PASEO Meeting

July 15-16, 2010 – Socorro, NM

Commissioning and Science Verification

Joseph McMullin, Group Lead for EVLA Science Support

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

Overview

- Commissioning Scope and Goals
- Commissioning Planning: Near Term through Conclusion
  - Relationship to construction deliverables
  - Current results
- Commissioning Process and Structure
  - Resource Organization
  - Activity Organization/Scheduling
  - Tracking/Accountability
- Conclusion:
  - Able to maintain simultaneous science operations with incrementally increasing capabilities during the commissioning test phase.
  - Working toward an end-2012 delivery for the projected science capabilities (end-to-end observing modes with full WIDAR correlator over the 1-50 GHz spectral range).

Commissioning Scope and Goals

- EVLA construction project is delivering predictable capabilities as a function of time; for these capabilities to be usable by the astronomy community, we need to:
  - Integrate components into the EVLA and test to ensure they meet the requirements of the Project Book and produce scientifically valid data ("commissioned"; c.f. Perley's talk, Rupen's talk)
  - Develop procedures for optimizing use of the capabilities need to be developed, and, to the level possible, automated ("scientific commissioning")
    - includes development of observing procedures, testing of end-to-end software, ongoing system performance checks
- Approach:
  - Maximize the science capabilities of the system and availability to the community during the commissioning process as possible with the available hardware/software and without impacting the end-of-2012 operations start.

Commissioning Planning:

- Capabilities delivered by the EVLA as a function of time
  - These deliveries are determined through a combination of construction hardware delivery schedules in consultation with priorities determined by various EVLA advisory committees.
    - WIDAR is at the heart of the system (Rupen's talk – complex mix of hardware and software components).
  - Similarly, science commissioning priorities have also been determined in consultation with EACs and SAGE and are reflected in the timelines.
  - Must advance on many areas in parallel (significant development time required with intermediate tests to validate)
  - Overall context is a fixed end date for the start of full operations, resource-limited commissioning effort (aided by RSRO program), commissioning activities are triggered by availability of delivered equipment/functionality (dynamically re-assessed).

Construction Deliverables Timetable:

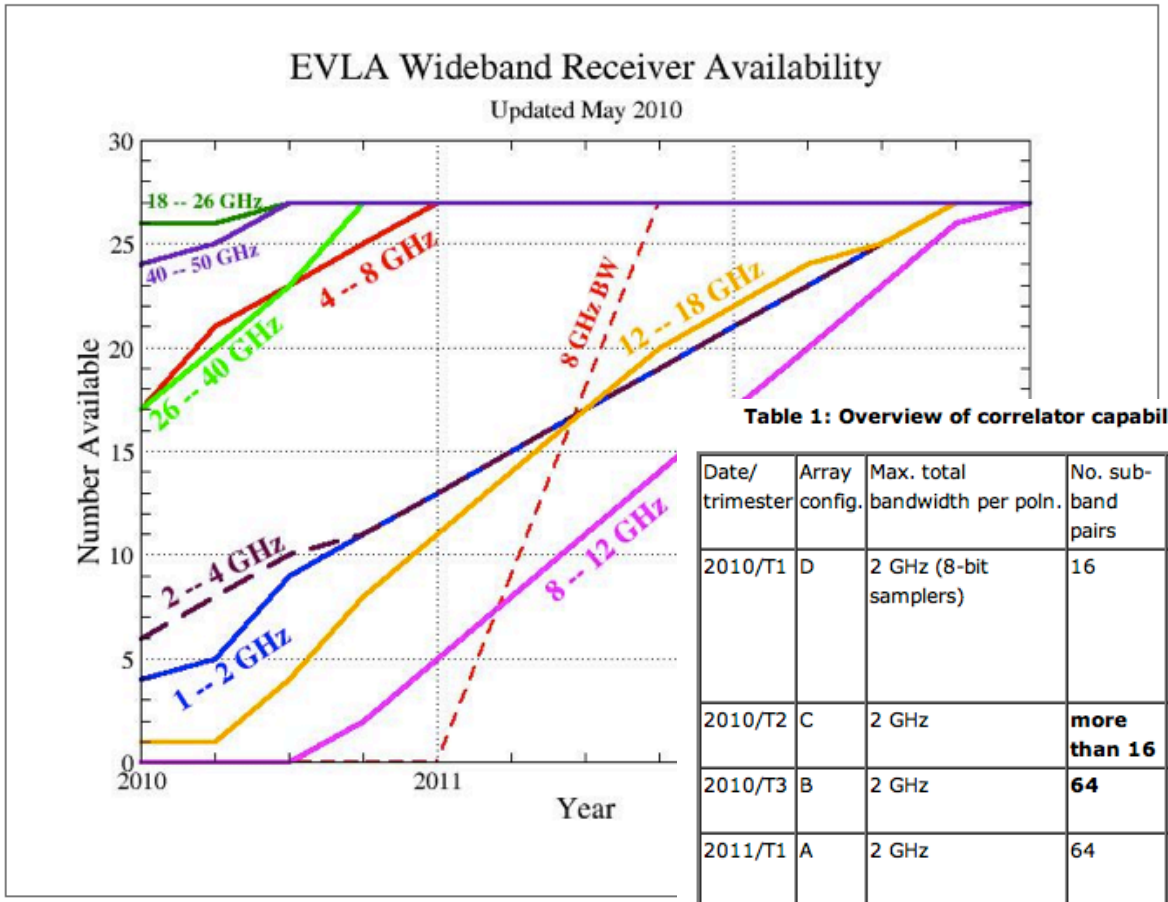


Figure 1: Availability of EVLA antennas and final EVLA r

Table 1: Overview of correlator capabilities for RSRO; further details are described below

Date/ trimester	Array config.	Max. total bandwidth per poln.	No. sub-band pairs	Channels per sub-band pair (4 poln products)	Max allowed data rate	Cumulative Capabilities
2010/T1	D	2 GHz (8-bit samplers)	16	64	15 MB/s	- Sub-bands identical - Sub-bands indep. tunable with restrictions - Can trade polarization products for channels
2010/T2	C	2 GHz	**more than 16**	64	**75 MB/s**	- Can trade sub-bands for channels
2010/T3	B	2 GHz	**64**	64	75 MB/s	- 64 Sub-band pairs available
2011/T1	A	2 GHz	64	**up to 16,384**	75 MB/s	- Recirculation enabled - Fewer restrictions on Sub-band tuning - N_chan * N_pol restricted by max data rate
2011/T2	D	2 GHz	64	up to 16,384	75 MB/s	- Sub-bands can be independently tuned - Sub-bands may have different BW & N_chan
2011/T3	C	**2/8 GHz (3-bit or 8-bit samplers)**	64	up to 16,384	75 MB/s	- Basebands either 1 GHz or 4 GHz BW

Commissioning Planning: Initial Focus

- Following the VLA correlator shutdown, the highest commissioning priority has been to establish operation of science enabled through the basic OSRO modes:
  - Need end-to-end user-level and data acquisition functionality:
    - Proposals submitted via PST and reviewed, SBs submitted via OPT, executed using full data acquisition system (Executor, TelCal, WIDAR (and associated software), MCAF), retrieved by PI via AAT.
  - Need modest correlator configuration capability:
    - 2 x 128 MHz BW sub-bands, 2 or 4 polarization products, 64 or 256 channels/polarization products, minimum channel width of 488 Hz (OSRO1) or 122 Hz (OSRO2).
- VLA correlator was shutdown 11 Jan 2010; science operations resumed ~7 weeks later with WIDAR (2 March 2010).
- Initially all projects were reviewed internally for quality and issues (each new SB was a unique test); relaxed incrementally (low->high frequency).

Commissioning: OSRO Summary

- Since March 02, approximately 1000 hours of observing and 50 projects completed; graphic shows percentage completion by priority.
  - Essentially all low frequency high priority projects were completed.
  - Working to complete remaining high frequency projects as possible.
    - High frequency observing complicated by:
      - Weather issues, band changes, overall increasing complexity of the observation configuration – requires more of the system to be commissioned.

- Monthly tracking shows distribution of science/testing, dynamically adjusted based on commissioning needs.
- Next priorities are pushing to improve the robustness of the system, push to multiple sub-band operation (needed for wide bandwidths = 2010 RSRO).

Commissioning Scheduling

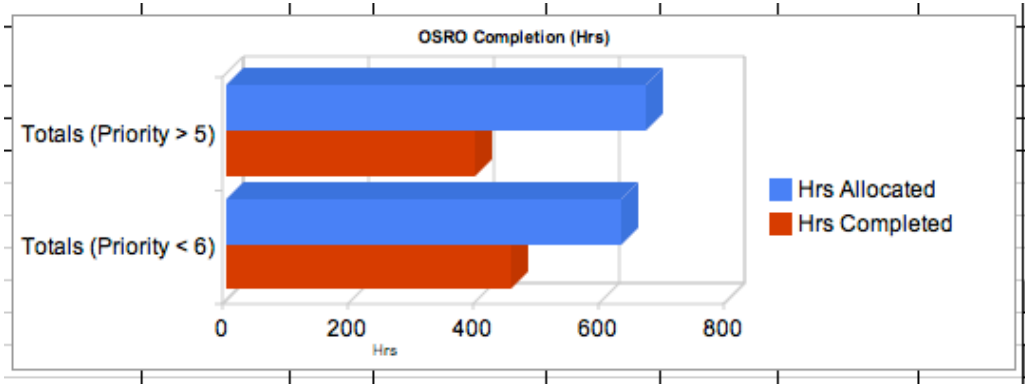
(General, Early CSV) Time Allocations:

- 88 hr/week: OSRO/RSRO/ECSO Observing
  - Efficiency of useful data is approximately 80%
- 80 hr/week: Critical Commissioning activities
  - 20 hrs Observing support (software systems: OPT, Executor, etc)
  - 40 hrs System verification including WIDAR testing
  - 20 hrs Observing mode, Observing band commissioning

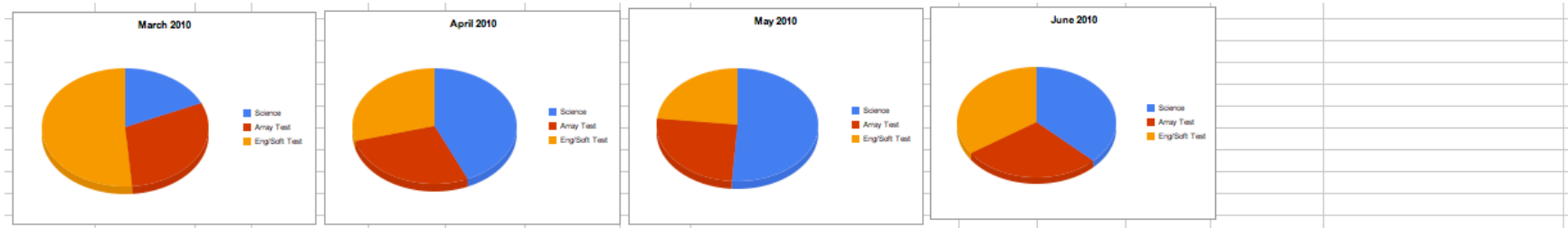
- Planning reviewed weekly with commissioning staff.
- Daily review of day's activities for planning during the evening
  - Currently, the scheduling is principally done manually.

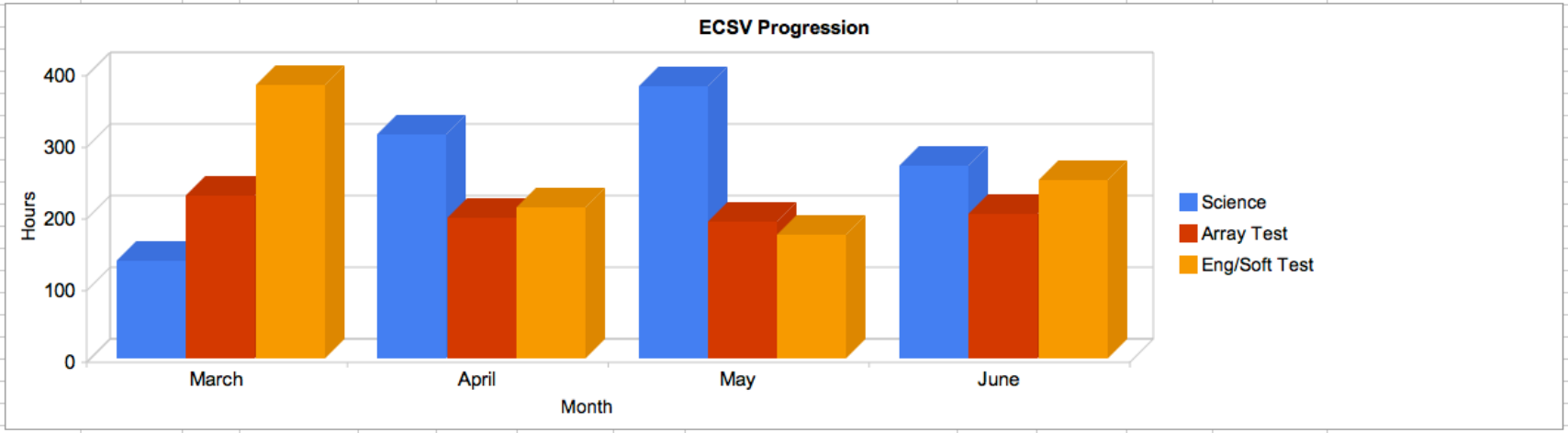
This mix of activities has overhead; experimenting with different scheduling options.

Commissioning: OSRO Status



	Hrs Allocated	Hrs Completed	Fraction Allocated	Fraction complete
Totals (Priority < 6)	**629**	**454**	**1**	**0.72**
Totals (Priority > 5)	**668.5**	**396.5**	**1**	**0.59**
Totals (Priority <= 4)	451.5	368	1	0.82
Totals (Priority <= 3)	431	313	1	0.73
Totals (Priority <= 2)	279	232	1	0.83
Totals (Triggered/ToO)	193	105.75	1	0.55
Total Fraction Rapid Response		0.11058823		
Total Science Observing		**956.25**		
Completed Projects		**50**		





Commissioning Results: Milestones

- 11 Jan: VLA correlator shutdown
- 2 Mar: First Science Observing with WIDAR
- 19 Mar: Automated single correlator configuration path established (OPT->Corr)
- 20 Mar: First rapid response observation
- 28 Mar: First high frequency observing
- 20 Apr: First Multiple correlator configuration path observations
- 24 Apr: First narrow-band (125 kHz BW, 488 Hz channels) science observations
- 28 May: Last VLA antenna retrofitted for EVLA
- 25 Jun: First fringes with 3-bit samplers
- 01 Jul: First OST use for science observing.
- 03 Jul: First RSRO science observations

Commissioning Capability Timeline: High Level View

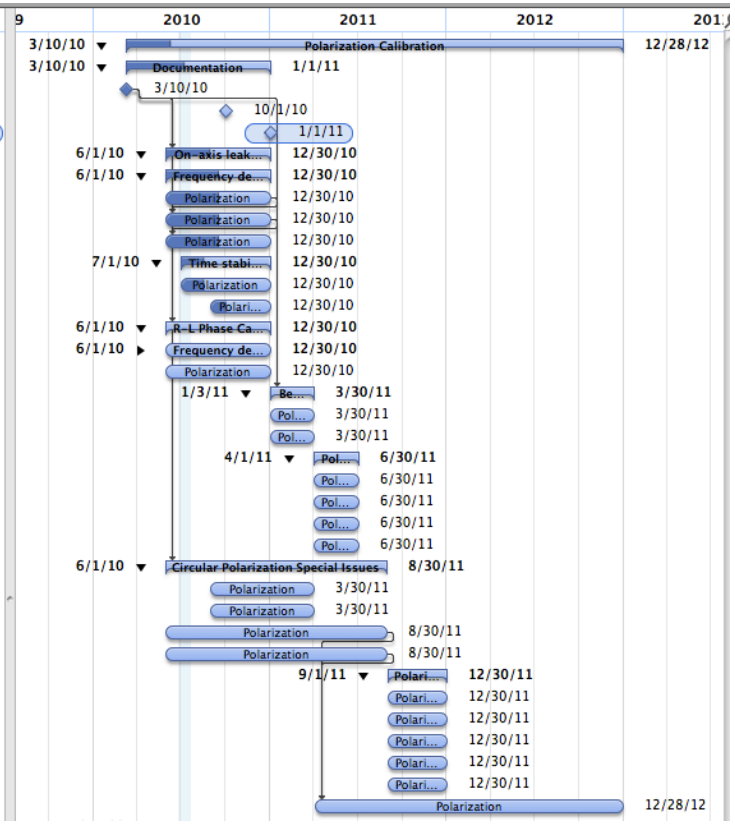
Now/Near term (2010)	Mid term (2011)	Long term (2012)
•Robust OSRO •Stable RSRO •Testing for hw/sw for wider bandwidths	•Expanded frequency coverage •Basic Observing Modes available end-to-end	•Full frequency coverage (end of construction) •Full WIDAR capabilities •Also supporting Advanced Observing Modes and Data Techniques

Commissioned Capabilities Timeline: Mid-level

Area	Now/Near term (2010)	Mid term (2011)	Long term (2012)
Antennas:	25+ available	27	27
Bands:	L C X (narrow) Ka Q	L OMT upgrade S (10) X (8-12 GHz; 17) Low band testing	Low band
Correlator:	2 GHz BW/pol 16 sub-band pairs 64 ch/sbp 3-bit sampler testing	2 GHz BW/pol >16 sub-band pairs, independently tunable Recirculation	2/8 GHz BW/pol 64 sub-band pairs Up to 16,384 ch/sbp
Observing Modes	Continuum Spectral Line Polarimetry	+Phased Array +Planetary +VLBI	+Pulsar +Solar +Astrometry
Observing Support	PST, OPT, AAT	PST, OPT, AAT Flux calibrator models	PST, OPT, AAT Pipeline
Algorithm		Wideband, narrow field	Wideband, wide field

Commissioned Capabilities Timeline: Detailed exam.

Task	Start	End	Assigned	RSRO Support	Completed
▼ 1.19.5) Polarization Calibration	3/10/10	12/28/...		Green, Heesen,...	8.84%
▼ 1.19.5.1) Documentation	3/10/10	1/1/11			40%
◆ 1.19.5.1.1) Calibration Draft plan	3/10/10	3/10/10	Polarization		100%
◆ 1.19.5.1.2) Observer Recommendations	10/1/10	10/1/10	Polarization		10%
◆ 1.19.5.1.3) Polarization Service Observation Plan	1/1/11	1/1/11	Polarization		10%
▼ 1.19.5.2) On-axis leakage calibration	6/1/10	12/30/...			41.95%
▼ 1.19.5.2.1) Frequency dependence	6/1/10	12/30/...			50%
• 1.19.5.2.1.1) LCK: Measure freq-depend; determine optimal channelization.	6/1/10	12/30/10	Polarization		50%
• 1.19.5.2.1.2) LCXKAQ: Determine for OSRO modes	6/1/10	12/30/10	Polarization		50%
• 1.19.5.2.1.3) All bands: As above.	6/1/10	12/30/10	Polarization		50%
▼ 1.19.5.2.2) Time stability	7/1/10	12/30/...			25%
• 1.19.5.2.2.1) Test variability over different time intervals	7/1/10	12/30/10	Polarization		25%
• 1.19.5.2.3) Parallel-hand leakage	9/1/10	12/30/10	Polarization		25%
▼ 1.19.5.3) R-L Phase Calibration	6/1/10	12/30/...			0%
▶ 1.19.5.3.1) Frequency dependence	6/1/10	12/30/...			0%
• 1.19.5.3.2) Time stability	6/1/10	12/30/10	Polarization		0%
▼ 1.19.5.4) Beam Squint (R vs. L)	1/3/11	3/30/11			0%
• 1.19.5.4.1) Theoretical modelling	1/3/11	3/30/11	Polarization		0%
• 1.19.5.4.2) Measurement	1/3/11	3/30/11	Polarization		0%
▼ 1.19.5.5) Polarization Primary Beam (off-axis) calibration	4/1/11	6/30/11			0%
• 1.19.5.5.1) Modelling	4/1/11	6/30/11	Polarization		0%
• 1.19.5.5.2) Measurement	4/1/11	6/30/11	Polarization		0%
• 1.19.5.5.3) Frequency dependence	4/1/11	6/30/11	Polarization		0%
• 1.19.5.5.4) Time stability	4/1/11	6/30/11	Polarization		0%
▼ 1.19.5.6) Circular Polarization Special Issues	6/1/10	8/30/11			0%
• 1.19.5.6.1) R and L gain stability	9/1/10	3/30/11	Polarization		0%
• 1.19.5.6.2) R and L beam squint accuracy	9/1/10	3/30/11	Polarization		0%
• 1.19.5.6.3) Wide band issues	6/1/10	8/30/11	Polarization		0%
• 1.19.5.6.4) Wide field issues	6/1/10	8/30/11	Polarization		0%
▼ 1.19.5.7) Polarization Calibration Sources and Monitoring	9/1/11	12/30/...			0%
• 1.19.5.7.1) Primary IQU standards	9/1/11	12/30/11	Polarization		0%
• 1.19.5.7.2) Secondary IQU standards	9/1/11	12/30/11	Polarization		0%
• 1.19.5.7.3) Low-polarization leakage calibrators	9/1/11	12/30/11	Polarization		0%
• 1.19.5.7.4) EVLA Calibrator survey (polarization component)	9/1/11	12/30/11	Polarization		0%
• 1.19.5.8) Polarization calibration processing	9/1/11	12/30/11	Polarization		0%
• 1.19.5.9) Polarization Imaging	4/4/11	12/28/12	Polarization		0%



Commissioning Process

- Testing hierarchy:
  - Engineering checkout -> component performance verification ->
  - system verification -> end-to-end mode verification -> deployment.
- Checkout example:
  - Engineering: antenna has functioning digitizers, formatters, optical link, de-formatters, bandpass shapes, synchronization, ability to optimize power levels, etc
  - Component performance verification (component): e.g., Tsys/Trx meets specification over the band, antenna meets pointing specs, etc
  - System performance verification: e.g., bandpass stability
  - End-to-end mode verification: OPT can generate desired science; OPT generates script that reflects observation; script executes; fringes on all antennas/IFs; delays ok; data is written to the archive; data can be extracted from the archive; Data review: frequency labeling, sky orientation, gain stability, tuning robustness, integrates down, phase transfer (high frequency), RFI issues identified; science goal can be achieved (spectral S/N, image dynamic range, etc).

CSV Organization: Activities

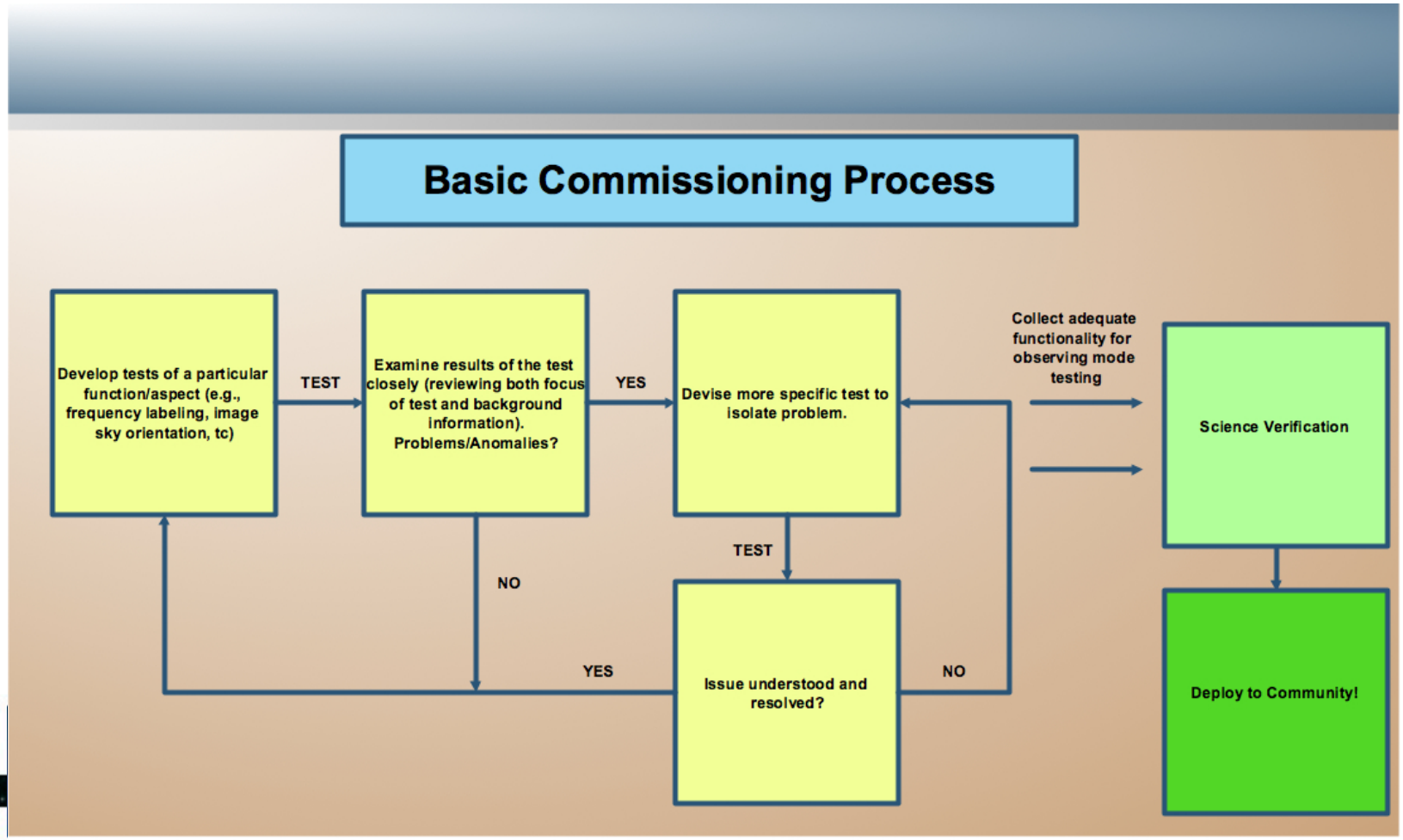
- Coarse priority level:
  - **Critical Commissioning** (OSRO/RSRO)
    - System verification: Testing and characterization of the array based on the design goals.
    - Observing Band Checkout: Testing and development within broad frequency ranges distinguished by their calibration strategies.
    - Observing Mode Checkout: Testing and development within broad observing modes distinguished by their science goals (e.g., continuum, spectral line, polarimetry, etc)
    - Observing Support: Testing and development of the end-to-end capability of the array to support observations to the community (documentation, OPT, scheduling, instrument models, calibrator survey/models DB, rapid response observing, demo science, post-processing.

CSV Organization: Activities

- Coarse priority level:
  - **Advanced Science Support** – work needed to take full advantage of the EVLA science capabilities during operations.
    - Advanced Observing Modes: Testing and development for additional observing modes (Pulsar, VLBI, Time Domain, Survey Modes, etc)
    - Advanced Data Techniques: Testing and development for astrometry, mosaicing, time domain processing, advanced algorithms.
    - Advanced Post-processing Techniques: Testing and development of algorithms improving imaging and calibration.
    - Pipelines: Testing and development of automated flagging, pipeline calibration, pipeline imaging, pipeline analysis and quality

Commissioning Process

- Testing hierarchy:
  - Engineering checkout -> component performance verification -> system verification -> end-to-end mode verification -> deployment.



CSV Organization: Resources

- Commissioning is run out of the EVLA Science Support Group which merges into the group's role during operations (see Chandler talk on ASC).
- Responsibilities:
  - **Commissioning and Science Verification**
  - Receiver/antenna performance
  - Maintenance of calibration data
  - Array performance
  - Low frequency support
  - High frequency support
  - Data quality assurance
  - Technical documentation
  - Specs for future EVLA developments
- ~7 FTEs within the group with additional support from:
  - Scientists in other areas of the ASC; principal: Rick Perley (Proj Sci)
  - RSRO program scientists.

Commissioning Organization: Teams

- Attempted to utilize the NRAO/RSRO expertise to advance commissioning based on broad data flow/observing mode aspects
  - Given the expertise of the EVLA scientific staff and the participating RSRO scientists, they can act as representatives and advocates of the range of science needed by the community.
- The goal of the groups is to enable these modes to be deployed to the community and to drive the development to obtain the best capabilities (and thus the best science) in these broad areas.
  - Specify detailed tests needed.
  - Develop observing scripts.
  - Provide analysis
  - Present status/updates
  - Organize user-level documentation

Commissioning Summary

- Able to maintain simultaneous science operations with incrementally increasing capabilities during the commissioning test phase.
- Working toward an end-2012 delivery for the projected science capabilities (end-to-end observing modes with full WIDAR correlator over the 1-50 GHz spectral range).
  - In the context of predictable deliveries from the construction project, the planned staffing profile for EVLA scientific staff, and continued RSRO participation through to end of 2012.

Backup Slides/Additional Information

Useful Link:

- EVLA Commissioning and Science Verification Wiki:
  - https://staff.nrao.edu/wiki/bin/view/EVLA/EVLACommissioning

EVLA Commissioning, Science Verification Twiki

Group List

- ecsv mail list
- http://listmgr.cv.nrao.edu/mailman/listinfo/ecsv

EVLA Commissioning Links:

- EVLA Project Book
- EVLA Main
  - EVLA Observational Status Summary
  - OSRO Program
  - RSRO Program
  - EVLA Coordination Meeting Targets
  - EVLA Science Coordination Targets *
  - EVLA Observing Band Checkouts
- EVLA Commissioning Planning
-
  - ECSV Meetings
  - 2010 D Configuration
    - OSRO Readiness Tasks
    - OSRO Proposals Readiness Cycle 1 (protected)
    - RSRO Proposals Readiness Cycle 1
    - Tracking Sheet for EVLA Commissioning Issues
  - EVLA Commissioning Organization
  - EVLA System Verification
  - EVLA Software Versioning
-
  - EVLA Commissioning presentation, 05 Feb 2010: (PowerPoint; Pdf)
  - Commissioning target spreadsheet, 08 Feb 2010: (Excel; Pdf, data flow view; Pdf, team lead view)
- EVLA Guides
  - Commissioning Task Leader Guide
  - Resident Shared Risk Observer Guide
  - Test Observation Submission
  - Test Observation Project Codes
  - Real-time Monitoring with D10
  - Understanding the Scheduling Priority Algorithm
  - Key to calcodes

ECSV Calendar Events

ECSV Testing/Observations

Today ◀ ▶ Friday, July 2

Friday, July 2	
8:45am	Engineering Data Review
4:00pm	EVLA Commissioning Daily Review
Monday, July 5	
9:30am	EVLA Coordination
11:00am	EVLA Commissioning Planning
Tuesday, July 6	
9:00am	EVLA Software Testing
9:00am	CASA Mtg
10:00am	EVLA Commissioning and Science Verification
Wednesday, July 7	
8:00am	EVLA Maintenance
9:00am	AIPS Mtg
10:15am	EVLA WIDAR
Thursday, July 8	
9:00am	EVLA Software Testing
Friday, July 9	
8:45am	Engineering Data Review
4:00pm	EVLA Commissioning Daily Review
Monday, July 12	
9:30am	EVLA Coordination
11:00am	EVLA Commissioning Planning
Tuesday, July 13	
9:00am	EVLA Software Testing
9:00am	CASA Mtg

Events shown in time zone: Mountain Time

RSRO Scientists

Today ◀ ▶ Friday, July 2

Friday, July 2
Laura Chomiuk (AS1015/AK726: RSRO-11/RSRO-6): 200C
Joseph Lazio (AC982: RSRO-4): 266
Laura Perez (AC982: RSRO-4): 200E
Volker Heesen (AH1006: RSRO-5): 200G
Russ Taylor (AT374: RSRO-12): 300G
Saturday, July 3
Laura Chomiuk (AS1015/AK726: RSRO-11/RSRO-6): 200C
Joseph Lazio (AC982: RSRO-4): 266
Laura Perez (AC982: RSRO-4): 200E
Volker Heesen (AH1006: RSRO-5): 200G
Russ Taylor (AT374: RSRO-12): 300G
Sunday, July 4

Communication/Tracking

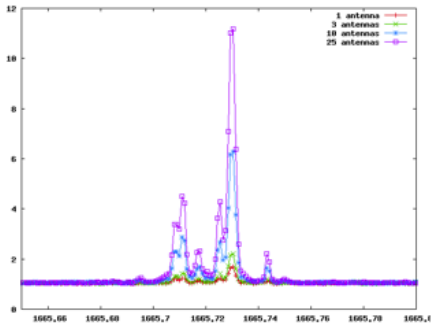
- JIRA Projects
  - ECSV (https://bugs.aoc.nrao.edu/browse/ECSV) : Commissioning tasks
  - ECDATA (https://bugs.aoc.nrao.edu/browse/ECDATA) : Commissioning data set review
  - RSRO (https://bugs.aoc.nrao.edu/browse/RSRO): RSRO Projects
- EVLA Commissioning Twiki: https://staff.nrao.edu/wiki/bin/view/EVLA/EVLACommissioning
  - Provides general information to commissioners, status, calendar, etc
  - Weekly Meeting agendas/minutes
- "EVLA Guides" information for users:
  - http://evlaguides.nrao.edu

Example Group Page: Phased Array

Phased Array

Adam D. and Michael R. (with Joe L. present at the start) re-ran the 16 MHz band phasing test on W3(OH).

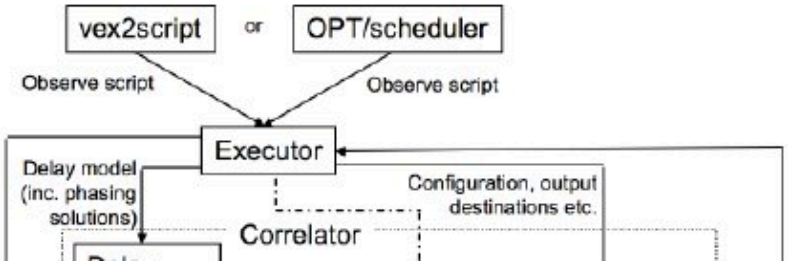
This figure image shows the increase in SNR as more antennas are added. The improvement is not quite the expected linear increase. However, at one stage an antenna with no L band receiver was included, and it is not clear that phasing was maintained over the entire duration of the test. The image itself is made by autocorrelating the VDIF output frames, from about a few 100 ms of data.



This document is intended to capture progress toward the state of demonstrating the phased array (also sometimes called "tied array") capabilities of the EVLA-WIDAR correlator.

Background

Much of the discussion is based on an EVLA memorandum (in prep.) by A. De



		Bandwidth		
Band	**Pol'n**	**16 MHz**	**64 MHz**	**128 MHz**
L	RCP	demonstrated		demonstrated
[S]	RCP			
C	RCP	demonstrated	demonstrated	demonstrated
X	RCP			fail
[U]	RCP			
K	RCP			demonstrated