Expanded **Very** **Large** **Array**	EVLA-SW-001 Revision:1.0 2002-09-13 *Requirements* Steven T. Myers

EVLA Software Science Requirements

Requirements

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1 Introduction

This document intends to define science-driven software requirements of the EVLA project. Because of the increased capability of this instrument and the greatly expanded capacity of the correlator, we foresee a number of new software developments that will need to be in place when the EVLA comes online. In particular, the goal of end-to-end (e2e) processing requires some specifications based on science drivers. Thus, we will plan to combine in the software the high level of automation needed to deal with the large data rates that will be attained, while for simple projects the multi-wavelength astronomer with little or no experience of radio techniques should be able to use the instrument and obtain scientific quality results.

1.1 Overview

The EVLA requirements are structured according to the EVLA contract with e2e. Thus, we have generated EVLA specific requirements in each of the 6 areas that Data Management has contracted to do work for EVLA:

1. Proposal generation and submission (2.1)
2. Observation preparation (2.2)
3. Observation scheduling (2.3)
4. Data archive (2.4)
5. Image pipeline (2.5)
6. Data post processing

The first five of these are dealt with in this document. The final area of Data post-processing is dealt with in a separate set of EVLA Offline Data Processing Requirements. In addition, there are a number of Operational Issues described in (2.6).

The prioritizing scheme is described at the top of 2. We have done our best to make the requirements quantitative, and to clearly define the meaning of qualifiers and adjectives. However, there are instances where the substance of particular requirements is necessarily subjective (e.g. “ease of use” and “robustness” type requirements). Rather than spelling these out in detail, we have have left these “squishy” requirements as-is, and will rely upon the SSR and Package representatives to take these properly into account during the evaluation process.

There are also a number of places, such as the headers to sections, where we discuss the philosophy behind our choice of requirements. In those cases, the discussions are given as *italicized* text and are not meant as requirements in and of themselves.

In Section 2 we enumerate requirements in a formal way; these are grouped in sub-sections corresponding to the main software components outlined in the present Introduction. In Appendix A we define the main entities, used to manage the whole observing process, that are referred to in the Requirements. An example list of scheduling block operations is given in Appendix B.

This document is heavily based upon the ALMA Science Software Requirements and Use Cases document.

1.2 General Assumptions

The expert user/developer will need to be able to send direct commands to the instrument through a simple, easily editable command language. Atomic commands in a script language will directly send orders to the basic software elements controlling the hardware: antenna motion, instrument setup, or transmitting parameters to the data processing (pipeline). The script language will support loops, structured conditional tests, parametrized procedures, global variables and arrays. These scripts, once fully developed and tested, will evolve into the basic observing procedures of the instrument.

The general user will need more user-friendly graphic interfaces to many components of the system. They will propose several templates, corresponding to the available observing modes, and provide a simple way to pass astronomy parameters to the basic observing process, and to the corresponding data reduction procedures of the pipeline. Input parameters will preferably be expressed in terms of astronomical quantities, which will be translated into technical parameters by sophisticated configuration tools.

Proposal submission will be in two phases, the first before proposal evaluation, the second to provide information needed for the actual scheduling and observation.

We believe that dynamic scheduling is an essential feature of the instrument and should be installed from the very beginning of its operational life. To improve the total efficiency we must be able to make the best use of all weather conditions, by selecting in quasi-real time the project most suited to the current weather and to the state of the array. This means we should always be able to observe a given project in appropriate weather conditions. This philosophy can be extended to the point where a given project can change its own observing parameters according to variations in observing conditions (such as atmospheric phase rms). We explain how these two levels of dynamic scheduling can be implemented and what are the requirements on software.

The whole real-time system will be under control of a telescope operator, through a specially designed interface. This must provide an overview of what observation is occurring, the state of the instrument, and observing conditions on the site, and should enable the operator to react to any unexpected event. A general monitoring interface must be also accessible through the network.

The instrument should produce images, aiming to be final for most projects, even when projects are spread over several sessions and configurations, and/or include short/zero spacings. For this purpose an on-line pipeline is required. For most projects the data pipeline will produce results in a form suitable for quality evaluation, and astronomical processing, hopefully leading to fast publication. Uncalibrated *uv* data will be archived together with the calibration curves and the resulting images. The archive should enable fast access to the observing parameters and full reprocessing of the data set with improved processing algorithms.

A general requirement is that the various parts of the system should be developed in a highly consistent way, from the very beginning of design; they may however be installed progressively, provided the critical elements are implemented first.

In writing this set of requirements, we have made a number of specific assumptions about the EVLA to appear to users and staff. These are:

1. The EVLA software shall offer an easy to use interface to any user and should not assume detailed knowledge of radio astronomy and of the EVLA hardware.
2. The EVLA software shall provide simple ways for the staff or expert astronomers to refine observing modes and develop new ones.
3. The expert user/developer shall be able to send direct orders to the hardware and to basic quasi real-time software through simple scripts in a Command Control Language. These scripts, once fully developed and tested, will evolve into standard observing modes.
4. The general user shall be offered fully supported, standard observing modes to achieve the project goals, expressed in terms of science parameters rather than technical quantities. Observing modes shall allow automatic fine tuning of observing parameters to adapt to small changes in observing conditions.
5. All user interaction with the EVLA system shall be through **Graphical User Interfaces** (GUIs) except for the low level Command Control Language.

6. The instrument shall be dynamically scheduled in near real time (a few minutes in advance of real time) to take full advantage of the atmospheric conditions and of instrument availability.
7. The EVLA final product shall be images for the large majority of projects. The data shall be calibrated and processed in pipelines.
8. Raw data, monitor data, calibration data, and images will be archived; archived data shall be easily accessible to the users.
9. The EVLA processing system shall be able to handle the peak data rate of 20 MB/s. This corresponds roughly to one million (double-precision complex) visibilities per second (1.0 MVPS), and one-half million (double-precision) image pixels per second (0.5 MPPS). See Tim Cornwell's EVLA Memo 24 for an analysis of the EVLA processing needs.

   Comments: STM: put real numbers here
10. An Alarm System shall allow hardware and software faults to be uniquely identified and suppress error cascades. Identification of the faults shall be available to the operator and used in operating EVLA. The faults shall be logged and used as input for system maintenance and for the dynamic scheduling.

    Comments: STM: is this in the EVLA plans? should it be?
11. Poorly behaving system hardware components detected by the data pipelines will also be managed at the system level; their status will also be made available to the system maintenance staff and to the dynamic scheduler.

    Comments: STM: I don't think the EVLA system will be as integrated as the ALMA system, so this may not make sense.

2 Requirements

The *Requirement priorities* reflect the importance and the time frame in which the requirement must be met in the project.

The priorities can have the following four values:

1 = essential

2 = important

3 = desirable, but not critical

It is intended that Priority 1 items must be present in the Package and work with high efficiency. Priority 2 items should be in the Package, though there may have to be sacrifices in performance or availability may be delayed. Fulfilling Priority 2 items well should give a boost to a given Package's rating. We expect that the Package will fulfill all Priority 1 and 90% or more of Priority 2 requirements. Priority 3 items should be considered for upgrades or development.

The timeframe of deployment is matched to the EVLA Phase I Project schedule (see the EVLA Project Book). The timescale phases are:

A transition phase (2004 Q2)

B prototype correlator (2005 Q4)

C shared-risk Science operations (2007 Q2)

D full science operations, completion of EVLA Phase I (2010 Q2)

E "eventually" sometime after completion (ongoing)

These are same as the priorities and timescales used in the EVLA OFFLINE DATA PROCESSING REQUIRMENTS.

2.1 Proposal generation and submission

It is assumed as an operational model for the EVLA (as was done for ALMA) that the observer input shall be obtained in two phases: Phase I occurs prior to scientific evaluation, and Phase II occurs after successful scientific evaluation and before schedule submission. During transition observing and testing, input may be in a single stage, e.g. Phase I and Phase II are coincident, which is the current mode for VLA proposal submission. Furthermore, it may be eventually decided that a single proposal phase will be sufficient for the EVLA, again in which case the two Phases are coincident in time.

1.0–R1 The proposals shall be submitted electronically and all observer input shall be in digital form.
Priority: 1 *Timescale:* A

- **1.0–R1.1** The scientific justification shall be provided (e.g. at Phase I) in a easily printable format (Postscript, pdf, ...), including figures.
  Priority: 1 *Timescale:* A

1.0–R2 There shall be an Proposal Tool for the preparation and submission of proposals for the EVLA.
Priority: 1 *Timescale:* A

- **1.0–R2.1** The same tool shall be used for both phases, with a subset of input being required for Phase I to judge technical feasibility and observing time needed, and the remaining input (optional at Phase I) required at Phase II to fully specify the observations to be done.
  Priority: 1 *Timescale:* C
- **1.0–R2.2** This tool shall be the same Observing Tool that is used in the generation of schedules (2.2);
  Priority: 2 *Timescale:* C

1.0–R3 The tool shall allow storing of intermediate stages to local disks (e.g. to enable trying out different parameter settings, for backup).
Priority: 1 *Timescale:* A

1.0–R4 The science goals should be input into the Proposal Tool at Phase I; they include:

- **1.0–R4.1** full source identification and coordinates (note — if there are more than 10 sources the list may be replaced by selection criteria if allowed by EVLA policy);
  Priority: 1 *Timescale:* C
- **1.0–R4.2** angular resolution and largest structure;
  Priority: 1 *Timescale:* C
- **1.0–R4.3** source flux and S/N or rms;
  Priority: 1 *Timescale:* C
- **1.0–R4.4** line identification or frequencies;
  Priority: 1 *Timescale:* C
- **1.0–R4.5** desired velocity resolution;
  Priority: 1 *Timescale:* C
- **1.0–R4.6** desired dynamic range.
  Priority: 1 *Timescale:* C

1.0–R5 At Phase I the Proposal Tool shall perform certain calculations, including

- **1.0–R5.1** the integration time required:
  - **1.0–R5.1.1** for a given bandwidth and channel (e.g. velocity) width;
    Priority: 1 *Timescale:* C
  - **1.0–R5.1.2** under average environmental conditions;
    Priority: 1 *Timescale:* C
  - **1.0–R5.1.3** using real observing statistics;
    Priority: 2 *Timescale:* D

- **1.0–R5.2** the appropriate configuration needed given desired sensitivity, resolution, and source angular size.
  Priority: 1 Timescale: C
- **1.0–R5.3** the scheduled time required given stringency of required conditions (e.g. required phase stability at the specified frequency).
  Priority: 2 Timescale: D

1.0–R6 The tool shall calculate the data rate and the total data volume for the project.

Priority: 1 Timescale: C

1.0–R7 The tool shall react to user input by providing warnings based on the situation and selected observing mode, including:

- **1.0–R7.1** hardware limitations;
  Priority: 1 Timescale: C
- **1.0–R7.2** data rate/volume;
  Priority: 1 Timescale: C
- **1.0–R7.3** expected data quality;
  Priority: 2 Timescale: D
- **1.0–R7.4** expected stringency limitations (e.g. weather efficiency).
  Priority: 2 Timescale: D

1.0–R8 The basic input parameters shall be translated by the tool into control parameters (e.g. observing mode, configurations, observing time, correlator setup) which the expert shall be able to check. These can be overridden manually (e.g. by EVLA staff).

Priority: 2 Timescale: C

1.0–R9 A database of already conducted observations shall be available at time of submission, accessible for interactive searching prior to proposal writing.

Priority: 2 Timescale: D

- **1.0–R9.1** Checking for conflicts against the observation archive shall give instant (and automatic) warning to the proposer in case of conflicts.
  Priority: 3 Timescale: D

2.2 Observation Preparation

These requirements cover the preparation of schedules for submission to the Scheduler by the observer using the Observing Tool.

2.2.1 The Observing Tool

The Observing Tool is mainly used for schedule preparation and for interactive observing. It is the main interface to EVLA for the general user. It is highly desirable that the Proposal and Observing Tools be one and the same.

2.1–R1 There shall be an Observing Tool for the generation of schedules for the EVLA.

Priority: 1 Timescale: A

- **2.1–R1.1** This tool shall be the same as the Proposal Tool that is used in the Proposal Preparation phases (2.1).
  Priority: 2 Timescale: C

2.1–R2 Since the Observing Tool is the primary interface of the observer to the EVLA, it should be easy-to-use and robust.

Priority: 1 Timescale: A

- **2.1–R2.1** This tool shall operate using a GUI;
  Priority: 1 Timescale: A
- **2.1–R2.2** There shall be a batch or script mode for automated generation of schedules;
  Priority: 1 Timescale: C

2.1–R3 Since the Observing Tool is the primary interface of the observer to the EVLA, it should be easy-to-use and robust.

Priority: 1 Timescale: C

- **2.1–R3.1** There shall be built-in help capability;
  Priority: 1 Timescale: C
- **2.1–R3.2** The use of the tool shall not entail an excessive learning curve. Average users, with some knowledge of radio astronomy (as obtained by attending the NRAO Summer School) shall be able to become proficient in EVLA scheduling in a timescale of approximately 8 hours dedicated use, and truly neophyte users (e.g. graduate students in other areas of astronomy, or the dreaded theorists) should be reach proficiency with an investment not exceeding 24 hours of dedicated use.
  Priority: 2 Timescale: D

2.1–R4 The Observing Tool shall allow its state and intermediate output to be saved and restored at any time. Saved outputs shall be local. Saved outputs shall be distinguished by name and easy to use as templates.

Priority: 1 Timescale: A

2.1–R5 Schedules output from the tool shall be readable by the tool.

Priority: 1 Timescale: A

- **2.1–R5.1** Schedules output from the tool shall contain the entirety of information needed for the scheduling process (ie. you can use a schedule or set of SBs as the start of a new schedule creation, with minimal extra input).
  Priority: 3 Timescale: D

2.1–R6 The Observing Tool shall include as components tools for:

- **2.1–R6.1** observation setup;
  Priority: 1 Timescale: A
- **2.1–R6.2** correlator setup;
  Priority: 1 Timescale: B
- **2.1–R6.3** data reduction setup;
  Priority: 2 Timescale: D
- **2.1–R6.4** observation simulation;
  Priority: 2 Timescale: D

2.1–R7 The Observing Tool shall be able to produce a human-readable observing script that can be directly executed, or used as an input for further development.

Priority: 1 Timescale: A

2.1–R8 The Observing Tool shall allow the user to select from and manipulate source catalogs derived from:

- **2.1–R8.1** a built-in calibrator catalog;
  Priority: 1 Timescale: A
- **2.1–R8.2** user-supplied source lists in ASCII format;
  Priority: 1 Timescale: A
- **2.1–R8.3** access to standard astronomical catalogs (CDS, NED);
  Priority: 2 Timescale: C

2.1–R9 The Observing Tool shall allow the user to easily construct a *Source List* of coordinates and velocities. This shall be possible based on:

- **2.1–R9.1** interactive selection from a catalog list;
  Priority: 1 Timescale: A
- **2.1–R9.2** sequential extraction of targets from a list of sources (e.g. to conveniently schedule survey programs);
  Priority: 1 Timescale: A
- **2.1–R9.3** user input of selection parameters (e.g. area of sky, flux density, source size, depending on what is available in the catalog);
  Priority: 2 Timescale: C
- **2.1–R9.4** on the basis of an image (e.g. from survey databases, or from the EVLA image archive) one shall be able to define the area to be mapped interactively (e.g. with a mouse).
  Priority: 3 Timescale: D

2.1–R10 Target source lists produced by the tool shall be exportable, editable and re-usable for further sessions.

Priority: 1 Timescale: C

2.1–R11 The Observing Tool shall only require specification of science goals (1.0–R4) as input.

Priority: 2 Timescale: C

2.1–R12 The Observing Tool shall provide to the user a list of standard observing modes that may be used to achieve the science goals, from which they could choose defaults.

Priority: 2 Timescale: C

2.1–R13 For the selected standard observing mode the Observation setup component shall offer for all parameters sensible defaults deduced from the science goals, making these parameters unnecessary to manipulate for the general user.

Priority: 1 Timescale: C

- **2.1–R13.1** Some parameters (loop cycle times, integration times) may be selected to be automatically calculated at run-time by the scheduler depending on actual weather, phase fluctuations, pipeline results.

Priority: 3 Timescale: E

2.1–R14 It shall be possible for the Observing Tool to set integration times and cycle repeats based upon a desired level of sensitivity under the requested atmospheric conditions.

Priority: 2 Timescale: C

2.1–R14.1 Limits imposed by the TAC, such as hard limit on the total project integration time, shall be also factored in (through a settable parameter).
Priority: 2 Timescale: D

2.1–R15 The Correlator setup component shall provide:

2.1–R15.1 A *Hardware Menu*, based on actual hardware setup (e.g. number of channels, width in Hz);
Priority: 1 Timescale: B

2.1–R15.2 A *Spectral Menu*, based on observational parameters (e.g. selection of spectral windows based on molecular transitions, velocity widths and line brighnesses);
Priority: 2 Timescale: C

2.1–R15.3 Pre-configured setups shall be available for frequently observed transitions;
Priority: 2 Timescale: D

2.1–R15.4 Links to a standard provided line catalog (e.g. based on the JPL catalog);
Priority: 2 Timescale: D

2.1–R15.5 Links to simulated spectra based on physical models.
Priority: 3 Timescale: E

Note: the correlator setup component acts as a translator between these two views; both can be visible at the same time with a split screen if desired (see e.g. the BIMA and SMA setup programs). The correlator setup component shall be linked to existing line surveys for a variety of sources, to be able to place correlator units visually at interesting regions.

2.1–R16 The Observing Tool shall be able to run a simulator component (see 2.2.3) to:

2.1–R16.1 estimate S/N;
Priority: 2 Timescale: D

2.1–R16.2 estimate syntesized beam size;
Priority: 2 Timescale: D

2.1–R16.3 estimate surface brighness sensitivity;
Priority: 2 Timescale: D

2.1–R16.4 produce dirty beams;
Priority: 3 Timescale: D

2.1–R16.5 for suitable source models, simulate maps with the desired array configurations;
Priority: 3 Timescale: E

2.2.2 Generation of Schedules

2.2–R1 The observing programmes shall be divided into scheduling blocks:

2.2–R1.1 from expert observer input, e.g. by specification of cycle times and counts;
Priority: 1 Timescale: A

2.2–R1.2 automatically, for standard observing modes with "science oriented" input (e.g. sensitivity).
Priority: 2 Timescale: D

2.2–R2 For complex programs with several different scheduling blocks the observer shall be able to set up dependency rules between these scheduling blocks. The dependency rule for a given SB shall be a logical expression involving the execution status parameters of one or several among the other scheduling blocks in the programme:

- **2.2–R2.1** previous SB execution successful;
  Priority: 2 Timescale: C
- **2.2–R2.2** previous specific SB execution successful;
  Priority: 2 Timescale: C
- **2.2–R2.3** previous SB execution failed;
  Priority: 3 Timescale: D
- **2.2–R2.4** number of SB executions;
  Priority: 3 Timescale: D
- **2.2–R2.5** SB sensitivity reached;
  Priority: 3 Timescale: D

Note: There will be at least one SB in the program with a dependency rule that evaluates as `false` *(i.e. SB is independent) when the program is started, as there has to be a first block.*

2.2–R3 The proposer shall be able to define breakpoints after which observations shall be stopped and only resumed (possibly in modified form) after examination of the data obtained so far by the proposer. Observations after the breakpoint will have to stay within the project scope, as defined in the observing proposal and accepted by the reviewers.

Priority: 2 Timescale: D

Breakpoints shall be settable in terms of project goals, such as:

- **2.2–R3.1** completion of a specific subset of targets or observing block;
  Priority: 2 Timescale: D
- **2.2–R3.2** fraction of targets observed;
  Priority: 2 Timescale: D
- **2.2–R3.3** a target has reached a given rms or S/N.
  Priority: 3 Timescale: E

2.2–R4 The proposer shall be able to specify what is needed for real-time checking of data quality (should this be available in the EVLA system), including:

- **2.2–R4.1** choosing a standard calibrator as a *test source* to be observed to assess the conditions for stringency;
  Priority: 3 Timescale: D
- **2.2–R4.2** option for the system to automatically choose the test source at execution time.
  Priority: 3 Timescale: E

2.2.3 Simulation

Capability of simulating all EVLA modes of observation is needed for planning observations (with the Observing Tool), and comparison of data with models (in data reduction, e.g. in order to test data reduction procedures and their reliability). Various levels of complexity and speed of execution will be necessary.

The data reduction related components of the simulator are given in the Simulation section of the Offline Data Processing Requirements.

2.3–R1 A primary use of the EVLA simulator is to provide guidance during the proposal and schedule preparation phases. As such, it is critical that the relevant parts of the simulation software be compatible with the Observing Tool, preferably integrated seamlessly into its interface.

Priority: 1 Timescale: C

2.3–R2 It shall be possible to compute simple expected sensitivity levels, dirty beams, and dynamic ranges, given the basic observing mode parameters (including integration time, bandwidths and spectral resolutions, array configuration, mosaicing strategy, atmospheric quality limits), used for proposal and schedule preparation. It shoud be possible to compute the integration time from a required sensitivity. Timescale for execution should be 0.1-5 minutes and should not require significant computational resources.

Priority: 2 Timescale: C

2.3–R3 The sensitivity calculation shall be available to the users through the Observing Tool at Proposal Preparation stage.

Priority: 2 Timescale: C

2.3–R4 Based on the simulator the Observing Tool shall estimate the data processing resources needed for science data processing. If the resources needed for image deconvolution are significant, the proposer shall be asked when image deconvolution needs to be executed ('monitor points'), for instance:

2.3–R4.1 after observing session;
Priority: 2 Timescale: D

2.3–R4.2 only at the end of program execution;
Priority: 2 Timescale: D

2.3–R4.3 after each breakpoint (if any);
Priority: 3 Timescale: D

2.3–R4.4 every time a given amount of integration time is obtained.
Priority: 3 Timescale: E

2.3–R5 Data simulation shall be available to the general user at proposal preparation stage. In that case the data will be simulated according to the needs of the observing program, translated into observing parameters by the Observing Tool.

Priority: 3 Timescale: D

2.3 Observation scheduling

These requirements refer to the scheduling of programs for actual observation (i.e. using the Scheduler), with the actual Scheduling Blocks being provided by an Observing Tool (see 2.2.2).

3.0–R1 EVLA observing programs shall be dynamically scheduled in quasi-real time.

Priority: 1

3.0–R2 The observing programs shall be split into Scheduling Blocks (SB); the execution of an SB shall not be interrupted by the scheduling process (though possibly through an error condition or manual intervention). A SB can be executed again (in order to reach the required sensitivity level, or if it had failed for hardware reasons), but cannot be restarted in the middle of its execution.

Priority: 1

3.0–R3 The rating of all possible SBs shall be evaluated at the end of SB execution and the best rated SB shall be executed. That rating will depend on:

3.0–R3.1 Science rating
3.0–R3.2 source visibility, and remaining visibility time in current transit
3.0–R3.3 preferred LST
3.0–R3.4 UT (for ephemeris dependent projects)
3.0–R3.5 elapsed UT since previous execution (for monitoring projects, e.g. observe a given source about every week)
3.0–R3.6 system noise (including atmosphere) averaged over antennas, to define sensitivity
3.0–R3.7 synthesized beam size and ellipticity, and required resolution
3.0–R3.8 phase noise at observing frequency, to define calibration feasibility and dynamic range
3.0–R3.9 seeing parameter
3.0–R3.10 SB interdependency rules (see 3.0-R15)
3.0–R3.11 breakpoint reached or released
3.0–R3.12 total time limit, noise limit, SNR limit reached ?
3.0–R3.13 Programme execution status (started, approaching completion, currently on the telescope ...)
3.0–R3.14 SB execution time
3.0–R3.15 Preamble/postamble execution times
3.0–R3.16 Hardware availability and status (from quality control)
3.0–R3.17 Stringency factor: SBs requiring rare conditions should get a preference whenever these conditions do occur.

The scheduling algorithm must be tuned for optimum overall efficiency, and agreement with observatory policy, according to the distribution of program requirements and the weather statistics on the EVLA site. The ordering of programs according to scheduling probabilities should match that of science ratings, in each range of observing conditions.

Priority: 1

3.0–R4 Fully interactive observing shall be available (as a special case), using the whole array or a sub-array (when justified).

Priority: 1

3.0–R5 A manual mode shall be available to the staff (as a special case), for testing new observing procedures, by sending commands directly to the observing system, using the whole array or a sub-array

Priority: 0

3.0–R6 The time-contiguous execution of one or more SBs of a given program may be started by a special setup SB (or a preamble block), and ended by a final SB (or postamble block). These are needed to ensure proper execution (instrument setup, choice and flux measurements of phase and amplitude calibrators) and calibration (bandpass, phase, ...)

Priority: 1

3.0–R7 Pipeline results from the astronomical targets themselves (for instance, test point sources) can be used in computing scheduling block priorities.

Priority: 3

3.0–R8 It shall be possible to run the scheduler off-line using recorded historical weather data, or model atmospheric data, as input.

Priority: 1

3.0–R9 As SBs are scheduled, feedback to the observer (PI) shall be the following:

- **3.0–R9.1** An e-mail is sent to the PI when the first of his/her SBs gets for the first time into the top ~ 10 ranked ones, as an announcement of approaching execution (but not a guarantee, the weather being not easily predicted)
- **3.0–R9.2** An e-mail is sent to the PI when the first of his/her SBs is executed for the first time
- **3.0–R9.3** At this point, a Web page is created (password-protected) that will be updated at regular intervals (e.g. each SB, or $\sim$ 10min whichever the greatest). This includes the quick look image, quality check information from the quick look pipeline, and general execution status of the programme.
- **3.0–R9.4** An email is sent at the end of each session (either due to a change in scheduling or a breakpoint status).
- **3.0–R9.5** A final email is sent at the end of the project (when all the data are archived and available).

Priority: 1

2.4 Archiving

2.4.1 Introduction

4.1–R1 The archive enables astronomers and engineers to access and use data which has been obtained with EVLA, regardless of where the information physically resides. When requested, the archive shall let a user know the list of available data.

Priority: 0

4.1–R2 The archive contains the observational data and the technical and environmental data.

Priority: 1

2.4.2 Archive of Observational and Technical Data

4.2–R1 The archive shall include raw data, header information, calibration data, and images produced by the pipeline.

Priority: 1

- **4.2–R1.1** Not only scientific observations but also technical test observation and measurements shall be archived to allow the system check. By default, all data taken by the array is archived. *Priority: 1*
- **4.2–R1.2** The quick-look data is not stored in the final archive by default (see requirements for quick-look and scientific imaging pipelines). *Priority: 1*

4.2–R2 The archive shall also include:

- **4.2–R2.1** all user (observer) input including the scientific justification of the project
- **4.2–R2.2** high-level observing scripts as they have been used to obtain the data
- **4.2–R2.3** the low-level actual observation descriptors which are made by expanding the high-level observing scripts and (time-variable) instrumental/environmental parameters
- **4.2–R2.4** the pipeline or offline software versions and data reduction scripts
- **4.2–R2.5** dataquality information (e.g. noise level and dynamic range, based on pipeline results)
- **4.2–R2.6** whether the observational data is scientifically meaningful or not (This is to allow a user to eliminate test observation for technical purpose, e.g., out-of-focus astronomical observation, etc.)
- **4.2–R2.7** catalogs of line data or calibration sources, which are to be used in observations
- **4.2–R2.8** all measured environmental data
- **4.2–R2.9** the water vapor radiometric raw data (at $\sim 1s$ timescale)
- **4.2–R2.10** all monitored data

Priority: 1

4.2–R3 In case of irreversible on-line data corrections such as the atmospheric phase correction on time scales shorter than the integration time, the default action is to archive both the corrected and the uncorrected data.

Priority: 1

4.2–R4 A user or staff member may submit the results of off-line reduction and imaging for attachment to the archive. Other data products, such as the scientific paper resulting from the observations, or catalogs derived from the data, might also be attached to the archive at a later date. The submission process should have the function to make a link from submitted data to the original raw data or dataset for effective use of these data by archive users.

Priority: 2

4.2–R5 All information describing the observation should be accessable through the header.

Priority: 1

4.2–R6 The observational raw data shall be archived (in the accessible archive) as soon as practical after they are taken, and the results from the Science Pipeline shall be archived after it runs.

Priority: 1

4.2–R7 There may be several "shadow" archives which hold all or subsets of data, which shall enable users over the world to access the observational data efficiently

Priority: 1.

4.2–R8 The principal archives should be easily accessed by users from all EVLA partners and major collaborators

Priority: 2.

4.2–R9 There shall be a backup for the archive to protect the data from catastrophic failure and loss.

Priority: 1

4.2–R10 The data within each scan shall be identifiable by its goal (phase calibrator, target observation, pointing scan ...)

Priority: 1

4.2–R11 The archive shall provide, in the observation header, the appropriate links to all technical data available for the observation period. This link is in addition to the set of technical data that is provided in the header. reqpri1

4.2–R12 Images produced by the pipeline are stored in the archive when appropriate:

- **4.2–R12.1** For long integrations or large numbers of channels, the images are stored in the archive.
- **4.2–R12.2** For short integrations or small datasets, images shall be generated on-the-fly from the visibilities upon extraction from the archive.
- **4.2–R12.3** The break point between image storage and on-the-fly extraction shall be determined by the computing capability of the archive extraction pipeline, and may evolve with time.

Priority: 1

4.2–R13 Updates to the calibration must be transparently incorporated in the archive.

Priority: 1

- **4.2–R13.1** The archive should provide the most up-to-date calibration by default. (*Priority: 1*)
- **4.2–R13.2** The archive should contain all calibrations which are applicable. (*Priority: 1*)
- **4.2–R13.3** If recalibration by using better calibration algorithm and/or better calibration data is recommended by the EVLA, then the stored image will be recalibrated (*Priority: 1*)
- **4.2–R13.4** If recalibration is made by the EVLA, then the old calibrated image will be also stored in the archive system. (*Priority: 2*)

4.2–R14 The archive shall include all technical/environmental data measured by the EVLA system (including times when the array was not observing). Each item shall contain a time-stamp.

Priority: 1

4.2–R15 The archive shall store all high- and low-level scripts, not only of the Dynamic Scheduler but also of interactive observing or other manual operation, whether they are made during observation or not.

Priority: 1

4.2–R16 The archive shall include an electronic logbook to record the notes of the observer and/or telescope operator.

Priority: 1

2.4.3 User Interface

4.3–R1 The archive shall be accessed through a web-tool GUI, the **Archive Search Tool**, on the internet.

Priority: 1

4.3–R2 A CLI must be available to interrogate the archive from scripts.

Priority: 1

4.3–R3 The Archive Search Tool shall allow searching the observation database to see if observations have been previously done. It shall also be used as a front end to the **Data Extractor Tool**, which manages the data extraction and delivery.

Priority: 1

4.3–R4 The Archive Search Tool shall operate on supported platforms as designated by the project.

Priority: 1

4.3–R5 Comprehensive help facility shall be provided for the Archive Search Tool.

Priority: 2

- **4.3–R5.1** Interactive context-based help shall be provided in the GUI. (*Priority: 2*)
- **4.3–R5.2** An introductory cookbook, including examples, shall be provided to let a user know how to utilize database efficiently or how to do data mining by using the archive. (*Priority: 1*)

4.3–R6 The Archive Search Tool shall have two interfaces: one mainly for astronomical product production; one mainly for technician use.

Priority: 2

4.3–R7 The search criteria shall include all the information in the observation headers, including any information pointed to in sub-headers. Search criteria based on combination of search fields should be possible (e.g. time * bandwidth). They shall include (but not be limited to):

- **4.3–R7.1** Object name
- **4.3–R7.2** Position on the Sky (Equatorial, Galactic, Ecliptic coordinates)
- **4.3–R7.3** Hour angle
- **4.3–R7.4** Elevation
- **4.3–R7.5** Observation Date
- **4.3–R7.6** Integration Time
- **4.3–R7.7** Molecular transition
- **4.3–R7.8** Frequency
- **4.3–R7.9** Array Configuration
- **4.3–R7.10** Observation mode
- **4.3–R7.11** Whether observation is for target or calibration
- **4.3–R7.12** Angular resolution
- **4.3–R7.13** Spectral resolution
- **4.3–R7.14** Weather condition
- **4.3–R7.15** Name of Principal Investigator
- **4.3–R7.16** Project name
- **4.3–R7.17** Project number
- **4.3–R7.18** Title of the proposal
- **4.3–R7.19** Observing Programs (OPs)
- **4.3–R7.20** Scheduling Blocks (SBs)
- **4.3–R7.21** Telescope operator or Astronomer on Duty
- **4.3–R7.22** Reduction date
- **4.3–R7.23** Data quality (noise level or dynamic range).

- **4.3–R7.24** Other header info

Priority: 1

4.3–R8 Regular expressions including wild card and ranges shall be available in search.

Priority: 1

4.3–R9 The search criteria used for database search shall be shown with search results and shall be able to be modified. reqpri2

4.3–R10 For the Archive, the Data Extractor Tool shall receive the information from the Archive Search Tool to identify data, and return information such as:

- **4.3–R10.1** A raw data file, with averaging in time or frequency (*Priority: 1*)
- **4.3–R10.2** A reduced image (*Priority: 2*)
- **4.3–R10.3** Run the pipeline on raw data with optional input parameters (*Priority: 3*)

4.3–R11 A preview image (e.g. a small image cube) of the data found in the search shall be made available before actual data transfer.

Priority: 1.

- **4.3–R11.1** The preview image cube of the images and dirty beams shall be made either on-the-fly upon request or produced by the pipeline in advance (using the same criteria as for full images). (*Priority: 1*)
- **4.3–R11.2** If a user requests a preview image without specifying the frequency/velocity information in the line data search, the Data Extractor Tool shall provide a sensible default velocity integrated intensity map (e.g. 10 km/s for Galactic, 300 km/s for extragalactic, centered on the observer-specified rest frequency and tracking velocity, or the intensity-weighted velocity of the detected line emission from the pipeline). (*Priority: 1*)
- **4.3–R11.3** A simple image viewer for preview image shall be also provided. (*Priority: 2*)

4.3–R12 An archive user shall be able to browse all of the header information for requested data.

Priority: 1

4.3–R13 An archive user as well as the Dynamic Scheduler, shall be able to use calibration data immediately after the calibration observation.

Priority: 1

4.3–R14 The Archive Search Tool shall attach a persistent link info to external archives and catalogs (e.g. DSS image) of the corresponding sky area, and to published papers e.g., ADS if available, that used the relevant data, upon request.

Priority: 2

4.3–R15 The Data Extractor shall be able to accept (properly verified) web-based search and extraction requests.

Priority: 1

4.3–R16 The Data Extractor Tool shall be invoked from the Offline reduction package (cf. OL-3.8-R1 to R3 of the Offline Requirements document).

Priority: 1

4.3–R17 The archive user can select network transfer or the physical data delivery (disk/tape) for data retrieval. The Data Extractor Tool shall have upper limits in total data size for each of them, which shall be determined by the EVLA project by taking into account the network bandwidth and the I/O speed.

Priority: 1

4.3–R18 If an archive user requests a disk file transfer operation, then the Data Extractor Tool shall put data in a user-accessible directory. The user will be informed about the estimated transfer time. An email message can be requested at the end of the transfer.

Priority: 1

4.3–R19 In any EVLA supported data transfer method, the data shall be delivered to a user within the EVLA project defined maximum time.

Priority: 1

4.3–R20 The Archive Search Tool shall use login identification to secure access to proprietary data. All information in the archive catalog tables (header data) should be accessable to any qualified user.

Priority: 1

2.4.4 Relationship with the Virtual Observatory Projects

4.4–R1 The archive shall be designed to meet the requirements, if practical, for on-going virtual observatory projects so that the EVLA data can be used more efficiently.

Priority: 2

4.4–R2 Whatever the final shapes of virtual observatories become, the EVLA archive system shall be able to provide the basic elements:

- **4.4–R2.1** the archived image (*Priority: 1*)
- **4.4–R2.2** catalogues derived from the archive, if available (*Priority: 1*)
- **4.4–R2.3** image quality information for archived images (*Priority: 1*)
- **4.4–R2.4** data quality information for selected observations (*Priority: 1*)

4.4–R3 The interface shall be designed to meet the requirements for virtual observatories. This assumes that the EVLA project receives the requirement information early enough to meet the project's development plan.

Priority: 1

2.5 Pipeline Data Processing

2.5.1 Introduction

This section describes the requirements for the EVLA on-line data processing pipeline. Note that the following observing modes are not considered in the present version:

The following observing modes are not considered in the present version:

- — VLBI observations;
- — solar observations;
- — pulsar observations;

2.5.1.1 Pipeline Operations We distinguish three different groups of pipeline operations, the *Real-time Calibration Operations*, the *Quick Look Operations*, and the *Science Operations.* Each of these groups has different functions; they should include (but are not limited to):

Real-time Calibration Operations
The Real-time Calibration Operations are performed to process all operations that are necessary to avoid the system halting.

- ○ Atmospheric modelling
- ○ Astronomical Calibration
  - — reduce and archive astronomical calibrations, e.g.
    - – bandpass calibration
    - – flux-density scale
    - – polarization calibration
    - – antenna gain vs. elevation curves
    - – atmospheric calibration
  - — compute preliminary phase rms and preliminary phase and amplitude calibration
- ○ Telescope/Array Calibration
  - — reduce and archive telescope/array calibrations, e.g.
    - – pointing
    - – focus
    - – delay
  - — allow use of “plug-ins” tools to reduce e.g.
    - – baselines measurements
    - – pointing models
    - – holography

Quick Look Operations
The Quick-Look Operations are processing data in a fast and/or approximate way, in order to allow the EVLA staff and the PI to monitor the on-going observations.

- ○ Monitoring
  - — display subsets of the current properties of the observations and/or array
- ○ Quick data processing
  - — works on subsets [channel ranges] or pre-processed data [resampled or integrated]
  - — apply preliminary phase and amplitude calibration
  - — produce and display images (no or simplified deconvolution)

Science Operation
The Science Pipeline process the data and produce images to be archived.

- Calibration: process the data acquired during the observing session, e.g.
  - bandpass calibration
  - final phase and amplitude calibration
  - flux scale
- Imaging: process all data of the project; results are preliminary after completion of observing session, final after completion of project
  - produce tables of visibilities
  - produce and archive deconvolved images

2.5.1.2 Sources We use the following terms in this document:

- *Astronomical Source*: any astronomical object or position in the sky observed by the EVLA for astronomical purposes. This excludes arbitrary positions observed for calibrations (OFF positions, skydips, etc.).

- *Target Source*: astronomical source whose observation is the goal of the current project.

- *Calibration Source*: astronomical source observed for calibration purpose. It could be a a point-like source (quasar) or any source with known flux or structure (including planets) or spectral features (e.g. masers).

2.5.1.3 Calibration The term "calibration" refers to several types of operations that have to be performed. We distinguish three categories of calibrations:

- *The instrumental calibration*: pointing, focus, delay, baseline, etc. A fast feedback to the control software is required. In particular, there are critical calibrations (focus, pointing, delay) which must be executed successfully before telescope operations can resume – these are the most time-critical and have highest priority.

- *The calibrations that do not require a time interpolation*, as the atmospheric calibration, or the bandpass and instrumental polarization measurements: each time such an observation is acquired, a certain quantity can be immediately derived and stored, to be applied to all following observations, until a new calibration of that kind is observed.

- *The calibrations that require a time interpolation*, as e.g. the phase and amplitude calibration: a calibration curve has to be fitted using data taken over a range in time. This curve is then applied to target observations that were observed in between calibrations.

The first two categories are real-time calibration operations, as described in section 2.5.3.

The third category will be handled partly as Real-time Calibration Operations (for calculating quantitites like phase noise up to a certain point or as function of time, to assess the data quality and interact with the scheduler), partly as Quick Look Operations (for producing intermediate images), and partly as final Science Operations. It will probably be sufficient to include only the simple methods in the Real-time Calibration and Quick Look Operations, with more elaborate calibrations occurring in the Science Calibration Operations.

Finally, we consider in this document that all data are taken and calibrated in spectral line mode, the continuum measurements being only the average of observed spectra on a given bandwidth. Similarly, polarization data are not distinguished, but are included in all steps, the model that we consider being the processing of one or more Stokes parameter; primary beams are polarized.

2.5.2 General Requirements

5.2–R1 The Pipeline shall be able to process all data coming from the array in standard modes designated by the project. It must not constitute a bottle-neck in the data flow.

Priority: 1

- **5.2–R1.1** Some projects will require unusually high data rates or processing requirements. These may require processing outside of the EVLA system and should be flagged appropriately so they are not processed by the EVLA pipeline.
  Priority: 1

5.2–R2 The Pipeline shall be data-driven. All necessary parameters will be specified either by the PI/CoIs at proposal preparation stages (science data) or by the EVLA staff (telescope calibration).

Priority: 1

5.2–R3 The Science Pipeline shall operate through readable and comprehensible data reduction scripts.

Priority: 1

- **5.2–R3.1** These scripts may be automatically generated from templates, on the basis of the observing mode being used
  Priority: 2

5.2–R4 The Pipeline shall include automatic flagging of data, to bypass data which do not fulfill some given conditions (in terms, e.g., of weather conditions, antenna temperature, difference from a running mean or rms, level of interference, etc.) The data must nevertheless be archived, and the flagging must be reversible in an off-line data reduction system.

Priority: 1

5.2–R5 The Pipeline should output and archive a comprehensible summary of the operations performed with diagnostic information to allow checking of results and a record of the processing.

Priority: 1

5.2–R6 A manual, interactive mode of operations shall be available for debugging, technical developments, inspection by qualified EVLA staff. In this mode, both a Command Line Interface (CLI) and a Graphical User Interface (GUI) shall be available.

Priority: 1

5.2–R7 The Pipeline (especially the Science Calibration and Imaging Operations) shall also be runnable at the Regional Centers. Some of the actions described below are not relevant in that case, as the interactions with the dynamic scheduling and with the real-time control system.

Priority: 2

5.2–R8 Antenna-based determination of calibration quantities shall be the primary form of calibration.

Priority: 1

- **5.2–R8.1** Baseline-based calibration shall also be available.
  Priority: 1
- **5.2–R8.2** Provision must be taken to accomodate more elaborate calibration schemes, e.g. physical modelling of antenna phases.
  Priority: 3

2.5.3 Real-time Calibration Operations

5.3–R1 The Real-time Calibration Operations shall be activated after each calibration scan.

Priority: 1

5.3–R2 Whenever the results of the Real-time Calibration allow one to identify poorly behaving hardware, a status report will be logged at system level for maintenance purposes, and made available both to the operator and to the Dynamic Scheduler. Affected data will be flagged.

Priority: 2

2.5.3.1 Atmospheric Model

5.3.1–R1 Atmospheric modelling shall be available in the Pipeline. The model shall be able to predict the absorption, emission and pathlength on the line of sight through the atmosphere at all EVLA bands. The prediction will be based on measured data, including, but not limited to:

- **5.3.1–R1.1** measured atmospheric parameters at the site: temperature, pressure, humidity;
- **5.3.1–R1.2** measured atmospheric emission in the observed EVLA bands;
- **5.3.1–R1.3** measured WVR data;
- **5.3.1–R1.4** measured atmospheric profiles of temperature and water content if available from atmospheric sounders;
- **5.3.1–R1.5** measured optical depths from tipper meters and/or FTS, if available.

Priority: 1

5.3.1–R2 Atmospheric modelling shall be used to derive the system temperatures corrected for atmospheric absorption in all astronomical bands in use, in order to correct the observed amplitudes at various elevations.

Priority: 1

5.3.1–R3 Atmospheric modelling shall also be usable to provide the conversion factors between WVR data and the water contribution to the astronomical phase in all EVLA bands.

Priority: 1

2.5.3.2 Astronomical calibration: Interferometric Data

5.3.2–R1 The Pipeline shall reduce, and store the results for further use:

- **5.3.2–R1.1** the receiver sideband ratios;
  Priority: 1
- **5.3.2–R1.2** the temperature scale calibration data, using the Atmospheric Model; in real-time mode, the results must be made available for access by the dynamic scheduling system; they must also be made available to later operations to convert the raw data into temperature scale whenever required.
  Priority: 1
- **5.3.2–R1.3** the bandpass calibration data;
  Priority: 1
- **5.3.2–R1.4** the instrumental polarization.
  Priority: 1

5.3.2–R2 For suitable observations of a calibration source, the Pipeline shall perform operations that include:

- **5.3.2–R2.1** compute the phase rms over the observed time;
  Priority: 1

- **5.3.2–R2.2** compute the antenna efficiencies using the known source flux;
  Priority: 1
- **5.3.2–R2.3** do the previous operations both with and without applying the atmospheric phase correction, and deduce from the comparison whether the atmospheric phase correction improves the results or not; this may involve having performed several observations with different parameters for the atmospheric phase correction;
  Priority: 2
- **5.3.2–R2.4** derive amplitude and phase time-dependent variations by fitting smoothed curves (e.g. polynomials, splines) using all observations of calibrators since the beginning of the session; fast-swtiching observations shall be supported; this derivation shall be done either per antenna or per baseline or both.
  Priority: 2

In real-time mode, these results shall be made available to the dynamic scheduling system. They must also be made available to later Science Operations for gain transfer to target sources.

Priority: 1

2.5.3.3 Astronomical Calibration: Single Dish Data

Comments: STM: It is expected that the EVLA will work in concjunction with single-dish telescopes e.g. GBT. We may want to consider allowing pipeline operations of this sort.

5.3.3–R1 The Pipeline shall reduce the temperature scale calibration, using sideband ratios determined from the most recent interferometric calibration. In real-time mode, the results must be made available for access by the dynamic scheduling system; they must also be made available to later operations to convert the raw data into temperature scale whenever required.

Priority: 1

2.5.3.4 Telescope/Array Calibration

5.3.4–R1 The Pipeline must reduce:

- **5.3.4–R1.1** measurements of the pointing offsets;
  Priority: 1
- **5.3.4–R1.2** the focus measurements;
  Priority: 1
- **5.3.4–R1.3** the delay measurements.
  Priority: 1

The results must be archived. They must be made available to the real-time control system.

Priority: 1

5.3.4–R2 The Pipeline shall have access to additional tools, in order to:

- **5.3.4–R2.1** determine the antenna locations from the observations of several calibration sources;
  Priority: 1
- **5.3.4–R2.2** determine pointing models from the observations of calibration sources;
  Priority: 1
- **5.3.4–R2.3** determine focus corrections from the observations of calibration sources;
  Priority: 2
- **5.3.4–R2.4** reduce holography measurements;
  Priority: 1

- **5.3.4–R2.5** derive generic primary beam properties, including shape, polarization pattern, and half-power beam size and the main-beam efficiency from the observations of planets or point sources of known fluxes or small sources of known visibility model.
  Priority: 2

The results shall be made available to the real-time control system to update the instrument parameters.

5.3.4–R3 Single Dish data – The Pipeline must reduce:

- **5.3.4–R3.1** the pointing measurements;
  Priority: 1
- **5.3.4–R3.2** the focus measurements;
  Priority: 1
- **5.3.4–R3.3** the skydip measurements;
  Priority: 1
- **5.3.4–R3.4** the holography measurements.
  Priority: 3

The results must be archived. They must be made available to the real-time control system. Note however that in most cases these determinations will be done interferometrically.

2.5.4 Quick Look Operation

2.5.4.1 Monitoring

5.4.1–R1 Quick Look monitoring Operations shall be activated automatically after each occurrence of the Real-time Calibration Operations.

Priority: 1

5.4.1–R2 The results of Quick Look monitoring must be made available in summary form to PI/CoIs astronomers of the project, via the Internet.

Priority: 2

5.4.1–R3 A Monitoring Tool shall be available, plotting and archiving in a log file various real-time calibration results, including:

- **5.4.1–R3.1** the results of the last pointing or focus scan;
  Priority: 1
- **5.4.1–R3.2** the phase rms computed over the last scan and computed over the current session.
  Priority: 1
- **5.4.1–R3.3** the corresponding seeing.
  Priority: 1
- **5.4.1–R3.4** the atmospheric opacity.
  Priority: 1

This tool shall include a variety of options, to control the display parameters, to plot the variation of these results with time, to allow the staff astronomer and operator to monitor one antenna or baseline in particular, etc. Since it is required that the EVLA staff can efficiently check out the status of ongoing observations, all the plots by the monitoring tool should be reasonably simple, and the plot option should be able to quickly be changed by the staff astronomer/operator.

5.4.1–R4 Automatic checks shall be available to detect anomalous or erroneous results, triggering alarms if necessary.

Priority: 1

5.4.1–R5 The Pipeline shall be able to detect interference, e.g. due to communication satellites operating at ar near the observed frequencies, flag the data accordingly, and trigger alarms if necessary.

Priority: 3

5.4.1–R6 A Monitoring Tool shall be available to plot the current properties of the array, such as:

- **5.4.1–R6.1** the current instantaneous *uv* coverage;
  Priority: 2
- **5.4.1–R6.2** the corresponding weight distribution (natural weighting);
  Priority: 2
- **5.4.1–R6.3** the corresponding dirty beam;
  Priority: 2
- **5.4.1–R6.4** the previous quantities, integrated over the session;
  Priority: 2
- **5.4.1–R6.5** the thermal noise rms reached since the beginning of the observing session (from theory, using actual system temperatures);
  Priority: 2
- **5.4.1–R6.6** for mosaic observations: the above quantities for each pointing center.
  Priority: 2

2.5.4.2 Data processing

- **5.4.2–R1** Quick Look Data processing Operations shall be activated automatically under given conditions (e.g. after a certain time interval, after each scheduling block, if a rms has been reached, etc.). It must also be possible to start those operations whenever requested by the staff astronomer or operator.

  Priority: 1

- **5.4.2–R2** The results of Quick Look Data processing must be made available to PI/CoIs astronomers of the project, via the Internet (see requirement 4.0-R9).

  Priority: 2

2.5.4.3 Data processing: Interferometric Data

- **5.4.3–R1** The visibilities observed on a target source shall be calibrated, using the results of the Real-time Calibration Operations:
  - **5.4.3–R1.1** convert the raw data into flux density;
Priority: 1
  - **5.4.3–R1.2** apply the current bandpass calibration;
Priority: 1
  - **5.4.3–R1.3** apply the current amplitude and phase correction (using the scaling factor between the calibration and observing frequencies);
Priority: 1
  - **5.4.3–R1.4** apply the flux conversion factor based on standard antenna efficiencies.
Priority: 1
- **5.4.3–R2** The spectra observed on an astronomical target shall be displayed (amplitude and phase) with various options such as:
  - **5.4.3–R2.1** time integration;
Priority: 1
  - **5.4.3–R2.2** choice of the baseline(s);
Priority: 1
  - **5.4.3–R2.3** baselines summation, with and without shifting phases to a specified position;
Priority: 2
  - **5.4.3–R2.4** intensity (amplitude and/or phase) as function of baseline and time (for a frequency), or time and frequency (for a baseline);
Priority: 1
  - **5.4.3–R2.5** phase and amplitude closure for calibrators.
Priority: 1
- **5.4.3–R3** The Quick Look Pipeline shall compute the dirty image of astronomical targets, using the fastest algorithm possible. The resulting maps shall be displayed. The supported observing modes should include:
  - **5.4.3–R3.1** normal single-field synthesis;
Priority: 1
  - **5.4.3–R3.2** multiple sources observations ("snapshots");
Priority: 1
  - **5.4.3–R3.3** mosaicing;
Priority: 2
  - **5.4.3–R3.4** on-the-fly mosaicing;
Priority: 3

5.4.3–R4 The processing described in the previous requirement shall be done for:

- **5.4.3–R4.1** the continuum data;
  Priority: 1
- **5.4.3–R4.2** the line-averaged spectra, over a pre-defined velocity range, or possibly a velocity range defined by the staff astronomer or operator.
  Priority: 1

5.4.3–R5 The following calibration modes shall be supported:

- **5.4.3–R5.1** calibration transfer (including fast switching);
  Priority: 1
- **5.4.3–R5.2** self-calibration;
  Priority: 1
- **5.4.3–R5.3** frequency-switching;
  Priority: 2
- **5.4.3–R5.4** temperature calibration (e.g. the VLBA).
  Priority: 3

5.4.3–R6 For the observations of point-like, bright sources (e.g. quasars) the Pipeline shall include tools allowing fast data analysis in the *uv* and image planes, in order to check the data consistency.

Priority: 2

2.5.4.4 Data processing: Single Dish Data

Comments: STM: It is expected that the EVLA will work in concjunction with single-dish telescopes e.g. GBT. We may want to consider allowing pipeline operations of this sort.

5.4.4–R1 The current spectra observed on the astronomical target shall be corrected from the emission at a reference position or frequency. All EVLA modes (as designated by the project) shall be supported, including:

- **5.4.4–R1.1** position switching;
  Priority: 1
- **5.4.4–R1.2** frequency switch;
  Priority: 1
- **5.4.4–R1.3** raster maps using one of the above modes;
  Priority: 1
- **5.4.4–R1.4** OTF maps using one of the above modes.
  Priority: 1
- **5.4.4–R1.5** nutator switch;
  Priority: 2

5.4.4–R2 The spectra shall be displayed with various options, such as:

- **5.4.4–R2.1** time integration;
  Priority: 1
- **5.4.4–R2.2** antenna summation;
  Priority: 1
- **5.4.4–R2.3** baseline fit, excluding a window automatically determined, or pre-defined, or defined by the Operator or Staff Astronomer;
  Priority: 1
- **5.4.4–R2.4** spectra on a grid corresponding to actually observed positions on a raster (a “stamp” or “profile” plot).
  Priority: 1

Science Calibration Operations: REMOVE THIS SECTION?

5.4–R1 The Science Calibration Operations shall be activated after reaching a break point or at the end of an observing session).

Priority: 1

5.4–R2 The Pipeline shall use all data observed during the session.

Priority: 1

2.5.4.5 Interferometric Data

5.4.5–R1 The Pipeline shall use calibration sources to derive:

- **5.4.5–R1.1** the bandpass calibration;
  Priority: 1
- **5.4.5–R1.2** derive amplitude and phase time-dependent variations by fitting smoothed curves (e.g. polynomials, splines) using all observations of calibrators since the beginning of the session; fast-switching observations shall be supported.
  Priority: 1

5.4.5–R2 The Pipeline shall check and correct the flux scale by using observations of source of known fluxes. Any effect due to the source being resolved shall be taken into account.

Priority: 1

5.4.5–R3 The Pipeline shall calibrate the source observations by applying:

- **5.4.5–R3.1** the bandpass calibration;
  Priority: 1
- **5.4.5–R3.2** the phase calibration (using the appropriate scaling factor the calibration and observing frequencies);
  Priority: 1
- **5.4.5–R3.3** the amplitude calibration.
  Priority: 1

2.5.4.6 Single Dish Data

5.4.6–R1 The data taken on the astronomical target shall be reduced, depending on the observing mode. All EVLA modes (as designated by the project) shall be supported, including:

- **5.4.6–R1.1** position switch;
  Priority: 1
- **5.4.6–R1.2** nutator switch;
  Priority: 1
- **5.4.6–R1.3** frequency switch;
  Priority: 1
- **5.4.6–R1.4** raster maps using one of the above modes;
  Priority: 1
- **5.4.6–R1.5** OTF maps using one of the above modes.
  Priority: 1

5.4.6–R2 The resulting spectra shall be corrected for a baseline, fitted on all spectra channels but a window automatically determined, or pre-defined, or defined by the Operator or Staff Astronomer.

Priority: 1

5.4.6–R3 The Pipeline shall check and correct the flux scale, using observations of sources of known fluxes.

Priority: 1

2.5.5 Science Operations

5.5–R1 The Science Operations shall be activated after reaching a monitor break-point defined by the user in the Observing Tool (see Section 2.2.1) or at the project completion.

Priority: 1

5.5–R2 The Science Operations shall be routinely completed no later than 24 h (?) after the end of the data acquisistion. There may be special cases for certain observing modes which will take longer.

Priority: 1

5.5–R3 The manipulation of data cubes shall be the default mode of operation of the imaging processing. The final product will be the deconvolved images.

Priority: 1

5.5–R4 The Science Pipeline must process all data from all standard modes and attach a quality measure to the result

Priority: 1

5.5–R5 All the data previously obtained since the project has been started shall be available for processing. This includes data obtained in different array configurations, as well as total power data for measurements of zero and short-spacings.

Priority: 2

5.5–R6 The results of the Science Operations Imaging must be made available to PI/CoIs astronomers of the project, via consultation with the Archive Operations.

Priority: 2

5.5–R7 The Science Pipeline shall process all data from all standard modes to the highest level of quality, reprocessing older archive projects when necessary

Priority: 3

2.5.5.1 Interferometric Data

5.5.1–R1 The Pipeline shall use calibration sources to derive:

- **5.5.1–R1.1** the bandpass calibration;
  Priority: 1
- **5.5.1–R1.2** derive amplitude and phase time-dependent variations by fitting smoothed curves (e.g. polynomials, splines) using all observations of calibrators since the beginning of the session; fast-switching observations shall be supported.
  Priority: 1

5.5.1–R2 The Pipeline shall check and correct the flux scale by using observations of source of known fluxes. Any effect due to the source being resolved shall be taken into account.

Priority: 1

5.5.1–R3 The Pipeline shall calibrate the source observations by applying:

- **5.5.1–R3.1** the bandpass calibration;
  Priority: 1
- **5.5.1–R3.2** the phase calibration (using the appropriate scaling factor the calibration and observing frequencies);
  Priority: 1
- **5.5.1–R3.3** the amplitude calibration.
  Priority: 1

5.5.1–R4 The Pipeline shall find in the Archive the calibrated data obtained during all previous observing sessions, and check whether the data are compatible with the current dataset (in terms of instrument setup and properties, noise rms, etc.) If not compatible, the data shall not be used together, and the Pipeline shall process only the current dataset.

Priority: 2

5.5.1–R5 Careful cross checks of the flux scales between the data sets shall be performed. In case of inconsistancies, the quality measure shall be affacted.

Priority: 2

5.5.1–R6 Direct comparison of the redundant data (obtained simultaneously or not) shall also be performed. In case of inconsistencies, the quality measure shall be affected.

Priority: 2

5.5.1–R7 The Pipeline shall extract the visibilities with the appropriate frequency resolution, plus the pseudo-continuum measurement if required.

Priority: 1

5.5.1–R8 The Pipeline shall compute images for each (non-blanked, possibly user-specified) frequency channel, as well as for the continuum emission if required. This includes gridding the whole data set and computing the Fourier transform, using the most appropriate algorithm. Several weightings shall be available (including natural, uniform, robust).

Priority: 1

5.5.1–R9 The images shall be deconvolved using the most appropriate algorithm. The algorithms supported shall include:

- **5.5.1–R9.1** CLEAN and its various flavors;
  Priority: 1
- **5.5.1–R9.2** multi-resolution and multi-scale CLEAN;
  Priority: 2
- **5.5.1–R9.3** Maximum Entropy Method (MEM).
  Priority: 1

5.5.1–R10 In the case of a complicated imaging problem, it should be possible to have several algorithms running in parallel, the best (according to criteria TBD) image being eventually selected.

Priority: 3

5.5.1–R11 Designated observing modes shall be supported, including:

- **5.5.1–R11.1** normal single-field synthesis;
  Priority: 1
- **5.5.1–R11.2** multiple sources and/or multiple frequency setups observations (“snapshots”);
  Priority: 1
- **5.5.1–R11.3** mosaic observations;
  Priority: 1
- **5.5.1–R11.4** on-the-fly mosaics;
  Priority: 3
- **5.5.1–R11.5** wide-field imaging;
  Priority: 3
- **5.5.1–R11.6** combination of single dish and interferometer data.
  Priority: 2

5.5.1–R12 Self-calibration techniques shall also be available to calibrate and image the data.

Priority: 3

5.5.1–R13 Subtraction of continuum level from spectral data may be required. This can be done in both Fourier and image domain. In the case of *uv*-plane subtraction, flexible setting of the frequency channel ranges for the calculation of the continuum level should be available. It shall eventually be possible to make trial subtractions and select the best solution in an automated manner.

Priority: 3

2.5.5.2 Single Dish Data

5.5.2–R1 The data taken on the astronomical target shall be reduced, depending on the observing mode. All EVLA + Single Dish (e.g. GBT) modes (as designated by the project) shall be supported, including:

- **5.5.2–R1.1** position switching;
  Priority: 1
- **5.5.2–R1.2** nutator switching;
  Priority: 1
- **5.5.2–R1.3** frequency switching;
  Priority: 1
- **5.5.2–R1.4** raster maps using one of the above modes;
  Priority: 1
- **5.5.2–R1.5** OTF maps using one of the above modes.
  Priority: 1

5.5.2–R2 The resulting spectra shall be corrected for a baseline, fitted on all spectra channels but a window automatically determined, or pre-defined, or defined by the Operator or Staff Astronomer.

Priority: 1

5.5.2–R3 The Pipeline shall check and correct the flux scale, using observations of sources of known fluxes.

Priority: 1

5.5.2–R4 The Pipeline shall find in the Archive previous observations and calibration data, and check whether the data are compatible with the current dataset.

Priority: 2

5.5.2–R5 The Pipeline shall then grid the whole data set if the project requires imaging. Combination of data observed on diffrent rasters, possibly with different (regular or irregular) spacings shall be supported.

Priority: 1

5.5.2–R6 Provision shall be taken to allow running appropriate algorithms (deconvolution, destriping), if required by the data or by the experience gained using the EVLA.

Priority: 3

2.6 Operational Issues

2.6.1 Basic Operation Modes

6.1–R1 A **Technical Interface** shall be available for engineers for debugging and maintenance purposes.

Priority: 0

6.1–R2 In **Manual Mode** a subset of the antennas shall be directly controlled through a **Control Command Language**.

Priority: 0

6.1–R3 In **Interactive Mode** the array shall be directly controlled by the (guest or staff) astronomer through a GUI. This will be done under the responsibility and with the assistance of the Operator.

Priority: 1

6.1–R4 In **Dynamically Scheduled Mode** the array shall execute the highest priority observations (scheduling blocks) selected by the dynamic scheduler. This shall be the default mode of operation.

Priority: 1

6.1–R5 The same **Observing Modes** shall be available in Interactive Mode and Dynamically Scheduled Mode. They shall include:

- **6.1–R5.1** Interferometric
  - **6.1–R5.1.1** Single Field Mapping.
  - **6.1–R5.1.2** Multi Field Mosaics
  - **6.1–R5.1.3** On-The-Fly Mosaics
  - **6.1–R5.1.4** Phased Array
- **6.1–R5.2** Total Power (drop for EVLA)?
  - **6.1–R5.2.1** On the Fly Mapping
  - **6.1–R5.2.2** Position Switched Mapping
  - **6.1–R5.2.3** Frequency Switched Mapping
- **6.1–R5.3** Special observations
  - **6.1–R5.3.1** Pulsar observations
  - **6.1–R5.3.2** Solar flare tracking.
- **6.1–R5.4** Project Calibrations
  - **6.1–R5.4.1** Gain Calibration (amplitude and phase)
  - **6.1–R5.4.2** Bandpass calibration
  - **6.1–R5.4.3** Pointing/Focus calibration
  - **6.1–R5.4.4** Flux calibration
  - **6.1–R5.4.5** Polarization calibration
- **6.1–R5.5** Array Calibration
  - **6.1–R5.5.1** Pointing calibration session
  - **6.1–R5.5.2** Baseline calibration session
  - **6.1–R5.5.3** Delays calibration
  - **6.1–R5.5.4** Beam shape calibration
  - **6.1–R5.5.5** Holography

Priority: 1

6.1–R6 The same GUI (**Observing Tool**) shall be used in both interactive and dynamically scheduled modes to select the observing modes and parameters.

Priority: 1

6.1–R7 The antennas shall be divided into one or more **sub-arrays**, operated simultaneously and independently, each sub-array being in any of the above modes. However there should be only one program in the dynamically scheduled mode at any time (see 2.1R11).

Priority: 0

6.1–R8 The allocation of antennas to sub-arrays/sessions shall take into account the hardware constraints imposed by local oscillator control (EVLA number here), and by the correlator (EVLA number here).

Priority: 0

6.1–R9 For allocation of resources the maintenance and array calibration sessions shall have the highest priority in the scheduling, unless otherwise decided by the staff, e.g. to make the best possible use of exceptional observing conditions.

Priority: 1

6.1–R10 EVLA software shall support a phased array mode for VLBI, using all or a sub-array of antennas.

Priority: 1

6.1–R11 As a baseline plan there shall be only one dynamically scheduled research program at a time, using all available antennas while some antennas have been taken out by the staff as one or several interactively controlled subarrays, for calibration or research. Remaining antennas shall be made available to filler science programs, either through a functionality of the scheduler, or by manual action of the operator. The filler programmes must be able to release these antennas on short notice as soon as they are needed by the main (dynamically scheduled) research programme. This does allow special cases where a continuous subarray (for monitoring etc.) runs while normal science ops continue with a reduced number of antennas.

Priority: 1

2.6.2 Control Command Language

6.2–R1 The minimum amount of observing activity that can be obtained by issuing a single observing command (**observation**) is described by an **observation descriptor** (see appendix). These parameters fully describe the data taking activity during that observation, including telescope motion and switching schemes.

Priority: 0

6.2–R2 The Control Command Language shall include commands to actually control the hardware (antennas, LOs, correlators) for data taking, according to the observation descriptor.

Priority: 0

6.2–R3 During an observation each antenna shall move following a pattern relative to the source direction. That pattern shall be independently defined for each antenna and shall be:

- **6.2–R3.1** a fixed position
- **6.2–R3.2** an arc of circle on the celestial sphere (defined by a starting point, the center point, the angular velocity)
- **6.2–R3.3** a general curve interpolated between a set of points on the celestial sphere, and the corresponding times (*Priority: 2*).

Priority: 0

6.2–R4 During an observation other possible switching schemes may include:

- **6.2–R4.1** subreflector nutation (TBD),
- **6.2–R4.2** LO1 frequency switching,
- **6.2–R4.3** load or noise diode switching for calibration (TBD)

Priority: 2

6.2–R5 The Control Command Language shall include commands to convert astronomer's input observing parameters into observation descriptor parameters when this can only be done at the time of the observation. This includes:

- **6.2–R5.1** coordinate conversion to the antenna system,
- **6.2–R5.2** LO and IF filter setting according to frequency and Doppler tracking parameters (in the current baseline system design).

Priority: 0

6.2–R6 The Control Command Language shall include commands to access pipeline results or current environmental parameters in order to tune up observing parameters (integration times, loop cycles) in quasi real time, according to pre-defined formulae, when so requested.

Priority: 2

6.2–R7 The Control Command Language shall include commands to setup the pipeline for data reduction.

Priority: 1

6.2–R8 Features in the language built-in functionalities should include:

- **6.2–R8.1** macros for abbreviation of frequently typed sequences
- **6.2–R8.2** procedures to which parameters may be passed
- **6.2–R8.3** definition of variables and arrays, with numeric or character content
- **6.2–R8.4** evaluation of expressions, including built-in functions
- **6.2–R8.5** conditional execution facilities
- **6.2–R8.6** loops
- **6.2–R8.7** error recovery facilities including a time out

- **6.2–R8.8** interruption facility in procedure execution

Priority: 0

2.6.3 Data Collection and Data Rates

6.3–R1 Data taking shall be **blanked** (i.e. data from a correlator dump will not be integrated) on an antenna-based basis whenever:

- **6.3–R1.1** tracking errors are in excess of an observer specified value
- **6.3–R1.2** any LO in the data path is out of lock (base band based)
- **6.3–R1.3** the subreflector is out of position tolerance
- **6.3–R1.4** the receiver mechanical calibration system (e.g. vane) is out of position tolerance

The minimum amount of blanked data shall be:

- **6.3–R1.1** an integer multiple of the 16ms correlator dump time.
- **6.3–R1.2** smaller than (TBD) 5 percent fraction of the integration time (if this fraction is larger than 16ms). This means that for long integration times (tens of seconds), being able to blank a single correlator dump is not necessary.

Priority: 0

6.3–R2 It shall be possible to **flag** integration periods when the data is (or may be) affected in a way that could lead to wrong science. The flagging information shall identify, e.g. as boolean information, the origin of the malfunction. Conditions which shall cause flagging include at least:

- **6.3–R2.1** Antenna-based flags, integration based:
  - **6.3–R2.1.1** Last WVR calibration failed
  - **6.3–R2.1.2** Current WVR hardware defect
  - **6.3–R2.1.3** WVR currently degrades data (based on calibrator amplitude or phase)
  - **6.3–R2.1.4** Last pointing calibration failed (or no pointing calibration done)
  - **6.3–R2.1.5** Last temperature scale calibration failed (all data was blanked)
  - **6.3–R2.1.6** Temperature scale calibration system hardware defect
  - **6.3–R2.1.7** Last temperature scale calibration failed, Tsys is currently estimated and not measured (by baseband)
  - **6.3–R2.1.8** Shadowing: the antenna aperture is shadowed for any reason (the amount of shadowing shall be kept along with data, in addition to the flagging information).
  - **6.3–R2.1.9** Total power out of range (by baseband)
  - **6.3–R2.1.10** Integration partly blanked (including blanking condition identification): as a warning.
  - **6.3–R2.1.11** Integration totally blanked (including blanking condition identification): obviously quite severe.
  - **6.3–R2.1.12** Bad data (by baseband, reserved for use by pipeline)
- **6.3–R2.2** Baseline-based flags, observation based:
  - **6.3–R2.2.1** Correlator malfunction (baseband based) e.g.: Correlator chip failed last self-test; Excessive closure error last calibrator observation, ...

Parameters ranges leading to flagging shall be settable. Flagged integration periods can later be optionally used or discarded for further data reduction.

Priority: 0

6.3–R3 Data rates commensurate with the expected needs of the EVLA shall be supported by the system.

- **6.3–R3.1** (to be updated) The average data rate shall allow the recording of one million complex visibilities per second (1.0 MVPS) and one-half million image pixels per second (0.5 MPPS). These are the average over long periods of time and different programmes. These can be used to determine the archive size. The visibility data rate scales with the number of operational baselines. The image data rates scale rather like the longest baseline squared (and like the image area for mosaics). Both rates scale like the number of spectral channels actually recorded.
  Priority: 2
- **6.3–R3.2** The peak data rates are ten times higher than the average data rates.
  Priority: 2

6.3–R4 Each visibility shall be stored as two 16-bit scaled integers, with occasional need for higher precision. Switch to 32-bit scaled integers could be done automatically on each spectrum and baseline (for a spectrum normalized by its maximum channel, the number of bits should be at least $1/2 \log_2 B\tau$, where B is the channel bandwidth and τ the integration time). Alternately one may choose to always use 32-bit integers and rely on standard data compression techniques.

Priority: 0

6.3–R5 Visibility data that has been (radiometrically) corrected for atmospheric phase effects shall be available as well as the uncorrected data.

Priority: 0

- **6.3–R5.1** In the early phases of EVLA testing, both corrected and uncorrected data will be archived; (*Priority: 0*)
- **6.3–R5.2** When the EVLA is a mature instrument, it shall ideally automatically choose the best, on an antenna or perhaps baseline basis, based on heuristics learned over the course of testing. (*Priority: 1*)

Whether to archive corrected data, uncorrected, or both, or an automatic choice of the best will be a single observatory policy decision, in order to preserve the uniformity of the archive. For integration times shorter than the shortest atmospheric time scales, only corrected or uncorrected data shall be recorded, as the correction itself will be recorded too.

6.3–R6 The corrected and uncorrected visibility data shall be integrated over the same time periods. All baselines will be integrated over the same time periods.

Priority: 0

6.3–R7 The shorter integrations allowed by the hardware shall be supported (16ms for correlation, 1ms for autocorrelation only, 2ms for the continuum detectors).

Priority: 0

6.3–R8 The user shall be able to specify the number of spectral channels and integration time that is required in each spectral band to meet the science goals. Combined with the corrected/uncorrected selection, these choices will yield a data rate.

Priority: 1

6.3–R9 For each spectral band the average of all channels shall be kept with a shorter integration time ($<$ 1 sec.), whatever the integration time chosen for the spectral data, on the basis of mapping requirements. This allows a check for atmospheric phase fluctuations using the source continuum emission, if present. In this channel averaging band edges shall be taken into account. User-specified averaging regions (e.g. for celestial maser lines, or in order to avoid atmospheric lines) will be allowed.

Priority: 0

6.3–R10 The visibilities shall be stored as cross-correlation coefficients. At the data reduction stage they will have to be multiplied by stored system noise spectra to get $T_{\rm A}^*$ scale and by stored Jy/K values to get visibilities in Janskys. The relative channel weights will also be computed from the stored system noise spectra.

Priority: 0

Comments: STM: not applicable to EVLA?

2.6.4 Operator Interface

6.4–R1 The Operator Interface shall include a basic "current array status" display, including:

- — technical information such as current pointing position(s) in a variety of coordinate systems,
- — receiver status,
- — correlator configuration,
- — and live information on data acquisition (current observation, scan, scheduling block, project, etc.)

Priority: 0

6.4–R2 The Operator Interface shall include a weather display indicating the current site conditions, with warnings issued whenever the current conditions forbid outside activities by the local staff, or when hardware (antennas) must be safely docked.

Priority: 0

6.4–R3 The Operator interface shall include a video display from cameras at strategic locations on the site.

Priority: 0

6.4–R4 The Operator interface shall have a hierarchical structure with:

- **6.4–R4.1** a top level monitor to show integrated information, including the current observing plan, the array status, and telescope status.
- **6.4–R4.2** a second level to show important monitoring items for the current observations.
- **6.4–R4.3** a third level with on-demand monitoring.

Priority: 0

6.4–R5 The Operator Interface software shall be made available from any location where the Operator may work. It shall be available in a read-only mode from other locations, in order to support remote monitoring of the array system.

Priority: 1

A Observing Objects

In this Section we introduce the main entities, used to manage the whole observing process, that are constantly referred to in the Requirements. These entities have some kind of hierarchical structure that will be further refined at the analysis stage of software development.

Proposal:

An observer submits a proposal to perform a set of observations. This is done in the Phase I Proposal Preparation Phase. A proposal has uniquely associated with it:

- — A proposal identification code
- — A status (eg New, Being Observed, Partially Scheduled, Rejected, etc.)
- — A title
- — A list of requested frequency bands
- — A list of sources, explicit or generic (for large surveys)
- — A crude technical categorization (such as Detection/Mapping, Spectroscopie Line Survey, ...)
- — A crude scientific categorization (such as SolarSystem/Stars/Galaxies/Cosmology) in order to help reviewers
- — A first author
- — A contact person and contact information
- — A staff contact person
- — An author list
- — A scientific justification
- — A synoptic referee rating

It has associated with it an author list, a time request list, and an optional source list.

Although there certainly are groups of proposals (and the submission tool should have a box to list associated or previous proposals), it is proposed to take no formal cognizance of them.

Project:

When approving a proposal, the observing program committee creates a project. The project consists of the approved part of the proposal.

The project refers back to the proposal through the proposal identification code. It has associated with it additional information.

At the discretion of the Program Committee, the proposal may be split in several projects with different scientific ratings.

- — A project identification code
- — A list of requested bands (possibly subset of those in proposal)
- — A list of requested configurations (possibly subset of those in proposal)
- — A scientific rating assigned by the observing program committee.
- — An optional source list (subset of that in proposal if that exists)
- — A limitation of observing resources (reassessment of sensitivity level, maximum observing time).

Program:

Once a Project has been created, it has to be described by an observing Program in order to be scheduled. This is the reason for Phase II Program Preparation.

For the simplest proposals, Phase II may not require observer intervention, if all the necessary information has been entered at Phase I.

A Program is a set of Scheduling Blocks (SB) and Break Points (BP).

The program refers back to the proposal and project through the proposal and project identification codes.

The program includes at least one scheduling block and may include break points.

Break Point:

The observer may wish (or be required) to have break points in his program, to check on progress and be able to interact.

If so, he/she creates a breakpoint, which refers back to the proposal through program, project, and proposal identification codes. It has associated with it additional information.

- A breakpoint identification code
- A logical condition required for the scheduling of any SB of the programme. This condition is a logical expression based on the execution status of any scheduling block in the program. It must be "true" if no scheduling block has been executed. It must be "false" before all scheduling blocks have reached their goals.

Scheduling Block: (SB)

When the observer is notified that their project is approved for phase II, they make a set of scheduling blocks. The division into scheduling blocks is under the observer's control, but for standard observing modes, a template is provided, and observers warned that deviating from spirit of the templates may result in a reduced likelihood of being scheduled. The SB refers back to the proposal through the proposal, project, program, identification code. It has associated with it additional information.

- An observing script to be executed.
- A maximum single execution duration of the SB.
- A maximum total observing time to be spent using this SB.
- A main target direction, to be used by the scheduler to evaluate observing priority for the SB. All actual targets must lie within a limited area around this direction ($\sim$ 5 degrees, TBD).
- Required calibration operations (do we want this for EVLA?)
- The sensitivity goal to be reached by repeated executions to be checked using the nominal radiometry formula, expressed in $T_{\rm A}^*$ units
- The maximum water content required for scheduling. Normally defaulted from frequency.
- The maximum phase fluctuation (after phase correction) required for scheduling. Normally defaulted from technical characterization, frequency and requested angular resolution.
- Conditions on the array configuration.
- An optional, observer assigned logical condition to be satisfied before scheduling. This is used for dependencies between SBs.
- A maximum pointing error (systematic and random components) including wind speed
- An optional preferred LST range, and preference for rising sources, which may be used to increase the likelihood of contiguous UV tracks, over a system preference for high elevations.
- Status information, including at least:
  - The number of successful executions
  - The integration time, and theoretical rms for each execution
  - The total integration time, and current resulting theoretical rms
  - The total array time used so far
  - Whether the block goals are reached.

Each source in the SB should be checked to be either a member of the proposal source list or a calibrator.

Calibration operations have several possible functions. They may collect data for use in the data reduction phase:

- They may do a bandpass calibration on a strong calibrator.
- They may do a polarization leakage bootstrap if partial calibration or source polarization is known
- They may do a polarization orthogonal receiver phase difference determination

Observing Session:

The time contiguous execution of one or more scheduling blocks in a program constitutes an observing session.

Scan:

The scan is the lowest level object normally used by an observer. It is a sequence of one or more observations that share a single goal: for instance pointing and focus scans involve a pattern of observations.

Observation:

An Observation is the minimal amount of data taking that can be commanded at the script language level. It is highly desirable that it should be a simple enough element so that the script language may be used to define the content of scans (at the staff member/expert level), as a means to develop and debug new observing modes. Ideally a single generic command could execute any observation as described by the Observation Descriptor. The Observation Descriptor features:

- a simple driving pattern for each antenna,
- a simple driving pattern for nutating subreflector
- a simple driving pattern for the array phase center
- a single receiver band
- a single frequency or a simple frequency switching pattern
- a single correlator configuration

Integration:

An Integration is the basic written unit of data. It is the average of a set of Correlator Dumps.

Correlator Dump:

A Correlator Dump corresponds to the minimum available integration time output from the correlator backend. In the Project Book this is defined as 100ms for all products.

B Examples of Scheduling Blocks

Comments: STM: these are from ALMA. Is this useful here? If so, they need to be changed.

We give here a few examples of Scheduling Blocks, in order to provide a guide as to our thinking about how observing might be organized. These are not specifications.

- Strong source, low frequency, interferometry:
  - One minute point source calibrator scan
  - Nine minutes target scan
- Strong source, high frequency, interferometry:
  - Pointing scan
  - Focus scan
  - One minute point source calibrator scan
  - Nine minutes target scan
  - One minute point source calibrator scan
  - Nine minutes target scan
  - One minute point source calibrator scan
  - Nine minutes target scan
- Weak source, low frequency, interferometry:
  - Twenty seconds point source calibrator scan
  - Forty seconds target scan
- Weak source, high frequency, interferometry:
  - Pointing scan
  - Focus scan
  - Twenty cycles of
    - Twenty seconds point source calibrator scan
    - Forty seconds target scan
- Dual band, low frequency, interferometry:
  - Target, band 1, two minutes
  - Calibrator, band 1, 30 seconds
  - Calibrator, band 2, 20 seconds
  - Target, band 2, two minutes
- Accurate polarization:
  - Pointing scan
  - Focus scan
  - Leakage calibrator scan, 1 minute
  - Thirty cycles of
    - Point source calibrator 20 seconds
    - Target 40 seconds
- Mosaicing, interferometry:
  - Pointing scan
  - Focus scan
  - Up to 30 mosaic points at 30 seconds each
- Mosaicing, single dish, OTF:
  - Pointing scan
  - Focus scan
  - Off source point 1 minute
  - Scan 300 map points at 5s each
  - Off source point 1 minute
  - Scan 300 map points at 5s each