Requirement list

ALMA Software Science Requirements Committee
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Requirement priorities in the following have four values:

Value	Meaning
0	Essential feature
1	Must be there for Interim Science period
2	Must be there when the system is widely open for Science
3	Desirable feature

1 General Requirements

1.0–R1 The ALMA software shall offer an easy to use interface to any user and should not assume detailed knowledge of millimeter astronomy and of the ALMA hardware.

Priority: 2

1.0–R2 The ALMA software shall provide simple ways for the staff or expert astronomers to refine observing modes and develop new ones.

Priority: 0

1.0–R3 The expert user/developer shall be able to send direct orders to the hardware and to basic quasi real-time software through simple scripts in a Command Control Language. These scripts, once fully developed and tested, will evolve into standard observing modes.

Priority: 0

1.0–R4 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.

Priority: 2

1.0–R5 All user interaction with the ALMA system shall be through **GUIs** except for the low level Command Control Language.

Priority: 1

1.0–R6 The instrument shall be dynamically scheduled in near real time to take full advantage of the atmospheric conditions and of instrument availability.

Priority: 1

1.0–R7 A data pipeline shall be available to calibrate the data. The ALMA final product shall be images for the large majority of projects.

Priority: 1-3

1.0–R8 Raw data, monitor data, calibration data, and images will be archived; archived data shall be easily accessible to the users.

Priority: 1

1.0–R9 ALMA shall be able to handle the average data rate of one million visibilities per second (1.0 MVPS), and one-half million image pixels per second (0.5 MPPS). The peak sustained data rates will be 10 time higher.

Priority: 2

2 Real time software

2.1 Basic Operation Modes

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

Priority: 0

2.1–R2 In **Manual Mode** a subset of the antennas shall be directly controlled through a **control command language**.

Priority: 0

2.1–R3 In **Interactive Mode** the array shall be directly controlled by the (guest or staff) astronomer through a GUI.

Priority: 1

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

Priority: 1

2.1–R5 The same **Observing Modes** shall be available in Interactive Mode and Dynamically Scheduled Mode.

Priority: 1

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

Priority: 1

2.1–R7 The antennas shall be divided into one or more **sub-arrays**, operated simultaneously and independently, each sub-array being in any of the four above modes.

Priority: 0

2.1–R8 The allocation of antennas to sub-arrays/sessions shall take into account the hardware constraints imposed by local oscillator control (up to 4 different simultaneous LO setups), and by the correlator (up to 16 different correlator sub-arrays).

Priority: 0

2.1–R9 For allocation of resources the maintenance and array calibration sessions shall have the highest priority.

Priority: 1

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

Priority: 1

2.2 Control Command Language

2.2–R1 The minimum amount of data taking (**observation**) is described by an **observation descriptor** (see appendix). These parameters fully describe the data taking activity during that observation, including telescope motion and switching schemes.

Priority: 0

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

Priority: 0

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

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

Priority: 0

2.2–R4 During an observation other switching schemes shall include:

— subreflector nutation (TBD),
— LO1 frequency switching,
— load switching for calibration (TBD)

Priority: 0

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

— coordinate conversion to the antenna system,
— LO and IF filter setting according to frequency and Doppler tracking parameters (in the current baseline system design) ...

Priority: 0

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

Priority: 2

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

Priority: 1

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

— macros for abbreviation of frequently typed sequences
— procedures to which parameters may be passed
— definition of variables and arrays, with numeric or character content
— evaluation of expressions, including built-in functions
— conditional execution facilities
— loops
— error recovery facilities
— interruption facility in procedure execution

Priority: 0

2.3 Data Collection and Data Rates

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

- — tracking errors are in excess of an observer specified value
- — any LO in the data path is out of lock (base band based)
- — the subreflector is out of position tolerance
- — the receiver mechanical calibration system (e.g. vane) is out of position tolerance

The minimum amount of blanked data shall be:

- — an integer multiple of the 16ms correlator dump time.
- — smaller than (TBD) 5 percent fraction of the integration time (if this fraction is larger than 16ms).

Priority: 0

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

- — Antenna-based flags, integration based:
  - — Last WVR calibration failed
  - — Current WVR hardware defect
  - — WVR currently degrades data (based on calibrator amplitude or phase)
  - — Last pointing calibration failed (or no pointing calibration done)
  - — Last temperature scale calibration failed (all data was blanked)
  - — Temperature scale calibration system hardware defect
  - — Last temperature scale calibration failed, Tsys is currently estimated and not measured (by baseband)
  - — Shadowing: the antenna aperture is shadowed for any reason (the amount of shadowing shall be separately kept with data).
  - — Total power out of range (by baseband)
  - — Integration partly blanked (including blanking condition identification): as a warning.
  - — Integration totally blanked (including blanking condition identification): obviously quite severe.
  - — Bad data (by baseband, reserved for use by pipeline)
- — Baseline-based flags, observation based:
  - — Correlator malfunction (baseband based) e.g.: Correlator chip failed last self-test; Excessive closure error last calibrator observation, ...

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

Priority: 0

2.3–R3 The average data rate shall allow the recording of one million complex visibilities per second (1.0 MVPS) and one-half million image pixels per second (0.5 MPPS). These are the average over long periods of time and different programmes. These can be used to determine the archive size. The visibility data rate assumes 64 antennas and scales with the number of operational baselines. The image data rates scale rather like the longest baseline squared (and like the image area for mosaics). Both rates scale like the number of spectral channels actually recorded.

Priority: 2

2.3–R4 The peak data rates are ten times higher than the average data rates.

Priority: 2

2.3–R5 Each visibility shall be stored as two 16-bit scaled integers, with occasional need for higher precision. Switch to 32-bit scaled integers will be done automatically on each spectrum and baseline, based on the signal strength and the integration time-bandwidth product. Alternately one may choose to always use 32-bit integers and rely on standard data compression techniques.

Priority: 0

2.3–R6 Visibility data that has been (radiometrically) corrected for atmospheric phase effects shall be available as well as the uncorrected data. In the early phases of ALMA, both will be archived (*Priority: 0*). When ALMA is a mature instrument, it shall ideally automatically choose the best, on an antenna or perhaps baseline basis (*Priority: 1*). The user shall be able to select whether to archive corrected data, uncorrected, or both, or an automatic choice of the best (*Priority: 2*). This selection shall apply to all baselines. For integration times shorter than the shortest atmospheric time scales, only corrected data shall be recorded.

2.3–R7 The corrected and uncorrected visibility data shall be integrated over the same time periods. All baselines will be integrated over the same time periods.

Priority: 0

2.3–R8 The shorter integrations allowed by the hardware shall be supported (16ms for correlation, 1ms for autocorrelation only, 2ms for the continuum detectors).

Priority: 0

2.3–R9 The user shall be able to specify the number of spectral channels and integration time that is required in each spectral band to meet the science goals. Combined with the corrected/uncorrected selection, these choices will yield a data rate.

Priority: 1

2.3–R10 For each spectral band the average of all channels shall be kept with a short integration time ($<$ 1 sec.), whatever the integration time chosen for the spectral data. This allows a check for atmospheric phase fluctuations using the source continuum emission, if present.

Priority: 0

2.3–R11 The visibilities shall be stored as cross-correlation coefficients. At the data reduction stage they will have to be multiplied by stored system noise spectra to get $T_{\rm A}^*$ scale and by stored Jy/K values to get visibilities in Janskys. The relative channel weights will be also be computed from the stored system noise spectra.

Priority: 0

3 Proposal submission

3.0–R1 The proposals shall be submitted electronically and all observer input shall be in digital form.

Priority: 1

3.0–R2 The observer input shall be obtained in two phases: 1: prior to scientific evaluation, and 2: after successful scientific evaluation.

Priority: 1

3.0–R3 The same tool (**Observing Tool**) shall be used in both phases, a subset of input being required at phase 1 to judge technical feasibility and observing time needed; The remaining input shall be optional at phase 1 but required at phase 2 to fully specify the observations to be done.

Priority: 1

3.0–R4 The scientific justification shall be provided (at Phase 1) in a easily printable format (Postscript, pdf, ...), including figures.

Priority: 1

3.0–R5 The science goals should be input into the observing tool at Phase 1; they include:

— source identification or coordinates, unless there are more than 10 sources (selection criteria must then be given).
— angular resolution and largest structure;
— source flux and S/N or rms;
— line identification or frequencies;
— desired velocity resolution;
— desired dynamic range.

Priority: 1

3.0–R6 At Phase 1 the observing tool shall perform certain calculations, i.e. of time required under average conditions, fraction of time available at the site for the proposal requirements (e.g. required phase stability at the specified frequency), etc.

Priority: 1

3.0–R7 The basic input parameters shall be translated by the tool into observing mode, configurations, observing time, correlator setup, ... which the expert shall be able to check; he/she will be able to override all modes and parameters manually.

Priority: 2

3.0–R8 The tool shall react to user input by giving all sort of warnings on the expected data quality (*Priority: 2*), on hardware limitations (*Priority: 1*) , ... etc, depending on the selected observing modes.

3.0–R9 The tool shall calculate the data rate and the total data volume for the project.

Priority: 1

3.0–R10 Basic checking for conflicts against a database of already conducted observations shall be done at time of submission to give instant feedback to the proposer. This database shall also be accessible for interactive searching prior to proposal writing.

Priority: 2

3.0–R11 The tool shall allow storing of intermediate stages to local disks, to enable trying out different parameter settings.

Priority: 1

3.0–R12 The proposer shall specify what is needed for real-time checking of data quality. This may include choosing a standard calibrator as a *test source* to be observed with a short integration time and mapped.

Priority: 1

3.0–R13 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. Breakpoints shall be settable in terms of project goals: e.g. fraction of targets observed, given rms or S/N.

Priority: 1

3.0–R14 The observing programmes shall be divided into scheduling blocks either automatically (for standard observing modes) or from expert observer input.

Priority: 1

3.0–R15 For complex programmes with several different scheduling blocks the observer shall be able to set up dependency rules between these scheduling blocks.

Priority: 2

3.1 The Observing Tool

The Observing Tool is mainly used at Proposal Preparation and for interactive observing. It is the main interface to ALMA for the general user.

3.1–R1 The Observing Tool shall integrate as components: observation setup (*Priority: 1*), correlator setup (*Priority: 1*), data reduction setup (*Priority: 2*), and observation simulation (*Priority: 3*).

3.1–R2 The Observing Tool shall only require *specification of science goals* as input (see above).

Priority: 2

3.1–R3 The Observing Tool shall be able to produce an human-readable observing script than can be directly executed, or used as an input for further development.

Priority: 1

3.1–R4 The Observing Tool shall allow the user to easily construct a *Source List* of coordinates and velocities by accessing standard astronomical catalogs (CDS, NED). That Source List shall be editable and re-usable for further submissions.

Priority: 1

On the basis of a map (from survey databases, or from databases of previous observations) one shall be able to define the area to be mapped interactively with a mouse.

Priority: 2

3.1–R5 The Observing Tool shall allow sequential extraction of targets from a list of sources to conveniently drive survey programs.

Priority: 2

3.1–R6 The Observing Tool shall provide to the user a list of standard observing modes that may be used to achieve the science goals, so that he/she may choose the most efficient of the list.

Priority: 2

3.1–R7 For the selected standard observing mode the Observation setup component shall offer for all parameters sensible defaults deduced from the science goals, making these parameters unnecessary to manipulate for the general user. Some parameters (loop cycle times, integration times) may be selected to be automatically calculated at run-time depending on actual weather, phase fluctuations, pipeline results.

Priority: 1

3.1–R8 Projects shall be allocated a level of sensitivity under the requested atmospheric conditions, rather than a fixed amount of observing time. However a hard limit on the total integration time shall be set for each project to avoid an overflow due to misestimated sensitivity.

Priority: 1

3.1–R9 The Correlator setup component shall provide a Spectral view and a Hardware view. The Spectral view is oriented toward the observation and allows selection of spectral windows based on molecular transitions. The Hardware view gives the details of the actual hardware setup. 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). It shall be possible to use the component as an aid in rough sensitivity calculations. Pre-configured setups shall be available for frequently observed transitions. The spectral windows shall be graphically movable, reflecting hardware constraints.

Priority: 2

3.1–R10 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, or to simulated spectra (*Priority: 3*) based on physical models. This means a line database (such as the JPL catalog) shall also be linked to the tool.

Priority: 2

3.1–R11 The observing tool shall be able to run a simulator component to estimate S/N (*Priority: 1*), produce dirty beams (*Priority: 1*) and, for suitable source models, maps with the desired configurations (*Priority: 3*). The input model shall be taken from real data or from easy-to-construct models made up of basic source components: disks, Gaussians, tori ... etc. One should aim at getting something like the NCSA Astronomy Digital Image Library for ALMA and linking this to the simulator component.

Priority: 3

3.1–R12 The observing tool shall allow its state and intermediate output to be saved and restored at any time. Saved outputs shall be local. Saved outputs shall be distinguished by name and easy to use as templates.

Priority: 1

4 Dynamic Scheduling

4.0–R1 ALMA observing programmes shall be dynamically scheduled in quasi-real time.

Priority: 1

4.0–R2 The observing programmes shall be split into scheduling blocks; the execution of an SB shall not be interrupted by the scheduling process.

Priority: 1

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

— Science rating
— source visibility, and remaining visibility time in current transit
— preferred LST
— UT (for ephemeris dependent projects)
— elapsed UT since previous execution (for monitoring projects)
— system noise (including atmosphere) averaged over antennas, to define sensitivity
— synthesized beam size and ellipticity, and required resolution
— phase noise at observing frequency, to define calibration feasibility and dynamic range
— seeing parameter
— SB interdependency rules
— breakpoint reached or released ?
— total time limit, noise limit, SNR limit reached ?
— Programme execution status (started, approaching completion, currently on the telescope ...)
— SB execution time

The actual formula and coefficients must be tuned for optimum overall efficiency according to the distribution of programme requirements and the weather statistics on the ALMA site. The ordering of programmes according to scheduling probabilities should match that of science ratings.

Priority: 1

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

Priority: 1

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

Priority: 0

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

Priority: 1

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

Priority: 3

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

Priority: 1

5 Pipeline Data Processing

We distinguish between Array calibration, Quick look and Science data pipelines.

5.0–R1 The pipelines shall be able to process all the data coming from the array; it must not constitute in any case a bottle-neck in the data flow. There shall be no interference between pipelines.

Priority: 1

5.0–R2 The pipelines shall operate through readable and comprehensible data reduction scripts.

Priority: 1

5.0–R3 The pipelines shall be data driven. All necessary parameters will be specified by the observers at proposal preparation stages and will be present in the data headers.

Priority: 1

5.0–R4 A manual, interactive mode of operation shall be available for technical development, debugging, inspection by expert engineers and astronomers on duty. Such a mode will also be available to PI/CoI astronomers, for programmes to which interactive observations are allocated.

Priority: 1

5.1 Array calibration

5.1–R1 The pipeline shall reduce the baseline calibration scans, the pointing scans, and focus determination scans; the results shall be fed back as soon as possible (0.5 sec.) to the real time system.

Priority: 1

5.1–R2 Phase and amplitude calibration results (e.g. calibrator amplitudes, rms phases and seeing information) must be fed back both to the scheduler and the observing processes.

Priority: 1

5.2 Quick look

5.2–R1 The pipelines must display the results at the various stages:

- amplitude and phases on the calibrators: with short integration times for the current one, and with longer integrations since the programme was started; antenna-based and/or baseline-based (*Priority: 0*).
- on-line display of pointing scans, focus scans, ... (*Priority: 0*).
- on-line display of the current spectrum for total power spectroscopy (*Priority: 1*).
- on-line display of the interim uncleaned images for interferometry (*Priority: 2*).

5.3 Science data pipeline

5.3–R1 For standard observing modes the science data pipeline shall operate in fully automated mode; the final products will be deconvolved images.

Priority: 2

5.3–R2 The pipeline scripts shall be automatically generated from templates, on the basis of the observing mode being used.

Priority: 1

5.3–R3 The pipeline shall allow processing observing programmes in parallel. After a breakpoint is reached in an observing project, interim results will be produced at high priority, so that the program may resume after observer's input a few hours (typically 12 hours) later.

Priority: 2

5.3–R4 The science data pipeline shall be run either at or near the telescope, in quasi real time (*Priority: 1*), or later, off-line, at places where the official archives are kept (*Priority: 2*).

Priority: 1

5.3–R5 All the data previously obtained since the project has started shall be available for processing. This means raw data and calibration data obtained in different array configurations, including total power data for measurements of zero and short spacings.

Priority: 2

5.3–R6 Basic interferometer amplitude and phase calibration shall be obtained by interpolation between calibrator observations. The pipeline must also be able to self-calibrate the data when possible.

Priority: 1

5.3–R7 For continuum Total Power projects the data pipeline must subtract the atmospheric contribution, in a way that depends on the actual observing mode.

Priority: 2

5.3–R8 For line Total Power projects the data pipeline must subtract measurements obtained on an OFF position if needed, normalize by gains to scale the data into temperature units; it must also subtract spectral baselines.

5.3–R9 The pipeline must be able to grid the Total Power data for imaging. If these total power measurements are obtained by a sub-array while the other antennas are used for the cross correlations for the same target, the calibrations should be able to proceed in parallel such that when imaging both data sets are ready to be combined when the imaging stage begins.

Priority: 2

5.3–R10 The pipeline shall produce continuum and/or line images of the calibrated data obtained so far. These images must be visualized, interactively in the case of interactive observations.

Priority: 2

5.3–R11 The pipeline should also be able to compare redundant data (obtained simultaneously or not) to better assess the data quality. It must be possible to feed these interactive measurements back to the scheduler or to the observing process, if relevant.

Priority: 3

5.3–R12 The images shall be deconvolved using the most appropriate algorithm; it is desirable to allow several algorithms to compete in case of complex images for which there is no guaranty of a single optimum algorithm. In any case it must return information about the robustness of the results in these cases where a unique method is not available.

Priority: 2

5.3–R13 The imaging pipeline must be able to produce images with inclusion of zero and short spacings.

Priority: 2-3

6 Archiving

The archive enables astronomers to access and use data which has been obtained with ALMA

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

Priority: 1

6.0–R2 The archive shall also include as header data:

— all user input including the scientific justification of the project.
— observing scripts as they have been used to obtain the data
— the actual observation descriptors
— environmental data relevant to data reduction (e.g.weather data)
— the radiometric pathlength correction, on ($\sim 1s$ timescale)
— the pipeline data reduction scripts
— the monitor data

Priority: 1

6.0–R3 When long integrations are used for the images, they shall be stored in the archive. When shorter integrations are used, the images shall be generated on-the-fly from the visibilities upon extraction from the archive. The break point between these two techniques will be determined by the computing capability of the archive extraction pipeline, and may evolve with time. Images must always be archived if the pipeline cannot generate them upon extraction.

Priority: 1

6.0–R4 In case of irreversible on-line data corrections such as the atmospheric phase correction on time scales shorter than the integration time, it is desirable to keep both the corrected and the uncorrected data (see requirement 2.2–R6 page 7).

Priority: 1

6.0–R5 The data within each scan shall be identifiable by its goal (phase calibrator, target observation, pointing scan ...)

Priority: 1

6.0–R6 There may be several archives which hold all or subsets of data. The principal archives should be easily accessed by users from Europe and USA (*Priority: 2*). There shall be a backup for raw data (*Priority: 1*).

Priority: 2

6.0–R7 There needs to be an archive which is easily accessed from the ALMA site, to buffer the data from the telescope and provide data for on-line imaging of multiple array configuration projects.

Priority: 1

6.0–R8 The archive shall be accessed through a GUI, the **Archive Search Tool**.

Priority: 1

6.0–R9 The Archive Search Tool shall allow searching the data base to see if observations have been previously done. It will also be used as a front end to the Data Extractor Tool.

Priority: 1

6.0–R10 The search criteria shall include:

— Object name
— Region of Sky
— Molecular transition

Filters will also be available on:

- — Frequency
- — Time
- — Array Configuration
- — Angular resolution

Priority: 1

6.0–R11 The Data Extractor Tool shall use the Search Tool to identify data, and return either

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

Priority: 1

6.0–R12 The Data Extractor Tool shall use login identification to access proprietary data. The header data is never proprietary.

Priority: 1

A Observation Descriptor

[Note: this attempts to list the actual hardware control parameters, they are normally derived in quasi real time from high level astronomer input]

```
Project ID
Sub-array ID
Observation Block ID
Number of Antennas=NA
Antenna(NA)
  Antenna ID
  Position of Antenna (X,Y,Z)
  Antenna Station
  Pointing Model
    Axes Offset
    Encoder Zeroes
    Collimations
    Az Inclinations
    Focus Corrections (X0,Y0,Z0, X1,Y1,Z1, ...)
    Pointing Offsets of Optical Telescope
    ...
  Pattern
    System (Hor, Eq)
    Mode {"None", "Circle", "Points"}
    Start coords
    Center coords (Circle)
    Angular Velocity (Circle)
    Number of points (Points)
    List of coords, times (Points)
    ...
  Calibration Parameters
    Number of frequency points=NPC
    Point(NPC)
      Frequency
      Forward Efficiency
      Aperture Efficiency
      ... Other Efficiencies (e.g. vane transparency)
    Atmospheric Model

  Frequency Band(NFB)
    Pointing offset (Az,El) for H
    Pointing offset (Az,El) for V
    Focus offset (Z) for H
    Focus offset (Z) for V
    LO1 Phase offset
    Frequency Window (NFW)
      LO2 Phase Offset
    SideBand Gain Ratio


Number of Frequency Bands = NFB
Frequency Band(NFB)
  Frequency Band ID
```

```
  Mode {Active, Standby}
  LO1 Frequency
  Number of Spectral Windows =  NFW
  Window(NFW)
    Setup Mode {EXPLICIT, AUTO}
    Polarization {H, V, HH&VV, ALL}
    Line ID
    Line Rest Frequency
    Velocity Interval (min,max)
    Velocity Resolution
    LO1 SideBand
    LO2 Frequency
    LO2 SideBand
    IF Frequency
    IF Frequency Bandwidth
    Frequency Resolution

Number of Sources (=NS)
Source(NS)
  Source ID
  Catalog {YES NO}
  Catalog name
  Source Status {Active, Standby}
  SolSys Object {YES, NO}
  SolSys Name or FileName
  Coordinate System {EQ GA HO ...}
  Epoch
  Lambda at Epoch
  Beta at Epoch
  Lambda Motion at Epoch
  Beta Motion at Epoch
  Velocity
  Velocity Frame {OBS, GEO, HEL, LSR}  ... (EMBar, SSBar ?)
  Doppler Track {YES, NO}
  Flux
    Number of Frequencies
    Frequencies
    Fluxes
  Source Info {PHASE_CAL,FLUX_CAL,BAND_CAL,TEST_TARGET,SCIENCE_TARGET...}

Phase Center
  Pattern
    System (Hor, Eq)
    Mode {"None", "Circle", "Points"}
    Start coords
    Center coords (C)
    Angular Velocity (C)
    Number of points (P)
    List of coords, times (P)
    ...


Integration
  Time
```

```
  SwitchingMode
    Number of States
    State
      Duration
      Blanking
      Nutator Offsets
      LO1 Frequency Offset
      LO2 Frequency Offsets (4)
      Weight (for Pipeline)
      ...

Water Vapour Radiometer
  Use {YES NO}


Data Processing
  Script
    Telescope Calibration
    Project Calibration
    Imaging
```