phase/amplitude closure, system temperature, elevation effects, efficiency dominate through 1978.

Value of Early Testing/Commissioning

- It is clear from the short time from the initial occupation of the site (Nov 1973) to 'first light' (Oct 1975) and 'first fringes' (Feb 1976) that the project understood the need to get hardware on the ground, and basic tests started.
- The critical role of the early single-dish and (especially) early interferometer tests is shown in their revealing shortcomings in the initial design.
  - The LO system was inadequate and had to be redesigned.
  - All the early cryogenic receivers were replaced.
  - Numerous other technical shortcomings were found and corrected.
- PJN emphasizes the importance of a large contingency, and a flexible approach to construction/implementation.

Early Commissioning – Regular Meetings

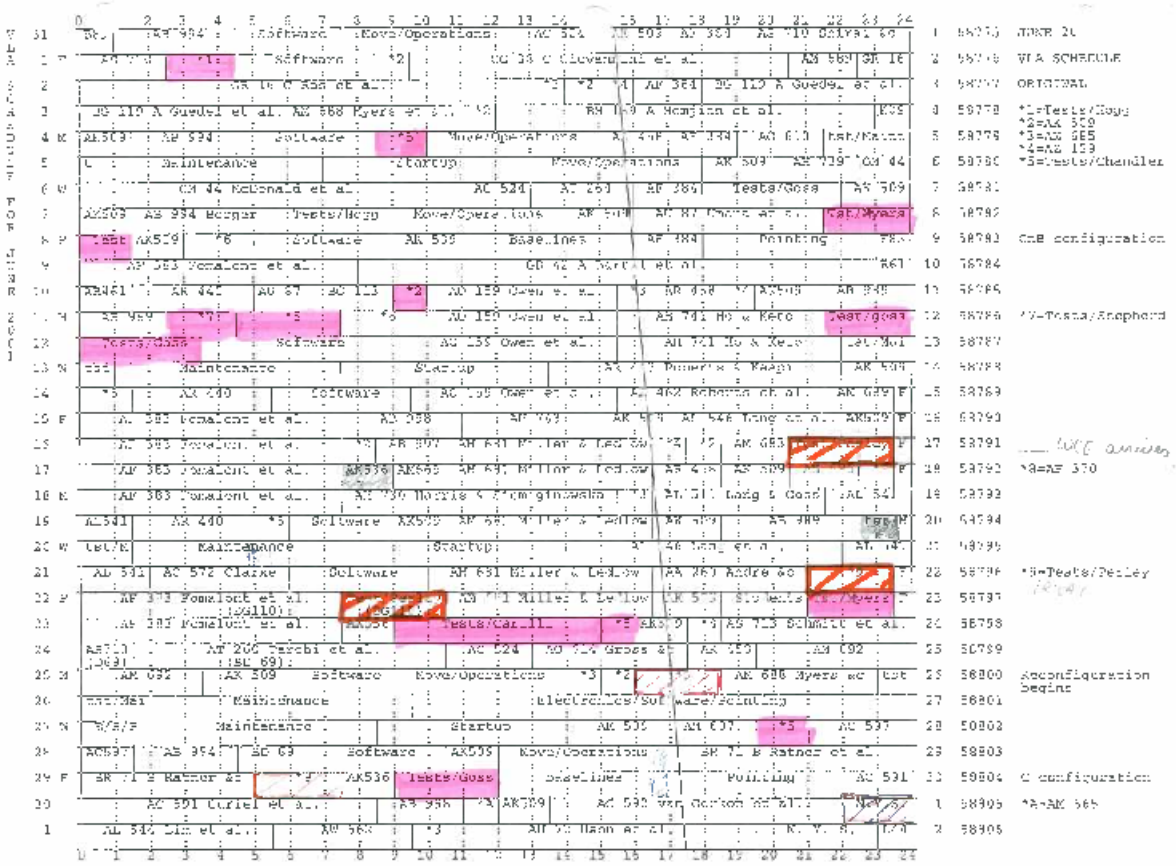
- Also early in the project, a regular meeting regimen was begun, which has been carried on through to the present:
  1. **Monday Morning Meeting:** First thing on Monday, all heads of all departments, plus all interested parties, met to discuss the upcoming week's activities.
  2. **Monthly Test-Coordination Meetings.** Started at the instigation of the NRAO Director, Dave Heeschen, who visited the site monthly. Was found to be useful for site personnel, so was continued throughout the project (and its successor, the EVLA).

Early Commissioning -- Individuals

- Personnel: The earliest memos (prior to 1977) are from a limited number of people: B. Clark, C. Wade, D. Thompson, E. Raimond (75 – 76), E. Fomalont, P. Napier, R. Hjellming, L. D'Addario. All except Ed were resident in Socorro.
- Starting ~ 1976, many new people joined the staff in various capacities: C. Bignell, R. Sinha, D. Bagri, J. Archer, R. Perley, J. Dreher, J. Burns, P. Crane, D. Sramek, S. Spangler, A. Rots (all came on between late 1976 and 1980).
- With the arrival of Ron Ekers in 1980 as site director came more new scientists, including J. van Gorkom, R. Braun, T. Cornwell and P. Diamond
  - These were young scientists (age <30) hired to use the array, and support visitors.
  - Indeed, virtually nobody in the project was over 40 yr old!
- The sudden increase in staff (hence, testers), required a slightly more formal test assignment and review structure.
- It also required an entire new building – the Science Library Office Building.
- Regular scientific observing began in 1977 – typically a dozen visiting observers resident at the site. These visitors played an important role in assisting in the commissioning work.
- As the data reduction could only be done on-site, this was a lively scene!

Commissioning – 1977 – 1980.

- In early1977, regular scheduled science observing began.
- A regularized scheduling and review system was set up (all by Barry):
- Monthly scheduling:
  - Shown is the June, 2001 schedule
  - The purple areas denote specified Test Time.
  - Mine are the red striped ones
- Monthly Test Meetings:
  - Paper/Verbal Reports
  - Often 'lively' discussions.
  - No formal write-ups required.
  - Notes were kept by Barry, and distributed
  - (He still has them!)



Getting Test Time on the VLA

- An obvious question is: How was valuable test time apportioned out?
- Answer: By Barry. There were no requirements, no proposals, no panels, and no established procedures. I don't think there was ever 'a plan'.
- What happened:
  1. Barry would appear in your doorway, about the third week of a given month, asking what test time you wanted.
  2. You would give him a brief verbal response.
  3. Your assigned time would appear on the next month's schedule.
  4. In a typical month, perhaps six people were given 'test time'.
- Although it was understood you should give a report on the results at a subsequent Test-Coordination meeting, this was not required (and nobody was keeping track).

VLA Commissioning – 1980 -- 2000

- With the VLA Dedication in late 1980, full-time operations began.
- 'Testing' continued in the same way as before, with more people involved.
- Increasingly, tests focused on proofing the various instrumental improvements and initiatives, such as:
  - New P-band, L-band, K-band, X-band, and Q-band receivers.
  - New pointing modes (referenced pointing)
  - Holographic surface measurements
  - Implementation of fast switching
  - Etc.
- Much has been written about the computing crisis at the VLA in the 1980s. The crisis was real (I lived through it), and was not resolved until the 1990s, and not by the implementation of the pipeline.
  - For those interested, see VLA computer memo #172 (R. Duquet, 1984).
- But this is not a subject for a 'commissioning' talk.

VLA Commissioning Plan and Management

- VLA Commissioning was informal, and almost completely unmanaged, from the modern 'Project Management' point of view.
- Barry's philosophy of 'take data, and let us know' was applied to essentially all commissioning.
- None of us involved in the process (certainly after 1977) had any sense of 'schedule', or 'requirements'.
- Barry was open to any and all ideas – individuals were free to roam about as they pleased.
- It was rather like being put into a great big playground, filled with shiny new toys, from which we were asked only to 'take data, and let us know'.
- Certainly, nobody complained about the system. We were moving forwards rapidly, and the VLA was working well – better than anticipated.

Why Did This Work?

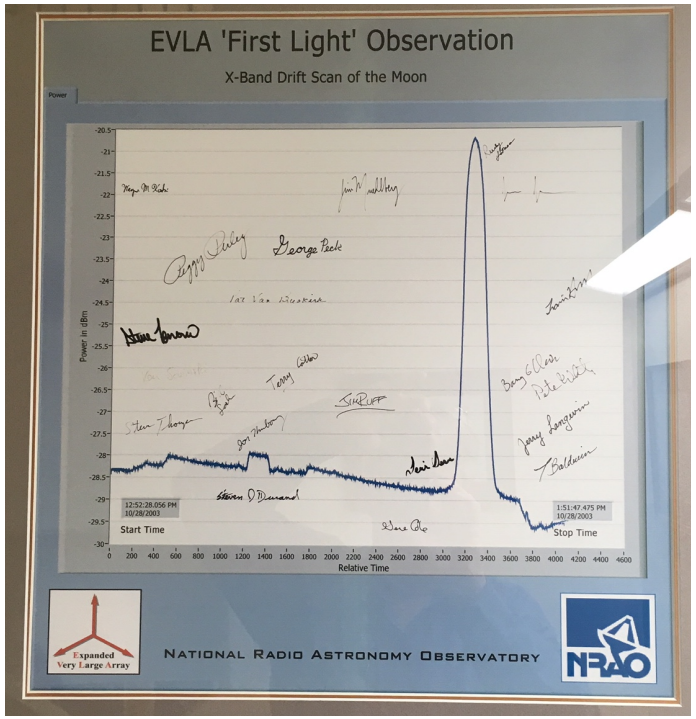
- It worked – and worked well. But why? Some thoughts:
  1. **Intellectual Center:** Barry was the center – the only person in the project with a full view and understanding of the entire project.
     - Barry rarely did any tests himself – he relied completely on the skilled individuals around him.
     - He claims now that 'We had no idea of what we were doing' … but I'm not sure I believe that…
  2. **Restriction to implementing Simple Modes.**
     1. Only basic continuum modes were implemented early.
     2. Spectral line delayed for years
     3. All other 'fancy' modes developed in time (long time, in some cases).
  3. **Small 'elite' team**, especially in the critical early years (prior to 1977).
  4. **Short lines of communication.** Everybody lived in Socorro (population 7000). Everybody took the bus to/from the site (one hour journey).
  5. **Everybody 'had skin' in the game.** The scientists doing the testing wanted – first and foremost – to get their science done. They had motivation!

The EVLA Project

- The VLA, following the 1980 dedication, was an operating telescope, and hence frozen in its technology.
- New and improved receivers were added, and many operational improvements were made, but otherwise, no change to its basic operating modes (correlator, signal transport, bandwidth, etc.)
- As early as 1980, discussions and memos began to appear on how new technologies could be implemented to greatly increase scientific productivity.
- An early proposal to the NSF in for a modest upgrade1990 failed (largely because ALMA was a higher priority). A good thing!
- By 2000, we developed a much more comprehensive upgrade – the EVLA.
- Key improvements were: 8 GHz instantaneous BW, full frequency coverage from1– 50 GHz with 8 cassegrain receivers, and a hugely flexible correlator (contributed by Canada).
- NSF approval came in 2001, the project was completed in 2012.

Key EVLA timeline

- 2001: Project approved by NSF at ~5M/year, for 11 years.
  - Significant contributions from VLA Operations
  - Total cost (all sources, incl. Canada and Mexico) $95M.
- 2003: First Light obtained (on the moon).
- 2003 – 2010. Antennas converted at rate of ~4/year.
- August 7, 2008: First fringes, using WIDAR prototype.
  - Testing continued with 4-element prototype,
  - Test correlator expanded to 10-station by April 2009.
- 2010 (March) Array shut down for one month to install WIDAR correlator.
- 2012 Project completed. Array renamed 'Jansky VLA'
- **Key Requirement: VLA Operations had to continue throughout the EVLA construction duration.**
  - No more than two antennas could be out of the array at any time during science time.



Effect of Continuing Operations

- Because of the length of the project (11 years), it was necessary to continue operations throughout the upgrade.
- With the WIDAR correlator arrival significantly delayed , the only option was to 'degrade' the wideband digital EVLA antenna signal to the analog form needed for input to the old correlator.
- This required a significant effort to design 'throwaway' hardware.
- From PM point of view – not good.
- From the Commissioning point of view – a godsend. We had a well tested and stable correlator, and 'old' antennas to match against the 'new' antennas.
- From the science (user) point of view – wonderful.
- Another important decision was to utilize the 'AIPS' software package to analyze the test data.

Commissioning the EVLA – recycling staff…

- From the outset, we had the enormous advantage of retaining many of the key people associated with commissioning the VLA. This includes (but not limited to): Barry Clark, Ken Sowinski, Peter Napier, Dick Sramek, Eric Greisen, and myself.
- Additionally, we utilized the entire electronics and scientific staff working in Socorro in support of the VLA. People like Bryan Butler, Michael Rupen, Vivek Dhawan and Claire Chandler were key in moving the project forwards.
  - Noted in the project as 'contributed effort'.
- Notable is that there was very little staff turnover throughout the project.
- Given the success of the VLA commissioning approach, it should not be surprising that we utilized the same informal approach for the EVLA.

Test Meetings and Memo Series

- The same test time arrangements were set up (i.e., Barry did it).
- Two sets of commissioning report meetings were set up:
  - Weekly briefing, (Monday morning, following the regular 'MMM')
  - Monthly meeting – I ran these, with Barry taking notes and summarizing.
- Two memo series set up:
  - EVLA Test Memos (208 memos)
  - EVLA Computing Memos.
  - There was also a WIDAR memo series, out of Penticton.
- In my role as 'Project Scientist' (and Major Tester), I proclaimed a rule which said: 'Tests done on one day need to be reported by COB of the next day'.
  - Rationale: The project was very dynamic, with constantly changing issues. If test results were delayed a week, likely the engineers/technicians have forgotten what the issues were, and have moved on to other projects.
- A major assistance in fast communication of test results was the 'EVLA Listserver', which included virtually all those active in the project.

Role of the Prototype Correlator

- In 2008, a 'prototype' (narrower band, limited antenna number) of the WIDAR correlator was installed.
- M. Rupen published a Test memorandum (Oct 2008) describing the critical suite of needed tests. These were certainly done, but there are no formal reports in the Memo series.
- As noted, AIPS was the platform used for data analysis. Reasons:
  - CASA was not stable or mature enough to serve. We could not debug two emerging systems at the same time.
  - Equally important: Eric Greisen has available to make any and all necessary changes, usually within a few hours.
  - 'Wideband' AIPS was a rather major investment.

The Resident Shared Risk Observing Program (RSRO)

- With the arrival of the WIDAR correlator (2010), and the need to commission a very wide range of observational modes in a short time, (and with a data rate orders of magnitude larger than we had faced before) it was feared we did not have the staff in hand to maintain the required commissioning pace.
  - Indeed, our scientific staff at that time was no larger than prior to the project start.
  - Thanks to the VLA Commissioning, we had a pretty good idea of what needed to be done.
- A program to attract external users to Socorro was set up – 'RSRO'. In exchange for being permitted to use untested observation/correlator modes, they agreed to visit for extended periods (weeks – months) to work with local staff in commissioning.
- In my view, this program was only of limited success.
  - We didn't attract as many of the skilled individuals we were hoping for
  - In some cases, the advertised modes were not yet available.
  - Visitors had ongoing obligations to their home institutions and projects (and, thanks to the internet, could continue working on them).
- But RSRO was effective at advertising our new instrument and its capabilities, by bringing in people to Socorro.

Short-Term Hires

- The crush of required testing, particularly after the WIDAR correlator arrived, certainly did exceed the staff's capabilities.
- One small program which did work was to make specific short-term hires, to attack certain problems. Two examples:
  - Michiel Brentjens (ASTRON) was in residence for 5 months to work on our holography software.
  - Bob Sault (CSIRO) spent > 1 year visiting (in three or four medium-length visits) working on specific issues with the WIDAR correlator, and polarization.
- These were highly effective, and I would have liked to have seen more resources available to attract more people like these.

EVLA Test Plan?

- At project close-out, the NSF commissioned a 'lessons learned' panel to review the project.
- One question was: 'What was the test plan, and how was it implemented?'.
- The answer was 'There was no formal test plan. Decisions were made on a daily basis, depending on the current situation'.
- How did we get away with this? Because of the experience and co-location of the people involved.
- By contrast, there was a detailed test plan developed for the correlator (by Brent Carlson and Michael Rupen). It is unclear to me if it was ever followed.
  - But we are mindful of the famous adage 'Planning is essential, but plans are useless'.

A More Managed Approach …

- With the rapid rise of EVLA capabilities, due to the arrival of the WIDAR correlator, and a relatively small staff to manage it, management felt that a more structured, organized approach was needed.
- Joe McMullin instituted a structured weekly review of tests and results in ~2010/2011. Tasks were assigned, and regular meetings scheduled.
- Opinions on the efficacy of this are mixed.
  - Most felt that they did little to improve or accelerate commissioning.
  - But they did improve information exchange, especially for those peripheral to the project.

Are there Lessons Here for the SKA?

- I hope so. Although it is clear that the SKA can not adopt the simple, unstructured approach that worked for the VLA and EVLA, some central themes are clear:
  - Employ experienced interferometrists. Steal them if you have to. Pay them a fortune, if needed. If none are to be found, start training them.
  - Short lines of communication between commissioners and engineers/technicians. Ideally, they all live in the same small town, and work together in a common site.
  - Give the testers easy access to the array! Don't burden them with reporting requirements. Keep it simple.
  - Make the work environment a 'management-free' zone, to the extent possible.
  - Reports to the group are essential, but not all tests need formal write-up.
  - Keep the overhead down, and give the testers some space to move around and try out unusual ideas. Encourage creativity, and be prepared to accept some risk.

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