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EVLA e2e Software Science Requirements

Requirements

EVLA Software Science Requirements Committee:
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1 Introduction

Because of the increased capability of the EVLA, including 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. One necessary input to proceed in these developments is a set of scientific requirements on the software. This document defines these requirements for the part of the EVLA software which has been contracted to the Data Management division of NRAO (under the e2e project).

1.1 Overview of this document

The requirements herein are structured according to the EVLA contract with the Data Management Division of NRAO, which has 6 specific areas:

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 (separate document).

We have generated EVLA specific requirements in the first five of these areas in this document. The final area of data post-processing is dealt with in a separate document - *EVLA Offline Data Processing Science Requirements*. Requirements for EVLA software which is being completed by the EVLA project itself (not contracted to the DMD) are also considered in a separate document - *EVLA Project Software Science Requirements*. Requirements relevant to operating the EVLA are contained in yet another document - *EVLA Project Software Operations Requirements*.

We stress here that this is a living document, and subject to revision at any time by the EVLA SSR committee. The intent is to write down as much as we can at a given time regarding the requirements, but we must retain the ability to remedy oversights, or reflect changes in philosophy with respect to the software.

The prioritizing scheme is described at the top of Section 2. Where possible we have made the requirements quantitative, and clearly defined 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 those charged with evaluating and accepting the software to take these properly into account.

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 subsections 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.

The e2e project is described in much more detail in the *e2e project book*.

1.2 General description

Proposals will be submitted by prospective users of the EVLA for evaluation by a scheduling committee (with input from external referees). Proposals contain all information that is necessary for the scheduling committee to make a decision on awarding observing time, including sources to be observed (with characteristics), frequencies, configurations, etc..., and a scientific justification. It is envisioned that the preparation and submission of proposals is contained in a single software "Tool" - the Proposal Tool. This tool might also be used to manage the proposals for the observatory, but that is an operations decision which is beyond the scope of this document.

A Tool could be a stand-alone program or set of scripts, or might be an integrated part of a larger software package. This is a question of implementation and as such is beyond the scope of this document. We do require in many instances, however, that different Tools be able to "speak" to each other, i.e., can pass information back and forth. We also strongly recommend that if they are separate implementations that they at least have a common look-and-feel.

If awarded time by the scheduling committee, the observer must then provide more detailed information on how to go about observing the desired sources. The intent should be to make this process as simple as possible for inexperienced users (e.g., as simple as saying "I would like a map of Cygnus A at 8.5 GHz with $1''$ resolution and 1 μJy rms noise"), and yet should allow the experienced observer enough power and flexibility to command the telescope in any desired (but still sensible) way. It is envisioned that this task is handled by another Tool - the Observing Tool.

Both the Proposal Tool and the Observing Tool will include at least minimal models of the EVLA and the site in order to give guidance, e.g., on whether a proposed observation is possible, or whether a different method of observing will produce superior results. This will aid in the preparation of proposals and also in the creation of the program blocks (observation description). This can build on common software, as discussed above. Note that it might be possible to do more complex, and more realistic, simulations of EVLA observing using the Offline Data Processing Package, but this will not be discussed in this document further.

The Observing Tool creates a description of an observing program which is then sent to the Scheduling Tool. The Scheduling Tool is what actually tells the telescope what to go off and observe next. 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).

At this point in the information flow, we leave the regime which is under the e2e project, and control is passed over to the EVLA real-time software, described in a separate document. The instrument collects the requested data, and provides it at the backend, where control is handed back over to the e2e software. The dividing lines between the control in these two areas need much firmer definition, but that too is outside the scope of this document.

After data are collected and archived, they must be retrieved by the Archive Tool. All related observational and technical auxiliary data must be accessible to the observer through the archive. The Archive Tool is conceptually divided into two sections: the Archive Search Tool (which finds the data), and the Archive Retrieval Tool (which actually goes and gets it). The archive stores not only raw data, but also processed images and spectra, calibration data, and even pointers to outside references relevant to projects contained therein. In addition to having its own search tool, the archive allows access via queries from the National Virtual Observatory (or its moral equivalent).

At the same time as data are fed to the archive, they may also be fed to a data reduction pipeline

(conceptually, at any rate - whether the data are first fed into the archive and then immediately retrieved from the archive for input into the pipeline is a question of implementation). We envision the following types of operations which might be considered as 'pipeline' related: real- (or near-real) time calibrator analysis; production of quick-look images and/or spectra; production of default images and/or spectra for the archive; user-controlled production of images and/or spectra from data contained in the archive. The 3^{rd} and 4^{th} of these are really off-line processing operations, and so we defer most discussion of them to the document discussing that topic. The pipeline that produces the quick-look images and/or spectra must be able to take data as they are produced by the EVLA and flag, calibrate, map, deconvolve, etc... it to produce the final images and spectra. Because of this, the pipeline must have access to current calibration data including bandpass, polarization, flux density scale, phase and amplitude, antenna efficiency, etc..., and to other parameters like current atmospheric opacity. The pipeline then produces images and spectra which are made available to the operator(s) and to the observer(s). The calibration data necessary for not only the quick-look pipeline, but also for things like phasing the array, are obtained by the real- (or near-real) time calibrator analysis tool. This is a set of high level functions built around what in the current system is called ANTSOL.

The Tools described herein all interact with each other. For instance, we imagine a prospective observer invoking the Proposal Tool, and while creating the proposal, requesting a simulation of the observation (from within the Proposal Tool). To simulate the observation, the Observing Tool is invoked from the Proposal Tool to determine how to actually perform the observations. The data created by the simulation are fed to the Pipeline Tool, which reduces the data (e.g., makes a map and deconvolves it). The results are then available in the Proposal Tool. The observer then makes a query into the Archive Tool to see if this observation has already been done, and if so, may request the data, and feed them into the Pipeline Tool (although this last exercise may be considered part of the off-line data processing). Again, these can all be separate 'programs' (or the moral equivalent), but they need to be callable from each other, and it is extremely desirable that they have a common look-and-feel for any interactive access. They should also 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.

1.3 Some details

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, parameterized 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 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.

In writing this set of requirements, we have made a number of specific assumptions about how the EVLA is 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 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.

4. All user interaction with the EVLA shall be through **Graphical User Interfaces** (GUIs) with only a few exceptions (e.g., the ability to type Control Scripts directly into the real-time system when observing in manual mode).
5. The instrument shall be dynamically scheduled on timescales from near real time (a few minutes in advance of real time) to several hours in into the future, to take full advantage of the atmospheric conditions and of instrument availability. The scheduler will work from a queue of scheduling blocks with priorities. For interactive or manual mode, the observer will have control of the queue.
6. The EVLA final product shall be images for the large majority of projects. The data shall be calibrated and processed in pipelines.
7. Observing descriptions (Program Blocks, Schedule Blocks, and Control Scripts), raw data, monitor data, calibration data, and images will be archived; archived data shall be easily accessible to the users.
8. 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
9. Data processing pipelines will make available and display for the use of operations any system element performance measures they develop in the course of calibration.
10. It is expected that there will be close and frequent collaboration between the e2e programmers and the EVLA SSR committee members during software development (on a much shorter timescale than the 9 month formal development cycle for e2e).

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 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 Science Requirements*.

2.1 Proposal generation and submission

These requirements cover the preparation and submission of proposals for EVLA observing time, which are to be evaluated by the scheduling committee.

1.0–R1 There shall be a Proposal Tool for the preparation and submission of proposals for the EVLA.

Priority: 1 Timescale: A

1.0–R1.1 The Proposal Tool, Observing Tool, Scheduling Tool, Pipeline Tool, and Archive Tool shall be integrated into a common software package, or at least be able to be invoked from each other and pass data back and forth, and have a common look-and-feel for any interactive access.
Priority: 1 Timescale: C

1.0–R2 The proposals shall be submitted electronically and all observer input shall be in digital form.

Priority: 1 Timescale: A

1.0–R2.1 The scientific justification shall be provided in an easily printable format (e.g., Postscript, PDF), with figures incorporated (i.e., it is all in one file).
Priority: 1 Timescale: A

1.0–R3 Upon the first submission of a Proposal, the Proposal Tool (or the proposal handling system of EVLA operations) shall provide a unique Project Code for use by the observer for all correspondence, as well as further updates and tracking of the Proposal through the system.

Priority: 1 Timescale: A

1.0–R4 The Proposal 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–R4.1 This stored version shall be easily transferred (across platforms) between co-authors and collaborators.
Priority: 2 Timescale: C

1.0–R4.2 This stored version shall be easily editable with normal text editors (i.e., should be normal printable ASCII text).
Priority: 3 Timescale: D

1.0–R5 Proposals output from the tool shall be readable by the tool.

Priority: 1 Timescale: A

1.0–R6 The proposal submission tool should support source lists.

1.0–R6.1 The tool must encourage entry, for all sources, of all fields useful to decide scientific priority. These include:

1.0–R6.1.1 Coordinates;
1.0–R6.1.2 Common name;
1.0–R6.1.3 Continuum flux density;
1.0–R6.1.4 Angular size of largest structure;
1.0–R6.1.5 Required continuum rms (or, equivalently, required dynamic range);
1.0–R6.1.6 Requested VLA configurations;
1.0–R6.1.7 Requested observing frequencies.

Spectroscopic observations also include:

1.0–R6.1.8 Line identifications or frequencies;
1.0–R6.1.9 Requested frequency or velocity resolution;
1.0–R6.1.10 Requested frequency, velocity or redshift range;
1.0–R6.1.11 Requested rms in a spectral channel;

1.0–R6.1.12 Flux density at line peak.
Priority: 1 Timescale: A

1.0–R6.2 The submission tool shall supply a flexible interface for importing the above from another medium, e.g., as an imported file listing the above information.
Priority: 1 Timescale: A

1.0–R6.3 There shall be a mechanism for specification of source selection parameters in lieu of an enumerated source list, in order to facilitate the target definition for large surveys.
Priority: 2 Timescale: C

1.0–R6.4 The submission tool shall provide access to catalogs such that sources can be imported by common name, including at least 3C, 4C, NGC, Markarian, and UGC. Consistency between positions and names of type Bnnnn+nnn, Jnnnn+nnn, and Gnnn.n+n.n shall be enforced. Consistency between entered names, positions, and the above catalogs shall be enforced.
Priority: 2 Timescale: C

1.0–R6.5 The submission tool shall be able to calculate the position, distance, size, and flux density as a function of frequency of the Sun, Moon, major planets, satellites, and asteroids (all bodies $\gtrsim$200 km diameter), and be able to insert them into the source list. Note that at this point, extremely accurate positions are not needed - they are merely a guide to the scheduling committee.
Priority: 2 Timescale: C

1.0–R6.6 The submission tool should allow for entry of orbital elements (as a 6 element vector) for other solar system bodies, and from those orbital elements, calculate coordinates.
Priority: 3 Timescale: E

1.0–R6.7 A connection to commonly available astronomical databases (e.g., the CDS and NED databases) shall be available.
Priority: 3 Timescale: E

1.0–R7 The Proposal Tool shall perform certain calculations, including:

1.0–R7.1 the integration time required:

1.0–R7.1.1 for a given bandwidth and channel (e.g., velocity) width;
Priority: 1 Timescale: C

1.0–R7.1.2 under average environmental conditions;
Priority: 1 Timescale: C

1.0–R7.1.3 using real observing statistics;
Priority: 2 Timescale: D

1.0–R7.1.4 for the measured RFI enviroment;
Priority: 2 Timescale: D

1.0–R7.1.5 given sky coordinates, for low frequency (the Tool should know about the distribution of background temperature and confusing sources);
Priority: 3 Timescale: E

1.0–R7.2 the appropriate configuration needed given desired sensitivity, resolution, and source angular size.
Priority: 1 Timescale: C

1.0–R7.3 the amount of time required to achieve a specified rms level, given the stringency of required conditions (e.g., required phase stability at the specified frequency).
Priority: 2 Timescale: D

1.0–R8 The tool shall calculate the data rate and the total data volume for the project.

Priority: 1 Timescale: C

1.0–R9 The tool shall allow for the specification of preferred dates, or dates that should not be allowed (i.e., prioritization as a function of date).

Priority: 1 Timescale: C

1.0–R10 The tool shall react to user input by providing warnings based on the situation and selected observing mode, including:

1.0–R10.1 hardware limitations;
Priority: 1 Timescale: C

1.0–R10.2 data rate/volume;
Priority: 1 Timescale: C

1.0–R10.3 expected data quality;
Priority: 2 Timescale: D

1.0–R10.4 expected stringency limitations (e.g., weather, RFI, ionospheric conditions).
Priority: 2 Timescale: D

1.0–R11 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–R12 There shall be the facility to search a database of previous observations of objects for a proposal, with the results returned to the proposer, as well as being made accessible to the scheduling committee.

Priority: 2 Timescale: D

1.0–R12.1 The search results should be ordered by relevance.
Priority: 3 Timescale: D

1.0–R13 There should be a facility to choose (from a number of observatory approved) keywords which apply to the proposal.

Priority: 2 Timescale: D

2.2 Observation preparation

These requirements cover the preparation of Program Blocks (collections of Schedule Blocks) for submission to the Scheduling Tool by the observer using the Observing Tool.

It is envisioned that a Project consists of one or more sets of Program Blocks, which are in turn sets of Scheduling Blocks that are submitted as a group to the Scheduling Tool for scheduling purposes. For example, a Project might include Program Blocks in each of A and B configuration for a given target.

We note here that the Observing Tool is extremely important, in that it is the second point of contact for many observers (the first being the Proposal Tool), and the first one in which they interact in a more detailed way with the EVLA instrument. Because of this, it is very important that this tool be robust and easy to learn and use. We do not want to repeat the experience of OBSERVE and JOBSERVE.

2.2.1 The Observing Tool

2.1–R1 There shall be an Observing Tool for the generation of Program Blocks as input to the Scheduling Tool.

Priority: 1 Timescale: A

2.1–R1.1 The Proposal Tool, Observing Tool, Scheduling Tool, Pipeline Tool, and Archive Tool shall be integrated into a common software package, or at least be able to be invoked from each other and pass data back and forth, and have a common look-and-feel for any interactive access.
Priority: 1 Timescale: C

2.1–R2 The Observing Tool shall support and enforce (at least via the checking for validity of format) the use of the unique Project Code used to identify a given Project.

Priority: 1 Timescale: A

2.1–R3 The Observing Tool shall be able to read in the output from the Proposal Tool, and use the information therein to initialize parameters.

Priority: 1 Timescale: A

2.1–R4 The output of the Observing Tool shall consist of a Program Block, which is a set of Scheduling Blocks that are to be considered as an ensemble by the Scheduling Tool.

Priority: 1 Timescale: A

2.1–R4.1 The Program Blocks produced by the Observing Tool shall be human-readable (i.e., not binary).
Priority: 2 Timescale: C

2.1–R5 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–R5.1 This tool shall operate using a GUI;
Priority: 1 Timescale: A

2.1–R5.2 There shall be a batch or script mode for automated generation of Program Blocks;
Priority: 1 Timescale: C

2.1–R5.3 There shall be built-in help capability;
Priority: 1 Timescale: C

2.1–R5.4 The use of the Observing 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 using the tool on a timescale of roughly 1 working day of

dedicated use, and truly neophyte users (e.g., graduate students in other areas of astronomy) should reach proficiency with an investment not exceeding a few working days of dedicated use.
Priority: 2 Timescale: D

2.1–R6 Program Blocks output from the tool shall be readable by the tool.

Priority: 1 Timescale: A

2.1–R6.1 Program Blocks output from the tool shall contain the entirety of information needed by the Scheduling Tool (i.e., you can use a Program Block as a template for creation of a new Program Block, with minimal modification).
Priority: 3 Timescale: D

2.1–R7 The Observing Tool shall allow its state and intermediate output to be saved and restored at any time.

Priority: 1 Timescale: A

2.1–R7.1 Saved outputs shall (by default) be distinguished by name.
Priority: 2 Timescale: A

2.1–R7.2 Saved outputs shall be local.
Priority: 2 Timescale: C

2.1–R7.3 Saved outputs shall be easily editable with normal text editors (i.e., should be normal printable ASCII text).
Priority: 3 Timescale: D

2.1–R8 The Observing Tool shall include as components tools for:

2.1–R8.1 Observation setup;
Priority: 1 Timescale: A

2.1–R8.2 Hardware setup (including a Correlator setup subcomponent);
Priority: 1 Timescale: B

2.1–R8.3 Calibrator selection;
Priority: 1 Timescale: B

2.1–R8.4 Pipeline data reduction setup;
Priority: 2 Timescale: D

2.1–R8.5 Observation prediction;
Priority: 2 Timescale: D

2.1–R9 The Observation setup component shall:

2.1–R9.1 Allow the user to select from and manipulate source catalogs derived from:

2.1–R9.1.1 a built-in calibrator catalog;
Priority: 1 Timescale: A

2.1–R9.1.2 user-supplied source lists in ASCII format;
Priority: 1 Timescale: A

2.1–R9.1.3 the source list from the proposal;
Priority: 1 Timescale: A

2.1–R9.1.4 a list of solar system bodies;
Priority: 2 Timescale: C

2.1–R9.1.5 access to standard astronomical catalogs (CDS, NED).
Priority: 2 Timescale: C

2.1–R9.2 Allow the user to easily construct a *Source List* of coordinates and velocities. Note that the coordinates and velocities must be allowed to be functions of time, either as parameterized trajectories, or as tabulated values (to allow for moving sources). Specification of the Source List shall be possible based on:

2.1–R9.2.1 interactive selection from a catalog list;
Priority: 1 Timescale: A

2.1–R9.2.2 sequential extraction of targets from a list of sources (e.g., to conveniently schedule survey programs);
Priority: 1 Timescale: A

2.1–R9.2.3 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–R9.2.4 a built-in ephemeris calculator, for all solar system bodies $\gtrsim 200$ km in diameter (note that at this point, extremely accurate positions are not needed - they are merely a guide to choosing calibrators and for the Scheduling Tool);
Priority: 2 Timescale: C

2.1–R9.2.5 user input orbital elements (6 element vector) for other solar system bodies;
Priority: 3 Timescale: E

2.1–R9.2.6 user input solar longitude and latitude;
Priority: 3 Timescale: E

2.1–R9.2.7 on the basis of an image (e.g., from survey databases, or from the EVLA archive) one shall be able to define the area to be mapped interactively (e.g., with a mouse).
Priority: 3 Timescale: E

2.1–R9.3 Produce target source lists which are exportable, editable (easily with text editors, i.e., it is normal printable ASCII), and re-usable for further sessions;
Priority: 1 Timescale: C

2.1–R9.4 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–R9.5 Offer, for the selected standard observing mode, sensible defaults for all parameters deduced from the science goals, making these parameters unnecessary to manipulate for the general user.
Priority: 1 Timescale: C

2.1–R9.5.1 Should this be supported by the Scheduling Tool, the Observing Tool shall support the facility for some parameters (e.g., calibrators, loop cycle times, integration times) to be selected automatically at run-time by the Scheduling Tool depending on actual weather, phase fluctuations, and pipeline results.
Priority: 2 Timescale: E

2.1–R9.6 Allow integration times and cycle repeats to be set based upon a desired level of sensitivity under the requested stringency (e.g., atmospheric, ionospheric, RFI) conditions.
Priority: 2 Timescale: C

2.1–R9.6.1 Limits imposed by the scheduling committee, such as hard limit on the total project integration time, shall also be factored in (through a settable parameter).
Priority: 2 Timescale: D

2.1–R9.7 Provide a warning if "interfering sources" are near any target source over the date/time range of interest. Such sources are defined as: Sun, Moon, planets, strong sources at low frequency (Cas A, Cyg A, galactic plane, etc...), or others TBD. If desired, such warnings should be allowed to be turned into date/time constraints attached to the SBs in the PB.
Priority: 3 Timescale: E

2.1–R10 The Hardware setup component shall provide:

2.1–R10.1 The ability to specify the central observing frequency or velocity (in any of geocentric, LSR, or heliocentric velocity frames), or choose from a number of defaults based on band (for continuum) or known line transition.
Priority: 1 Timescale: B

2.1–R10.2 The ability to specify how the velocity (doppler) tracking is to be done (e.g., continuous, per scan, per session, etc...).
Priority: 1 Timescale: C

2.1–R10.3 The ability to specify multiple central observing frequencies, as allowed by the correlator and hardware (e.g., observing simultaneously in C- and Q-bands).
Priority: 2 Timescale: D

2.1–R10.4 Links to a standard provided line catalog (e.g., based on the JPL or Lovas line catalogs), in order to facilitate selection of less common line transition frequencies.
Priority: 2 Timescale: D

2.1–R10.5 The ability to specify the required polarization products.
Priority: 1 Timescale: B

2.1–R10.6 A Correlator setup subcomponent, which shall provide:

2.1–R10.6.1 The ability to choose a correlator setup from a menu based on actual hardware setup (e.g., number of channels, width in Hz);
Priority: 1 Timescale: B

2.1–R10.6.2 The ability to choose a correlator setup from a menu based on observational parameters (e.g., based on molecular transitions and velocity widths);
Priority: 2 Timescale: C

2.1–R10.6.3 The ability to specify desired total bandwidth or velocity width and channel width in frequency or velocity units (the tool should then display close available matches in correlator setup parameter space, and make them available for selection).
Priority: 2 Timescale: C

2.1–R10.6.4 Pre-configured setups (templates) shall be available for frequently observed transitions and standard continuum frequencies for each band;
Priority: 2 Timescale: C

2.1–R10.6.5 The ability to choose the correlator setup (in any of the ways described above) separately for each IF (so that, e.g., simultaneous wide- and narrow-band observations can be done);
Priority: 1 Timescale: C

2.1–R10.7 A warning if the combination of center frequency plus correlator setup causes known RFI to be observed.
Priority: 2 Timescale: D

2.1–R11 The Calibrator selection component shall provide:

2.1–R11.1 A built-in calibrator catalog;
Priority: 1 Timescale: A

2.1–R11.2 The ability to import calibrators from a user-supplied source list in ASCII format;
Priority: 1 Timescale: A

2.1–R11.3 The ability to directly input calibrators;
Priority: 1 Timescale: A

2.1–R11.4 The ability to select the following types of calibrators, based on source location, frequency, and array configuration:

2.1–R11.4.1 primary and secondary flux density scale calibrator(s);
Priority: 1 Timescale: A

2.1–R11.4.2 reference pointing calibrator(s);
Priority: 1 Timescale: A

2.1–R11.4.3 bandpass calibrator(s);
Priority: 1 Timescale: A

2.1–R11.4.4 polarization calibrator(s).
Priority: 1 Timescale: A

2.1–R11.5 The ability to display, and then interactively select nearby sources to be used for tracking time variable complex gain, based on source location, frequency, and array configuration.
Priority: 1 Timescale: A

2.1–R11.6 The ability to have the software automatically select any of the above calibrators, based on source location, frequency, and array configuration, in combination with a set of selection

heuristics (to be provided by NRAO staff).
Priority: 2 Timescale: C

2.1–R11.7 The ability to do any of the above as a function of date, attaching the appropriate date range to the calibrator (for moving target sources).
Priority: 2 Timescale: C

2.1–R12 The Pipeline data reduction setup component shall provide:

2.1–R12.1 The ability to specify the desired spatial extent of the final image cube.
Priority: 1 Timescale: D

2.1–R12.2 The ability to specify the desired frequency or velocity selection, averaging, smoothing, etc..., of the final image cube.
Priority: 1 Timescale: D

2.1–R12.3 The ability to specify the desired u-v tapering and weighting (e.g., robustness parameter) for creation of the final image cube.
Priority: 1 Timescale: D

2.1–R12.4 A mechanism for the observer to convey intent to the pipeline, including the following information:

2.1–R12.4.1 How calibrators are to be used (see Requirement 2.1–R11.4);
2.1–R12.4.2 Level of flagging (e.g., light, medium, heavy);
2.1–R12.4.3 Preferred deconvolution algorithm and associated parameters;
2.1–R12.4.4 Preferred mosaicing algorithm and associated parameters;
2.1–R12.4.5 Any other necessary pipeline control parameters.
Priority: 2 Timescale: D

2.1–R12.5 A mechanism for the observer to select from a number of pre-defined heuristics for pipeline data reduction, for common observing modes (e.g., flag; set flux density scale; compute time variable complex gain from calibrator; compute bandpass calibration from calibrator; apply calibrations to target source; decimate in frequency; loop: image, deconvolve, self-calibrate). The specific heuristics are TBD.
Priority: 2 Timescale: D

2.1–R12.6 A mechanism for the software to impose constraints on the observer's specification of all of the above items.
Priority: 1 Timescale: D

2.1–R12.7 Estimates for the Pipeline to evaluate 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, for instance:

2.1–R12.7.1 after observing session;
Priority: 2 Timescale: D

2.1–R12.7.2 at the end of program execution;
Priority: 2 Timescale: D

2.1–R12.7.3 when certain sensitivity levels are reached.
Priority: 3 Timescale: E

2.1–R12.8 The ability to specify all of the above quantities separately for both the default archive image pipeline, and the quick-look pipeline.
Priority: 2 Timescale: D

2.1–R12.9 The ability to specify times at which the Quick-look Pipeline Tool should be run during execution, e.g., at the end of each SB.
Priority: 2 Timescale: D

2.1–R12.10 The ability to specify pulsar dispersion measure.
Priority: 2 Timescale: E

2.1–R13 The Observation prediction component shall be able to:

2.1–R13.1 estimate S/N;
Priority: 2 Timescale: D

2.1–R13.2 estimate synthesized beam size;
Priority: 2 Timescale: D

2.1–R13.3 estimate surface brighness sensitivity;
Priority: 2 Timescale: D

2.1–R13.4 produce dirty beams;
Priority: 3 Timescale: D

2.1–R13.5 effect its calculations on execution timescales on the order of 10 seconds or less, and should not require significant computational resources;
Priority: 3 Timescale: D

2.1–R13.6 for suitable source models, simulate maps with the desired array configurations;
Priority: 3 Timescale: E

2.1–R13.7 provide simulated spectra based on physical models and given observing parameters.
Priority: 3 Timescale: E

Note: The observation prediction component of the Observing Tool would preferably use common software to the prediction components of the Proposal Tool (see above) to ensure consistency.

2.1–R14 The Observing Tool will support specification of science goals (e.g., in the form of source lists from the proposal - see Requirement 1.0–R6) in lieu of detailed specification of total time, integration times, configurations, etc...

Priority: 2 Timescale: D

2.1–R15 The Observing Tool shall have a "check" function, in which it presents expected sensitivities on all target sources, as well as verifying correlator modes, LO setups, etc.

Priority: 2 Timescale: D

2.1–R16 The Observing Tool shall be cognizant of the Project and Program parameters as allocated by the scheduling committee, and will, unless requested otherwise, apply those limits to the time being scheduled.

Priority: 3 Timescale: D

2.2.2 Generation of Program Blocks

2.2–R1 The Observing Tool shall divide a Program Block into Scheduling Blocks based upon parameters chosen:

2.2–R1.1 by 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 The observer shall be able to assign Scheduling Blocks a relative priority, to ensure the proper order of execution.

Priority: 1 Timescale: C

2.2–R2.1 There shall be the facility to support contingent priority (see below), such that the priorities of subsequently queued blocks are adjusted based upon the results of execution of previous blocks, e.g., the time since execution of a previous block to ensure the desired time spacing of monitoring observations.
Priority: 2 Timescale: D

2.2–R3 The proposer shall be able to specify what is needed for real-time checking of data quality, including:

2.2–R3.1 choosing a standard calibrator as a *test source* to be observed to assess the conditions for stringency;
Priority: 3 Timescale: D

2.2–R3.2 option for the system to automatically choose the test source at execution time.
Priority: 3 Timescale: E

2.3 Observation scheduling

These requirements refer to the scheduling of programs for actual observation (i.e., using the Scheduling Tool), with the actual Scheduling Blocks that form a given Program Block being provided by the Observing Tool (see Section 2.2.2).

It is envisioned that the Scheduling Tool is a software program (or equivalent), accessed only by the operator and NRAO staff.

2.3.1 The Scheduling Tool

3.1–R1 There shall be a Scheduling Tool Scheduling Tool whose function is to pass a Control Script to the EVLA real-time system to control the telescope.

Priority: 1 Timescale: B

3.1–R1.1 The Proposal Tool, Observing Tool, Scheduling Tool, Pipeline Tool, and Archive Tool shall be integrated into a common software package, or at least be able to be invoked from each other and pass data back and forth, and have a common look-and-feel for any interactive access. Note that it is not required that observers be given access to the Scheduling Tool, but operators and NRAO staff must have access to it.
Priority: 1 Timescale: C

3.1–R2 The input to the Scheduling Tool shall consist of Program Blocks (PB), each of which is a set of Scheduling Blocks (SB) from the same Program.

3.1–R2.1 The execution of an SB shall not be interrupted by the scheduling process (except possibly through an error condition or manual intervention).
Priority: 1 Timescale: B

3.1–R2.2 An 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 Timescale: B

3.1–R3 The Scheduling Tool shall handle the observing for the EVLA in the main modes:

3.1–R3.1 Manual mode: a facility shall be provided for direct submission of Control Scripts to the real-time system, either from a file, or directly from keyboard input.
Priority: 1 Timescale: B

3.1–R3.2 Normal mode: normal EVLA observing shall be dynamically scheduled in quasi-real time based upon the queue of SBs.
Priority: 1 Timescale: C

3.1–R3.3 Interactive mode: a facility shall be provided for the normal dynamic queue to be suspended, and control passed over to an observer (e.g., overriding priorities in the main queue, or through use of an auxiliary queue) so that the observer can submit a PB or SBs for immediate observing.
Priority: 1 Timescale: C

3.1–R4 The Scheduling Tool should display in a window the current status of the queue, including the SB currently being observed, the next few scheduled SBs, and SBs currently under consideration with high priority.

Priority: 1 Timescale: C

3.1–R5 The Scheduling Tool shall have a facility enabling the operator or NRAO staff to abort the current SB, interrupt the normal operation of the queue, and enter interactive or manual mode.

Priority: 1 Timescale: C

3.1–R6 The Scheduling Tool shall have a facility enabling the operator or NRAO staff to modify the priorities of SBs in the queue.

Priority: 1 Timescale: C

3.1–R7 The Scheduling Tool shall be able to run off-line using recorded historical inputs or simulated inputs, to facilitate debugging and tuning of parameters.

Priority: 1 Timescale: B

3.1–R8 The objective of dynamic scheduling shall be to produce the highest scientific output per unit time. Because of uncertainties in future weather and the possibility of transient phenomena that might occur, an absolute solution for this is not possible. A heuristic approach is required.

3.1–R8.1 Algorithms and heuristics shall be clearly documented.
Priority: 1 Timescale: C

3.1–R8.2 Parameters and weights involved in the heuristics shall be documented, and easily adjustable.
Priority: 1 Timescale: C

3.1–R9 The Scheduling Tool shall check submitted Scheduling Blocks for correctness, to prevent malformed SBs from being executed.

Priority: 1 Timescale: C

3.1–R10 For observations of moving sources, the Scheduling Tool must insert appropriate calibrators into the Control Script (lists with dates are provided in the SB), and must calculate accurate target source position and velocity trajectories based on:

3.1–R10.1 an internal ephemeris calculator (for all solar system bodies $\gtrsim$200 km diameter - note that this must be a very accurate ephemeris);
Priority: 1 Timescale: C

3.1–R10.2 provided orbital elements;
Priority: 1 Timescale: C

3.1–R10.3 provided tabulated positions and velocities as a function of time (e.g., output from the JPL horizons system);
Priority: 1 Timescale: C

3.1–R10.4 provided solar longitude and latitude;
Priority: 3 Timescale: E

3.1–R11 As SBs are scheduled, feedback to the observers (PIs) shall be the following:

3.1–R11.1 A Scheduler web page is maintained which lists priority ranked programs;
Priority: 1 Timescale: C

3.1–R11.2 An email is sent to the PI when the first of his/her SBs is executed for the first time;
Priority: 1 Timescale: C

3.1–R11.3 A final email is sent at the end of the program (when all the data are archived and available).
Priority: 2 Timescale: C

3.1–R11.4 A Project Web page is created (with password or other access protection) which gives the current status of the Project.
Priority: 2 Timescale: D

3.1–R11.5 An email is sent to the PI when the first of his/her SBs gets for the first time into the top $\sim$ 10 ranked ones, as an announcement of approaching execution (but not a guarantee, the weather being not easily predicted);
Priority: 2 Timescale: D

3.1–R11.6 The Project web page is updated at regular intervals (e.g., each SB, or $\sim$ 10min whichever is longest). This includes the quick look image, quality check information from the quick look pipeline, and general execution status of the program;
Priority: 3 Timescale: D

2.3.2 Scheduling Operations

3.2–R1 The order of execution of Scheduling Blocks from the queue shall be on the basis of an assigned dynamic priority.

Priority: 1 Timescale: B

3.2–R1.1 The decision for the next SB to execute shall be made shortly before the end of the scheduling block currently in execution.
Priority: 1 Timescale: C

3.2–R2 The dynamic priority of a given SBs shall be calculated at the decision time based upon the criteria:

3.2–R2.1 Availablity of the SB for scheduling. An SB will not be scheduled (dynamic priority set to zero) if its principal direction is below the horizon (or if some other staff-entered LST constraint is not met), if the phase stability (atmospheric and possibly ionospheric) is too bad for the band being observed, if the opacity is too high for the band being observed, or if solar or radio interference would compromise observations with the observing parameters being used;
Priority: 1 Timescale: B

3.2–R2.2 Scientific Value (see below);
Priority: 1 Timescale: B

3.2–R2.3 Relative Priorities assigned by the observer using the Observing Tool;
Priority: 1 Timescale: C

3.2–R2.4 Environmental Priority Modifiers based upon current conditions;
Priority: 1 Timescale: C

3.2–R2.5 Contingent Priorities (see below);
Priority: 2 Timescale: D

3.2–R2.6 Operational Priorities (see below);
Priority: 2 Timescale: D

3.2–R3 The following criteria will be used in evaluating the Scientific Value of an SB:

3.2–R3.1 Science rating as determined by the scheduling committee and the referees;
Priority: 1 Timescale: B

3.2–R3.2 Proximity to a preferred date or LST (e.g., for emulation of fixed-time scheduling for placing observations near observations made with another instrument, or hitting a particular phase of a variable object);
Priority: 1 Timescale: C

3.2–R3.3 Suitability of the phase of a periodic phenomenon (for instance the phase of a close binary star, or the orbital phase of a planetary satellite);
Priority: 2 Timescale: C

3.2–R3.4 The contribution of the execution of the scheduling block to the program. (That is, the contribution to the sensitivity, taking into account the system temperature at the current elevation, atmospheric opacity and/or ionospheric conditions, current or past RFI environment, and the number of available antennas, is to be considered, not just the time.);
Priority: 3 Timescale: D

3.2–R4 There can also be Contingent Priorites, which are modifiers arising at decision time based upon the results of the execution of other SBs from the same Program Block. These might include:

3.2–R4.1 Elapsed time since previous execution (for monitoring variable objects at a regular rate);
Priority: 2 Timescale: D

3.2–R4.2 Hour Angle or Parallactic Angle spacing since previous execution (for improving uv or parallactic angle coverage);
Priority: 2 Timescale: D

3.2–R5 Environmental Priority Modifiers include:

3.2–R5.1 Local weather conditions (temperature, dew point, wind speed);
Priority: 1 Timescale: C

3.2–R5.2 Current atmospheric conditions (opacity and phase rms at the observing frequencies used in the SB - note that this assumes the availability of this information in the Scheduling Tool, which may require auxiliary instruments such as an atmospheric phase monitor or a tipper meter, the data from which must be treated appropriately [e.g., raw output from the phase monitor is turned into phases vs. time which are then used to derive the rms phase at the frequency of the phase monitor, which is then used to derive the rms phase at the observing frequency; or raw output from the tipper is turned into atmospheric temperatures vs. elevation which are then used to derive opacity at the tipper meter frequency which is then used to derive the opacity at the observing frequency]);
Priority: 1 Timescale: C

3.2–R5.3 Current ionospheric conditions (phase rms at the observing frequencies used in the SB - this may require processing of raw data from GPS receivers or other auxiliary devices to derive the phase rms);
Priority: 1 Timescale: C

3.2–R5.4 Current RFI conditions at the observing frequency (or frequencies), if known.
Priority: 1 Timescale: C

3.2–R5.5 Stringency factor: SBs requiring rare conditions may be preferred when those conditions occur.
Priority: 2 Timescale: D

3.2–R5.6 Weather predictions.
Priority: 3 Timescale: D

3.2–R6 Depending upon the algorithm chosen for implementation of the system, the following heuristics may also be appropriate to consider for Operational Priorities:

3.2–R6.1 The status of the Program as a whole (preference should be given to finishing a Program Block once it is started);
Priority: 2 Timescale: D

3.2–R6.2 The status of the Project as a whole (preference should be given, for example, to getting a small amount of D configuration time to provide short spacings for a project that already has a large amount of B configuration time).
Priority: 2 Timescale: D

3.2–R7 Special calibration observations may be required at the beginning and/or end of execution of one or more SBs, which we denote as preamble and postamble blocks. These are particular versions of Control Scripts. The Scheduling Tool must account for these when determining priority, e.g., if a particular SB requires long preamble and postamble blocks, that should be factored into the required time to complete the SB, modifying its priority.

Priority: 2 Timescale: D

3.2–R8 Pipeline results from the astronomical targets themselves (for instance, test point sources) can be used in computing scheduling block priorities.

Priority: 3 Timescale: D

2.4 Archiving

2.4.1 Archive Definition

4.1–R1 There shall be an EVLA archive which stores all data obtained with the EVLA. This archive shall include:

- **4.1–R1.1** interferometer data taken for any reason (science, testing, calibration);
  Priority: 1 Timescale: A
- **4.1–R1.2** environmental data (e.g., weather data, WVR, APM, GPS);
  Priority: 1 Timescale: A
- **4.1–R1.3** monitor and control data;
  Priority: 1 Timescale: C
- **4.1–R1.4** data products (e.g., calibrated data and images from the pipeline);
  Priority: 1 Timescale: D
- **4.1–R1.5** project data (e.g., proposal, schedules, papers, links).
  Priority: 2 Timescale: D

4.1–R2 There shall be an Archive Tool capable of accessing (including searching and retrieving) the information in the archive.

Priority: 1 Timescale: C

- **4.1–R2.1** The Proposal Tool, Observing Tool, Scheduling Tool, Pipeline Tool, and Archive Tool shall be integrated into a common software package, or at least be able to be invoked from each other and pass data back and forth, and have a common look-and-feel for any interactive access.
  Priority: 1 Timescale: C

4.1–R3 There shall be a backup for the archive to protect the data from catastrophic failure and loss.

Priority: 1 Timescale: C

4.1–R4 The archive shall enable 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: 1 Timescale: D

4.1–R5 The data shall be archived and made accessible (with access control) as soon as practical after they are taken or produced.

Priority: 2 Timescale: C

4.1–R6 The principal archive(s) should be easily accessed by users from all EVLA partners and major collaborators.

Priority: 2 Timescale: D

4.1–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: 3 Timescale: C

2.4.2 Raw Data

4.2–R1 The raw data in the archive shall include:

- **4.2–R1.1** raw interferometer data;
  Priority: 1 Timescale: A
- **4.2–R1.2** header information;
  Priority: 1 Timescale: A

4.2–R1.3 calibration data, including WVR data (at $\sim$ 1s intervals).
Priority: 1 Timescale: C

4.2–R2 In the presence of irreversible on-line data corrections such as RFI excision on time scales shorter than the integration time, the archive must be able to store and recognize both the corrected and uncorrected data.

Priority: 1 Timescale: C

4.2–R3 All information describing the observation shall be accessible through the header (or an equivalent object).

Priority: 1 Timescale: C

4.2–R4 Each scan within the data shall be identifiable by its goal (phase calibrator, target observation, pointing scan ...).

Priority: 1 Timescale: D

4.2–R5 There shall be a mechanism to identify whether the observational data is scientifically meaningful or not (this is to allow a user to eliminate test observations for technical purpose, e.g., out-of-focus astronomical observation, etc.);

Priority: 2 Timescale: D

2.4.3 Environmental Data

4.3–R1 The environmental data in the archive shall include:

4.3–R1.1 all measured weather data (e.g., temperature, relative humidity, wind speed and direction, barometric pressure);
Priority: 1 Timescale: A

4.3–R1.2 any available atmospheric electron content data (from GPS, e.g.);
Priority: 2 Timescale: C

4.3–R1.3 any available RFI monitoring data;
Priority: 2 Timescale: C

4.3–R1.4 other atmospheric sounding data, if available (e.g., Atmospheric Phase Monitor, tipping radiometer, FTS);
Priority: 3 Timescale: D

4.3–R2 Each item shall contain a time-stamp that is referenced to the data time stamps (i.e., not off by some large arbitrary offset due to internal clock slews within modules).

Priority: 1 Timescale: C

4.3–R3 All archived environmental data shall be indexed by time, to facilitate the linking of this data with appropriate observation periods.

Priority: 2 Timescale: D

2.4.4 Monitor and Control Data

4.4–R1 Monitor and control data stored in the archive shall include:

4.4–R1.1 instrumental parameters (pointing model parameters, referenced pointing offsets, antenna locations, transmission delays, subreflector rotation, focus curve parameters, etc...).
Priority: 1 Timescale: C

4.4–R1.2 status of instrumentation (e.g., error flags);
Priority: 2 Timescale: D

4.4–R1.3 monitor point information (e.g., module temperatures, voltages).
Priority: 3 Timescale: D

4.4–R2 The archive shall include all technical/environmental data measured by the EVLA system including times when the array was not observing.

Priority: 1 Timescale: C

4.4–R3 Each item shall contain a time-stamp that is referenced to the data time stamps (i.e., not off by some large arbitrary offset due to internal clock slews within modules).

Priority: 1 Timescale: C

4.4–R4 All archived technical data shall be indexed by time, to facilitate the linking of this data with appropriate observation periods.

Priority: 2 Timescale: D

2.4.5 Data Products

4.5–R1 Data products stored in the archive shall include:

4.5–R1.1 calibrated data (or the ability to generate on-the-fly), with the most up-to-date calibration;
Priority: 1 Timescale: D

4.5–R1.2 images/image cubes (or the ability to generate on-the-fly);
Priority: 1 Timescale: D

4.5–R1.3 the pipeline or offline software versions and data reduction scripts;
Priority: 2 Timescale: D

4.5–R1.4 data quality information (e.g., noise level and dynamic range, based on pipeline results);
Priority: 2 Timescale: D

4.5–R1.5 history of flux density determinations of calibration sources;
Priority: 2 Timescale: D

4.5–R1.6 catalog information (e.g., flux density, spectral index, source size) extracted from images or data;
Priority: 3 Timescale: D

4.5–R2 Submission of products to the archive shall be controlled.

4.5–R2.1 the Pipeline and Calibrator Analysis Tools shall have access to the archive to deposit resulting calibration information (possibly the fully calibrated data, or information on how to obtain it) and images;
Priority: 1 Timescale: D

4.5–R2.2 an EVLA staff member may submit the results of off-line reduction and imaging for inclusion in the archive (e.g., in cases where there was fault in the pipeline reduction);
Priority: 2 Timescale: D

4.5–R2.3 an observer or archive user, who has been granted authorization, may submit the results of off-line reduction and imaging for inclusion in the archive;
Priority: 3 Timescale: D

4.5–R2.4 the pipeline, staff, or authorized users shall be able to deposit catalog information extracted from data into the archive.
Priority: 3 Timescale: D

4.5–R3 The submission process shall provide a link between the submitted data and the original raw data.

Priority: 1 Timescale: D

4.5–R4 Images produced by the pipeline are stored in the archive when appropriate:

4.5–R4.1 For long integrations or large numbers of channels, the images are stored in the archive.
Priority: 1 Timescale: D

4.5–R4.2 For short integrations or small datasets, images shall be generated on-the-fly from the visibilities upon extraction from the archive.
Priority: 2 Timescale: D

4.5–R4.3 The decision 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: 3 Timescale: D

Priority: 1 Timescale: C

4.5–R5 Updates to the calibration must be transparently incorporated in the archive.

4.5–R5.1 The archive should contain all calibrations which are applicable.
Priority: 1 Timescale: D

4.5–R5.2 The archive should support different versions of the same image, made with differing calibrations, imaging parameters, deconvolutions, or software.
Priority: 2 Timescale: D

4.5–R5.3 If recalibration by using better calibration algorithm and/or better calibration data is recommended by the EVLA, then the stored image will be recomputed based on the new calibration.
Priority: 2 Timescale: D

4.5–R6 Quick-look data products are not stored in the final archive by default (see pipeline requirements).

Priority: 3 Timescale: D

2.4.6 Project Data

4.6–R1 Project data stored in the archive shall include:

4.6–R1.1 all user (observer) input including the scientific justification of the project (i.e., the proposal);
Priority: 2 Timescale: D

4.6–R1.2 the Program Block as submitted to the Scheduling Tool, and the resulting Control Scripts submitted by the Scheduling Tool to the real-time system, and any Scheduling Blocks or Control Scripts submitted during interactive or manual observing mode;
Priority: 2 Timescale: D

4.6–R2 Submission of Project data to the archive shall be controlled.

4.6–R2.1 an EVLA staff member may submit data to the archive as needed;
Priority: 2 Timescale: D

4.6–R2.2 an observer or archive user, who has been granted authorization, may submit data for inclusion in the archive;
Priority: 3 Timescale: D

4.6–R3 The submission process shall provide a link between the submitted data and the original raw data.

Priority: 2 Timescale: D

4.6–R4 The archive shall include any relevant maintenance forms, e.g., detailing problems with receivers during observation.

Priority: 2 Timescale: D

4.6–R5 The archive shall include an electronic logbook to record the notes of the observer and/or telescope operator.

Priority: 3 Timescale: D

4.6–R6 The archive shall have the ability to attach a persistent link to external archives and catalogs (e.g., DSS image) of the corresponding sky area.

Priority: 3 Timescale: E

4.6–R7 The archive shall have the ability to attach references and/or links to published papers (e.g., via ADS) that used the data.

Priority: 3 Timescale: E

2.4.7 Archive Search Tool

4.7–R1 There shall be an Archive Search Tool to access the archive.

Priority: 1 Timescale: B

4.7–R1.1 The Archive Search Tool shall be operated through a web-based GUI.
Priority: 2 Timescale: B

4.7–R1.2 The Archive Search Tool shall have a CLI to interrogate the archive from scripts or other Tools.
Priority: 2 Timescale: B

4.7–R1.3 The Archive Search Tool shall serve as a front end to the Archive Retrieval Tool, which manages the data extraction and delivery.
Priority: 2 Timescale: C

4.7–R2 The Archive Search Tool shall operate on supported platforms as designated by the project.

Priority: 2 Timescale: B

4.7–R2.1 The appearance and operation of the Archive Search Tool shall be platform independent.
Priority: 3 Timescale: D

4.7–R3 There shall be a variety of help and documentation facilities available from the UI and on the Internet for the Archive Search Tool. These shall include:

4.7–R3.1 An up-to-date and complete Reference Manual for the Archive Search Tool functions, operation, and installation.
Priority: 2 Timescale: B

4.7–R3.2 An introductory cookbook, including examples, designed to let a novice user, possibly without extensive knowledge of radio astronomy, know how to utilize the database efficiently and how to do data mining by using the archive.
Priority: 2 Timescale: C

4.7–R3.3 Interactive context-based help provided in the GUI.
Priority: 3 Timescale: E

4.7–R4 The Archive Search Tool interfaces shall present a look-and-feel suitable for the differing needs of types of archive users. These should include:

4.7–R4.1 a technical interface aimed at EVLA staff users of the archive, and for Archive Tool development and debugging;
Priority: 2 Timescale: D

4.7–R4.2 a user-friendly but comprehensive interface aimed at EVLA observers and archive users with knowedge of radio astronomy;
Priority: 2 Timescale: E

4.7–R4.3 a user-friendly interface aimed at novice users or astronomers outside the expert radio astronomy community (e.g., casual browsers, NVO users);
Priority: 3 Timescale: E

4.7–R5 The search criteria shall include all the information in the observation headers, including any information pointed to in sub-headers. They shall include (but not be limited to):

4.7–R5.1 Object name;
4.7–R5.2 Position on the Sky (Equatorial, Galactic, Ecliptic coordinates);
4.7–R5.3 Hour angle;
4.7–R5.4 Elevation;
4.7–R5.5 Observation Date;
4.7–R5.6 Integration Time;
4.7–R5.7 Molecular transition;
4.7–R5.8 Frequency;
4.7–R5.9 Array Configuration;
4.7–R5.10 Observation mode;
4.7–R5.11 Whether observation is for target or calibration;
4.7–R5.12 Whether the object is a moving source or not;
4.7–R5.13 Angular resolution;
4.7–R5.14 Spectral resolution;
4.7–R5.15 Weather condition;
4.7–R5.16 Name of Principal Investigator;
4.7–R5.17 Project name;
4.7–R5.18 Project number;
4.7–R5.19 Title of the proposal;
4.7–R5.20 Observing Program;
4.7–R5.21 Program Blocks;
4.7–R5.22 Scheduling Blocks;
4.7–R5.23 Control Scripts;
4.7–R5.24 Telescope operator or duty astronomer;
4.7–R5.25 Reduction date;
4.7–R5.26 Data quality (noise level or dynamic range);
4.7–R5.27 A list of observatory supplied keywords;
4.7–R5.28 Other header info.

Priority: 1 Timescale: C

4.7–R6 The Archive Search Tool shall allow searching the observation database to see if observations for particular targets have been previously done.

Priority: 2 Timescale: D

4.7–R7 Regular expressions including wild card and ranges shall be available in search.

Priority: 2 Timescale: D

4.7–R8 The search criteria used for database search shall be shown with search results and shall be able to be modified.

Priority: 2 Timescale: E

4.7–R9 The Archive Search Tool shall allow search criteria based on a combination of search fields (e.g., the product of time and bandwidth).

Priority: 3 Timescale: D

4.7–R10 An archive user shall be able to browse all of the header information for requested data.

Priority: 2 Timescale: C

2.4.8 Archive Retrieval Tool

4.8–R1 There shall be an Archive Retrieval Tool to access the archive.

Priority: 1 Timescale: A

4.8–R1.1 The Archive Retrieval Tool shall have a CLI to access the archive from scripts or other Tools.
Priority: 1 Timescale: A

4.8–R1.2 The Archive Retrieval Tool shall be operated through a web-based GUI (possibly the same one as the Archive Search Tool).
Priority: 1 Timescale: A

4.8–R1.3 The Archive Retrieval Tool shall be accessible from the Archive Search Tool.
Priority: 2 Timescale: C

4.8–R1.4 The Archive Retrieval Tool shall be able to accept (properly verified) web-based search and extraction requests.
Priority: 2 Timescale: D

4.8–R1.5 The Archive Retrieval Tool shall be accessible from the Offline Data Processing Package.
Priority: 3 Timescale: D

4.8–R2 The Archive Retrieval Tool shall receive the parameters for the retrieval from the calling interface or Tool, and in response, assuming the user has authorization, shall return the requested information such as:

4.8–R2.1 a raw uv data file;
Priority: 1 Timescale: A

4.8–R2.2 header information;
Priority: 1 Timescale: A

4.8–R2.3 environmental data;
Priority: 1 Timescale: A

4.8–R2.4 calibration data.
Priority: 1 Timescale: C

4.8–R2.5 monitor and control data;
Priority: 1 Timescale: C

4.8–R2.6 a calibrated uv data file;
Priority: 1 Timescale: D

4.8–R2.7 an image;
Priority: 1 Timescale: D

4.8–R2.8 other data products;
Priority: 2 Timescale: D

4.8–R2.9 project data;
Priority: 2 Timescale: D

4.8–R2.10 a raw data file, with averaging in time or frequency;
Priority: 3 Timescale: D

4.8–R2.11 Run the pipeline on raw data with optional input parameters;
Priority: 3 Timescale: E

4.8–R3 The archive user can select network transfer or physical data delivery (disk/tape) for data retrieval. The Archive Retrieval 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: 2 Timescale: D

4.8–R4 If an archive user requests a disk file transfer operation, then the Archive Retrieval 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: 2 Timescale: D

4.8–R5 In any EVLA supported data transfer method, the data shall be delivered to a user within the EVLA project defined maximum time.

Priority: 2 Timescale: D

4.8–R6 At user request, 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: 2 Timescale: B

4.8–R6.1 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: 2 Timescale: B

4.8–R6.2 If a user requests a preview image without specifying the frequency/velocity information in the line data search, the Archive Retrieval Tool shall provide a sensible default velocity integrated intensity image (e.g., 10 km/s for Galactic, 300 km/s for extragalactic, centered on the observer-specified rest frequency and tracking velocity).
Priority: 2 Timescale: D

4.8–R6.3 A simple image viewer for the preview image shall be also provided.
Priority: 2 Timescale: D

2.4.9 Relationship with the Virtual Observatory projects

4.9–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 Timescale: D

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

4.9–R2.1 the archived image
Priority: 2 Timescale: D

4.9–R2.2 image quality information for archived images
Priority: 2 Timescale: D

4.9–R2.3 data quality information for selected observations
Priority: 2 Timescale: D

4.9–R2.4 catalogues derived from the archive, if available
Priority: 3 Timescale: E

4.9–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: 2 Timescale: D

2.4.10 Proprietary requirements

Whether data is public or proprietary will usually be decided on the basis of the associated proposal, with rare exceptions based on the project or on the proposal group.

4.10–R1 Astronomical data may be public or proprietary.

4.10–R1.1 Technical data and header information shall be freely available;
Priority: 1 Timescale: A

4.10–R1.2 Calibration observations and staff test observations shall be public;
Priority: 1 Timescale: C

4.10–R1.3 Access to proprietary data shall be restricted to authorized users;
Priority: 1 Timescale: C

4.10–R1.4 Image data, and other data products, will be proprietary if the data from which the image is made is proprietary.
Priority: 1 Timescale: D

4.10–R1.5 Astronomical calibration observations, as well as the calibration pipeline output, can be extracted from the midst of otherwise proprietary data.
Priority: 2 Timescale: D

4.10–R2 The enforcement of access control to proprietary data will be consistent with EVLA policy.

Priority: 1 Timescale: C

4.10–R2.1 Proprietary data will considered to be owned by the associated proposal. A mechanism shall be provided to designate the authors of that proposal as authorized users of that data.
Priority: 1 Timescale: C

4.10–R2.2 The EVLA staff shall have the capability of marking data associated with any given proposal or project as public.
Priority: 1 Timescale: C

4.10–R2.3 The EVLA staff shall have the capability of making proprietary data accessible to a designated user other than the owner.
Priority: 2 Timescale: C

4.10–R2.4 The data associated with a given proposal will (usually) be made public on the basis of the expiration of a proprietary interval after the latest observation done on the basis of the proposal. The archive software must recognize and enforce this interval.
Priority: 2 Timescale: D

4.10–R3 The Archive Retrieval Tool will maintain a record of data extracted.

Priority: 3 Timescale: D

4.10–R4 For data younger than a "data notification age", the Archive Retrieval Tool will send an email to the last known address of the contact person of the associated proposal, informing them of the data being extracted and including the comment solicited above.

Priority: 3 Timescale: D

2.5 Pipeline data processing

Most of the Pipeline data processing is done by the off-line processing package - what is contained herein describes only those things that could be considered 'pipeline-ish' which are in the on-line system: real-(or near-real) time calibrator analysis; and production of quick-look images and/or spectra. We present a single requirement for the Default Archive Image Pipeline which impacts the on-line system.

The real-time calibrator analysis is a set of higher level functions built around an algorithm capable of returning antenna-based complex gains given observed visibilities and a source model (what is in the current on-line system called ANTSOL, or in AIPS called CALIB), with some additional capabilities not tied to that specific algorithm.

We envision the quick-look pipeline as a subset of the full-blown off-line processing package pipeline which can execute quickly and return first-cut images and/or spectra to the operator(s) and observer(s).

2.5.1 Real-time Calibrator Analysis

The real-time calibrator analysis is a set of higher level functions built around an algorithm capable of returning antenna-based complex gains given observed visibilities and a source model (what is in the current on-line system called ANTSOL, or in AIPS called CALIB), with some additional capabilities not tied to that specific algorithm.

5.1–R1 The Real-time Calibrator Analysis Tool shall be activated after each calibration scan, except during autophasing, where it must be able to run during scans.

Priority: 1 Timescale: C

5.1–R1.1 It should be possible to also specify shorter or longer intervals between activations, e.g., execute at the end of every integration, rather than just at the scan end, or, do not execute at the end of every scan, but rather only at the end of some number or grouping of scans.
Priority: 2 Timescale: D

5.1–R2 The Real-time Calibrator Analysis Tool shall determine the autophasing phase for each antenna, IF, and sub-band, and make it available to the real-time observing system.

Priority: 1 Timescale: C

5.1–R2.1 It shall be possible to select either on-the-fly autophasing (with appropriate simple source model input), which is done on each integration, or to specify that phases determined during calibrator scans are to be used to phase the array during scans on the astronomical source.
Priority: 1 Timescale: C

5.1–R2.1.1 For phases determined on the calibrator and applied to the astronomical source, simple extrapolation schemes should be available, including but not limited to: last sampled value, or mean of last N sampled values.
Priority: 3 Timescale: E

5.1–R3 The Real-time Calibrator Analysis Tool shall have the capability of taking visibility data along with a source model for a calibrator and deriving antenna-based complex gains therefrom.

Priority: 1 Timescale: C

5.1–R3.1 There should be a capability of specifying simple u-v restrictions on the input visibilities (e.g., boxes or circles in the u-v plane).
Priority: 1 Timescale: C

5.1–R3.2 There should be a capability of specifying the following simple parametric source models:

5.1–R3.2.1 point source (flux density, position, spectral index);
Priority: 1 Timescale: C

5.1–R3.2.2 elliptical gaussian (flux density, position, major and minor axis width and position angle, spectral index);
Priority: 3 Timescale: D

5.1–R3.2.3 elliptical limb-darkened disk (flux density, position, major and minor axis width and position angle, limb-darkening parameter, spectral index);
Priority: 3 Timescale: D

5.1–R3.2.4 combinations of the above simple single sources.
Priority: 3 Timescale: D

5.1–R3.3 There should be a capability of specifying more complex source models, via input as a FITS image cube or set of CLEAN components as a function of frequency (or other, relatively simple and easily manipulated, image-plane description).
Priority: 2 Timescale: D

5.1–R4 The Real-time Calibrator Analysis Tool should have the capability of determining the current phase stability of the instrument + atmosphere, given the visibilities and complex gain solutions. This quantity should be accessible by the Scheduling Tool.

Priority: 2 Timescale: D

5.1–R5 The Real-time Calibrator Analysis Tool should have the ability to recognize bad data (via some auto-flagging procedure, or by analyzing residuals from its own gain solutions) and reject them. This includes RFI recognition. Such data and flagging must be reported to operations.

Priority: 2 Timescale: D

5.1–R6 The Real-time Calibrator Analysis Tool should have the capability to recognize misbehaving antennas based on its results, and should be able to report this information to the real-time system and to operations.

Priority: 2 Timescale: D

5.1–R7 The Real-time Calibrator Analysis Tool should support the following higher level functions:

5.1–R7.1 antenna location determination;
Priority: 1 Timescale: D

5.1–R7.1.1 residuals from the solutions shall be examined, and poor solutions reported to operations staff.
Priority: 2 Timescale: D

5.1–R7.2 global pointing model determination, per antenna;
Priority: 1 Timescale: D

5.1–R7.2.1 residuals from the solutions shall be examined, and poor solutions reported to operations staff.
Priority: 2 Timescale: D

5.1–R7.3 pointing offset determination, per antenna and frequency band;
Priority: 1 Timescale: D

5.1–R7.3.1 arbitrary 'pointing patterns' (e.g., 5-point, triangles, the 'Craig cross', etc...) shall be specifiable as an ordered table of offsets and dwell times;
Priority: 2 Timescale: D

5.1–R7.3.2 residuals from the solutions shall be examined, and poor solutions reported to operations staff.
Priority: 2 Timescale: D

5.1–R7.3.3 single-dish pointing determination should also be supported;
Priority: 3 Timescale: D

5.1–R7.4 complex bandpass, per antenna, given frequency band, correlator and backend setup;
Priority: 1 Timescale: D

5.1–R7.5 focus, per antenna and frequency band;
Priority: 1 Timescale: D

5.1–R7.5.1 arbitrary 'focus patterns' shall be specifiable either parametrically (i.e., arbitrary center point, number of points, delta focus between points, dwell time per point), or as an ordered table of focus positions and dwell times.
Priority: 2 Timescale: D

5.1–R7.5.2 residuals from the solutions shall be examined, and poor solutions reported to operations staff.
Priority: 2 Timescale: D

5.1–R7.5.3 single-dish focus determination should also be supported.
Priority: 3 Timescale: D

5.1–R7.6 delays (including the crossed-hands), per antenna, frequency band, IF, and sub-band;
Priority: 1 Timescale: D

5.1–R7.7 polarization calibration terms, per antenna and frequency band;
Priority: 1 Timescale: D

5.1–R7.8 flux density scale determination (i.e., the conversion factor from correlation coefficient to Janskys);
Priority: 1 Timescale: D

5.1–R7.9 TIP analysis to derive antenna parameters (Tcal) and atmospheric opacity at the observed frequency;
Priority: 2 Timescale: D

5.1–R7.10 antenna aperture efficiency determination, per frequency, given knowledge of source flux density, atmospheric opacity, and other system quantities.
Priority: 3 Timescale: E

5.1–R8 There should be simple commands to invoke the higher level functions, e.g., "determine focus at W frequency using X calibrator", as well as a capability for more detailed commands, e.g., "determine focus at W frequency using X calibrator using Y points centered at Z focus, and here is the calibrator model image cube."

Priority: 2 Timescale: D

5.1–R9 The outputs from the Real-time Calibrator Analysis Tool should be archived (probably by passing them to the Archive Tool).

Priority: 1 Timescale: D

5.1–R10 The outputs from the Real-time Calibrator Analysis Tool should be available to the Quick-look Pipeline Tool.

Priority: 1 Timescale: D

2.5.2 Quick-look Pipeline

The quick-look pipeline produces images and/or spectra on short timescales for feedback during observing - both to the operator and to the observer. It is most likely that this is a streamlined version of the full off-line science pipeline.

5.2–R1 The Quick-look Pipeline Tool shall be activated automatically under given conditions (e.g., after a certain time interval, after each scheduling block, etc...). These intervals should be specified in the Observing Tool.

Priority: 1 Timescale: D

5.2–R2 It should also be possible to run the Quick-look Pipeline Tool whenever requested by the staff astronomer, operator, or observer (assuming a reasonable request).

Priority: 1 Timescale: D

5.2–R3 It should be possible to abort execution of the Quick-look Pipeline Tool gracefully, including cleaning up of files, killing all spawned processes, etc...

Priority: 1 Timescale: D

5.2–R4 The time-lag between when data is collected by the real-time system and when it is available to the Quick-look Pipeline Tool should be less than 30 seconds. This may guide a decision on whether data is all archived first, and then retrieved from the archive into the Tool, or fed directly from the real-time system into it (the fear is that the time lag between when data is collected and when it is actually available in the archive could be as long as minutes).

Priority: 1 Timescale: D

5.2–R5 The Quick-look Pipeline Tool should use the pipeline data reduction parameters as specified in the Observing Tool, including the heuristic for data reduction.

Priority: 1 Timescale: D

5.2–R5.1 If the Quick-look Pipeline Tool is being run on request by a person, then that person should be able to modify the pipeline data reduction parameters for that particular run of the Tool, i.e., that person should have access to the Pipeline data reduction setup component of the Observing Tool.
Priority: 2 Timescale: D

5.2–R6 The Quick-look Pipeline Tool should apply all flags generated by the real-time system, and should include facilities for generating flags based on the data itself, either of calibrators or of data taken on the target object. This includes recognition of RFI. Flags generated from data taken on the target object must be reported to operations. The setup parameters of the pipeline shall include a list of such facilities to be used, and a selectable level of flagging, e.g., light, nominal, heavy.

Priority: 1 Timescale: D

5.2–R7 The Quick-look Pipeline Tool should create calibrated image cubes and/or spectra, with the best calibration information currently available, including:

5.2.0–R7.1 conversion of correlation coefficients into flux density, including an opacity correction;
5.2.0–R7.2 bandpass calibration;
5.2.0–R7.3 polarization calibration;
5.2.0–R7.4 transfer of amplitude and phase correction from calibrator(s) (using the scaling factor between the calibration and observing frequencies if necessary);
5.2.0–R7.5 WVR phase correction, if desired and available.

Priority: 1 Timescale: D

5.2–R8 The following calibration modes shall be supported:

5.2.0–R8.1 calibration transfer (including fast switching);
Priority: 1 Timescale: D
5.2.0–R8.2 self-calibration.
Priority: 1 Timescale: D

5.2–R9 The Quick-look Pipeline Tool shall always compute the dirty image of astronomical sources when directed to do so (the operator or astronomer should be able to select spectra only), using the fastest algorithm possible. The supported observing modes should include:

5.2.0–R9.1 normal single-field synthesis;
Priority: 1 Timescale: D
5.2.0–R9.2 multiple source observations (“snapshots”);
Priority: 1 Timescale: D
5.2.0–R9.3 mosaicing;
Priority: 2 Timescale: E

5.2–R10 The Quick-look Pipeline Tool should deconvolve the dirty images, if possible in the short time allowed, using a fast deconvolution algorithm, with minimal controlling inputs.

Priority: 1 Timescale: D

5.2–R11 The processing described in the previous requirement shall be done for:

5.2.0–R11.1 the continuum data;
5.2.0–R11.2 the line-averaged spectra, over a pre-defined velocity or frequency range (defined either by the astronomer or by the staff astronomer or operator).

Priority: 1 Timescale: D

5.2–R12 The Quick-look Pipeline Tool should allow for a modest number of self-calibration + imaging/deconvolution iterations, if time allows.

Priority: 2 Timescale: D

5.2–R13 The Quick-look Pipeline Tool should complete its execution on a time scale which is reasonable for astronomy decision making (current thinking is a few minutes at most). If the astronomer is asking for too much from the Quick-look Pipeline Tool (e.g., "I want an image cube which covers the full primary beam over 32000 channels every 100 milliseconds"), the Tool should indicate that what is being asked for is unreasonable.

Priority: 2 Timescale: D

2.5.3 Default Archive Image Pipeline

It is envisioned that when all of the data has been collected for a given Program, a pipeline will be invoked which creates the default image for the archive for that program. There is a single requirement on the on-line software that connects with this pipeline, which we specify here. The rest of the requirements for that pipeline are contained in the off-line processing document.

5.3–R1 The default image pipeline needs to be triggerable from the on-line system (i.e., the on-line system recognizes that a Program has been completed, and sends a signal to the default image pipeline that it should commence with its processing. The default image pipeline may have to delay execution until all necessary calibration quantities are obtained, but it should have the capability of receiving the indication from the on-line system that all of the visibility data has been collected for that program).

Priority: 2 Timescale: D

2.5.4 Atmospheric Model

5.4–R1 Atmospheric modelling shall be available in the Pipeline and to the Scheduling Tool. 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:

5.4.0–R1.1 measured atmospheric parameters at the site: temperature, pressure, humidity;
5.4.0–R1.2 measured atmospheric emission in the observed EVLA bands;
5.4.0–R1.3 measured WVR data;
5.4.0–R1.4 measured atmospheric profiles of temperature and water content if available from atmospheric sounders;
5.4.0–R1.5 measured optical depths from tipper meters and/or FTSs, if available;
5.4.0–R1.6 measured electron content from GPS or other techniques.

Priority: 2 Timescale: C

5.4–R2 Atmospheric modelling shall be used to derive the opacities in all astronomical bands in use, in order to correct the observed amplitudes at various elevations.

Priority: 2 Timescale: C

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

Priority: 2 Timescale: D

2.5.5 The Astronomer's "what's up" Screen

The astronomer shall be able to access via the internet a GUI which displays information about observations currently being undertaken by the EVLA. BGC has coined the term: "what's up screen" for this, and we adopt that terminology here. It is a screen that makes available, e.g., information on current meteorological parameters, phase stability, observing Program, source, real-time calibrator analysis output, quick-look pipeline output, raw visibility information, etc...

5.5–R1 There shall be made available over the internet an astronomer's "what's up" screen, giving current observational and instrumental information for the EVLA.

Priority: 1 Timescale: C

5.5–R2 The following quantities and their time histories (where appropriate) shall be able to be displayed via the "what's up" screen:

- **5.5–R2.1** current date and time.
  Priority: 1 Timescale: C
- **5.5–R2.2** begin and end time of current scan.
  Priority: 1 Timescale: C
- **5.5–R2.3** source being observed, with frequency or velocity (selectable), and position (selectable as sky or azimuth/elevation).
  Priority: 1 Timescale: C
- **5.5–R2.4** correlator setup.
  Priority: 1 Timescale: C
- **5.5–R2.5** surface meteorological parameters (temperature, dew point temperature [or humidity], wind speed and direction, pressure);
  Priority: 1 Timescale: C
- **5.5–R2.6** auxiliary monitoring device output:
  - **5.5–R2.6.1** Atmospheric Phase Monitor - raw data and related derived quantities (structure function, rms phase, corner time, exponent);
    Priority: 1 Timescale: C
  - **5.5–R2.6.2** current opacity estimate for all observing bands, from either surface data, seasonal estimate, TIPs of the array itself, separate tipping radiometers, separate FTS devices, etc...
    Priority: 2 Timescale: D
  - **5.5–R2.6.3** Water Vapor Monitor byproduct data (e.g., derived precipitable water vapor from WVM data);
    Priority: 2 Timescale: E
  - **5.5–R2.6.4** RFI monitor (if available);
    Priority: 3 Timescale: E
  - **5.5–R2.6.5** Atmospheric electron content information (if available, via GPS, e.g.);
    Priority: 2 Timescale: D
- **5.5–R2.7** visibility amplitude and phase, on a specified baseline, over a specified frequency or velocity range, for all polarization products (u, v, and w should also be displayed).
  Priority: 1 Timescale: C

5.5–R2.8 array properties, such as:

5.5–R2.8.1 array status (error flags, e.g.).
Priority: 1 Timescale: C

5.5–R2.8.2 the *uv* coverage and dirty beam, integrated over the current session, for a chosen target source;
Priority: 2 Timescale: D

5.5–R2.8.3 the thermal noise rms reached since the beginning of the observing session (from theory, using actual system temperatures);
Priority: 2 Timescale: D

5.5–R2.8.4 for mosaic observations: the above quantities for each pointing center.
Priority: 3 Timescale: E

5.5–R2.9 results of real-time calibrator analysis output for the current session, including any focus, delay, reference pointing, complex gain, etc..., data. There should be 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 should be reasonably simple, and the plot option should be able to quickly be changed by the staff astronomer/operator.
Priority: 1 Timescale: C

5.5–R2.10 the (uncalibrated) spectrum observed on an astronomical source (amplitude/phase or real/imaginary) with various options such as:

5.5–R2.10.1 time integration;
Priority: 1 Timescale: C

5.5–R2.10.2 choice of a single baseline (antennas selectable) or all baselines;
Priority: 1 Timescale: C

5.5–R2.10.3 vector or scalar averaging.
Priority: 1 Timescale: C

5.5–R2.11 the resultant image cube and/or spectrum from all quick-look pipeline executions related to the current observing session.
Priority: 1 Timescale: D

5.5–R2.12 pulsar information, including:

5.5–R2.12.1 Pulsar name and its current period (calculated for ongoing observation);
Priority: 2 Timescale: E

5.5–R2.12.2 Dispersion measure (provided by astronomer) and derived quantities (dispersion smearing time at observed frequency/bandwidth);
Priority: 2 Timescale: E

5.5–R2.12.3 Time bin configuration, as required by hardware;
Priority: 2 Timescale: E

5.5–R2.12.4 A time averaged pulse profile made using time bins. A dispersion correction should be applied to the data. This display could be analogous to the display of an uncalibrated spectrum, with similar options. If pulse-phase dependent trigger(s) is/are generated (for gating or for driving external hardware), it/they should be marked. The zero-phase (as defined by the provided polynomial) should be marked also.
Priority: 2 Timescale: E

5.5–R3 The time-lag between when data is collected by the real-time system or produced from the Quick-look Pipeline Tool and when it is available to the "what's up" screen should be less than 10 seconds. This may guide a decision on whether data is all archived first, and then retrieved from the archive into the "what's up" screen, or fed directly from the real-time system into it (the fear is that the time lag between when data is collected and when it is actually available in the archive could be as long as minutes).

Priority: 1 Timescale: C

5.5–R4 It should also be possible for the staff astronomer, operator, or observer to initiate execution of the quick-look pipeline from the "what's up" screen (assuming a reasonable request).

Priority: 2 Timescale: D

5.5–R4.1 The person initiating the execution of the quick-look pipeline should be able to modify the pipeline data reduction parameters associated with the Program Block, i.e., should have access to the Pipeline data reduction setup component of the Observing Tool.
Priority: 2 Timescale: D

5.5–R5 There should be a link to the Scheduling Tool web page from the "what's up" screen (see Requirement 3.1-R11.1).

Priority: 2 Timescale: D

5.5–R6 There should be a link to the Project web page from the "what's up" screen (see Requirement 3.1-R11.4).

Priority: 2 Timescale: D

A Definitions and descriptions

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. A proposal has uniquely associated with it:

- A proposal identification code;
- A status (e.g., 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 (Detection/Mapping, Spectroscopic Line Survey, etc...);
- A crude scientific categorization (solar system, stars, galaxies, cosmology, etc...) in order to help reviewers;
- An author list;
- A contact person and contact information;
- A staff contact person;
- A scientific justification;
- A synoptic referee rating.

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

Note that "staff contact person" and "synoptic referee rating" are assigned well after submission. Additional information it might be useful to include later on are:

- Total array time scheduled under the aegis of this proposal;
- Sensitivity weighted time scheduled under the aegis of this proposal (for observations at unfavorable elevations or high system temperature.);
- Number of observing sessions scheduled under this proposal;

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, with the exception that the proprietary period of a group of proposals may be considered to extend through the last member of the group.

Project:

When approving a proposal, the observing program committee creates one or more Projects. A Project is a scientifically independent subset of the observations proposed in the Proposal which have been approved by the observing program committee. Each project may have a different scientific rating.

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

- 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);
— Number and status (e.g., Observed, Partially Observed, Not Observed) of the underlying programs.

Program:

Within each project, observations in different configurations are each assigned to a separate program.

Each program has associated with it an observing description (a Program Block), which describes (in greater detail than is available in the proposal) how the observations are to be completed for the program.

The Program Block is a set of Scheduling Blocks (SB).

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

A Program has associated with it the additional information:

— Configuration(s) in which its Scheduling Blocks may be run (including whether move time is acceptable). Note that if multiple configurations are required, then it must be split into separate Programs - if any one of several configurations are acceptable, they can be specified here;
— List of requested bands (a subset of those in the project);
— A limitation of observing resources;
— Total array time scheduled under the aegis of this program;
— Sensitivity weighted time scheduled under the aegis of this program;
— An optional scientific rating assigned by the observing program committee;
— A Program Block (observing description).

Program Block (PB):

The set of Scheduling Blocks derived from a single Program that are to be submitted to the Scheduling Tool for queuing at the same time. An observer would normally create these in a single run of the Observing Tool.

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 are warned that deviating from the 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:

— A Control Script to be executed;
— A maximum single execution duration of the SB;
— A maximum total observing time to be spent using this SB;
— The sensitivity goal to be reached by repeated executions;
— The maximum atmospheric water vapor 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);
— An optional, observer assigned relative priority to be used when scheduling. This is used for dependencies between SBs in a given project;
— 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;
- A list of dates for which priority modifiers exist (either lowering or raising priority);
- A list of alternative calibrators, with an indication of time range to be used (used, e.g., for moving target sources);
- 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 noted as either a member of the proposal source list or a calibrator.

Control Script:

A script in the language of the on-line computer system directing the EVLA or a subarray thereof to collect data with a specified receiver setup, phase tracking center, and antenna pointing. The EVLA is operated by having the Scheduling Tool, human operator, or observer pass a Control Script to the real-time computer system. Specifically, a Control Script contains:

- A simple driving pattern for each antenna;
- A simple driving pattern for the array phase center;
- A single receiver and frequency setup (although this setup may specify more than one receiver/frequency);
- A single correlator configuration.

Preambles and postambles are particular versions of Control Scripts, and have several possible functions. The purpose of these scripts is to collect calibration data for use in the data reduction phase, e.g.:

- Flux density scale calibration;
- Bandpass calibration;
- Polarization leakage term calibration;
- Receiver phase difference calibration.

Observing Session:

The time contiguous execution of one or more scheduling blocks in a program constitutes an observing session. An observing session has a common preamble and postamble for each SB which requires one.

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. A scan is usually a single observation of a target source or a calibrator, but, 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 within a Control Script. 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 Control Script.

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 hardware.

Pipeline:

A sequence of data reduction operations performed according to a script present at the initiation of Pipeline operation, usually resulting in an image cube. The script may include conditional operations based on results or conditions generated by individual data reduction operations. A Pipeline Tool consists of a supervisor to execute such scripts, a collection of standard scripts, and an interface to the archive or the real-time system, from which it may extract the data upon which it operates.

B Scheduling Block Templates

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, however, they might be useful templates to provide to the Observing Tool, possibly with the numbers below being default values for the associated parameters.

- Strong source, low frequency, interferometry:
  - One minute phase calibrator scan
  - Nine minutes target scan
- Strong source, high frequency, interferometry:
  - Pointing scan
  - (optional) Focus scan
  - One minute phase calibrator scan
  - Nine minutes target scan
  - One minute phase calibrator scan
  - Nine minutes target scan
  - One minute phase calibrator scan
  - Nine minutes target scan
- Weak source, low frequency, interferometry:
  - Twenty seconds phase calibrator scan
  - Forty seconds target scan
- Weak source, high frequency, interferometry:
  - Pointing scan
  - (optional) Focus scan
  - Twenty cycles of
    - Twenty seconds phase 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
  - (optional) Focus scan
  - Leakage calibrator scan, 1 minute
  - Thirty cycles of
    - Phase calibrator 20 seconds
    - Target 40 seconds
- Mosaicing:
  - Pointing scan
  - (optional) Focus scan
  - Phase calibrator 20 seconds
  - Up to 30 mosaic points at 30 seconds each