Expanded Very Large Array	EVLA-SW-001 Revision:1.1 2002-Oct-11 *Requirements* S. Myers, B. Butler

EVLA e2e Software Science Requirements

Requirements

EVLA Software Science Requirements Committee:
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Contents

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 (2.4)
4. Data archive (2.5)
5. Image pipeline (2.6)
6. Data post processing (separate document)

We have generated EVLA specific requirements in the first five of these areas. 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*.

The prioritizing scheme is described at the top of Section 2. We have done our best to make the requirements quantitative, and to clearly define the meaning of qualifiers and adjectives. However, there are instances where the substance of particular requirements is necessarily subjective (e.g., "ease of use" and "robustness" type requirements). Rather than spelling these out in detail, we have have left these "squishy" requirements as-is, and will rely upon the SSR and 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, submission, and handling of proposals is contained in a single software "Tool" - the Proposal Tool.

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.

In order to aid in the preparation of proposals and also in the creation of the observing scripts, we envision the existence of a Simulation Tool. This Tool can simulate observations by the EVLA, 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.

The Observing Tool creates an *observing script* 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 is 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 is collected, it must be archived - this is handled 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 is fed to the archive, it is also fed to a data reduction pipeline (conceptually, at any rate - whether the data is first fed into the archive and then immediately retrieved from the archive for input into the pipeline is a question of implementation).

Most of the functions of the pipeline are under the domain of the off-line data processing, and will therefore not be treated in this document. What is needed in our present context is a subset of the pipeline which is capable of taking data as it is produced by the EVLA and producing real-time images or spectra. We envision that this is effected by a Quick Look Pipeline Tool, which would be a subset of the full off-line Pipeline Tool. The Quick Look Pipeline Tool must be able to take data as it is produced by the EVLA and flag, calibrate, map, deconvolve, etc... it to produce the final images and spectra. Because of this, it must have access to current calibration data including bandpass, polarization, flux density, phase and amplitude, antenna efficiency, etc..., and to other parameters like current atmospheric opacity. The Quick

Look Pipeline Tool then produces images and spectra which are made available to the Operator(s) and to the observer(s) as well.

The Proposal Tool, Observing Tool, Simulation Tool, Pipeline Tool, and Archive Tool 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. The Simulation Tool requires an observing script, so the Observing Tool is invoked to generate a simple script which is fed into the Simulation Tool. The Simulation Tool then feeds its output into 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 it 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 astronomy parameters to the basic observing process, and to the corresponding data reduction procedures of the pipeline. Input parameters will preferably be expressed in terms of astronomical quantities, which will be translated into technical parameters by sophisticated configuration tools.

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 system shall be through **Graphical User Interfaces** (GUIs) except for the low level Command Control Language.
5. The instrument shall be dynamically scheduled in near real time (a few minutes in advance of real time) to take full advantage of the atmospheric conditions and of instrument availability.
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 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 operations use any system element performance measures they develop in the course of calibration.

2 Requirements

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

The priorities can have the following four values:

1 = essential

2 = important

3 = desirable, but not critical

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

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

A transition phase (2004 Q2)

B prototype correlator (2005 Q4)

C shared-risk Science operations (2007 Q2)

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

E "eventually" sometime after completion (ongoing)

These are same as the priorities and timescales used in the *EVLA Offline Data Processing 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, Simulation 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 (Postscript, pdf, etc...), with figures incorporated (i.e., it is all in one file).
  Priority: 1 Timescale: A

1.0–R3 The Proposal Tool shall allow storing of intermediate stages to local disks (e.g., to enable trying out different parameter settings, for backup). This stored version shall be easily editable with normal text editors (i.e., should be normal printable ASCII text), and easily shared with co-authors and collaborators.

Priority: 1 Timescale: A

1.0–R4 Proposals output from the tool shall be readable by the tool.

Priority: 1 Timescale: A

1.0–R5 The proposal submission tool should support source lists.

- **1.0–R5.1** The tool must encourage entry, for all sources, of all fields useful to decide scientific priority. These are:
  - **1.0–R5.1.1** Source coordinates;
  - **1.0–R5.1.2** Source common name;
  - **1.0–R5.1.3** Source continuum flux density;
  - **1.0–R5.1.4** Required continuum rms (or, equivalently, required dynamic range);
  - **1.0–R5.1.5** Requested VLA configurations;
  - **1.0–R5.1.6** Requested observation bands;
  - **1.0–R5.1.7** Angular size of largest structure.

  Spectroscopic observations also include:
  - **1.0–R5.1.8** Line identifications or frequencies;
  - **1.0–R5.1.9** Requested frequency or velocity resolution;
  - **1.0–R5.1.10** Requested velocity or redshift range;
  - **1.0–R5.1.11** Requested rms in a spectral channel;
  - **1.0–R5.1.12** Source flux density at line peak.

  Priority: 1 Timescale: A
- **1.0–R5.2** The submission tool shall supply a flexible interface for importing the above from another medium.
  Priority: 1 Timescale: A
- **1.0–R5.3** 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: 1 Timescale: A

1.0–R5.4 A connection to the NED database for obtaining sources should be available.
Priority: 2 Timescale: C

1.0–R6 The Proposal Tool shall perform certain calculations, including:

1.0–R6.1 the integration time required:
1.0–R6.1.1 for a given bandwidth and channel (e.g., velocity) width;
Priority: 1 Timescale: C
1.0–R6.1.2 under average environmental conditions;
Priority: 1 Timescale: C
1.0–R6.1.3 using real observing statistics;
Priority: 2 Timescale: D

1.0–R6.2 the appropriate configuration needed given desired sensitivity, resolution, and source angular size.
Priority: 1 Timescale: C

1.0–R6.3 the scheduled time required given stringency of required conditions (e.g., required phase stability at the specified frequency).
Priority: 2 Timescale: D

1.0–R7 The tool shall calculate the data rate and the total data volume for the project.

Priority: 1 Timescale: C

1.0–R8 The tool shall react to user input by providing warnings based on the situation and selected observing mode, including:

1.0–R8.1 hardware limitations;
Priority: 1 Timescale: C
1.0–R8.2 data rate/volume;
Priority: 1 Timescale: C
1.0–R8.3 expected data quality;
Priority: 2 Timescale: D
1.0–R8.4 expected stringency limitations (e.g., weather efficiency).
Priority: 2 Timescale: D

1.0–R9 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–R10 Upon proposal submission, a database of previous observations of the objects will be searched, and the results returned to the proposer, as well as being made accessible to the scheduling committee.

Priority: 1 Timescale: D

1.0–R10.1 The search results should be ordered by relevance.
Priority: 2 Timescale: D

1.0–R11 The Proposal Tool or its functional equivalent shall be usable by local staff to edit or modify submitted proposals.

Priority: 1 Timescale: A

2.2 Observation preparation

These requirements cover the preparation of observing scripts for submission to the Scheduling Tool by the observer using the Observing Tool. It is envisioned that the Scheduling Tool is a software program (or equivalent), accessed only by the Operator, NRAO staff, and possibly expert external users.

2.2.1 The Observing Tool

2.1–R1 There shall be an Observing Tool for the generation of input (*observing scripts*) to the Scheduling Tool.

Priority: 1 Timescale: A

2.1–R1.1 The Proposal Tool, Observing Tool, Simulation 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 Since the Observing Tool is the primary interface of the observer to the EVLA, it should be easy-to-use and robust.

Priority: 1 Timescale: A

2.1–R2.1 This tool shall operate using a GUI;
Priority: 1 Timescale: A

2.1–R2.2 There shall be a batch or script mode for automated generation of observing scripts;
Priority: 1 Timescale: C

2.1–R2.3 There shall be built-in help capability;
Priority: 1 Timescale: C

2.1–R2.4 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 approximately 8 hours dedicated use, and truly neophyte users (e.g., graduate students in other areas of astronomy) should reach proficiency with an investment not exceeding 24 hours of dedicated use.
Priority: 2 Timescale: D

2.1–R3 The Observing Tool shall produce one observing script per program.

Priority: 1 Timescale: D

2.1–R4 An observing script consists of a collection of Scheduling Blocks and Break Points.

Priority: 1 Timescale: D

2.1–R5 The Observing Tool shall allow its state and intermediate output to be saved and restored at any time. Saved outputs shall be local. Saved outputs shall be distinguished by name, and shall be easily editable with normal text editors (i.e., should be normal printable ASCII text).

Priority: 1 Timescale: A

2.1–R6 Observing scripts output from the tool shall be readable by the tool.

Priority: 1 Timescale: A

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

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

Priority: 1 Timescale: A

2.1–R8 The Observing Tool shall only require specification of science goals (see Requirement 1.0–R51.0–R5req.5) as input.

Priority: 2 Timescale: C

2.1–R9 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: 1 Timescale: C

2.1–R10 The observing tool shall be cognizant of the project and program as allocated by the scheduling committee, and will, unless requested otherwise, apply those limits to the time being scheduled.

Priority: 1 Timescale: D

2.1–R11 The Observing Tool shall include as components tools for:

- **2.1–R11.1** Observation setup;
  Priority: 1 Timescale: A
- **2.1–R11.2** Correlator setup;
  Priority: 1 Timescale: B
- **2.1–R11.3** Calibrator selection;
  Priority: 1 Timescale: A
- **2.1–R11.4** Pipeline data reduction setup;
  Priority: 2 Timescale: D
- **2.1–R11.5** Observation simulation;
  Priority: 2 Timescale: D

2.1–R12 The Observation setup component shall:

- **2.1–R12.1** Allow the user to select from and manipulate source catalogs derived from:
  - **2.1–R12.1.1** a built-in calibrator catalog;
    Priority: 1 Timescale: A
  - **2.1–R12.1.2** user-supplied source lists in ASCII format;
    Priority: 1 Timescale: A
  - **2.1–R12.1.3** access to standard astronomical catalogs (CDS, NED).
    Priority: 2 Timescale: C
- **2.1–R12.2** Allow the user to easily construct a *Source List* of coordinates and velocities. This shall be possible based on:
  - **2.1–R12.2.1** interactive selection from a catalog list;
    Priority: 1 Timescale: A
  - **2.1–R12.2.2** sequential extraction of targets from a list of sources (e.g., to conveniently schedule survey programs);
    Priority: 1 Timescale: A
  - **2.1–R12.2.3** 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–R12.2.4** on the basis of an image (e.g., from survey databases, or from the EVLA image archive) one shall be able to define the area to be mapped interactively (e.g., with a mouse).
    Priority: 3 Timescale: D
- **2.1–R12.3** 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–R12.4** 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–R12.5 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–R12.5.1 Some parameters (loop cycle times, integration times) may be selected to be automatically calculated at run-time by the Scheduling Tool depending on actual weather, phase fluctuations, pipeline results.
Priority: 2 Timescale: E

2.1–R12.6 Allow integration times and cycle repeats to be set based upon a desired level of sensitivity under the requested atmospheric conditions.
Priority: 2 Timescale: C

2.1–R12.6.1 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–R13 The Correlator setup component shall provide:

2.1–R13.1 A *Hardware Menu*, based on actual hardware setup (e.g., number of channels, width in Hz);
Priority: 1 Timescale: B

2.1–R13.2 A *Spectral Menu*, based on observational parameters (e.g., selection of spectral windows based on molecular transitions, velocity widths and line brighnesses);
Priority: 2 Timescale: C

2.1–R13.3 Pre-configured setups shall be available for frequently observed transitions;
Priority: 2 Timescale: D

2.1–R13.4 Links to a standard provided line catalog (e.g., based on the JPL or Lovas line catalogs);
Priority: 2 Timescale: D

2.1–R13.5 Links to simulated spectra based on physical models.
Priority: 3 Timescale: E

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

2.1–R14 The Calibrator selection component shall provide:

2.1–R14.1 A built-in calibrator catalog;
Priority: 1 Timescale: A

2.1–R14.2 The ability to import calibrators from a user-supplied source list in ASCII format;
Priority: 1 Timescale: A

2.1–R14.3 The ability to directly input calibrators;
Priority: 1 Timescale: A

2.1–R14.4 The ability to select the following types of calibrators, based on source location, frequency, and array configuration:

2.1–R14.4.1 primary and secondary flux density scale calibrator(s);
Priority: 1 Timescale: A

2.1–R14.4.2 bandpass calibrator(s);
Priority: 1 Timescale: A

2.1–R14.4.3 polarization calibrator(s).
Priority: 1 Timescale: A

2.1–R14.5 The ability to display, and then select nearby sources to be used for tracking time variable complex gain, based on source location, frequency, and array configuration, either:

2.1–R14.5.1 interactively (by the user), or,

Priority: 1 Timescale: A

2.1–R14.5.2 automatically (by the software).

Priority: 2 Timescale: C

2.1–R15 The Pipeline data reduction setup component shall provide:

2.1–R15.1 A mechanism for the observer to convey intent to the pipeline, including the following information:

2.1–R15.1.1 How calibrators are to be used;

2.1–R15.1.2 Level of flagging (e.g., light, medium, heavy);

2.1–R15.1.3 Deconvolution algorithm and associated parameters;

2.1–R15.1.4 Mosaicing algorithm and associated parameters;

2.1–R15.1.5 Any other necessary pipeline control parameters.

Priority: 1 Timescale: D

2.1–R16 The Observation simulation component shall be able to:

2.1–R16.1 estimate S/N;

Priority: 2 Timescale: D

2.1–R16.2 estimate syntesized beam size;

Priority: 2 Timescale: D

2.1–R16.3 estimate surface brighness sensitivity;

Priority: 2 Timescale: D

2.1–R16.4 produce dirty beams;

Priority: 3 Timescale: D

2.1–R16.5 for suitable source models, simulate maps with the desired array configurations.

Priority: 3 Timescale: E

Note: see Section 2.3 for more details.

2.2.2 Generation of observing scripts

2.2–R1 The Observing Tool shall divide the observing programs into scheduling blocks:

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

Priority: 1 Timescale: A

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

Priority: 1 Timescale: D

2.2–R2 For complex programs with several different scheduling blocks the observer shall be able to assign these scheduling blocks a relative priority, to ensure the proper order of execution.

Priority: 1 Timescale: D

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

Priority: 2 Timescale: D

2.2–R4 Breakpoints shall be settable in terms of project goals, such as:

2.2–R4.1 completion of a specific subset of targets or observing block;

Priority: 2 Timescale: D

2.2–R4.2 fraction of targets observed;

Priority: 2 Timescale: D

2.2–R4.3 a target has reached a given rms or S/N.

Priority: 3 Timescale: E

2.2–R5 The proposer shall be able to specify what is needed for real-time checking of data quality (should this be available in the EVLA system), including:

- **2.2–R5.1** choosing a standard calibrator as a *test source* to be observed to assess the conditions for stringency;
  Priority: 3 Timescale: D
- **2.2–R5.2** option for the system to automatically choose the test source at execution time.
  Priority: 3 Timescale: E

2.3 Simulation

Capability of simulating all EVLA modes of observation is needed for planning proposals (with the Proposal Tool), planning observations (with the Observing Tool), scheduling observations (with the Scheduling Tool), and comparison of data with models (in data reduction, e.g., in order to test data reduction procedures and their reliability). Because it spans so many different areas of the contract between EVLA and DM, the requirements for the Simulation Tool are contained in this separate section.

3.0–R1 There shall be a Simulation Tool capable of simulating all EVLA modes of observation, possible observing schemes, target sources, calibrator characteristics, etc...

Priority: 1 Timescale: A

3.0–R1.1 The Proposal Tool, Observing Tool, Simulation 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

3.0–R1.2 The Simulation Tool shall be able to interact with the Scheduling Tool.
Priority: 1 Timescale: D

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

Priority: 2 Timescale: C

3.0–R3 The sensitivity calculation shall be available to the users through the Proposal Tool and the Observing Tool.

Priority: 1 Timescale: C

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

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

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

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

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

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

Priority: 3 Timescale: D

2.4 Observation scheduling

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

4.0–R1 There shall be a Scheduling Tool which generates a list of commands which are input to the EVLA real-time system to control the telescope.

- **4.0–R1.1** The Proposal Tool, Observing Tool, Simulation 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

4.0–R2 EVLA observing programs shall be dynamically scheduled in quasi-real time.

Priority: 1 Timescale: D

4.0–R3 The observing programs shall be split into Scheduling Blocks (SB); the execution of an SB shall not be interrupted by the scheduling process (except possibly through an error condition or manual intervention). 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

4.0–R4 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.

- **4.0–R4.1** Algorithms and heuristics shall be clearly documented.
  Priority: 1 Timescale: C
- **4.0–R4.2** Parameters and weights involved in the heuristics shall be documented, and easily adjustable.
  Priority: 1 Timescale: C

4.0–R5 The queue of all approved SBs shall be examined shortly before the end of the scheduling block currently in execution, to choose the next SB to execute.

- **4.0–R5.1** Each SB will be examined to see if it is available for scheduling. An SB will not be scheduled 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, or if solar interference would compromise observations with the observing parameters being used.

Priority: 1 Timescale: C

4.0–R6 The following criteria will be used in evaluating the scientific value of an SB:

- **4.0–R6.1** Science rating as determined by the scheduling committee and the referees;
- **4.0–R6.2** 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 HA and opacity and the number of available antennas, is to be considered, not just the time.);
- **4.0–R6.3** 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);
- **4.0–R6.4** Elapsed time since previous execution (for monitoring variable objects at a regular rate);
- **4.0–R6.5** Proximity to a preferred date (for placing observations near observations made with another instrument, for instance);
- **4.0–R6.6** The status of the program as a whole (preference should be given to finishing programs once they are started);

4.0–R6.7 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: 1 Timescale: C

4.0–R7 Depending on the algorithm chosen for implementation of the system, the following heuristics may be appropriate to consider:

4.0–R7.1 SB dependency rules, or an observer specified relative priority;
4.0–R7.2 Deviation from the preferred LST;
4.0–R7.3 Preamble/postamble execution times;
4.0–R7.4 Stringency factor: SBs requiring rare conditions may be preferred when those conditions occur.

Priority: 1 Timescale: C

4.0–R8 A manual mode shall be available to the staff (as a special case), for testing new observing procedures, by sending commands directly to the observing system, using the whole array or a sub-array.

Priority: 1 Timescale: B

4.0–R9 The time-contiguous execution of one or more SBs of a given program should be started by a special setup SB (or a preamble block), and ended by a final SB (or postamble block). These are needed to ensure proper execution (flux density measurements of phase and amplitude calibrators) and calibration (bandpass, polarization, phase, etc...).

Priority: 1 Timescale: D

4.0–R10 Pipeline results from the astronomical targets themselves (for instance, test point sources) can be used in computing scheduling block priorities.

Priority: 2 Timescale: D

4.0–R11 The Scheduling Tool shall be able to run off-line using recorded historical inputs or simulated inputs.

Priority: 1 Timescale: D

4.0–R12 The Scheduling Tool shall check submitted Scheduling Blocks for correctness, to prevent malformed SBs from being executed.

Priority: 1 Timescale: D

4.0–R13 As SBs are scheduled, feedback to the observers (PIs) shall be the following:

4.0–R13.1 A web page is maintained which lists priority ranked programs;
4.0–R13.2 An e-mail is sent to the PI when the first of his/her SBs gets for the first time into the top ~ 10 ranked ones, as an announcement of approaching execution (but not a guarantee, the weather being not easily predicted);
4.0–R13.3 An e-mail is sent to the PI when the first of his/her SBs is executed for the first time;
4.0–R13.4 At this point, a web page is created (password-protected) that will be updated at regular intervals (e.g., each SB, or $\sim$ 10min whichever is longest). This includes the quick look image, quality check information from the quick look pipeline, and general execution status of the program;
4.0–R13.5 An email is sent at the end of each session (either due to a change in scheduling or a breakpoint status);
4.0–R13.6 A final email is sent at the end of the program (when all the data are archived and available).

Priority: 1 Timescale: D

2.5 Archiving

2.5.1 Introduction

5.1–R1 There shall be an EVLA archive which stores all data obtained with the EVLA and any environmental, monitoring, or other associated data pertinent to observations undertaken with the EVLA or the reduction thereof.

Priority: 1 Timescale: A

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

Priority: 1 Timescale: C

5.1–R2.1 The Proposal Tool, Observing Tool, Simulation 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

5.1–R3 The archive enables astronomers and engineers to access and use data which has been obtained with EVLA, regardless of where the information physically resides. When requested, the archive shall let a user know the list of available data.

Priority: 1 Timescale: C

2.5.2 Archive of observational and technical data

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

Priority: 1 Timescale: C

5.2–R1.1 Not only scientific observations but also technical test observation and measurements shall be archived to allow the system check. By default, all data taken by the array is archived.
Priority: 1 Timescale: C

5.2–R1.2 The quick-look data is not stored in the final archive by default (see requirements for quick-look and scientific imaging pipelines).
Priority: 1 Timescale: C

5.2–R2 The archive shall also include:

5.2–R2.1 all user (observer) input including the scientific justification of the project;
Priority: 1 Timescale: A

5.2–R2.2 high-level observing scripts as they have been used to obtain the data;
Priority: 1 Timescale: C

5.2–R2.3 the low-level actual observation descriptors which are made by expanding the high-level observing scripts and (time-variable) instrumental/environmental parameters;
Priority: 1 Timescale: C

5.2–R2.4 the pipeline or offline software versions and data reduction scripts;
Priority: 1 Timescale: C

5.2–R2.5 data quality information (e.g., noise level and dynamic range, based on pipeline results);
Priority: 1 Timescale: C

5.2–R2.6 whether the observational data is scientifically meaningful or not (This is to allow a user to eliminate test observation for technical purpose, e.g., out-of-focus astronomical observation, etc.);
Priority: 1 Timescale: C

- **5.2–R2.7** histories of flux densities of calibration sources, which are to be used in observations;
  Priority: 1 Timescale: C
- **5.2–R2.8** all measured environmental data;
  Priority: 1 Timescale: A
- **5.2–R2.9** the water vapor radiometric raw data (at $\sim 1s$ timescale);
  Priority: 1 Timescale: A
- **5.2–R2.10** any available atmospheric electron content data (from GPS, e.g.);
  Priority: 1 Timescale: A
- **5.2–R2.11** all monitored data.
  Priority: 1 Timescale: A

5.2–R3 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: D

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

Priority: 2 Timescale: E

5.2–R5 All information describing the observation should be accessible through the header.

Priority: 1 Timescale: D

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

Priority: 1 Timescale: C

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

Priority: 3 Timescale: C

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

Priority: 2 Timescale: D

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

5.2–R11 All archived technical data shall be indexed by time, to facilitate the linking of this data with appropriate observation periods.

Priority: 2 Timescale: C

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

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

5.2–R13.1 The archive should provide the most up-to-date calibration by default.
Priority: 1 Timescale: C

5.2–R13.2 The archive should contain all calibrations which are applicable.
Priority: 1 Timescale: C

5.2–R13.3 If recalibration by using better calibration algorithm and/or better calibration data is recommended by the EVLA, then the stored image will be recalibrated.
Priority: 1 Timescale: D

5.2–R13.4 If recalibration is made by the EVLA, then the old calibrated image will also be stored in the archive system.
Priority: 2 Timescale: D

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

Priority: 1 Timescale: A

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: D

5.2–R17 The archive shall have the ability to attach a persistent link info to external archives and catalogs (e.g., DSS image) of the corresponding sky area, and to published papers, e.g., ADS if available, that used the relevant data, upon request.

Priority: 2 Timescale: E

2.5.3 Archive Search Tool

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

Priority: 1 Timescale: A

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

Priority: 1 Timescale: A

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

Priority: 1 Timescale: A

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

Priority: 1 Timescale: A

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

Priority: 1 Timescale: C

5.3–R5.1 Interactive context-based help shall be provided in the GUI.
Priority: 2 Timescale: D

5.3–R5.2 An introductory cookbook, including examples, shall be provided to let a user know how to utilize database efficiently or how to do data mining by using the archive.
Priority: 1 Timescale: C

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

Priority: 2 Timescale: E

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

5.3–R7.1 Object name
5.3–R7.2 Position on the Sky (Equatorial, Galactic, Ecliptic coordinates)
5.3–R7.3 Hour angle
5.3–R7.4 Elevation
5.3–R7.5 Observation Date
5.3–R7.6 Integration Time
5.3–R7.7 Molecular transition
5.3–R7.8 Frequency
5.3–R7.9 Array Configuration
5.3–R7.10 Observation mode
5.3–R7.11 Whether observation is for target or calibration
5.3–R7.12 Angular resolution
5.3–R7.13 Spectral resolution
5.3–R7.14 Weather condition
5.3–R7.15 Name of Principal Investigator
5.3–R7.16 Project name
5.3–R7.17 Project number
5.3–R7.18 Title of the proposal
5.3–R7.19 Observing Programs (OPs)
5.3–R7.20 Scheduling Blocks (SBs)
5.3–R7.21 Telescope operator or Astronomer on Duty
5.3–R7.22 Reduction date
5.3–R7.23 Data quality (noise level or dynamic range).
5.3–R7.24 Other header info

Priority: 1 Timescale: C

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

Priority: 1 Timescale: D

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

Priority: 2 Timescale: E

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

Priority: 1 Timescale: C

2.5.4 Archive Retrieval Tool

5.4–R1 For the archive, the Archive Retrieval Tool shall receive the information from the Archive Search Tool to identify data, and shall return information such as:

5.4–R1.1 A raw data file, with averaging in time or frequency
Priority: 1 Timescale: C

5.4–R1.2 A reduced image
Priority: 2 Timescale: D

5.4–R1.3 Run the pipeline on raw data with optional input parameters
Priority: 2 Timescale: D

5.4–R2 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: D

5.4–R2.1 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: D

5.4–R2.2 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 map (e.g., 10 km/s for Galactic, 300 km/s for extragalactic, centered on the observer-specified rest frequency and tracking velocity, or the intensity-weighted velocity of the detected line emission from the pipeline).
Priority: 2 Timescale: D

5.4–R2.3 A simple image viewer for preview image shall be also provided.
Priority: 2 Timescale: D

5.4–R3 An archive user as well as the Scheduling Tool, shall be able to use calibration data immediately after the calibration observation.

Priority: 1 Timescale: C

5.4–R4 The Archive Retrieval Tool shall be able to accept (properly verified) web-based search and extraction requests.

Priority: 1 Timescale: D

5.4–R5 The Archive Retrieval Tool shall be able to be invoked from the Offline reduction package.

Priority: 1 Timescale: D

5.4–R6 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: 1 Timescale: D

5.4–R7 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: 1 Timescale: D

5.4–R8 In any EVLA supported data transfer method, the data shall be delivered to a user within the EVLA project defined maximum time.

Priority: 1 Timescale: D

2.5.5 Relationship with the Virtual Observatory projects

5.5–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

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

5.5–R2.1 the archived image
Priority: 1 Timescale: D

5.5–R2.2 catalogues derived from the archive, if available
Priority: 1 Timescale: E

5.5–R2.3 image quality information for archived images
Priority: 1 Timescale: D

5.5–R2.4 data quality information for selected observations
Priority: 1 Timescale: D

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

Priority: 1 Timescale: D

2.5.6 Proprietary requirements

5.6–R1 Astronomical data may be public or proprietary. Access to proprietary data shall be restricted to authorized users. Technical data and header information shall be freely available. Image data will be proprietary if the data from which the image is made is proprietary.

Priority: 1 Timescale: A

5.6–R2 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: A

5.6–R3 Calibration observations and staff test observations shall be public. That is, astronomical calibration observations, as well as the calibration pipeline output, can be extracted from the midst of otherwise proprietary data.

Priority: 1 Timescale: A

5.6–R4 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.

Priority: 1 Timescale: A

5.6–R5 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.

Priority: 1 Timescale: A

5.6–R6 The VLA staff shall have the capability of marking data associated with any given proposal or project as public.

Priority: 1 Timescale: A

5.6–R7 The VLA staff shall have the capability of making proprietary data accessible to a designated user other than the owner.

Priority: 1 Timescale: A

5.6–R8 The Archive Retrieval Tool, for users other than the data owner, will request information from the user as to the purpose for which the data is being extracted.

Priority: 1 Timescale: A

5.6–R9 The Archive Retrieval Tool will maintain a record of data extracted, including the comment solicited above.

Priority: 1 Timescale: A

5.6–R10 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 him of the data being extracted and including the comment solicited above.

Priority: 1 Timescale: A

2.6 Pipeline data processing

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

— *VLBI observations;*
— *solar observations;*
— *pulsar observations.*

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

Real-time Calibration Operations

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

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

Quick Look Operations

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

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

Science Operations

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

- *Calibration: process the data acquired during the observing session, e.g.:*
  - — *bandpass calibration*

  - — *polarization calibration*
  - — *final phase and amplitude calibration*
  - — *flux density scale*
- ◦ *Imaging: process all data of the project; results are preliminary after completion of observing session, final after completion of project*
  - — *produce tables of visibilities*
  - — *produce and archive deconvolved images*

We define the following terms:

- — Astronomical Source*: any astronomical object or position in the sky observed by the EVLA for astronomical purposes. This excludes arbitrary positions observed for calibrations (e.g., skydips).*
- — Target Source*: astronomical source whose observation is the goal of the current project.*
- — Calibration Source*: astronomical source observed for calibration purpose. It could be a a point-like source (quasar) or any source with known flux density or structure (including planets) or spectral features (e.g., masers).*

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

- — Instrumental calibration*: pointing, focus, delay, baseline, etc. A fast feedback to the control software is required. In particular, there are critical calibrations (focus, pointing, delay) which must be executed successfully before telescope operations can resume – these are the most time-critical and have highest priority.*
- — Calibrations that do not require time interpolation*: as the atmospheric calibration, or the bandpass and instrumental polarization measurements: each time such an observation is acquired, a certain quantity can be immediately derived and stored, to be applied to all following observations, until a new calibration of that kind is observed.*
- — Calibrations that require time interpolation*: as, e.g., the phase and amplitude calibration: a calibration curve has to be fitted using data taken over a range in time. This curve is then applied to target observations that were observed in between calibrations.*

The first two categories are real-time calibration operations, as described in section 2.6.2.

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

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

2.6.1 General requirements

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

Priority: 1 Timescale: C

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

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

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

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

Priority: 1 Timescale: D

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

Priority: 1 Timescale: C

6.1–R6 All pipeline operations shall be supported in the off-line data reduction package debugging, technical developments, inspection by qualified EVLA staff. In this mode, both a Command Line Interface (CLI) and a Graphical User Interface (GUI) shall be available.

Priority: 1 Timescale: B

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

Priority: 3 Timescale: D

2.6.2 Real-time calibration operations

6.2–R1 The Real-time Calibration Operations shall be activated after each calibration scan, except during autophasing, where it must run during scans.

Priority: 1 Timescale: C

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

Priority: 2 Timescale: C

2.6.2.1 Atmospheric Model

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

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

Priority: 1 Timescale: C

6.2.1–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: 1 Timescale: C

6.2.1–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

2.6.2.2 Astronomical calibration: Interferometric Data

6.2.2–R1 The Pipeline shall reduce, and store the results for further use in the archive in such a fashion that they are accessible to all users:

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

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

- **6.2.2–R2.1** compute the rms phase over the observed time and the rms phase change since the last observation of a phase calibrator;
  Priority: 1 Timescale: C

6.2.2–R2.2 compute the antenna efficiencies using the known source flux density;
Priority: 1 Timescale: C

6.2.2–R2.3 do the previous operations both with and without applying the atmospheric phase correction, and deduce from the comparison whether the atmospheric phase correction improves the results or not; this may involve having performed several observations with different parameters for the atmospheric phase correction;
Priority: 2 Timescale: D

6.2.2–R2.4 derive amplitude and phase time-dependent variations by fitting smoothed curves (e.g., polynomials or splines) using all observations of calibrators since the beginning of the session; fast-swtiching observations shall be supported; this derivation shall be done either per antenna or per baseline or both.
Priority: 2 Timescale: D

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

Priority: 1 Timescale: C

2.6.2.3 Telescope/Array Calibration

6.2.3–R1 The Pipeline must reduce:

6.2.3–R1.1 measurements of the pointing offsets;
Priority: 1 Timescale: C

6.2.3–R1.2 the focus measurements;
Priority: 1 Timescale: C

6.2.3–R1.3 the delay measurements.
Priority: 1 Timescale: C

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

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

6.2.3–R2.1 determine the antenna locations from the observations of several calibration sources;
Priority: 1 Timescale: C

6.2.3–R2.2 determine pointing models from the observations of calibration sources;
Priority: 1 Timescale: C

6.2.3–R2.3 determine focus corrections from the observations of calibration sources;
Priority: 1 Timescale: C

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

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

6.2.3–R3.1 the pointing measurements;
Priority: 2 Timescale: E

6.2.3–R3.2 the focus measurements;
Priority: 2 Timescale: E

6.2.3–R3.3 the skydip measurements;
Priority: 1 Timescale: D

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

2.6.3 Quick Look operation

2.6.3.1 Monitoring

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

Priority: 1 Timescale: C

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

Priority: 2 Timescale: D

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

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

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

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

Priority: 3 Timescale: D

6.3.1–R6 An Array Monitoring Tool shall be available to plot the current properties of the array, such as:

- **6.3.1–R6.1** the *uv* coverage and dirty beam, integrated over the current session;
- **6.3.1–R6.2** the thermal noise rms reached since the beginning of the observing session (from theory, using actual system temperatures);
- **6.3.1–R6.3** for mosaic observations: the above quantities for each pointing center.

Priority: 2 Timescale: D

2.6.3.2 Data processing

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

Priority: 1 Timescale: C

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

Priority: 2 Timescale: D

2.6.3.3 Data processing: Interferometric Data

6.3.3–R1 The visibilities observed on a target source shall be calibrated, using the results of the Real-time Calibration Operations:

- **6.3.3–R1.1** convert the raw data into flux density, including a factor based on antenna efficiency;
- **6.3.3–R1.2** apply the current bandpass calibration;
- **6.3.3–R1.3** apply the current amplitude and phase correction (using the scaling factor between the calibration and observing frequencies);

Priority: 1 Timescale: C

6.3.3–R2 The spectra observed on an astronomical source shall be displayed (amplitude/phase or real/imaginary) with various options such as:

- **6.3.3–R2.1** time integration;
  Priority: 1 Timescale: C
- **6.3.3–R2.2** choice of a single baseline (antennas selectable) or all baselines;
  Priority: 1 Timescale: C
- **6.3.3–R2.3** vector or scalar averaging.
  Priority: 1 Timescale: C

6.3.3–R3 The Quick Look Pipeline shall compute the dirty image of astronomical sources, using the fastest algorithm possible. The resulting maps shall be displayed. The supported observing modes should include:

- **6.3.3–R3.1** normal single-field synthesis;
  Priority: 1 Timescale: C
- **6.3.3–R3.2** multiple sources observations ("snapshots");
  Priority: 1 Timescale: C
- **6.3.3–R3.3** mosaicing;
  Priority: 2 Timescale: D
- **6.3.3–R3.4** on-the-fly mosaicing.
  Priority: 3 Timescale: E

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

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

Priority: 1 Timescale: C

6.3.3–R5 The following calibration modes shall be supported:

- **6.3.3–R5.1** calibration transfer (including fast switching);
  Priority: 1 Timescale: C
- **6.3.3–R5.2** self-calibration.
  Priority: 1 Timescale: C

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

Priority: 2 Timescale: D

2.6.4 Science Calibration operations:

REMOVE THIS SECTION?

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

Priority: 1 Timescale: D

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

Priority: 1 Timescale: D

2.6.4.1 Interferometric Data

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

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

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

Priority: 1 Timescale: C

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

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

Priority: 1 Timescale: C

2.6.4.2 Single Dish Data

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

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

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

Priority: ? Timescale: ?

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

Priority: ? Timescale: ?

2.6.5 Science operations

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: D

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

Priority: 1 Timescale: D

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

Priority: 1 Timescale: D

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

Priority: 2 Timescale: D

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

Priority: 2 Timescale: D

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

Priority: 3 Timescale: E

2.6.5.1 Interferometric Data

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

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

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

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

Priority: 1 Timescale: C

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

Priority: 2 Timescale: D

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

Priority: 2 Timescale: D

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

Priority: 2 Timescale: D

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

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

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

Priority: 1 Timescale: C

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

Priority: 3 Timescale: E

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

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

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

Priority: 2 Timescale: D

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

Priority: 2 Timescale: D

2.6.5.2 Single Dish Data

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

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

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

Priority: 1 Timescale: C

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

Priority: 2 Timescale: D

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

Priority: 1 Timescale: D

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

Priority: 3 Timescale: E

A Observing objects

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

Proposal:

An observer submits a proposal to perform a set of observations. 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.

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 a project. The project consists of the approved part of the proposal.

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

— 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).

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

Program:

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

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

The observing script is a set of Scheduling Blocks (SB) and Break Points (BP).

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

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:

— An observing script to be executed;
— A maximum single execution duration of the SB;
— A maximum total observing time to be spent using this SB;
— A main target direction, to be used by the scheduler to evaluate observing priority for the SB. All actual targets must lie within a limited area around this direction ($\sim$ 5 degrees, TBD);
— Observing scripts for preamble and postamble observations
— The sensitivity goal to be reached by repeated executions to be checked using the nominal radiometry formula, expressed in $T_{\rm A}^*$ units;
— The maximum water content required for scheduling (normally defaulted from frequency);
— The maximum phase fluctuation (after phase correction) required for scheduling (normally defaulted from technical characterization, frequency and requested angular resolution);
— 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;
— Status information, including at least:
  — The number of successful executions;
  — The integration time, and theoretical rms for each execution;
  — The total integration time, and current resulting theoretical rms;
  — The total array time used so far;
  — Whether the block goals are reached.

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

Preamble and postamble operations have several possible functions. The purpose of these operations is to collect data for use in the data reduction phase:

— Bandpass calibration;
— Polarization leakage term calibration;
— Receiver phase difference calibration.

Break Point (BP):

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

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

— A breakpoint identification code;

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

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: for instance pointing and focus scans involve a pattern of observations.

Observation:

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

— A simple driving pattern for each antenna;
— A simple driving pattern for the array phase center;
— A single receiver and frequency setup;
— A single correlator configuration.

Integration:

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

Correlator Dump:

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

B Examples of Scheduling Blocks

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

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

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